NONRESIDENT
TRAINING
COURSE

Hull Maintenance Technician

NAVEDTRA 14119

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

COURSE OVERVIEW: In completing this nonresident training course, you will demonstrate an understanding of course materials by correctly answering questions on the following: safety; ship repair; woodworking cuts and joints; small boat repair and deck coverings; tools and equipment; metallurgy; introduction to cutting and welding; oxyacetylene cutting and welding; brazing and braze welding; metal-are welding and cutting; nondestructive tests and inspection of welds; sheet metal layout and fabrication; structural steel fabrication; shop mathematics; piping systems; piping system repairs; and sewage systems.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

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Published by
NAVAL EDUCATION AND TRAINING
PROFESSIONAL DEVELOPMENT
AND TECHNOLOGY CENTER

NAVSUP Logistics Tracking Number
0504-LP-026-7820

CONTENTS

CHAPTER 1

SAFETY

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Identify the basic safety requirements, and how the role of responsibility starts with you.*
- *Identify various sources of information regarding safety.*
- *Identify various warning signs, placards, tags, and labels.*
- *Describe the safety precautions to be followed when working on or with electrical welding equipment.*
- *Describe the safety procedures to follow when working with chemicals and solvents.*
- *Describe the safety procedures to follow when working on or with various tools, equipment, and machinery.*
- *Describe the safety procedure, and precautions to follow before and after hotwork operations.*
- *Describe the safety procedures to follow when performing cutting operations.*
- *Describe the Navy's Hearing Conservation and Noise Abatement programs.*
- *Describe the Navy's Heat Stress Control Program.*

INTRODUCTION

It is Navy policy to provide a safe and healthy work place for all personnel. These conditions can be ensured through an aggressive and comprehensive occupational safety and health program fully endorsed by the Secretary of the Navy and implemented through the appropriate chain of command. Safety begins with you.

The material discussed in this chapter stresses the importance of observing standard safety precautions and procedures. As a Hull Technician, you will be working with different types of equipment, such as electrical welding equipment. All electrical equipment is hazardous; therefore, all safety precautions must be strictly observed. The primary goals of an effective safety program are to protect personnel and material and to ensure that unsafe equipment operations do not occur. As a petty officer or chief petty officer, you have the responsibility to recognize unsafe conditions and to take appropriate actions to correct any discrepancies.

A number of safety precautions that are likely to concern HTs at one time or another are listed in this chapter. You need to observe all of these precautions. The purpose of this chapter is not to teach safety but to stress emphatically to all personnel that to work safely and to be safety conscious at all times is as much a part of their trade as may be any of its finer secrets or skills and to keep forever in mind, in the execution of their duties, this one simple slogan: WORK SAFELY.

SAFETY RESPONSIBILITIES

All individuals have the responsibility to understand and observe safety standards and regulations that are established for the prevention of injury to themselves and other people and damage to property and equipment. As an individual, you have a responsibility to yourself and to your shipmates to do your part in preventing mishaps. As a petty officer or chief petty officer, you have the responsibility of setting a good example; you cannot ignore safety regulations and expect others to follow them.

Personnel should always observe the following safety practices:

- Observe all posted operating instructions and safety precautions.
- Report any unsafe condition or any equipment or material deficiency you think might be unsafe.
- Warn others of hazards and the consequences of their failing to observe safety precautions.
- Wear or use approved protective clothing or protective equipment.
- Report any injury or evidence of impaired health that occurs during your work or duty to your supervisor.
- Exercise reasonable caution as appropriate to the situation in the event of an emergency or other unforseen hazardous conditions.
- Inspect equipment and associated attachments for damage before using the equipment. Be sure the equipment is suited for the job.

Lessons learned from many industrial mishaps that have been investigated and studied have been compiled into easily understandable booklets and pamphlets published to propagate and market safety awareness and familiarity with various rules and regulations. Also, many safety devices and aides of all types have been developed to save lives and to provide a means for avoiding mishaps. However, all of the safety literature, devices, or aides that have been developed thus far and those that will be developed in the future can only help the one real instrument of safety play its part. That one real instrument of safety is a careful and safety-conscious worker.

All personnel should make it a habit to observe the following "ten commandments of safety."

1. LEARN the safe way to do your job before you start.
2. THINK safety and ACT safely at all times.
3. OBEY safety rules and regulations—they are for your protection.
4. WEAR proper clothing and personal protective equipment (PPE).
5. CONDUCT yourself properly at all times—horseplay is prohibited.
6. OPERATE only the equipment you are authorized to use.
7. INSPECT tools and equipment for safe condition before starting work.
8. ADVISE your superior promptly of any unsafe conditions or practice.
9. REPORT any injury immediately to your superior.
10. SUPPORT your safety program and take an active part in safety meetings.

In addition to these rules, there are other good work habits that will help you perform your job more efficiently as well as safely.

Remember: Mishaps seldom just happen; they are caused. Another point to remember is to never let familiarity breed contempt. Most mishaps could have been prevented had the individuals involved heeded the appropriate safety precautions. Preventing mishaps that are avoidable will help you in the Navy and possibly determine whether or not you survive.

PROMOTING SAFETY

Promoting safety will require you to become safety conscious to the point that you automatically consider safety in every job or operation. By safety reminders and your personal example, you pass this safety consciousness on to other personnel.

ENFORCING SAFETY

Safety precautions, as all rules, laws, or regulations, must be enforced. It is your duty to take appropriate action any time you see someone disregarding a safety precaution. You should ensure that all jobs are done according to applicable safety precautions.

Doing a job the safe way in some cases may take a little longer or be a little more inconvenient, however, there is no doubt as to the importance of doing it this way.

SOURCES OF SAFETY INFORMATION

To be an effective petty officer and supervisor, you should become familiar with the types of safety programs implemented throughout the Navy. You should also be familiar with all safety directives and precautions concerning your division. Safety instructions vary from command to command. This makes it impossible to give you a complete listing of manuals and instructions with which you should be familiar. Besides studying the information on safety described in this chapter and throughout this training manual, you should read and have knowledge of the safety information in the following references:

- *Standard Organization and Regulations of the U. S. Navy*, OPNAVINST 3120.32B, chapter 7—Outlines the safety program and the safety organization.

- *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat*, OPNAVINST 500.19C—Provides general shipboard safety precautions and specific occupational health program guidance.

- *Navy Occupational Safety and Health (NAVOSH) Program Manual*, OPNAVINST 5100.23C—Encompasses all safety disciplines, such as systems safety, aviation safety, weapons/explosives safety, off-duty safety (recreation, public, and traffic), and occupational safety and occupational health.

- *Naval Ships' Technical Manual*, chapter 074—Provides general welding safety precautions.

Personnel are also advised and informed on mishap prevention through the following periodicals:

Fathom magazine, the afloat safety review, is published bimonthly for the professional benefit of all hands by the Navy Safety Center. *Fathom* presents the most accurate information currently available on the subject of shipboard mishap prevention.

Ships' Safety Bulletin is published monthly by the Navy Safety Center. This bulletin contains articles on shipboard safety problems, trends, mishap briefs, and statistics.

Deckplate magazine is published bimonthly by the Naval Sea Systems Command. This magazine contains information on the design, construction, conversion, operation, maintenance, and repair of naval vessels and their equipment. It also contains articles on safety hazards and their prevention.

Flash, a monthly mishap prevention bulletin, provides a summary of research from selected reports of submarine hazards to assist in the prevention program. It is intended to give advance coverage of safety-related information while reducing individual reading time.

These publications, as well as notices and instructions distributed by the cognizant bureaus, make excellent reference materials. When these publications are available, you should read them and incorporate them into your training program.

Other sources of safety information that you will be dealing with on a day-to-day basis in your work as a Hull Technician are manufacturers' technical manuals and PMS maintenance requirement cards (MRCs).

These are not all of the safety resources that are available to you. However, these sources give you a good starting point from which you can expand your knowledge of safety procedures. The *Naval Safety Supervisor*, NAVEDTRA 12971, is also a very good resource for strengthening your awareness of safety procedures.

WARNING SIGNS, PLACARDS, TAGS, LABELS, AND MARKINGS

Warning signs, placards, tags, labels, and suitable guards/markings should be provided to prevent personnel from coming into accidental contact with dangerous equipment; for warning personnel of the possible presence of airborne contaminants as a result of grinding operations; and for warning personnel of other dangers that may cause injury to them. Equipment installations should not be considered complete until appropriate warning signs have been posted in full view of operating and maintenance personnel.

Warning signs (red/white) and caution signs (yellow/black) should be located in an area where known hazardous conditions exist or may exist. Some of the areas that are hazardous aboard ship include workshops, pump rooms, and machinery spaces. However, hazards may be encountered anywhere aboard ship.

Signs designating an entire space as hazardous must be posted at eye level or above in full and clear view of entering personnel. Signs designating a specific piece of equipment as hazardous must be posted on or near equipment (in full view of the equipment operator) that is particularly dangerous.

Warning placards (fig. l-l) should be located on the door to the entrance of any space where noise levels are consistently high, requiring single- or double-hearing protection. A warning placard should also be displayed on all portable equipment capable of emitting noise in excess of 84 dB(A) when operated. Remember that the messages are aimed at YOU. It is your responsibility to "read and heed."

Tags and labels are used in the Navy to identify a defective piece of equipment or instrument. Tags and labels are also used to ensure the safety of personnel and to prevent improper operation of equipment. They will be posted according to authorized procedures and must not be removed or violated without proper authorization and adequate knowledge of the consequences.

The use of tags and labels is not a substitute for other safety measures, such as locking valves or removing fuses from a fuse panel. Also, tags or labels associated with tag-out procedures must never be used for anything other than their intended purpose.

Figure 1-1.—A warning placard.

Remember, once a tag or label is used, it should only be removed by signed authorization of the authorizing officer. You should always follow your command's procedures for logging and recording tag-out actions.

Markings consisting of paint or tape are used to designate safe traffic lanes, operator caution areas, operator working areas, and observer safe areas.

Safe traffic lanes are designated in workshops. These lanes start and stop at all exits and entrances for workshops and are marked by continuous white lines, 3 inches wide, painted on the deck.

Operator caution areas, operator working areas, and observer safe areas are designated for each equipment working area deemed hazardous. Operator caution areas are marked by a continuous yellow tine, 3 inches wide, outlining the caution area. Operator work areas are marked by painting the deck yellow in areas where it is safe for an operator of machinery or equipment. The outer perimeter of this area is designated by alternate black and yellow lines, or checkerboard pattern, 3 inches wide. Observer safe areas are designated as all areas outside of this perimeter and are the normal color of the deck within the space.

Eye hazardous areas are marked with a black and yellow checkerboard, or chevron, pattern and a label plate made up of black letters on a yellow background that reads: "WARNING EYE HAZARD."

SAFETY EQUIPMENT

Safety equipment is for you. It will protect you from injury and may possibly save your life. Some of the more common types of safety equipment for your personal protection are described in the following paragraphs.

EYE PROTECTION

Proper eye protection is of the highest importance for all personnel. Eye protection is necessary because of hazards caused by infrared and ultraviolet radiation or by flying objects such as sparks, globules of molten metal, or chipped concrete and wood. These hazards are always present during welding, cutting, soldering, chipping, grinding, and a variety of other operations. It is absolutely necessary for you to use eye protection such as helmets, face shields, goggles, and safety glasses during eye-hazard operations. Appropriate use of goggles will limit eye hazards. Some goggles have plastic windows that resist shattering upon impact. Others are designed to limit harmful infrared and ultraviolet radiation from arcs or flames by use of appropriate filter lenses. Remember, eye damage can be extremely painful. Protect your eyes.

HEARING PROTECTION

Proper hearing protection is a must when working with or around certain types of power tools. Some tools are capable of producing dangerously high noise levels which, if ignored, can result in serious hearing loss or injury. You should use hearing protection regularly. Examples of hearing protection are aural hearing protectors, single-flanged earplugs, double-flanged earplugs, triple-flanged earplugs, and foam earplugs.

SAFETY SHOES/BOOTS

Safety shoes/boots protect and prevent injury or loss of toes. Some safety shoes are designed to limit damage to your toes or feet from falling objects. A steel plate is placed in the toe area of such shoes so that your toes are not crushed if an object falls on them. Other safety shoes are designed for use where danger from sparking could cause an explosion. Such danger is minimized by elimination of all metallic nails and eyelets and the use of soles that do not cause static electricity. Examples of safety shoes are boondockers, high-steel toe, and molder boots.

RESPIRATORS AND MASKS

Respirators and masks protect personnel from the inhalation of many toxic materials. The wearing of a respirator is required when performing grinding, welding, brazing, and wood operations. It is also required when you are exposed to high concentrations of hazardous vapors or fumes. Respirators and masks provide protection against aerosols, dusts, fumes, and vapors. Some respirators are disposable and others are reusable. A filter or disposable respirator protects against dust; and the reusable chemical cartridge type of air-purifying respirator protects against gaseous contaminants. Particle masks, air line hose masks, and vapor masks are also reusable.

SAFETY HAZARDS AND PRECAUTIONS

HTs perform plan, supervise, and perform tasks necessary for fabrication, installation, and repair of all types of shipboard structures, plumbing, and piping systems. This includes performing welding, cutting, brazing, and grinding operations. Because of this, HTs must be aware of the general and specific safety precautions involved in their work. The following paragraphs will discuss some of the safety hazards and precautions that you should be familiar with.

MACHINE/EQUIPMENT SAFETY

Before using any machine or piece of equipment, you must be familiar with all safety precautions pertaining to its operation. Carelessness around any moving machinery is extremely dangerous. When moving machinery is equipped with sharp cutting tools, the dangers are greatly increased. The following list includes some of the more general safety precautions for machines/equipment. Specific safety and operating precautions should be posted in plain sight on or by every machine.

—Before operating a machine, make sure there is plenty of light to work by.

—Do not distract the attention of a machine operator.

—Do not lean against any machine that is in motion. Keep clear of all gears, belts, and other moving parts. Never remove the guards from any part of an operating machine.

—Never start a machine unless you are thoroughly familiar with its operation.

—Do not attempt to clean, adjust, or repair a machine while it is in motion. Shut off the power supply to the machine. NEVER attempt to clean running gears.

—PROTECT YOUR EYES. Do not hold your head too close to the cutting tool-flying bits of metal or scale may get into your eyes. Always wear goggles when there is any danger of flying particles getting in your eyes; for example, when using a grinding or drilling machine.

—PROTECT YOUR HEARING. Always wear appropriate hearing protection. Either aural hearing protectors (mickey mouse ears) or ear plugs will reduce the noise from running machinery. Prolonged exposure may damage your hearing.

—Keep your fingers away from the cutting edges when the machine is in operation; otherwise, you could lose some fingers.

—Do not wear gloves or loosely hanging clothes. They can be caught by moving parts of the shop machinery and cause serious injuries. Keep your sleeves rolled down and buttoned up tightly Do not wear neckties or loose neckerchiefs. If clothing becomes caught in a machine, shut off the power immediately.

—When using portable electric equipment around machine tools, take special care so that electrical cords are clear of moving parts.

—Do not exceed the recommended depth of cut, cutting speeds, and feeds.

—Keep areas around machines clear of obstructions and ensure a nonskid surface is available for the equipment operator.

—Remove chips with a brush or other suitable tool; never by hand or with compressed air.

—When operating the brake press, always disconnect the foot switches and ensure that the eccentrics are in the bottom stroke before setting or adjusting the punch and die.

—Place eccentrics on the bottom center of the drop shear bed.

—When operating the brake press, place hands under the plate. Be sure the head and upper body are clear from the plate. Do not lean over the work while bending the plate.

—Magnetic particle test equipment is capable of producing current in excess of 600 amperes. Follow all electrical safety precautions; failure to do so may result in serious injury or death.

—In all machine work, stress **SAFETY** first, **ACCURACY** second, and **SPEED** last. Excessive speed is both dangerous and unproductive.

SAFETY WITH PORTABLE POWER TOOLS

Safety is a very important factor in the use of portable power tools and cannot be overemphasized. The hazards associated with the use of portable power tools are electric shock, cuts, flying particles, explosions, and so on. Because you will be using portable power drills, hammers, and grinders in the shop and out on the job, you should be thoroughly familiar with the operation and care of these tools and with all applicable safety precautions. The portable power tools that you use may be powered by electric motors or by air (pneumatic) motors. Whether electrically powered or air powered, the tools and procedures for using them are basically the same. Safe pratice in the use of these tools will reduce or eliminate the mishap potential. By observing the following safety guidelines, you can ensure maximum benefits from the tools you use and reduce to a minimum the chances of serious injury.

- Never operate any portable power tools unless you are completely familiar with their controls and features.

- Inspect all portable power tools before using them. See that they are clean and in good condition.

- Make sure there is plenty of light in the work area. Never work with power tools in dark areas where you cannot see clearly.

- Before connecting power tools to a power source, be sure the tool switch is in the OFF position.

- When operating a power tool, give it your full and undivided attention.
- Do not distract or in any way disturb another person while they are operating a power tool.
- Never try to clear a jammed power tool until it is disconnected from the power source.
- After using a power tool, turn off the power, disconnect the power source, wait for all movement of the tool to stop, and then remove all waste and scraps from the work area. Store the tool in its proper place.
- Do not allow power cords to come in contact with sharp objects, nor should they kink or come in contact with oil, grease, hot surfaces, or chemicals.
- Never use a damaged cord. Replace it immediately.
- Check electrical cables and cords frequently for overheating. Use only approved extension cords, if needed.
- Always connect the cord of a portable power tool into the extension cord before the extension cord is inserted into a live receptacle.
- Always unplug the extension cord from the receptacle before the cord of the portable power tool is unplugged from the extension cord.
- See that all cables and cords are positioned carefully so they do not become tripping hazards.
- Treat electricity with respect. If water is present in the area of electrical tool operation, be extremely cautious and, if necessary, disconnect the power tool.
- The air pressure for any pneumatic tool must not exceed 90 psi.
- Never point the air hose at another person.
- When working with pneumatic tools, always stand so you are properly balanced while working so you will not slip and lose control of the tool.

CHEMICAL/SOLVENT HAZARDS

Exposure to chemical hazards may cause significant health problems. Solvents are capable of damaging your respiratory system in cases of prolonged inhalation. Chemicals and solvents come in the form of gas, vapor, mist, dust, or fumes. Materials ordinarily thought to be safe may be rendered hazardous under certain use conditions by the uninformed user. As an HT, you will inevitably come into contact with various chemicals/solvents. Most of these chemicals will have some type of hazard associated with them. Among these hazards are irritants, toxics, corrosives, and flammables.

Personnel engaged in the handling and use of chemicals must always use appropriate protective equipment for the class of chemical being used.

Such protective equipment includes, but is not limited to, the following items:

- Rubber gloves, boots, and aprons
- Air masks, respirators, and filter masks
- Eye protection, goggles, and face shields
- Protective skin creams, when sensitive or skin irritants are used
- Any other protective equipment that is necessary

Following is a list of safety precautions that you should observe when using and handling chemicals/ solvents:

—Review the Material Safety Data Sheet (MSDS) for any chemical prior to using or handling it.

—Do not work alone in a poorly ventilated space.

—Do not apply solvents to warm or hot equipment, since this increases the potential evaporation rate making it more hazardous.

—Never use a solvent in the presence of any open flame.

—Place a fire extinguisher close by, ready for use.

—Hold the nozzle close to the object being sprayed.

—Personnel who use potential irritants, such as epoxy, resins, and hardeners, should avoid direct skin contact. Should contact be made with an irritant, the area should be washed thoroughly with soap and water. Irritants require no special storage other than that required by their other properties, such as flammability or toxicity.

—All hazardous materials used by the Navy is required to be correctly labeled.

—In compliance with the Occupational Safety and Health Administration (OSHA). a fire resistant hydraulic fluid must be used when filling the reservoir of a hydraulic power rig.

—Dispose of solvent-soaked rags in a container designed for flammable disposal. Wear rubber protective gloves when handling solvents and be sure that ventilation is adequate.

—Do not allow eating, drinking, or smoking in the area where solvents are being used. Any chemicals or solvents should be handled with caution.

—Cutting and grinding of reinforced plastic laminates generate a fine dust that irritates the skin and eyes. Inhalation of the dust should be avoided.

—Keep chemical containers clearly labeled and tightly covered when they are not in use. When mixing a polyester resin, never mix the catalyst and accelerator directly together or an explosion may result. Always mix chemicals according to instructions.

—Many solvents give off toxic vapors and are dangerous upon contact with the skin. Wear respirators and rubber gloves, as appropriate, when handling solvents and ensure that the working area is well ventilated.

—Do not use solvents and degreasers of the halogen family (for example, freon and trichloroethane) near the cutting operation, because light from the arc can break them down into toxic components (phosgene gas).

—If clothing becomes contaminated, remove it and wash it thoroughly before reuse.

—When working in confined spaces, be sure there is adequate ventilation. Where such ventilation cannot be provided, organic respirators are required for protection against vapors.

—Always wash exposed skin areas thoroughly when you are finished working.

WELDING HAZARDS AND PRECAUTIONS

As an HT, one of your main jobs will be welding. You must use extreme care when welding. Safety must always be practiced by people working around or with arc welding equipment. Welding performed with proper safety equipment presents no great safety hazards. You should learn the correct procedures for arc welding in order that the hazards that exist may be properly observed and eliminated, and, if possible, injury avoided.

The chief hazards to be avoided in arc welding are as follows:

- Radiation from the arc, in the form of ultraviolet and infrared rays
- Flying sparks and globules of molten metal
- Electric shock
- Metal fumes
- Burns

Radiation from the arc presents some dangers. Eyes must be protected from radiation from the arc by use of an arc welding helmet or face shield with approved lenses.

Your face, hands, arms, and other skin surfaces must be covered to prevent exposure to the radiation. Gloves should be worn and other parts of the body covered by clothing of sufficient weight to shut out the rays of the arc. Without proper clothing, burns comparable to sunburn will result.

When possible, all arc welding operations should be shielded so that no one may accidentally look directly at the arc or have it shine or reflect into their eyes. An arc “flash” may cause a person to be temporarily blinded, by causing the person to see a white spot similar to a photographer's flash. The severity of an arc flash and the time it will take to recover varies with the length of time a person was exposed to the arc. A long exposure has been known to cause permanent damage to the retina of the eye. If someone is severely "flashed," special treatment should be administered at once by medical personnel.

Arc welding is usually accompanied by flying sparks, which present a hazard if they strike unprotected skin, lodge on flammable clothing, or hit any other flammable material. When arc welding, you should wear suitable weight clothing and cuffless trousers. Cover your pockets so they will not collect sparks, and remove any flammable materials, such as matches, plastic combs, or gas lighters. You should also ensure that you wear the proper foot protection. High top boots or boondockers with steel toes should be worn.

Hot metal will cause severe bums and should never be handled with bare hands until it has cooled naturally or has been quenched in the quenching tank. Therefore, you should use leather gloves with tight fitting cuffs that fit over the sleeves of the jacket. Many welders wear a full set of leathers that consists of the following:

- Jacket or set of sleeves
- Gauntlet gloves
- Leggings
- Spats
- Apron
- Welders hat liner

Following is a list of other safety precautions that you should keep in mind when performing welding operations:

—The possibility of dangerous electric shock can be avoided by using insulated electrode holders and wearing dry leathers and gloves. When possible, avoid using arc welding equipment in wet or damp areas. ARC WELDING SHOULD NEVER BE DONE IN AN AREA THAT IS NOT WELL VENTILATED.

—Use a welding helmet with a No. 10 or No. 12 shade along with good quality work clothing and gauntlet-type gloves. Wear ear protection when sound-pressure levels exceed 84 dB(A).

—In gas welding, the high temperatures of the welding flame and the sparks created by the welding process will burn skin. Gas welding can also cause radiation burns due to infrared rays emitted by the red hot material. Flame-resistant or flame-retardant clothing must be worn and the hair protected at all times.

—Fluxes used in certain welding and brazing processes produce vapors that are irritating to the eyes, nose, throat, and lungs. Oxides produced by these volatile elements are very poisonous. Therefore, welding must be performed in a well-ventilated area and approved safety goggles must always be worn. The darkest shade of the goggles that still show a clear outline of the work without producing eyestrain are recommended. Sun glasses are <u>not ad</u>equate.

—Do not smoke or work near hot surfaces or open flames.

SOLDERING AND BRAZING SAFETY PRACTICES

Soldering or brazing with or on alloys containing cadmium or beryllium can be extremely hazardous. Fumes from cadmium or beryllium compounds are extremely toxic. In fact, several deaths have been reported from inhaling cadmium oxide fumes.

Skin contact with cadmium and beryllium should also be avoided. An expert in industrial hygiene should be consulted whenever cadmium or beryllium compounds are to be used or when repairs are to be made on parts containing the metals.

Fluxes containing fluoride compounds are also toxic. Good ventilation is essential when soldering or brazing and the operator must always observe good safety practices.

A common hazard when soldering is exposure of the skin, eyes, and clothing to acid fluxes. You should observe the following safety precautions when soldering or brazing:

—Always work in a way that flux will not be spilled on the skin or clothing.

—Always wear chemical splashproof goggles, rubber gloves, and long sleeves when using cleaning solutions, pickling solutions, or acids.

—If at any time you are exposed to any chemical solutions, acids, or fluxes, wash the affected area at once, and seek medical attention immediately.

—Remember, heating soldering coppers sometimes presents a fire hazard if an open flame is used. Be sure all flammable material is removed or kept away from the heating flames.

—Make sure there are no flammable vapors present, such as gasoline, acetylene, or other flammable gases, where the hot work is to be performed.

—No job should ever be started until all safety precautions have been taken, and the fire marshal notified, if applicable.

CUTTING HAZARDS AND PRECAUTIONS

Another part of your job will involve cutting operations such as oxyacetylene cutting and plasma arc cutting. Observe the following safety precautions when performing any cutting operation:

—Never place hands or fingers between the metal plate and the bed. Never place hands under the holddowns or knife. Ensure that all personnel are clear from the piece being cut.

—Ensure that the plate is supported so that injuries to personnel can be avoided if the cut end of the metal falls away.

—When using oxyacetylene cutting equipment, ensure that the work area is gas-free. This is particularly important when working in bilges and other spaces where dangerous vapors may collect.

—The high-pressure oxygen stream used in cutting with an oxyacetylene torch can throw molten metal for a distance of 50 to 60 feet. Always post a fire watch to protect the surrounding areas and personnel.

—When using oxyacetylene cutting equipment, ensure that any interfering system has been removed and tagged out, if necessary.

—Install all covers, insulators, and handles before attempting to operate the plasma arc cutting equipment.

—When using plasma arc cutting equipment, open all primary disconnect switches before charging any electrical connections.

FIRST AID

You must always observe safety precautions when working on equipment or operating machinery. Because of the danger of electric shock from equipment and operating machinery, the possibility of receiving burns from welding, and the possibility of a body part being cut when performing cutting operations, it is important that you know and be able to perform the proper action when a mishap occurs. The following paragraphs will briefly describe some of first-aid techniques that you should be familiar with.

RESUSCITATION

Methods of resuscitating or reviving an electrical shock victim include artificial ventilation (to reestablish breathing) and cardiopulmonary resuscitation (to reestablish heartbeat and blood circulation).

Artificial Ventilation

A person who has stopped breathing is not necessarily dead, but is in immediate critical danger. Life depends on oxygen that is breathed into the lungs and then carried by the blood to every body cell. Since body cells cannot store oxygen, and since the blood can hold only a limited amount (and only for a short time), death will surely result from continued lack of breathing.

The heart may continue to beat and the blood may still be circulated to the body cells for some time after breathing has stopped. Since the blood will, for a short time, contain a small supply of oxygen, the body cells will not die immediately. Thus, for a very few minutes, there is some chance that the person's life may be saved. A person who has stopped breathing but who is still alive is said to be in a state of respiratory failure. The first-aid treatment for respiratory failure is called artificial ventilation/respiration.

The purpose of artificial ventilation is to provide a method of air exchange until natural breathing is reestablished. Artificial ventilation should be given only when natural breathing has stopped; it must NOT be given to any person who is still breathing. Do not assume that breathing has stopped merely because a person is unconscious or because a person has been rescued from an electrical shock Remember, DO NOT GIVE ARTIFICIAL VENTILATION TO A PERSON WHO IS BREATHING NATURALLY. There are two methods of administering artificial ventilation: mouth-to-mouth and mouth-to-nose.

For additional information on performing artificial ventilation, refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

Cardiopulmonary Resuscitation

When there is a complete stoppage of heart function, the victim has suffered a cardiac arrest. The signs include the absence of a pulse, because the heart is not beating, and the absence of breathing. In this situation, the immediate administration of cardiopulmonary resuscitation (CPR) by a rescuer using correct procedures greatly increases the chances of a victim's survival.

CPR consists of external heart compression and artificial ventilation. The compressions are performed by pressing the chest with the heel of your hands, and the lungs are ventilated either by mouth-to-mouth or mouth-to-nose techniques. To be effective, CPR must be started within 4 minutes of the onset of cardiac arrest.

CAUTION

CPR should not be attempted by a rescuer who has not been properly trained. Improperly done, CPR can cause serious damage to a victim. Therefore, CPR is **NEVER** practiced on a healthy individual. For training purposes, a training aid is used instead. To learn CPR, you should take an approved course from a qualified CPR instructor.

For additional information on administering CPR, refer to *Standard First Aid Training Course*, NAVEDTRA 10081-D.

WOUNDS

A wound, or breaking of the skin, is another problem that could be the result of an electrical shock. You could accidentally suffer an electrical shock, which could cause a loss of balance. This could result in a minor or serious injury. Because you could be in a critical situation to save someone's life, or even your own, you should know the basics of first aid.

Wounds are classified according to their general condition, size, location, how the skin or tissue is broken, and the agent that caused the wound.

When you consider the manner in which the skin or tissue is broken, there are four general kinds of wounds: abrasions, incisions, lacerations, and punctures.

Abrasions

Abrasions are made when the skin is rubbed or scraped off. Rope bums, floor burns, and skinned knees or elbows are common examples of abrasions. There is usually minimal bleeding or oozing of clear fluid.

Incisions

Incisions, commonly called cuts, are wounds made with a sharp instrument, such as a knife, razor, or broken glass. Incisions tend to bleed very freely because the blood vessels are cut straight across.

Lacerations

Lacerations are wounds that are torn, rather than cut. They have ragged, irregular edges and masses of torn tissue underneath. These wounds are usually made by blunt forces, rather than sharp objects. They are often complicated by crushing of the tissues as well.

Punctures

Punctures are caused by objects that penetrate some distance into the tissues while leaving a relatively small surface opening. As a rule, small punctures do not bleed freely; however, large puncture wounds may cause severe internal bleeding.

A puncture wound can be classified as penetrating or perforating. A perforation differs from a penetration in that it has an exit as well as an entrance site.

For additional information on the treatment of wounds refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

BLEEDING

The first-aid methods that are used to stop serious bleeding depend upon the application of pressure. Pressure may be applied in three ways: (1) directly to the wound, (2) at key pressure points throughout the body, and (3) with a tourniquet.

Direct Pressure

You should try the direct-pressure method first to control bleeding. Place a sterile first-aid dressing, when available, directly over the wound. Tie the knot only tight enough to stop the bleeding, and firmly fasten it in position with a bandage. In the absence of sterile dressings, use a compress made with a clean rag, handkerchief, or towel to apply direct pressure to the wound, as in figure 1-2. If the bleeding does not stop, firmly secure another dressing over the first dressing, or apply direct pressure with your hand or fingers over the dressing. Under no circumstances is a dressing to be removed once it is applied.

Pressure Points

If the direct-pressure method does not stop the bleeding, use the pressure point nearest the wound, as shown in figure 1-3. Bleeding from a cut artery or vein may often be controlled by applying pressure to the appropriate pressure point. A pressure point is a place where the main artery to the injured part lies near the skin surface and over a bone. Pressure at such a point is applied with the fingers or with the hand; no first-aid materials are required. Pressure points should be used with caution, as they may cause damage to the limb as a result of an inadequate flow of blood. When the use of pressure points is necessary, do not substitute them for direct pressure; use both.

Use of a Tourniquet

A tourniquet is a constricting band that is used to cut off the supply of blood to an injured limb. It cannot be used to control bleeding from the head, neck, or body, since its use in these locations would result in greater injury or death. A tourniquet should be used on an injured limb only as a last resort for severe, life-threatening hemorrhaging that cannot be controlled by any other method. A tourniquet must be applied ABOVE the wound—that is, towards the trunk—and it must be applied as close to the wound as practicable.

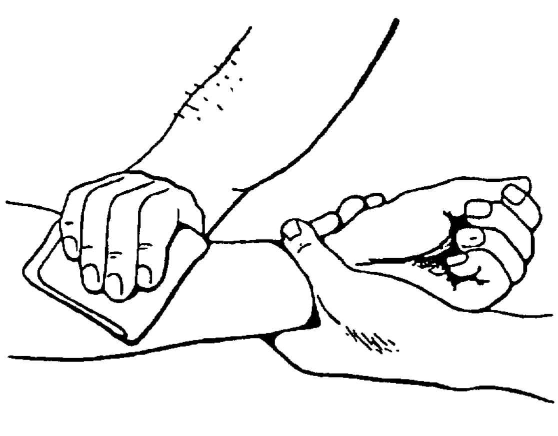


Figure 1-2.—Direct pressure.

Any long, flat material can be used as a band for a tourniquet—belts, stockings, flat strips of rubber, or a neckerchief. Only tighten the tourniquet enough to stop the flow of blood. Use a marker, skin pencil, crayon, or blood, and mark a large T on the victim's forehead.

WARNING

Remember, a tourniquet is only used as a last resort to control bleeding that cannot be controlled by other means. Tourniquets should be removed as soon as possible by medical personnel only.

BURNS

The causes of burns are generally classified as thermal, electrical, chemical, or radiation. Whatever the cause, shock always results if the burns are extensive.

Thermal burns are caused by exposure to intense heat, such as that generated by fire, bomb flash, sunlight, hot liquids, hot solids, and hot gases. Their care depends upon the severity of the bum and the percentage of the body area involved.

Electrical burns are caused by electric current passing through tissues or the superficial wound caused by electrical flash. They may be far more serious than they first appear. The entrance wound may be small; but as electricity penetrates the skin, it burns a large area below the surface. Usually there are two external burn areas: one where the current enters the body, and another where it leaves.

Chemical burns for the most part are not caused by heat, but by direct chemical destruction of body tissues. When acids, alkalies, or other chemicals come in contact with the skin or other body membranes, they can cause injuries that are generally referred to as chemical burns. The areas most often affected are the extremities, mouth, and eyes. Alkali burns are usually

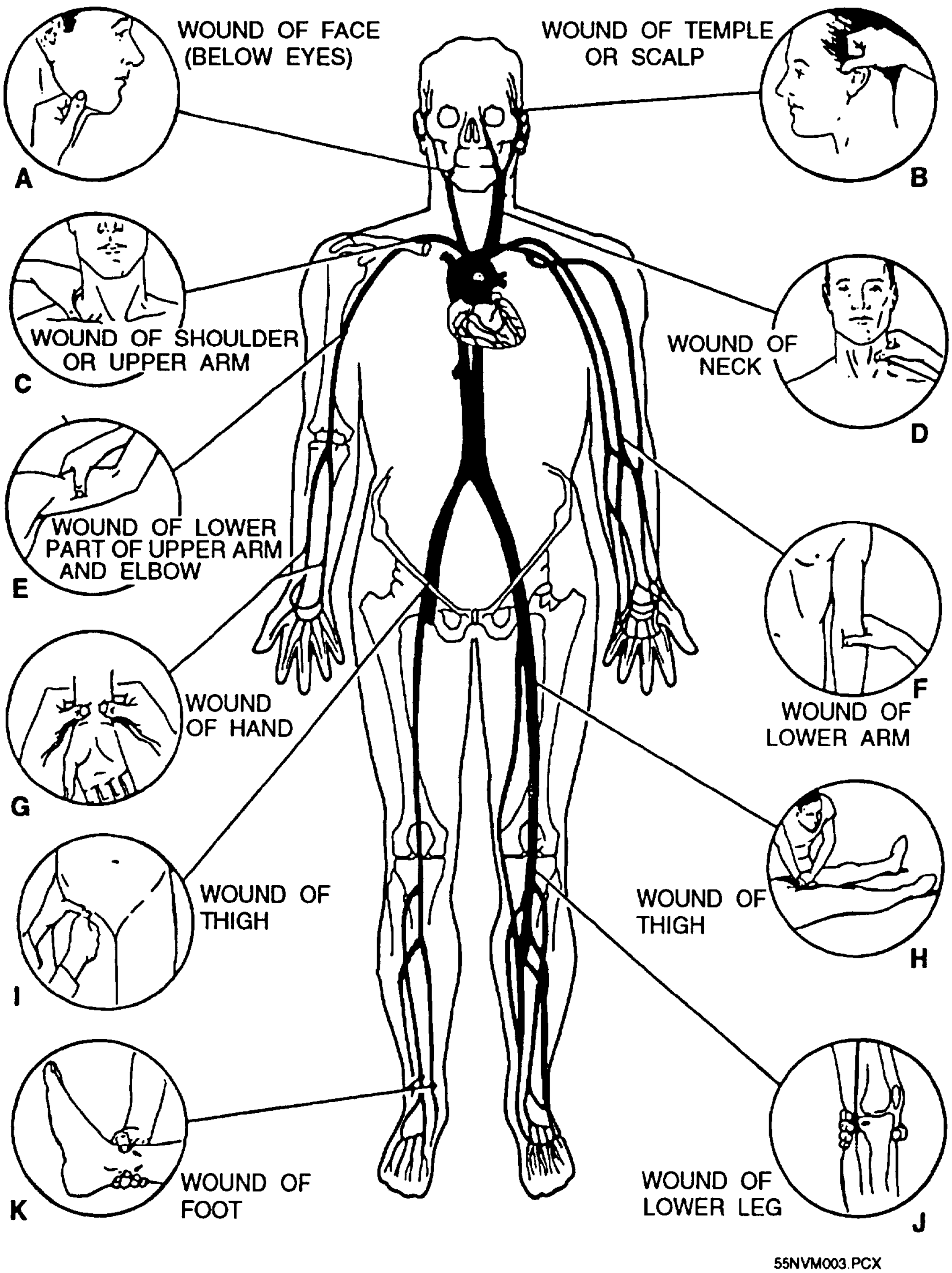


Figure 1-3.—Pressure points for control of bleeding.

more serious than acid burns, because they penetrate deeper and burn longer. When chemical burns occur, emergency measures must be carried out immediately. Do not wait for the arrival of medical personnel.

Radiation burns are the result of prolonged exposure to the ultraviolet radiation. First- and second-degree burns may develop. Treatment is essentially the same as that for thermal bums.

Classification of Burns

Burns are classified in several ways: by the extent of the burned surface, by the depth of the burn, and by the cause of the burn. The extent of the body surface burned is the most important factor in determining the seriousness of the burn and plays the greatest role in the victim's chances of survival.

Burns may also be classified as first, second, or third degree, based on the depth of skin damage (fig. 1-4). First-degree burns are mildest. Symptoms are reddening of the skin and mild pain. Second-degree burns are more serious. Symptoms include blistering of the skin, severe pain, some dehydration, and possible shock. Third-degree burns are worst of all. The skin is destroyed and possibly the muscle tissue and bone in severe cases. The skin may be charred or it may be white or lifeless. This is the most serious type of burn, as it produces a deeper state of shock and will cause more permanent damage. It is usually not as painful as a second-degree burn because the sensory nerve endings have been destroyed.

Emergency Treatment of Burns

The degree of the burn, as well as the skin area involved, determines the procedures used in the treatment of burns. Large skin areas require a different approach than small areas. To estimate the amount of skin area affected, the extent of burned surface, the "Rule of Nines" (fig. 1-5) is used. These figures aid in determining the correct treatment for the burned person.

As a guideline, consider that burns exceeding 15 percent of the body surface will cause shock; burns exceeding 20 percent of the body surface endanger life; and bums covering more than 30 percent of the body surface are usually fatal if adequate medical treatment is not received.

Minor burns, such as first-degree burns over less than 20 percent of the body area and small second-degree bums, do not usually require immediate medical attention unless they involve the facial area.

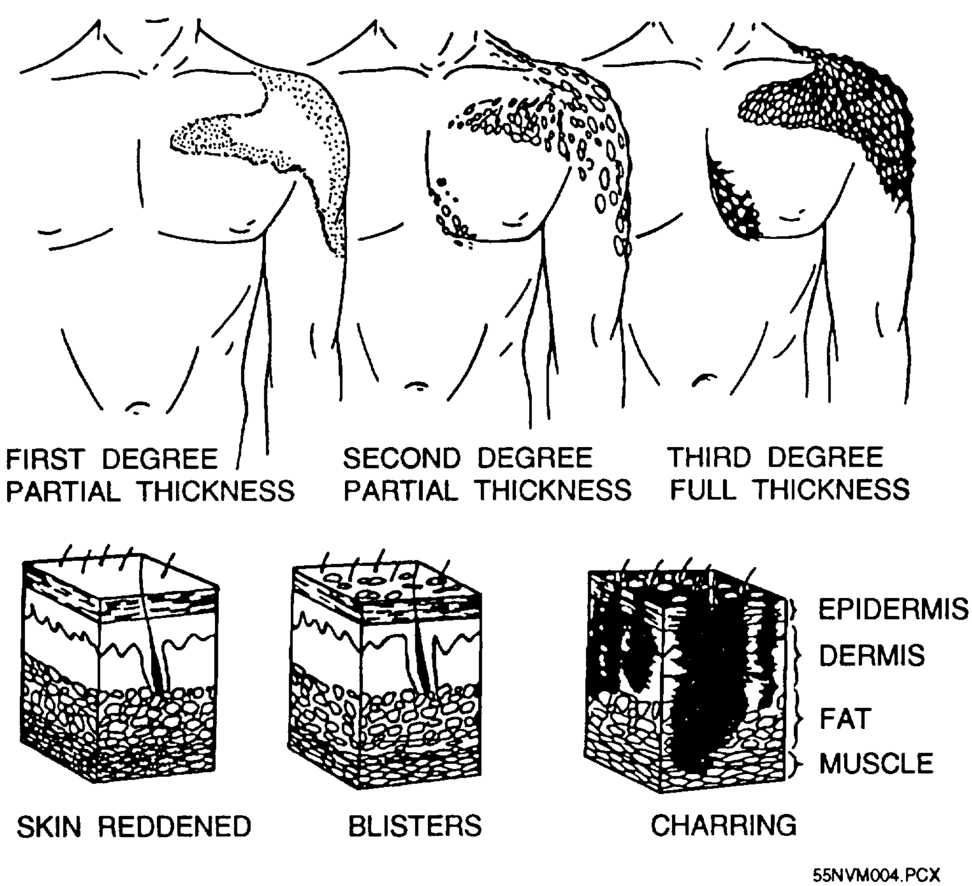


Figure 1-4.—First-, second-, and third-degree burns.

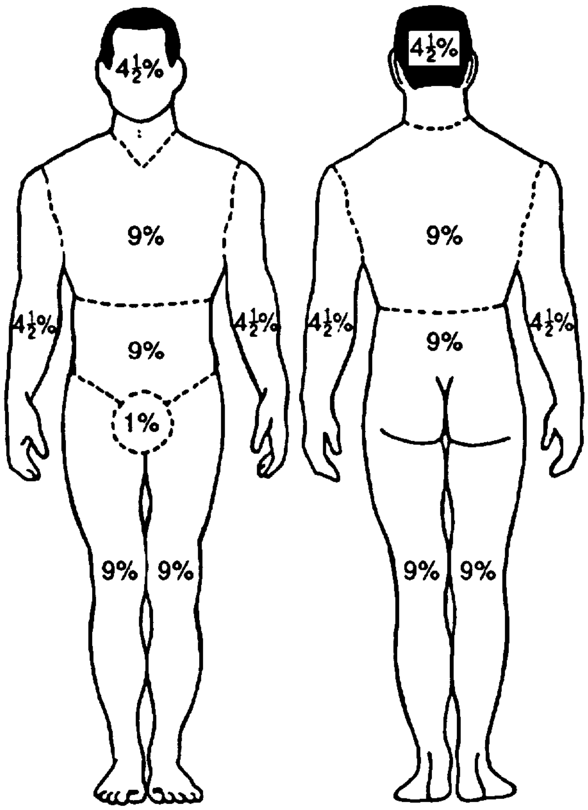


Figure 1-5.—Rule of Nines.

THERMAL BURNS.—When emergency treatment of the more serious thermal burns is required, first check the victim for respiratory distress. Burns around the face or exposure to hot gases or smoke may cause the airway to swell shut. If facial burns are present, place the victim in a sitting position to further ease breathing. Transport the victim with facial burns to a medical facility as soon as possible.

Remove all jewelry and similar articles, even from unburned areas, since severe swelling may develop rapidly.

To relieve pain initially, apply cold compresses to the affected area or submerge it in cold water. Cold water not only minimizes pain, but also reduces the burning effects in the deep layers of the skin. Gently pat dry the area with a lint-free cloth or gauze.

Cover the burned area with a sterile dressing, clean sheet, or unused plastic bag. Coverings such as blankets or other materials with a rough texture should not be used because lint may contaminate and further irritate the injured tissue. When hands and feet are burned, dressings must be applied between the fingers and toes to prevent skin surfaces from sticking to each other.

Do not attempt to break blisters, and do not remove shreds of tissue or adhered particles of charred clothing. Never apply greasy substances (butter, lard, or petroleum jelly), antiseptic preparations, or ointments.

If the victim is conscious and not vomiting, prepare a weak solution of salt (1 teaspoon) and baking soda (l/2 teaspoon) in a quart of warm water. Allow the victim to sip the drink slowly. Aspirin is also effective for the relief of pain.

Treat for shock. Maintain the victim’s body heat, but do not allow the victim to become overheated. If the victim’s hands, feet, or legs are burned, elevate them higher than the heart.

ELECTRICAL BURNS.—In electrical shock cases, burns may have to be ignored temporarily while the patient is being revived. After the patient is revived, lightly cover the burn with a dry, preferably sterile, dressing, treat for shock, and transport the victim to a medical facility.

CHEMICAL BURNS.—To treat most chemical burns, you should begin flushing the area immediately with large amounts of water. Do not apply the water too forcefully. If necessary, remove the victim’s clothing, including shoes and socks, while flushing.

Water should not be used for alkali burns caused by dry lime unless large amounts of water are available for rapid and complete flushing. When water and lime are mixed they create a very corrosive substance. Dry lime should be brushed from the skin and clothing.

Isopropyl or rubbing alcohol should be used to treat acid burns caused by phenol (carbolic acid). Phenol is not water soluble; therefore, water should only be used after first washing with alcohol or if alcohol is not available.

For chemical burns of the eye, flush immediately with large amounts of fresh, clean water. Acid bums should be flushed at least 15 minutes, and alkali burns for as long as 20 minutes. If the victim cannot open the eyes, hold the eyelids apart so water can flow across the eyes. After thorough irrigation, loosely cover both eyes with a clean dressing.

The after care for all chemical burns is similar to that for thermal burns. Cover the affected area and get the victim to a medical facility as soon as possible.

RADIATION BURNS.—For first- and second-degree sunburns, treatment is essentially the same as for thermal burns. If the bum is not serious, and the victim does not need medical attention, apply commercially prepared sunburn lotions and ointments.

For further information on the treatment of burns, refer to *Standard First Aid Training Course,* NAVEDTRA 10081-D.

HEARING CONSERVATION AND NOISE ABATEMENT

Historically, hearing loss has been recognized as an occupational hazard related to certain trades, such as blacksmithing and boilermaking. Modern technology has extended the risk to many other activities: using presses, forging hammers, grinders, saws, internal combustion engines, or similar high-speed, high-energy processes. Exposure to high-intensity noise occurs as a result of either impact noise, such as gunfire or rocket fire, or from continuous noise, such as jet or propeller aircraft, marine engines, and machinery.

Hearing loss has been and continues to be a source of concern within the Navy, both ashore and afloat. Hearing loss attributed to such occupational exposure to hazardous noise, the high cost of related compensation claims, and the resulting drop in productivity and efficiency have highlighted a significant problem that requires considerable attention. The goal of the Navy Hearing Conservation Program is to prevent occupational noise-related hearing loss among Navy personnel. The program includes the following elements:

- Work environments will be surveyed to identify potentially hazardous noise levels and personnel at risk.
- Environments that contain, or equipment that produces, potentially hazardous noise should be modified to reduce the noise to acceptable levels whenever technologically and economically feasible. When this is not feasible, administrative control (for example, stay times) and/or hearing protection devices should be used.
- Periodic hearing testing must be conducted to monitor the effectiveness of the program.
- Navy personnel must be educated on the Hearing Conservation Program to ensure the overall success of the program.

IDENTIFYING AND LABELING OF NOISE AREAS AND EQUIPMENT

Hazardous noise areas and equipment must be so designated and appropriately labeled. Areas and equipment that produce continuous and intermittent sound levels greater than 84 dB(A) or impact or impulse levels of 140 db peak are considered hazardous.

An industrial hygienist with a noise level meter will identify the noise hazardous areas. Noise hazardous areas will be labeled using a hazardous noise warning decal, NAVMED 6260/2 (fig. 1-6). This decal will be posted at all accesses. Hazardous noise labels, NAVMED 6260/2A, are the approved labels for marking portable and installed equipment.

All personnel that are required to work in designated noise hazardous areas or with equipment that produces sound levels greater than 84 db(A) or 140 db sound/pressure levels are entered in the hearing conservation program.

55NVM006.PCX

Figure 1-6.—Hazardous noise warning decal.

You will find further information on hearing conservation in OPNAVINST 5100.23C, *Navy Occupational Safety and Health (NAVOSH) Program Manual*, and OPNAVINST 5100.19B, *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat.*

MONITORING HEARING TESTS

All naval personnel receive an initial or reference audiogram shortly after entering the service. Thereafter, a hearing test will be conducted at least annually while you are assigned to a noise hazardous environment. Hearing tests will also be conducted when there are individual complaints of difficulties in understanding conversational speech or a sensation of ringing in the ears. The annual audiograms will be compared to the reference (baseline) to determine if a hearing threshold shift has occurred.

HEARING PROTECTIVE DEVICES

Hearing protective devices should be worn by all personnel when they must enter or work in an area where noise levels are greater than 84 dB(A). A combination of insert earplugs and circumaural muffs, which provides double protection, should be worn in all areas where noise levels exceed 104 db(A). Personnel hearing protective devices should be issued to suit each situation.

HEAT STRESS CONTROL PROGRAM

Heat stress may occur in many work spaces throughout the Navy. Heat stress is any combination of air temperature, thermal radiation, humidity, airflow, and workload that may stress the human body as it attempts to regulate its temperature. Heat stress becomes excessive when your body's capability to adjust is exceeded. This results in an increase in body core temperature. This condition can readily produce fatigue, severe headaches, nausea, and poor physical and/or mental performance. Prolonged exposure to heat stress could cause heatstroke or heat exhaustion and severe impairment of the body's temperature-regulating ability. Heatstroke can be life-threatening if not immediately and properly treated. Recognizing personnel with heat stress symptoms and getting them prompt medical attention is an all-hands responsibility.

As a petty officer or chief petty officer, your role in the command's Heat Stress Program involves adhering to the command's program and reporting heat stress conditions as they occur.

Primary causes that increase heat stress conditions are as follows:

- Excessive steam and water leaks
- Boiler air casing leaks
- Missing or deteriorated lagging on steam piping, valves, and machinery
- Clogged ventilation systems or an inoperative fan motor
- Operating in hot or humid climates

To determine heat stress conditions, permanently mounted dry-bulb thermometers are installed at key watch and work stations. Their readings should be recorded at least once a watch period. When a reading exceeds 100°F (38°C), a heat stress survey must be ordered to determine the safe stay time for personnel.

A heat stress survey is taken with a wet-bulb globe temperature (WBGT) meter. You should compare these readings to the physiological heat exposure limits (PHEL) chart. After comparing the readings with the PHEL chart, you will be able to determine the safe stay time for personnel.

As a petty officer or chief petty officer, you should have a working knowledge of all aspects of the Heat Stress Program so you can recognize heat stress conditions if they occur and take the proper corrective actions.

Further information and guidance of the Navy Heat Stress Program is contained in OPNAVINST 5100.19B, *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat.*

SUMMARY

In this chapter, we have described your responsibilities regarding general and equipment safety, both as an individual and as a petty officer and chief petty officer.

We have identified various sources of safety information that are available to you, and provided you with general and specific safety precautions to assist you in your day-to-day work as a HT.

We have discussed the danger of electrical shock, how to rescue a victim from electrical shock, and the procedures for giving first aid to the victim. We have also briefly discussed the Navy's Hearing Conservation, Noise Abatement, and Heat Stress programs.

Think safety! Always remain alert to possible danger.

CHAPTER 2

SHIP REPAIR

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Describe the different types of repairs and alterations on naval ships.*
- *Describe the basic organization of the Repair Department at intermediate maintenance activities (IMAs).*
- *Describe the basic duties of personnel assigned to IMAs.*
- *Define the Quality Assurance Program.*
- *Explain the quality assurance organization.*
- *Describe the basic requirements for the Quality Assurance Program and its link to maintenance.*
- *Identify the basic work center organization and the role of the work center supervisor.*
- *Be able to make a basic time line and identify its component parts.*
- *Identify the structural parts of a ship and discuss the purpose of the parts.*

INTRODUCTION

Ship's can operate only a certain length of time without repairs. To keep a ship in prime condition, constant attention should be given to material upkeep and definite intervals of time must be allotted for general overhaul and repair.

Even when regular maintenance procedures are carefully followed, accidents and derangements may necessitate emergency repair work. Defects and deficiencies that can be corrected by ship's force should be dealt with as soon as possible. When repairs are beyond the capacity of ship's force to accomplish, aid must be obtained from a repair activity afloat or ashore.

Ship repair is the basic duty of the HT whether ashore or afloat. The majority of personnel in the HT rate are assigned to billets at IMAs performing the basic functions of ship repair. Therefore, you can expect that sometime in your career you will be assigned to an IMA. It is important that you have a basic idea of the organization and role that an IMA plays in ship's maintenance.

Quality assurance (QA) also impacts every maintenance procedure performed by ship's personnel or maintenance personnel assigned to IMAs. QA has become a prime consideration when performing maintenance on any ship's system. You will use the QA guidelines as established by your command on a daily basis.

This chapter covers basic repair, alteration, and maintenance procedures for naval ships. It also covers the the IMA organization, the QA program, the the basic structural parts of a ship.

REPAIRS AND ALTERATIONS

Corrective maintenance and repairs to ships may be divided into the general categories of (1) repairs, (2) alterations equivalent to repairs, and (3) alterations. It is important that you have an understanding of the different types of repairs and the difference between a repair and an alteration.

REPAIRS

A repair is defined as the work necessary to restore a ship or an article to serviceable condition without a change in design, material, or in the number, location, or relationship of parts. Repairs may be done by ship's force, tenders, ship repair facilities, or by naval or civilian shipyards.

ALTERATIONS EQUIVALENTTO REPAIRS

Before we discuss alterations, we need to understand that NAVSEASYSCOM may determine that some work requested as an alteration may be better defined as an alteration equivalent to repair. In that case, NAVSEASYSCOM forwards the request to the appropriate type commander (TYCOM) to be handled as a repair. An alteration is considered to be an alteration equivalent to a repair if it meets one or more of the following conditions:

- Materials that have previously been approved for similar use and that are available from standard stock are substituted without other change in design.
- Worn out or damaged parts, assemblies, or equipment requiring renewal will be replaced by those of a later and more efficient design that have been previously approved.
- Parts that require repair or replacement to improve reliability of the parts and of the unit will be strengthened, provided no other change in design is involved.
- Equipment that requires no significant changes in design or functioning but is considered essential to prevent recurrence of unsatisfactory conditions will be given minor modifications.

ALTERATIONS

This section deals only with ship alterations (SHIPALTs) as opposed to ordnance alterations (ORDALTs). These are alterations to the hull, machinery, equipment, or fittings that include a change in design, materials, number, location, or relationship of the component parts. This is true regardless of whether the SHIPALT is undertaken separately from, incidental to, or in conjunction with repairs. NAVSEASYSCOM, the forces afloat, or CNO may originate requests for SHIPALTs.

NAVSEASYSCOM Responsibilities

One of NAVSEASYSCOM's prime responsibilities for ship maintenance is to administer SHIPALTs under its technical control. NAVSEASYSCOM keeps informed of technical developments in its day-to-day relations with the forces afloat, the naval shipyards, private industry, and research centers. NAVSEASYSCOM may determine that a particular ship or class of ships should be altered to bring them to a more efficient and modem state of readiness. These alterations may be changes to the hull, such as changes to bulkheads that will strengthen bulkheads or changes to deck arrangements that will provide space for installation of machinery; changes to machinery or substitution of newer and more efficient machinery; changes to equipment, such as the replacement of an item with a more efficient type; or changes in design. NAVSEASYSCOM relies on input from the fleet and unit commanders for the need of new SHIPALTs.

Commanding Officer Responsibilities

When the commanding officer of a ship believes a SHIPALT is necessary, he/she sends a request to NAVSEASYSCOM via the administrative chain of command (3-M systems). Copies of the request are sent to all ships of the type within the fleet for comments as to the value of the SHIPALT for other ships of the same type or class.

INSURV Responsibilities

The reports of the Board of Inspection and Survey (INSURV) are another source of recommended SHIPALTs. When the board completes each material inspection of a ship, it furnishes a list of recommended repairs, alterations, and design changes that it feels should be made. NAVSEASYSCOM normally will not act on those recommendations until the commanding officer of the inspected ship requests the changes, and the TYCOM approves.

TY COM Responsibilities

TYCOMs (or other administrative commanders) must endorse all requests for SHIPALTs addressed to NAVSEASYSCOM. Their endorsements must include recommendations for or against approval, classification, and applicability to other ships of the type. Copies of the basic request and endorsements are forwarded to other concerned TYCOMs with requests to comment on them for the information of NAVSEASYSCOM.

SHIPALTs

SHIPALTs fall into two broad categories: military SHIPALTS and technical SHIPALTs. If there is a question as to whether a proposed SHIPALT is military or technical, NAVSEA will forward the proposal to CNO for determination. You will most often install technical SHIPALTs.

- MILITARY SHIPALT—A military SHIPALT changes the ship's operational and military characteristics and improves the ship's operational capabilities. Only CNO can approve a military SHIPALT. An example of a military SHIPALT would be the installation of a new weapons system.

- TECHNICAL SHIPALT—A technical SHIPALT is one that improves the safety of personnel and equipment and/or improves reliability, ease of maintenance, and efficiency of equipment. A technical SHIPALT can only be approved at the NAVSEA level.

AMALGAMATED MILITARY AND TECHNICAL IMPROVEMENT PLAN

Approved military and technical SHIPALTs are ranked in order of priority on an annual basis in the Amalgamated Military and Technical Improvement Plan. The decision to install a SHIPALT is based on the priority of the alteration in the Amalgamated Military and Technical Improvement Plan, funding, ship availability, and whether material is available to complete the SHIPALT. When a decision is reached to install a SHIPALT during a given fiscal year, the alteration is entered into the Fleet Modernization Program (FMP). Approved SHIPALTs are authorized by letters issued not less than 180 days before the ship is scheduled to begin overhaul or other types of repair availabilities.

TYPES OF AVAILABILITIES

An availability is the period of time a ship is assigned to undergo maintenance or repair by a repair activity. Only the authority granting the availability can change the allotted period of time. However, a repair activity may recommend a completion date to the granting authority or request an extension of time to complete work already underway. There are several types of ship availabilities that we will define in the next paragraphs. For example, restricted and technical availabilities differ in whether the ship is or is not ready to carry out its mission.

- A RESTRICTED AVAILABILITY (RA) is used to complete specific items of work in a shipyard or SRF; the ship is NOT available to perform its mission during that time.

- A TECHNICAL AVAILABILITY (TA) is used to complete specific items of work in a shipyard or SRF; the ship IS available to perform its mission during that time.

Other types of availabilities identify the type of work to be done and where it will be done.

- A REGULAR OVERHAUL (ROH) AVAILABILITY is used to complete general repairs and alterations in a naval shipyard or other shore-based repair activity. The schedule for an ROH for a given ship varies between 2 and 5 years according to an established cycle. An overhaul can take as little as 2 months for small ships and as much as 18 months for larger ships. ROH planning begins about 18 months before the scheduled overhaul.

- A VOYAGE REPAIR AVAILABILITY is used for repairs while the ship is underway. These are emergency repairs that are necessary if the ship is to continue on its mission, and they can be done without changing the ship's operating schedule. These repairs will be done by the ship's force if possible, or if necessary, by personnel from an IMA, SIMA, or SRF.

- A REGULAR IMA AVAILABILITY is used for general repairs and authorized alterations that are not emergencies. This work is usually beyond the capability of the ship's force and is normally scheduled in advance.

- An EMERGENCY IMA AVAILABILITY is used to repair specific casualties and generally takes first priority at a fleet IMA.

- A CONCURRENT AVAILABILITY is used for ship-to-shop work by the shore IMA, tender, or repair ship. These availabilities are usually scheduled to take place just before a regular shipyard overhaul or restricted availability.

REPAIR ACTIVITIES

Repair activities are set up to do work the ship's forces cannot handle. Repair activities are IMAs, XMAS, SRFs, and shipyards. The type of work and available funds govern the assignment of repair work to repair activities. The office of the Supervisor of Shipbuilding (SUPSHIP) places and administers contracts for the repair or overhaul of naval ships at private shipyards, and contracts for civilian work to be done in IMAs, SIMAs, and SRFs.

Fleet and type commanders usually call on IMAs or SIMAs to handle repairs and alterations under regular, emergency, and concurrent availabilities. If work is beyond an IMAs or SIMA's capability, other activities ashore, such as an SRF or a shipyard, will do it. In the following paragraphs, we will discuss the work done by the ship's forces and IMAs. In addition, we will examine the organization, duties of personnel, and QA procedures used in an IMA.

SHIP'S FORCE MAINTENANCE AND REPAIRS

Each ship's force should be able to make its own normal repairs. To do that, each ship should have the necessary materials, repair parts, tools, and equipment. The most competent and experienced personnel should supervise these repairs. If ship's personnel are not familiar with the needed repairs and tests, or cannot handle a problem for any reason, the CO should request an IMA or shipyard availability. Personnel who are not familiar with these repairs and tests should take advantage of an IMA or SIMA availability to observe how such work is undertaken. If the ship's force needs technical assistance, they should request it from the local TYCOM's maintenance representatives.

The ship's force should follow a regular schedule of preventive maintenance to be sure that equipment and machinery are always ready for service. This includes cleaning, inspections, operations, and tests to ensure trouble-free operation and to detect faults before they become major problems. Some inspections and tests are quite simple; others require planning so they can be done during upkeep or overhaul periods.

INTERMEDIATE MAINTENANCE ACTIVITIES

A ship's effectiveness depends on its ability to function well; therefore, ship's personnel and IMAs have a dual responsibility to keep it in prime condition. That means that the ship's crew routinely handles normal maintenance and repairs and IMAs handle those repairs that a ship's crew cannot handle.

This section deals mostly with those jobs the ship's crew cannot handle and which are done by repair facilities. We will discuss what happens at an IMA or SIMA. The following is a list of the different types of repair facilities:

- An intermediate maintenance activity (IMA) is a repair ship (AR), destroyer tender (AD), or submarine tender (AS).

- A shore intermediate maintenance activity (SIMA) is based on land and offers services similar to those of an IMA.

- A ship repair facility (SRF) is similar to a naval shipyard but on a smaller scale and is usually based outside the continental United States.

- A shipyard is any full-service naval shipyard or a civilian shipyard contracted for Navy work.

While each type of IMA has its special purpose, all of them have many characteristics and facilities in common that make them suitable for general repair work on most ships. Repair ships and tenders perform battle and operational damage repairs on ships in the forward areas, and they provide logistic support to ships of the fleet. They also can provide other services, including medical and dental treatment, for the ships they tend. Their shops can handle hull, machinery, electrical, and ordnance work, and they stock parts to help them deal with most of the repairs they perform.

SIMAs are shore-based facilities that only do repair work, while other departments on a shore base handle the supply, medical, and administrative needs of the ship. Ships are assigned to IMAs with a flexible approach that considers unusual repair requirements and operational commitments, particularly for ships outside the continental United States.

IMA Availabilities

Ships are scheduled for regular IMA availabilities or upkeep periods at certain intervals of time that vary with different types of ships. There are numerous types of availabilities used by TYCOMs and they vary between the surface and submarine components. Therefore, you should always refer to the governing document associated with the command at which you are stationed. The availability periods are usually planned in advance and depend upon the quarterly deployment schedule of each ship.

A ship's commanding officer sends a request for an IMA availability with a forwarding letter to the TYCOM or his or her representative. The request must include job sequence numbers (JSNs) for work requests in the Current Ship's Maintenance Project (CSMP) and a listing of TYCOM master job catalogue work items.

A reviewing officer with TYCOM will review the request and make any necessary corrections to conform to established policies and procedures. Most of the ship's work list items will be approved, but the ship may have to furnish more detailed information on certain work requests.

The reviewing officer will forward the approved ship’s work requests to the appropriate IMA well in advance of the period of availability so the IMA repair department personnel can prepare for the work. Because you should know something about these personnel before you learn about the arrival conference, the shops, and the ship maintenance procedures, we will discuss them in the following paragraphs.

Repair Personnel

Standard Organization and Regulations of the U.S. Navy, OPNAVINST 3120.32, contains general information about the relative positions and responsibilities of IMA departments. These positions may vary between the submarine and surface components, but their responsibilities are generally the same. Also, TYCOMs issue standard ship organizations for their type that describe the organization for every routine function and most emergency conditions that can exist aboard ship. The following paragraphs explain the roles of the repair officer, the assistant repair officer, quality assurance officer, planning and estimating officer, repair division officers, diving and salvage officer, and enlisted personnel.

COMMANDING OFFICER.—The IMA's commanding officer has the overall responsibility for the daily operation and function of the IMA as a whole. The CO coordinates the activities of the IMA's departments and divisions and is responsible to the TYCOM.

REPAIR OFFICER.—The repair officer is head of the repair department on an IMA. The repair officer oversees the upkeep, operation, and maintenance of the equipment assigned to the repair department, and the training, direction, and coordination of its personnel. The repair officer keeps up with production and ensures efficient and economical operation of the production process.

ASSISTANT REPAIR OFFICER.—The assistant repair officer assumes the repair officer’s responsibilities in his/her absence and carries out the responsibilities the repair officer delegates. This officer usually handles the internal administration of the department and specifically keeps progress records on all work. In the submarine force, the assistant repair officer is called the production management assistant (PMA).

QUALITY ASSURANCE OFFICER.—The quality assurance officer (QAO) is responsible to the commanding officer for planning, monitoring, and executing the overall IMA QA program. The QAO ensures that all work done by the IMA meets all established technical and quality control requirements.

PLANNING AND ESTIMATING OFFICER.— The planning and estimating (P & E) officer is responsible to the assistant repair officer for planning and estimating all work assigned to the IMA. The P & E officer also is tasked with providing technical information for repairs, preparing detailed work packages for controlled work, and maintaining specifications, standards, process instructions, and procedures.

DIVISION OFFICERS.—The division officers (DOs) have both administrative and production responsibilities for the actual work that is done in shops under their supervision. They have administrative and production responsibility. Their administrative responsibility is in the administration of personnel in their respective divisions, including the assignment of berths and watches, and all training and training records. Their production responsibilities include oversight of all work requests and review of progress, requisitions for material, proper operation of division shops for which they are responsible, safety, and progress reports to the repair officer.

DIVING AND SALVAGE OFFICER.—The position of diving and salvage officer may be a separate assignment or a collateral duty for an officer in the repair department. In either case, the diving and salvage officer is responsible for the supervision of all diving operations, the maintenance of diving and salvage equipment, and compliance with diving instructions and precautions.

ENLISTED PERSONNEL.—Navy enlisted personnel provide the technical skills required aboard IMAs. The *Manual of Navy Enlisted Manpower and Personnel Classifcations and Occupational Standards,* NAVPERS 18068, contains detailed information on the enlisted rating structure.

Arrival Conference

An arrival conference is usually held immediately when a ship begins an IMA availability or an upkeep period. Representatives of the ship, the repair department, and the TYCOM usually attend the conference. They discuss the relative needs of the ship and the urgency of each job and approve/disapprove work requests, clarify uncertainties, and arrange for temporary services such as electricity and steam.

Work Requests

This section will briefly discuss the routing of the work request from the time the ship submits the ship's maintenance request action form (OPNAVINST 4790/2K) until you receive it to begin work.

As mentioned earlier, the ship will submit a 4790/2K to the TYCOM requesting specific maintenance work to be accomplished. The 2K is screened at the TYCOM level for completeness and to determine what type of repair facility to assign the maintenance action to. If the IMA is assigned the maintenance action, the 2K is routed to the Maintenance Document Control Office (MDCO) and the automated data processing (ADP) facility for processing. MDCO and ADP will process the 2K, entering it onto the CSMP and will issue an automated work request (AWR) (fig. 2-1) to the IMA.

When the AWR arrives at the IMA, it is screened by the RO for applicability, shop capability, urgency, and manning requirements. At this point, the AWR may be accepted or rejected by the IMA or deferred to a future IMA availability, depending on shop loading and material availability. Before the AWR is accepted, rejected, or deferred, it will be ship checked by the lead and assist work centers for applicability. If the AWR is accepted for work in the current availability, it will be checked by the P & E and QA divisions for technical and QA requirements and then issued to the shop. Remember, this is a general overview of the work request routing from the customer to the craftsman, and each IMA has different routing sequences as established by TYCOM.

Ship/IMA Work Coordination

Ship's engineering personnel must know the status of work underway during an IMA availability whether that work is being done by the ship's force or the IMA. You need this information to coordinate your own work with that being done by the ship's force. There are three basic kinds of work that require coordination: (1) equipment removed by the ship's force to be delivered to the IMA for repair, (2) equipment dismantled by the ship's crew so they can send parts to the IMA for repair (also known as ship-to-shop jobs), and (3) repairs the IMA force makes on the ship.

The IMA usually appoints a ship superintendent, normally a chief petty officer, who should always know the status of all jobs on the ship and on the IMA. The ship will also normally appoint a chief petty officer for that purpose to interface with the IMA. The person(s) in these positions are a liaison between the ship and the IMA for all work in progress and completed, and all tests required and completed. They should keep a daily running progress report of each job and should report that information daily to the ship's/IMA representative.

Repair Department

You need a general idea of the shops composing the repair department and their functions whether you are assigned to an IMA or are part of a ship's company. In this section, we will describe the shops as they are organized in the divisions on a destroyer tender (AD), which is representative of all surface IMAs. Submarine-related IMAs are organized differently but have the same capabilities.

HULL REPAIR DIVISION (R-1).—The hull repair division consists of the shipfitter shop, sheet metal shop, pipe and copper shop, weld shop, carpenter shop, diving locker, and canvas shop. As an HT, you

AWR
OPNAV 4790/2R (11-73) S/N 0107-LF-770-3005

AUTOMATED WORK REQUEST

SECTION I. IDENTIFICATION — COMP

JOB CONTROL NUMBER

1 SHIPS UIC	2 WORK CENTER	3 JOB NUMBER	4 APU AEL
Ø4669	EBØ1	Ø111	67382Ø134ØØ

A SHIPS NAME	5 EQUIPMENT NOUN NAME	13 IDENT/EQUIP SERIAL NO
USS JOHN KING	REEFER COMPRESS	

B HULL NUMBER	14 EIC	16 LOCATION COMPARTMENT	DECK	FRAME	SIDE	15 SAFETY HAZARD
DDG-3	T4Ø9	REEFER DECK	3	42	2	

18 CONFIGURATION CHANGES (SHIPALTS, ORDALTS, Field Changes, etc.)

FOR INSURV. BOARD USE: 19 '/' | 20 INSURV NUMBER | 21 SUFFIX | 22 U | 23 S | 24 P/F

SECTION II. DEFERRAL ACTION

26 DEFER DATE	27 S/F MHRS REMAINING	28 DEADLINE DATE	9 DEFER REASON	
6 1 Ø 5	A U T 0		2	LACK OF MATERIAL

SECTION III. COMPLETED ACTION

29 ACT TKN | 30 S/F MHRS | 31 COMPLETION DATE YR DAY | FOR SELECTED EQUIPMENT ONLY: 32 ACTIVE MAINT TIME | 33 TRBL ISO | 34 METER READING

SECTION IV. REMARKS/DESCRIPTION

35 REMARKS/DESCRIPTION: REEFER COMPRESSOR HAS EXCESSIVE NOISE AND VIBRATION REPAIR OR REPLACE COMPRESSOR

CONT

37 CSMP SUMMARY	46 SPECIAL PURPOSE
COMPRESSOR NOISE FIX/REPLACE	A B C D E F G H I J K L

38 FIRST CONTACT/MAINTENANCE MAN	39 SECOND CONTACT/SUPERVISOR	41 PRI	42 T/A	43 INTEGRATED PRIORITY
RYDER MM2	J. COOK ENC	2	2	

E COMMANDING OFFICER'S SIGNATURE	F TYCOM AUTHORIZATION	44 I/C SCREENING	45 TYCOM SCREENING
		2 IMA ACCOM	2 IMA ACCOM

SECTION V. SUPPLEMENTARY INFORMATION

47 S/F BLUEPRINTS TECH MANUAL, ETC	335-Ø665	Y: X / N; ON BRD Y N; Y N; ON BRD Y N
48 REPAIR ACTIVITY BLUEPRINTS PLANS TECH MANUALS, ETC		
49 PRE-ARRIVAL/ARRIVAL CONFERENCE ACTION	TYCOM-LIMIT REPAIRS TO 6ØØ M/H AND ROV MATERIAL	
50 REMARKS	REP OFF-LIMIT TO 4ØØ M/H	

SECTION VI. PLANNING

51 PERIODIC MAINT REQMNT | 52 PER | 53 YYMM ISSUED | 54 SPECIAL DATA

55 QUALITY ASSURANCE REQMNTS: a SUBSAFE | b LEVEL 1 | c NUCLEAR LEVEL 1 | d NON-DESTRUCT TEST | e NUCLEAR WORK PROCEDURES | f SUBMARINE ANTENNA ENGINEERING DIV | g SPECIAL CLEANING | h SPECIAL TESTING | i SPECIAL IDENTIFICATION | j NOISE CRITICAL | k RADIOLOGICAL CONTROLS | l OTHER CONTROLS

56 SPEC REQMNTS: a KEY EVENT | b SPECIAL INTEREST | c DRY DOCK REQUIRED | d PRE-OVERHAUL TEST REQUIRED | e POST-OVERHAUL TEST REQUIRED | f DEPARTURE REQUIRED

SECTION VII. REPAIR ACTIVITY PLANNING/SCHEDULING ACTION

LEAD/ASST WC	SCHED START	SCHED COMP	EST MHRS	K/O	TASK	ASST WC	SCHED START	SCHED COMP	EST MHRS	K/O	TASK
57 LEAD WC: 56B	58: 6151	59: 6175	60: Ø16Ø	61: Ø3	62: OVHL COMP	63	64	65	66	67	68
69 ASST WC: 51B	70: 6151	71: 6174	72: ØØØ5	73: Ø1	74: DISCON-RECON	75	76	77	78	79	80
81 ASST WC: 72A	82: 6151	83: 6173	84: ØØ2Ø	85: Ø2	86: DEL-RETURN	87	88	89	90	91	92

93 REPAIR ACT UIC	94 WORK REQ ROUTINE NO	95 EST MANDAYS	96 EST MANDAY COST $	97 EST MATERIAL COST $
	5 1 4 2 1			

98 EST TOTAL COST $ | 99 JOB ORDER NUMBER | 100 LEAD P & E CODE | 101 DATE OF ESTIMATE

102 FINAL ACTION | 103 MHRS EXPENDED | 104 DATE COMPLETED | G COMPLETED BY (Signature & Rank) | H ACCEPTED BY (Signature & Rate/Rank)

86NVM008

Figure 2-1.—Automated Work Request.

will probably be assigned to at least a tour of duty as a member of R-l division. We will explain the duties of personnel assigned to each of these shops in the following paragraphs. On submarine tenders, the carpenter shop, dive locker, and canvas shops are assigned to R-6 division.

Shipfitter Shop.—Personnel make repairs on the hull, manufacture and install various structural metal components, repair or replace watertight fixtures, and handle alterations designated for forces afloat.

Sheet Metal Shop.—Personnel make all types of repairs and fabrications on light gauge sheet metal and handle alterations designated for forces afloat.

Pipe and Copper Shop.—Personnel fabricate and repair most pipe and tubing, test completed work hydrostatically, and handle alterations designated for forces afloat.

Weld Shop.—Personnel weld most metals, including high-pressure welding on boilers. They repair castings, stress relieve castings and forgings, forge special tools and hull fittings, and case harden low-carbon steel.

NOTE: The nondestructive testing laboratory performs all nondestructive testing used to test the quality of the welds and is part of the quality control division, R-8.

Carpenter Shop.—Personnel repair and fabricate most items made of wood, and lay linoleum tile, magnetite, and terrazzo covers on decks. The pattern shop functions under the carpenter shop and fabricates patterns of wood, metal, and plastic for templates and foundry castings.

Canvas Shop.—Personnel fabricate miscellaneous canvas covers, awnings, and boat cloths, and they repair furniture using leather and cloth fabrics.

Diving Locker.—Personnel inspect the underwater portion of the hull and prepare the underwater hull reports for the repair officer. They also replace propellers on destroyers and small ships and repair or replace other items underwater as needed. They clean propellers, sonar domes, sea chests, and large injection valves; clear fouled propellers and sea chests; and maintain the diving boat and diving equipment in repair and operational readiness.

MACHINERY REPAIR DIVISION (R-2).—The machinery repair division consists of the inside machine shop, the outside machine shop, the boiler shop, and the foundry shop. We will explain the duties of personnel assigned to each of these shops in the following paragraphs.

Inside Machine Shop.—Personnel repair or fabricate mechanical parts that require work done on machine shop tools and equipment. They do metal plating and engraving, and they test metals to determine their characteristics. They also handle alterations designated for forces afloat.

Outside Machine Shop.—Personnel shop test and repair all types of machinery used in naval ships. They also handle alterations designated for forces afloat. On submarine tenders, they are assigned to R-9 division.

Boiler Shop.—Personnel shop test, inspect, and repair boilers of naval ships.

Foundry Shop.—Personnel pour castings of various metals to produce repair parts and whole items used on the ship. On submarine tenders, they are assigned to R-6 division.

ELECTRICAL REPAIR DIVISION (R-3).—The electrical repair division consists of the electric shop, the gyro shop, the printing shop, and the photo shop.

Electric Shop.—Personnel inspect, test, repair, and make adjustments to nearly all electrical equipment, and they also handle electrical alterations designated for forces afloat. (On submarine tenders, the print and photo shops are assigned to R-O division.)

ELECTRONICS REPAIR DIVISION (R-4).—The electronics repair division consists of the electronics shop and the calibration shop.

Electronics Shop.—Personnel align and repair all types of electronic equipment, make field changes, and maintain an electronics publications library.

Calibration Shop.—Personnel repair and calibrate most test equipment used on naval ships.

QUALITY ASSURANCE PROGRAM

As an HT, most repairs that you will make require a great deal of quality controls to ensure that the system you are working on is restored to its original conditions. The QA program provides a uniform policy of maintenance and repair on ships and submarines. It improves discipline in the repair of equipment, safety of personnel, and configuration control. It is essentially a program to ensure that all work meets specifications or that any departure from specifications is approved and documented. You, the supervisor or craftsman, are expected to carry out the QA program. This section will give you the broad knowledge you need to understand how it works.

CONCEPTS OF QUALITY ASSURANCE

The ever-increasing technical complexity of present-day surface ships and submarines has pointed to a need for special administrative and technical procedures known collectively as the QA program. The fundamental QA concept is that all maintenance personnel have the responsibility to prevent defects from the beginning to the end of each maintenance operation. You must consider QA requirements whenever you plan maintenance, and you must apply the fundamental rule—MEET TECHNICAL SPECIFICATIONS AT ALL TIMES.

Quality control (QC) means you regulate events rather than being regulated by them. It means that you work with proper methods, material, and tools. In other words, knowledge is the key, and knowledge comes from factual information.

The QA program provides a way to document and maintain information on the key characteristics of equipment. It helps you base decisions on facts rather than intuition or memory. It provides comparative data that will be useful long after you have forgotten the details of a particular time or event. You can get knowledge from data, ship's drawings, technical manuals, material references (such as APLs), and many other sources. As you use these sources, you will develop the special skills you need to analyze information and supervise QA programs.

A good QA program provides enough information so you can accomplish the following goals:

- Improve the quality, uniformity, and reliability of the total maintenance effort.
- Improve the work environment, tools, and equipment used in maintenance.
- Eliminate unnecessary man-hour and dollar expenses.
- Improve the training, work habits, and procedures of maintenance personnel.
- Store, locate, and distribute required technical information more effectively.
- Plan realistic material and equipment/ maintenance tasks.

THE QA MANUALS

The Navy’s fleet commanders in chief (CINCs) publish and update QA manuals that set forth minimum QA requirements for both the surface fleets and the submarine force. The TYCOMs then publish QA manuals that apply to their forces but are based on the fleet CINC manuals. Since these CINC and TYCOM manuals apply to a wide range of ship types, equipment, and resources, the instructions are general in nature. Therefore, each activity must implement its own QA program that meets the intent of the latest versions of the fleet CINC and TYCOM QA manuals. If higher authority imposes more stringent requirements, they will take precedence.

The Navy’s QA program applies to maintenance done aboard ship by the ship’s force, in IMAs, SIMAs, SRFs, and shipyards. However, this section will concentrate on QA work done by the ship’s force and IMAs since you may be assigned to either type of duty.

QA PROGRAM COMPONENTS

The basic thrust of the QA program is to ensure that you comply with technical specifications during all work on ships of both the surface fleet and the submarine force. The key elements of the QA program include administrative and job execution components. The administrative component includes the requirement to train and qualify personnel, monitor and audit programs, and complete the QA forms and records. The job execution component includes the requirement to prepare work procedures, meet controlled material requirements, requisition and receive material, conduct in-process control of fabrication and repairs, test and recertify equipment, and document any departure from specifications.

THE QA LINK TO MAINTENANCE

The Navy has a long-standing requirement that maintenance work must meet technical specifications. The person performing the maintenance is ultimately responsible for ensuring that this requirement is met. Therefore, any worker who is expected to do the job properly must be properly trained, provided with correct tools and parts, familiar with the technical manuals and plans, and adequately supervised.

These elements continue to be the primary means of assuring that maintenance is performed correctly.

Once there is a decision to proceed with maintenance, you must apply QA requirements at the same time you plan the maintenance and supervise its completion. Technical specifications will come from a variety of sources. The determination of which sources are applicable to the particular job will be the most difficult part of your planning effort. Once you decide, the maintenance objective becomes two-fold: (1) ensure the maintenance work meets all specifications, and (2) ensure the documentation is complete and accurate and can be audited.

THE QA ORGANIZATION

The Navy's QA program organization begins with the fleet CINCs, who provide the basic QA program organization responsibilities and guidelines. The TYCOMs provide instruction, policy, and overall direction to implement and operate the force QA program. Each TYCOM has a force QA officer assigned to administer the force QA program. Commanding officers are responsible to the TYCOM, via the chain of command, for QA of their organization. The CO is responsible for organizing and implementing a QA program within the organization to carry out the provisions of the TYCOM's QA manual, and assigns key QA personnel for that purpose. In most cases, it is a collateral duty assignment for these key personnel on ships and a primary duty for key personnel at IMAs. The following paragraphs will give you a brief description of the responsibilities of each of these positions followed by a discussion of their training and qualifications.

The Commanding Officer

The CO is responsible for the quality of material within a command, and he/she depends on the full cooperation of all hands to help meet this responsibility. The CO cannot maintain high standards of quality workmanship by merely creating a QA organization within a maintenance organization. The organization must have the full support of everyone within it. It is not the inspection instruments and instructions that bring high standards of quality; it is the attitudes of those who do the work.

The Quality Assurance Officer

The QAO is responsible to the CO for the organization, administration, and execution of the ship's QA program according to the QA manual. On most surface ships other than IMAs, the QAO is the chief engineer with a senior chief petty officer assigned as the QA coordinator. The QAO is responsible for the following:

— Coordinating the QA training program as an integral part of the ship's/IMA's overall training program

— Maintaining the ship's/IMAs QA records and test and inspection reports

— Maintaining departure-from-specifications records that can be audited

— Reviewing procedures and controlled work packages prepared by the ship/IMA

— Conducting QA audits as required and following up on corrective action to ensure compliance with the QA program

— Preparing QA/QC reports as required by higher authority

— Qualifying key personnel in the QA program.

The Division Officer

The DOs ensure that all division personnel receive the necessary QA training and qualifications for their positions and that they carry out their QA responsibilities.

The Quality Assurance Coordinator

The quality assurance coordinators (QACs) are senior petty officers assigned to this duty. Personnel assigned to this duty train other QA personnel, conduct interviews for prospective QA personnel, and administer written examinations for QA qualifications.

Ship Quality Control Inspector

If you are a work center supervisor, you will most often be appointed and trained in the collateral duty of ship quality control inspector (SQCI). IMAs have personnel permanently assigned to these positions within the QA division. As an SQCI, you will be deeply and directly involved in QA. You must be familiar with all aspects of the QA program and the QC procedures and requirements of your specialty. As an SQCI, you should act as an inspector or assign a collateral duty inspector at the same time you assign work to be sure the work is inspected in progress and on completion. Do not allow personnel in your shop to do a final inspection on their own work.

Inspections normally fall into one of the following three inspection areas:

- RECEIVING OR SCREENING INSPECTIONS. These inspections apply to material, components, parts, equipment, logs and records, and documents. They determine the condition of material, proper identification, maintenance requirements, disposition, and correctness of related records and documents.
- IN-PROCESS INSPECTIONS. These inspections are specific QA actions that are required in cases where you cannot know whether the job was done right without the inspections. They include witnessing, application of torque, functional testing, adjusting, assembling, servicing, and installation.
- FINAL INSPECTIONS. These inspections comprise specific QA actions performed following the completion of a task or a series of tasks. An example is an inspection of work areas after several personnel have completed tasks.

Most commands that have a QA program will issue you a special ID number that will identify you as a qualified SQCI. In addition, the QAO will assign a personal serial number to each shop SQCI as proof of certification to use on all forms and tags that require initials as proof that certified tests and inspections were made. This will provide documented proof and traceability to show that each item or lot of items meets the material and workmanship for that stage of workmanship.

Personnel who serve as SQCIs will be responsible for the following:

- Developing a thorough understanding of the QA program.
- Training all work center personnel until they are familiar with the QA/QC requirements that apply to your work.
- Ensuring that all controlled work done by your work center personnel meets the minimum requirements in the latest plans, directives, and specifications of higher authority and that controlled work packages (CWPs) are properly used on repair work.
- Inspecting all controlled work for conformance to specifications and witnessing and documenting all tests required on these systems.
- Maintaining records and files to support the QA program and ensuring the QA manual is followed.
- Ensuring test personnel use measuring devices, instruments, inspection tools, gauges, or fixtures that have current calibration stickers or records when acceptance tests are performed.
- Ensuring a qualified inspector accepts the work before the ship installs the product when an inspection is beyond the capability of the ship's/IMA's QA inspector.
- Reporting all deficiencies to the ship's QAC and keeping the division officer informed.
- Helping the DO and QAO conduct internal audits and correct discrepancies.

Work Center Controlled Material Petty Officer

If you supervise a work center that has level I or subsafe material, you must ensure the procedures that govern controlled material are followed. Your work center or division will usually appoint a controlled material petty officer (CMPO) to handle these responsibilities. After training, that person will inspect, segregate, stow, and issue controlled material in the work center.

Shop Craftsmen

Shop craftsmen are not normally trained in specific QA functions as are the key QA people. Still, they must do their work under QA guidelines if they apply. They will work closely with their shop supervisors and QA inspectors to ensure the work is done according to QA guidelines and procedures.

THE CONTROLLED WORK PACKAGE

As an HT, you will be required to document the repair work that you do on any ship's system. This documentation is done in an approved and issued CWP received from the P & E division. The CWP provides QC requirements and procedures to help ensure that fabrication or repair will produce a quality product. These requirements or procedures include both TYCOM and local command-generated information for work package processing and sign-off. The typical CWP will have QA forms, production task control forms, departure from specifications forms, material deficiency forms, QC personnel sign-off requirements, and hydro or test forms. Each CWP covers the entire scope of the work process and is a permanent and legal record of the performed work. The job control number (JCN) provides traceability from the work package to other certification documentation. When filled in, the CWP documents adherence to specified quality standards.

You must ensure that the CWP is at the job site during the performance of the task. Since the CWP is the controlling documentation for the performance of any repair work you accomplish, it is required on the work site to ensure that no steps or inspection are omitted. If the work procedure requires the simultaneous performance of procedure steps and these steps are done in different locations, use locally developed practices to ensure you maintain control for each step.

Immediately after a job is completed, each assigned work center and the QAO will review the CWP documentation to be sure it is complete and correct. If you and your workers have been doing the assigned steps as stated, this should not be a problem. Be sure all verification signature blocks are signed. Make sure all references, such as technical manuals or drawings, are returned to the appropriate place.

REPAIR PROCEDURES

As an HT, you may be required to organize and supervise an HT shop aboard ship or at a shore facility. It will be your responsibility to supervise and instruct personnel of lower rates in the techniques of carpentry and woodworking, plate and sheet metal layout and fabrication, pipefitting, and the welding of various types of metals. In addition, you will be required to estimate the time, materials, and personnel required for the completion of various wood and metalworking jobs; to maintain the HT shop, including all tools and equipment, in the best possible condition; and to ensure that all safety precautions are observed by your personnel. To supervise HT shop work efficiently, afloat or ashore, you will rely mostly upon your past experience in shop work and repair procedures.

The purpose of this section is to acquaint an HT with some of the most important things that must be considered by a person in charge of a work center. It is impossible, however, to cover all the procedures and problems that arise in the daily operations of a work center. By studying this section of the chapter, you will become aware of some of the things that occur, particularly in regard to the job of setting up shop procedures and the methods by which everyday problems are solved.

Leading petty officers, especially those who are in direct contact with personnel, often fail to recognize that they are part of the ship's administrative organization. Every petty officer in the shipboard organization is definitely part of the administrative group. In such a capacity, you have many responsibilities that you are expected to carry out by interpreting and executing the established policies and procedures. Supervisors can accomplish this properly only when they have a clear understanding of these policies and procedures, as well as their place within the command's organization.

As a supervisor, the petty officer is expected to spot operating difficulties in their shop and do something about them. You must have an understanding of your department, ship's organization, and the proper channels and lines of authority which are open to you. The further up the organizational chain that you progress, the greater your responsibilities become. The job of a supervisor is a detailed one, and most important with respect to the operation of any naval repair activity or facility. A weakness in the performance of any supervisory duty or responsibility reduces the effectiveness of the work center as a whole.

Obviously, then, the HT in charge of an HT shop should fully appreciate and understand the responsibility he/she holds as a member of a shipboard organization, and be able to identify each of his/her duties with respect to any assigned job. This is not an easy task in a field so complex and variable as the work of a shop supervisor.

Some administrative personnel have made long lists of the responsibilities of shop supervisors. A close examination of such lists might disclose to each leading petty officer points of differences as well as points of agreement. Many differences are of minor importance, and others represent major differences in responsibilities. After such a comparison, it might be concluded that an accurate list of duties for any given job can be made only by the individual occupying the particular job. The following list includes the duties and responsibilities that are common to most shop supervisors:

- Getting the right person on the right job at the right time
- Using tools and materials as economically as possible
- Preventing conditions that might cause accidents
- Keeping personnel satisfied and happy on the job
- Adjusting individual grievances
- Maintaining discipline
- Keeping records and making reports
- Maintaining the quality and quantity of repair work
- Planning and scheduling repair work
- Training personnel
- Requisitioning tools, equipment, and materials
- Inspecting and maintaining tools and equipment
- Giving orders and directions
- Cooperating with others
- Checking and inspecting completed repairs or replacement parts
- Promoting teamwork

From the extent of the preceding list it is obvious that the job of a supervisor covers a broad field. These items are quite general in nature; therefore, it is necessary for each HT shop supervisor to carry out a detailed study of his/her own specific duties and responsibilities.

The leading petty officer in charge of an HT shop should take advantage of every opportunity to provide personnel with specific information about their jobs. The type of petty officer who says, “Never mind why; just do as you are told,” is rapidly being replaced by the supervisor who recognizes the importance of each individual.

As the leading petty officer in charge of an HT shop, you should use all possible interest factors. You should study each of your personnel and use those interest factors that seem to obtain the best results according to individual characteristics. Your ability to interest your personnel in their work is important, as it determines your success or failure as a supervisor. Your proficiency in rating depends in part on the quality and quantity of work assigned personnel produce, which, in turn, reflects the morale of the shop personnel and their interest in their work.

PLANNING AND SCHEDULING JOBS

Careful planning is necessary to keep an HT shop running efficiently and productively. Remember that any time lost, whether on a job or between jobs, lowers the overall efficiency of the shop. To keep the work flowing smoothly, you will have to consider such factors as sizing up the job, checking on the availability of materials and supplies, time and material requirements, allowing for priority of work, assigning work, checking the progress of the work, and checking the completed work.

Sizing up the Job

When a new job order comes into the HT shop, check it over carefully to be sure that it contains all the necessary information. Don't start a job until you are sure that you understand in detail the scope of the job. If blueprints or drawings will be needed, check to be sure that they are available. Shipcheck each job as soon as possible to verify the scope of the job against available blueprints or other technical documentation.

Checking on Materials

Before starting a job, be sure that all the required materials will be available. This means not only the correct kind of wood or metal for the job, but also whatever other materials may be required to finish the job, such as glue, dowels, nails, welding rod, rivets, bolts, clips, and hinges. Ensure that all material used for the repair meets applicable specifications and are verifiable.

Estimating Time for a Job

Accuracy in estimating the required time for a specific job is primarily a matter of experience. When making a time estimate, you will compare the present problem with one you have solved in the past. An estimate, in a very real sense, is a guess, but it is an intelligent guess when based on the proper use of records and experience.

From time to time, you will probably be called upon to give the estimate of the time that will be needed to complete a repair job. For most of the routine jobs coming into the HT shop, a quick estimate made on the basis of your experience will probably be sufficient. For urgent jobs, however, the time required for completion may be an important consideration; and you should be very cautious in making these estimates. The estimate(s) that you make may have an effect on the operational schedule of a ship; therefore, it is important to consider all factors that might affect the time required for the job.

The following steps are generally required to make an accurate estimate of the time that will be required for a repair job.

1. Study the job order and any blueprints or other drawings that are applicable to determine the extent of the job. For a repair job, inspect the damaged item to determine whether or not it requires repairs or replacements in addition to those specified in the job order. In other words, the first thing to do is to get all possible information about the job.

2. Find out the priority of the job. If it has a lower priority than some of the work already scheduled to be done in the shop, you will not be able to start work immediately. Any delay in starting the job must, of course, be added to the total estimate of time required to complete the job.

3. Find out what materials will be required, and make sure they are available. If the specified materials are not available, time may be lost while you try to find a satisfactory substitute.

4. Find out what part of the job (if any) must be done in other shops. It is important to consider not only the time actually required by these other shops, but also the time that may be lost if one of the shops holds up the work of your shop. Never attempt to estimate the time that will be required by other shops. Each shop must make a separate estimate, and these estimates must be combined to obtain the final estimate.

5. Consider all the interruptions that might cause delay, over and above the time actually required for the work itself. Such things as ship's drills, inspections, field days, and working parties will affect the number of personnel that will be available to work on the job at any given time.

6. Next, try to estimate the time that will be required for the work itself. Perhaps the best way to do this is to divide the total job into its various phases or steps that will have to be done. The time required for each step depends partly on the nature of the job and partly on the number of personnel available. You may find it helpful to draw a diagram or chart showing how many persons can be assigned to each step of the job, and how long each step is likely to take. Figure 2-2 shows a chart made up to estimate the total time required to make certain repairs to a gangway.

The total job is divided up into nine phases or steps:

A. Making the template. This step might take one person about 1 hour.

B. Obtaining metal fittings (treads and padeyes). This step might take one person about 1 hour.

C. Renewing one stringer and six treads. This step might take four people about 6 hours.

D. Sanding the surface and using wood filler. This step might take two people about 2 hours.

E. Giving the first coat of varnish. This step might take one person about 1 hour.

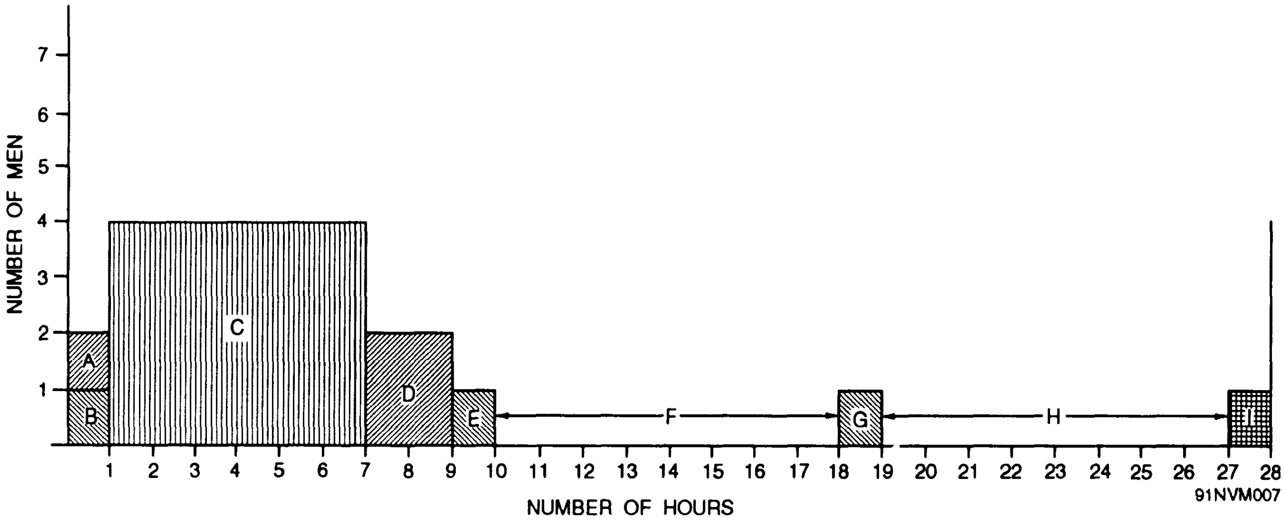


Figure 2-2.—Estimating time required for a gangway repair job.

F. Drying time (8 hours). This must be counted in the total estimate even though no work can be done on the gangway during this period.

G. Giving the second coat of varnish. This step might take one person about 1 hour.

H. Drying time (8 hours).

I. Putting on the metal fittings. This step might take one person about 1 hour.

Notice that, although there are four people available to work on this job, it is not possible for all four to be working on it at all times. Most of the work must be done in sequence; for example, you can't finish the surface before you have renewed the stringer and treads, and you can't make the new stringer and treads before you have made the template. Step A (obtaining the metal fittings) could be performed at any convenient time before step I (putting on the metal fittings). The advantage of using a diagram such as the one shown in figure 2-2 is that it shows at a glance the total number of hours that must be allowed for the work-in this case, 28 hours.

The diagram shows you something else, too: the number of man-hours required for each step. Let's add these up:

STEP A		1 man-hour
STEP B		1 man-hour
STEP C		24 man-hours
STEP D		4 man-hours
STEP E		1 man-hour
STEP F		0 man-hour
STEP G		1 man-hour
STEP H		0 man-hour
STEP I		1 man-hour
TOTAL	=	33 man-hours

So you find that the total job requires 33 man-hours of work. But what does this mean? Does the number of man-hours tell you how long the job is going to take? Is it safe to assume that a job requiring 33 man-hours can be done in 8 1/4 hours if you put four people to work on it? Obviously not, since there is a limit to the number of people who can work on the job at any given time.

The unit MAN-HOURS, then, is a measure of amount of work but not of total length of time. You should be very cautious about using man-hours when estimating how long a job will take, since this measure does not allow for the sequence in which the work must be performed, the number of steps required, or the number of people who can work on the job at each step.

Material Estimates

The material you will use on a given job will be determined from specifications or plans. If the material is not specified, you will decide what you need and select it. Your decision will be based on the purpose of the structure or object, and the conditions that it will meet in service. Some of the "in-service conditions" are resistance to corrosion, resistance to acids, or resistance to wear. You will have to consider the weight to be supported, pressures to be withstood, and working stresses that may be encountered. Safety, too, is an important point to consider in determining the material to use on a particular job. There is no set rule to follow. Each problem must be considered individually.

ALLOWING FOR WASTE.—In most jobs, a careful study of the detail plans will reveal the exact amount of material needed for a particular installation or repair. However, it is sometimes impossible to use every linear foot of a length of pipe or bar stock or to use every square foot of plate or sheet metal. Some waste is unavoidable, and an allowance for such waste is necessary in material estimates.

WEIGHT CONSIDERATIONS.—Weight considerations are important in shipboard repairs and alterations. Consequently, it not only may be necessary for you to determine the amount of material required for a job, but also to calculate the weight of the material going into the job. The weight of pipes, tubes, plates, sheets, and bars can be determined in either of two ways: (1) by referring to tables in a handbook and locating the weight per linear or square foot of the particular material in question; and (2) by arithmetical computation. For example, suppose you need to know the weight of a 30-foot length of 2 1/2-inch extra strong steel pipe. By referring to the appropriate table in a piping handbook, we find that this pipe weighs approximately 7.66 pounds per linear foot. Thus, a 30-foot length weighs 229.8 pounds.

But, suppose you do not have such tabulated information available. In that case, it is necessary to determine the volume of metal involved and multiply that result by the weight of the metal per cubic inch. To compute the volume of metal in a pipe or tube, think of it as being two cylinders. The outside diameter being cylinder 1 and the inside diameter being cylinder 2. The result obtained by subtracting the volume of cylinder 2 from the volume of cylinder 1 will be the volume of metal (in cubic inches) contained in the pipe or tube. The volume of a cylinder is equal to the area of the base times the height ($\pi R^2 H$. For example, to compute the weight of the 2 1/2-inch extra strong steel pipe shown in figure 2-3, you would use the following procedure:

Step 1. Compute the volume of metal contained in cylinder 1, using the formula volume = $\pi R^2 H$. Substituting known values we find that:

$$\pi = 3.1416$$

$$R = 1.4375$$

$$H = 30 \text{ ft (360 inches)}$$

$$V = 3.1416\,(1.4375)^2 360$$

$$V = 2337.0 \text{ cu in.}$$

Step 2. Compute the volume of metal contained in cylinder 2:

$$\pi = 3.1416$$

$$R = 1.1615$$

$$H = 30 \text{ ft (360 inches)}$$

$$V = 3.1416\,(1.1615)^2 360$$

$$V = 1525.7 \text{ cu in.}$$

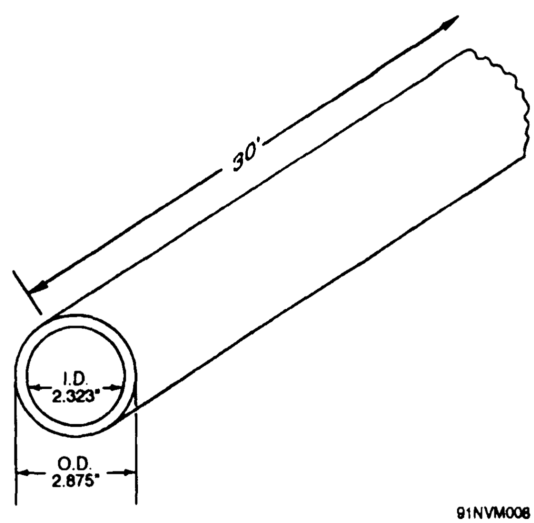


Figure 2-3.—Actual measurements of inside and outside diameters of 2 1/2-inch extra strong steel pipe.

Step 3. Find the volume of metal contained in the pipe by subtracting the volume of cylinder 2 from the volume of cylinder 1:

$$2337.0 - 1525.7 = 811.3 \text{ cu in.}$$

Step 4. Find the weight of the pipe by multiplying the volume of metal by the weight of steel, shown in table 2-1:

$$811.3 \times 0.284 = 230.4 \text{ lb}$$

The weight of plate and sheet metal structures may be found by computing the volume of metal contained (in cubic inches), and then multiplying the volume by the weight of the metal (per cubic inch), as shown in table 2-2. As an example, find the weight of a steel plate that is 68 inches in length, 44 inches wide and 1/2 inch thick. Using the formula weight = volume × weight of the metal per cubic inch, we use the following procedure:

Step 1. Compute the volume of metal contained.

$$\text{Volume} = \text{length} \times \text{width} \times \text{thickness}$$

$$V = 68 \times 44 \times 1/2$$

$$V = 1496 \text{ cu in.}$$

Step 2. Find the weight of the steel plate.

$$\text{Weight} = \text{volume of metal} \times \text{weight per cu in.}$$

$$W = 1496 \times 0.284$$

$$W = 424.86 \text{ lb}$$

Table 2-1.—Weight of Common Metals

Material	Pounds per cubic inch
Aluminum	0.098
Yellow brass	0.307
Naval brass	0.304
Copper-nickel	0.323
Cast iron	0.258
Steel	0.284
Lead	0.4106
Copper	0.321
Tin	0.265

Table 2-2.—Weight of Various Gauges of Uncoated Plain Steel Sheet Metal

Gauge	Decimal thickness (inches)	Weight (pounds per square foot per indicated thickness)
11	0.1196	4.89
12	0.1046	4.28
13	0.0897	3.67
14	0.0747	3.06
16	0.0598	2.45
18	0.0478	1.95
20	0.0359	1.47
22	0.0299	1.22
24	0.0239	0.98
26	0.0719	0.73
28	0.0149	0.61
30	0.0120	0.49

The weight of steel per square foot may be determined by multiplying the thickness of the metal by 40.9. Table 2-2 lists the weight per square foot of the various gauges of uncoated plain steel sheet metal, and also the decimal equivalents of the different gauges.

Obviously, to calculate the weight of a particular structure, you must be able to break the whole down into its component geometrical parts, circles, squares, rectangles, pyramids, and so on, and determine their respective volumes. Further, you need to know the weight of metal per cubic inch. This information can be found in a variety of handbooks readily available in the engineer or repair department office. Table 2-1 gives the information for a few of the more common metals.

When specific job requirements are known, estimating of material needed is no problem. However, when estimating requirements for future use, you will have to anticipate your needs. Referring to records of previous jobs and records of materials expended can help eliminate much guesswork.

Priority of Work

In scheduling work in an HT shop, you will have to consider the priority of each job. Most job orders will have a ROUTINE priority; this means that they must be done as soon as possible, within the normal capacity of the shop. Jobs having an URGENT priority must be done immediately, even at the expense of routine jobs that may be in progress. Jobs with a DEFERRED priority do not constitute a problem, since they are usually accomplished when the workload of the shop is light and there are no routine or urgent jobs to be done.

Assigning Work

The assignment of work in the HT shop is extremely important. As a rule, the more complicated jobs should be assigned to the more experienced personnel. When time and the workload of the shop permit, however, the less experienced personnel should be given difficult work to do under proper supervision so that they may acquire skill and self-confidence.

When assigning work, be sure that the person who is going to do the job is given as much information as necessary. An experienced person may need only a drawing and a general statement concerning the finished product. A less experienced person will probably require additional instructions concerning the layout of the job and the procedures to be followed.

Checking Progress of Work

When you are in charge of the HT shop, you will have to keep a constant check on the progress of all work. In particular, be sure that the proper materials are being used, that the work is set up properly, that personnel are using the correct tools properly, and that all safety precautions are being observed. Note the progress of each job in relation to the planned schedule of work; you will probably find that some jobs are ahead of schedule, while others are lagging behind. If necessary, reschedule the work to prevent the development of bottlenecks. By frequently talking to shop personnel and answering their questions, you can prevent jobs from being spoiled, as might happen if you were not available to give correct details on the jobs.

Checking Completed Work

When you are in charge of the HT shop, it will be your responsibility to inspect and approve all finished work before it is allowed to leave the shop. In addition, you must make sure that all shop records concerning finished work are complete, correct, and up to date.

SHOP MATERIALS

In all probability, your first experience with naval supplies and repair parts was as a member of a store's working party. At that time, however, you probably did not understand “how” or “why” the stores were placed aboard. As a HTI or HTC, you are expected to know the immediate supply channels in order to obtain the material you need. The fact that there are supply specialists aboard does not relieve you of the responsibility for aiding in procuring, handling, stowing, and accounting for the materials used in your shop.

The big job of supply is handled by the supply department. But if that department does not know what you need, you are not going to have the material you want when you need it. It is your responsibility to keep the proper people informed of your estimated needs so that you will have the required materials on board at all times. Most of your orders will be placed through your division officer or the head of the department, but in some cases, you may order directly from the supply officer.

Selecting Materials and Repair Parts

The materials and repair parts to be used are specified for many jobs, but not for all. When materials or parts are not identified in the instructions accompanying the job, you will have to use your own judgment or do some research to find out just what material or part should be used. When you must make the decision yourself, select the material on the basis of the purpose of the structure or part and the service conditions it must withstand. Operating pressure and operating temperature must be considered in selecting materials. For some applications, wear resistance or corrosion resistance will be important; for others (as, for example, for high-temperature steam piping), creep resistance will be a necessary property of the material.

The shipboard sources of information that will be helpful to you in identifying or selecting materials and repair parts include (1) nameplates on the equipment, (2) manufacturers’ technical manuals and catalogs, (3) stock cards maintained by the supply officer, (4) specifications for ships, (5) ship's plans, blueprints, and other drawings, and (6) allowance lists.

NAMEPLATES on equipment supply information regarding the characteristics of the equipment, and are therefore a useful source of information concerning the equipment itself. Nameplate data seldom, if ever, include the exact materials required for repairs; however, the information given on the characteristics of the equipment may be a useful guide for the selection of materials.

MANUFACTURERS' TECHNICAL MANUALS are furnished with practically all machinery and equipment on board ship. Materials and repair parts are sometimes described in the text of these technical manuals; usually, details of materials and parts are given on the drawings. Manufacturers' catalogs of repair parts are sometimes furnished with shipboard equipment.

The set of STOCK CARDS that is maintained by the supply officer is often a valuable source of information for the identification of repair materials and repair parts. One of these cards is maintained for each machinery repair part carried on board.

SHIP'S PLANS, BLUEPRINTS, and other drawings available on board ship are excellent sources of information on materials and parts to be used in making various repairs. Many of these plans and blueprints are furnished in regular large sizes; some drawings are being furnished on microfilm to naval shipyards and to repair ships and tenders.

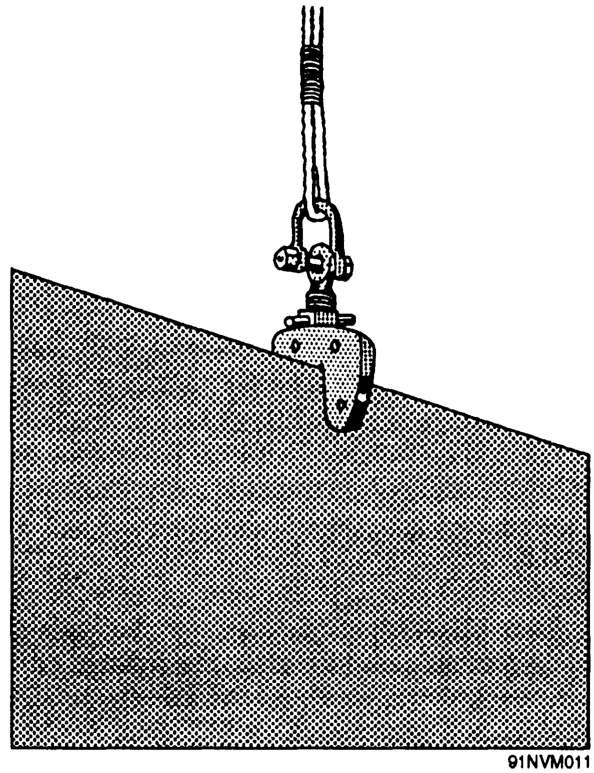


Figure 2-4.—Clamp for handling heavy plate.

Handling Materials and Equipment

As an HT, your duties will include the supervision of the handling, stowing, and inventory of all shop materials and repair parts. The rigging and actual transferring of the materials, parts, and equipment to your ship will be done under the supervision of the Boatswain's Mate. It is your responsibility to furnish the personnel and supervise the stowage of the materials or equipment in the proper shop stowage space.

Heavy plate is usually handled with wire rope slings or straps or with an approved-plate clamp such as the one shown in figure 2-4. These clamps should NOT be used for handling bundles of sheet metal, since the sheets in the middle could slip and cause the entire load to drop. Bulky items such as bars, strap, and structural shapes are usually handled with slings or straps. The chokers shown in figure 2-5 are effective devices for handling pipe and other materials that must be gripped tightly; when the hooks are used in pairs, the pull should be from opposite sides of the load, as shown in figure 2-5.

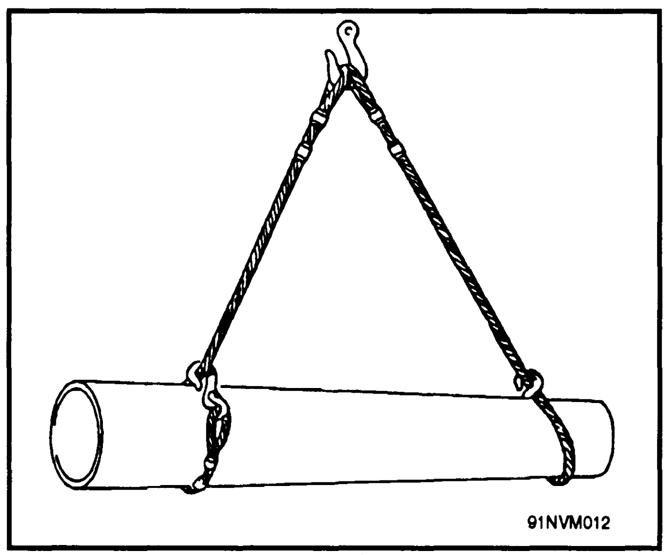


Figure 2-5.—Chokers for handling pipe.

STOWAGE.—Whenever possible, repair parts should be stowed in special storerooms. On small ships, where it may be impracticable to stow repair parts boxes in storerooms, the boxes are generally located in (or near) the same space as the machinery for which they are required. Where the supply department has custody of repair parts, storerooms with bins and drawers for individual stowage of repair part items are generally used instead of the repair parts boxes. The available space and the type of work done in the shop are factors that determine how much material is stowed in the shops and how much is stowed in storerooms.

Pipe Shop Stowage.—In a tender or repair ship pipe shop, for example, you will probably not have room for all the varied sizes and lengths of materials that you may use. However, storage should be provided in the pipe shop for the most commonly used pipe sizes and also for the leftover lengths that accumulate in the course of time. Overhead or bulkhead storage racks are often used for stowage of piping. Stowage should be provided in the pipe shop for the most commonly used valves, fittings, bolts, nuts, rivets, and other items required for piping repairs.

Weld Shop Stowage.—In a welding shop, you will have the problem of stowing welding machines, welding rods, protective equipment, and all the other gear required for welding. Particular precautions should be taken in stowing electrodes to make sure that they will be kept dry and that the coated surfaces will not be chipped.

Sheet Metal Shop Stowage.—In the sheet metal shop and in the shipfitter shop, the stowage of large sheets, bars, or structural shapes will present special problems. In a general-purpose HT shop, the requirements vary so much from day to day that you will probably find it impracticable to stow large amounts of any one material; instead, you will draw your material as you need it from a storeroom. The main stowage problem that you are likely to have in a general-purpose HT shop is the stowage of leftover materials.

STOWAGE REQUIREMENTS.—No matter what type of shop you are in, certain general rules apply to the stowage of material and equipment. Some of thest important of these are as follows:

- Stow material neatly and in such a way that you can get it when you need it.

- Identify all materials. A piece of carbon molybdenum steel looks just like a piece of mild steel, but you cannot use the two materials for the same purpose. Materials should be identified by labels for each bin or rack, by shipping tags attached to the materials, by color-code markings (when applicable), and by stock number. Keeping the stock number with the material will save you time and trouble when you need to reorder material.

- Protect all materials against rust and other corrosion and against other kinds of damage.

- Be sure that your stowage facilities include provision for securing for sea. Metal sheets, bars, structural shapes, pipes, and tubes must be secured so that they will not shift when the ship is underway. Padeyes, turnbuckles, wedges, bars, and C-clamps can be used to secure materials.

- Within the limits of available space, provide stowage facilities that will make the shop a convenient place to work.

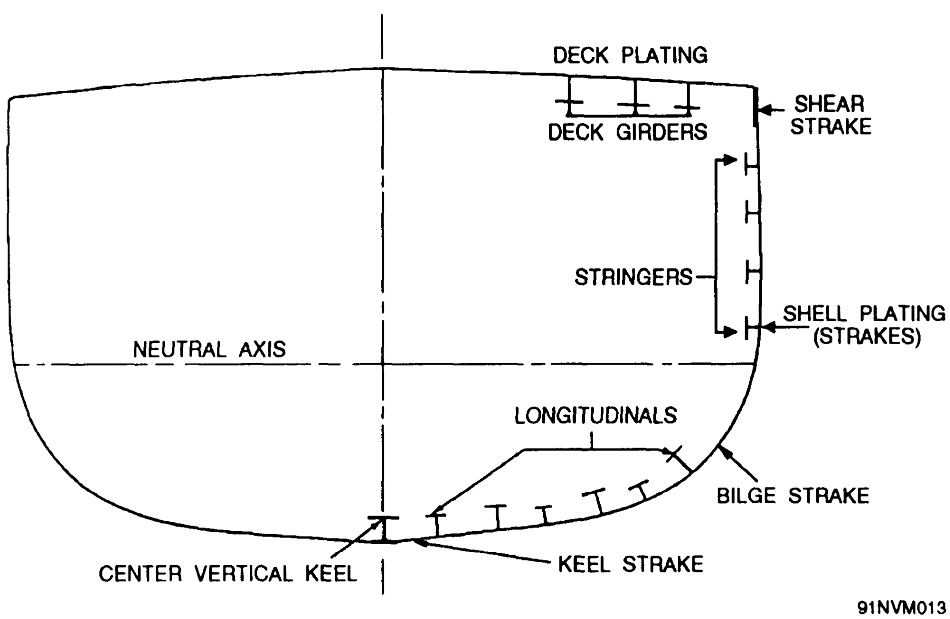


Figure 2-6.—Shell section of a destroyer.

HULL MEMBERS

In the repair of ships, it is important that you have an understanding of basic ship structure. Therefore, the following section will discuss the structural parts of a ship and the purpose of the parts.

The principal strength members of the ship's structure are located at the top and bottom of the hull where the greatest stresses occur. The top section includes the main deck plating, the deck girders, and the sheer strakes of the side plating. The bottom section includes the keel, the outer bottom plating, the inner bottom plating, and any continuous longitudinals in way of the bottom. The side webs of the ship girder are composed of the side plating, aided to some extent by any long, continuous fore-and-aft bulkheads. Some of the strength members of a destroyer hull girder are indicated in figure 2-6.

KEEL

The keel is the most important structural member of a ship. It is considered to be the backbone of the ship. The keel is built up of plates and angles into an I-beam shape (fig. 2-7). The lower flange of this I-beam structure is the flat keel plate, which forms the center strake of the bottom plating. (On large ships, an additional member is attached to this flange to serve as the center strake.)

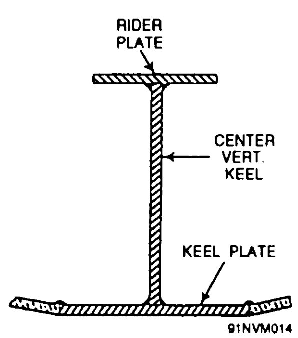


Figure 2-7.—Typical welded keel section.

The web of the I-beam is a solid plate that is called the vertical keel. The upper flange is called the rider plate; this forms the center strake of the inner bottom plating. An inner vertical keel of two or more sections, consisting of I-beams arranged one on top of the other, is found on many large combatant ships.

FRAMING

Frames used in ship construction may be of various shapes. Frames are strength members. They act as integral parts of the ship girder when the ship is exposed to longitudinal or transverse stresses. Frames stiffen the plating and keep it from bulging or buckling. They act as girders between bulkheads, decks, and double bottoms, and transmit forces exerted by load weights and water pressures. The frames also support the inner and outer shell locally and protect against unusual forces, such as those caused by underwater explosions. Frames are called upon to perform a variety of functions, depending upon the location of the frames in the ship. Figure 2-8 shows various types of frames used on board ship.

There are two important systems of framing in current use:the transverse framing system and the longitudinal framing system. The transverse system provides for continuous transverse frames with the widely spaced longitudinals intercostal between them. Transverse frames are closely spaced and a small number of longitudinals are used. The longitudinal system of framing consists of closely spaced longitudinals, which are continuous along the length of the ship, with transverse frames intercostal between the longitudinals.

Transverse frames are attached to the keel and extend from the keel outward around the turn of the bilge and up to the edge of the main deck. They are closely spaced along the length of the ship, and they define the form of the ship.

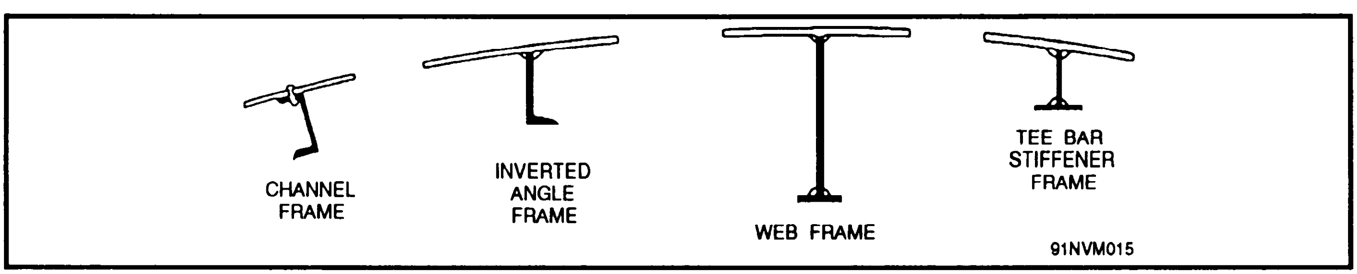


Figure 2-8.—Types of frames used on board ship.

Longitudinals (fig. 2-9) run parallel to the keel along the bottom, bilge, and side plating. The longitudinals provide longitudinal strength, stiffen the shell plating, and tie the transverse frames and the bulkheads together. The longitudinals in the bottom (called side keelsons) are of the built-up type (fig. 2-10).

Where two sets of frames intersect, one set must be cut to allow the other to pass through. The frames,

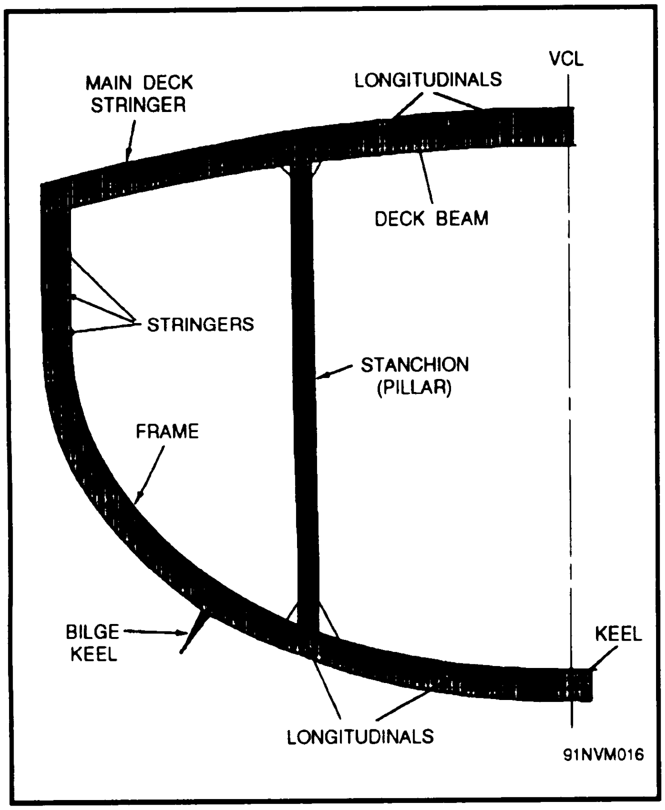


Figure 2-9.—Basic frame section (longitudinal framing).

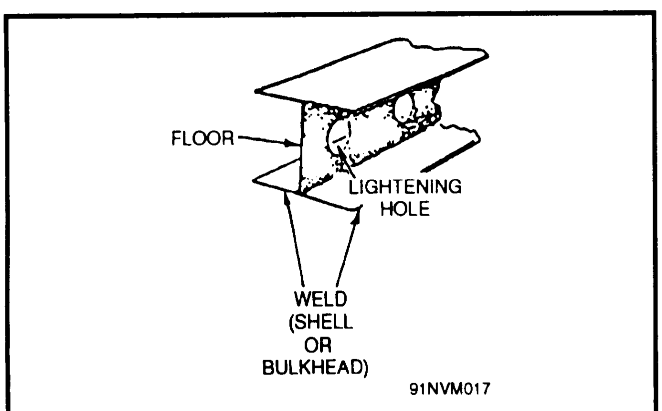


Figure 2-10.—Built-up longitudinal.

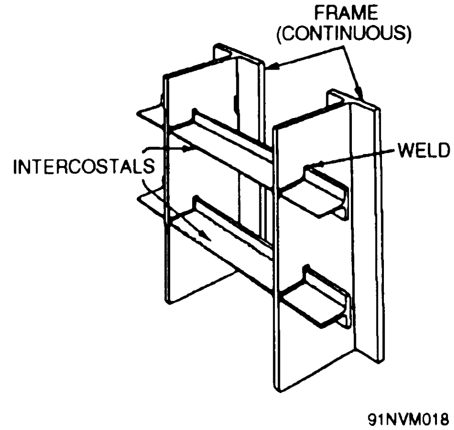


Figure 2-11.—Intercostal and continuous frames.

which are cut and thereby weakened, are known as intercostal frames; those that continue through are called continuous frames. Both intercostal and continuous frames are shown in figure 2-11.

A cellular form of framing results from a combination of longitudinal and transverse framing systems using closely spaced deep framing. Cellular framing is used on most naval ships.

In the bottom framing, which is normally the strongest portion of the ship's structure, the floors and keelsons are integrated into a rigid cellular construction (fig. 2-12). Heavy loads, such as the ship's propulsion machinery, are bolted to foundations that are built directly on top of the bottom framing (fig. 2-13). (This method is outdated and is being replaced by block assembly technology.)

In many ships, the top of this cellular region is covered with shell plating, which forms many tanks or voids in the bottom of the ship. The plating over the intersection of the frames and longitudinals is known as the inner bottom plating. The inner bottom plating is a watertight covering laid on top of the bottom framing. It is a second skin inside the bottom of the ship. It prevents flooding in the event of damage to the outer bottom, and it also acts as a strength member. The tanks and voids may be used for stowage of fresh water or fuel oil or they can be used for ballasting. This type of bottom structure, with inner bottom plating, is called double-bottom construction.

BOW AND STEM CONSTRUCTION

The ship's bow, which is the front of the ship, varies in form from one type of ship to another as the requirements of resistance and seakeeping dictate the

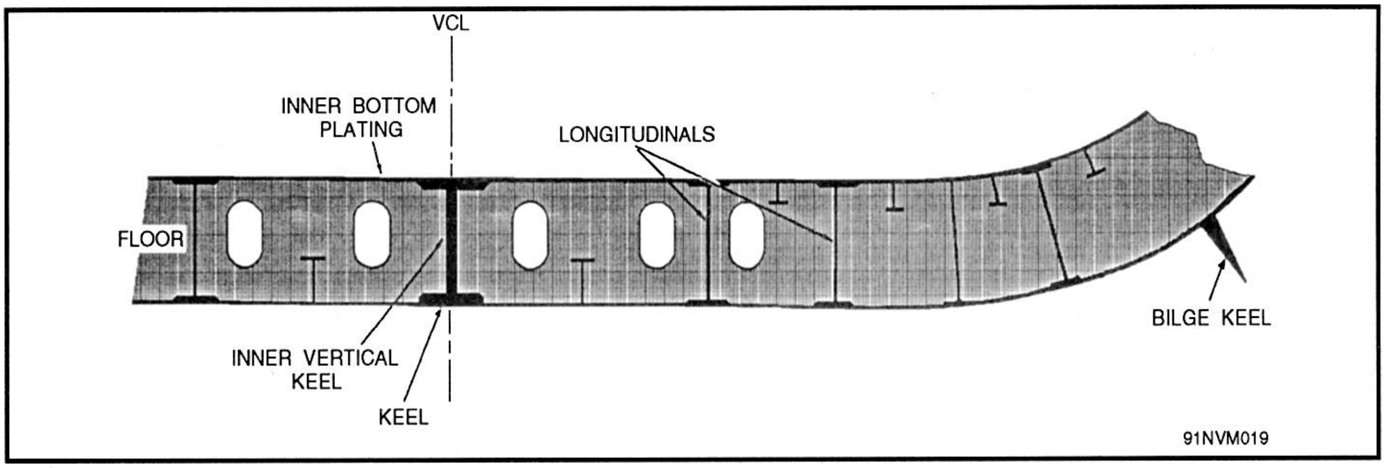


Figure 2-12.—Bottom structure.

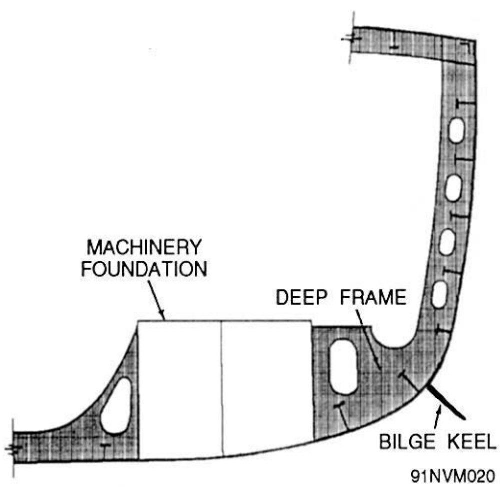


Figure 2-13.—Deep floor assembly for machinery foundations.

shape. The external shape is shown in figure 2-14 and is commonly used on combatant ships. This form is essentially bulbous at the forefoot, tapering to a sharp entrance near the waterline and again widening above the waterline. Internally, the stem assembly has a heavy centerline member that is called the stem post. The stem post is recessed along its after edge to receive the shell plating, so that the outside presents a smooth surface to cut through the water. The keel structure is securely fastened to the lower end of the stem by welding. The stem maintains the continuity of the keel strength up to the main deck. The decks support the stem at various intermediate points along the stem structure between the keel and the decks.

At various levels and at regular intervals along the stem structure between the keel and the decks are horizontal members called breast hooks. Breast hooks rigidly fasten together the peak frames, the stem, and the outside plating. Breast hooks are made of heavy plate and are basically triangular in shape.

Deep transverse framing and transverse bulkheads complete the stem assembly. The stem itself is fabricated from castings, forgings, and heavy plate, or in the case of smaller ships, heavy, precut structural steel plate.

STERN STRUCTURE

The after-most section of the ship's structure is the stem post, which is rigidly secured to the keel, shell plating, and decks. On single-screw ships, the stem post is constructed to accommodate the propeller shaft and rudder stock bosses. The stem post as such is difficult to define, since it has been replaced by an equivalent structure of deep framing. This structure (fig. 2-15) consists of both longitudinal and transverse framing that extends throughout the width of the bottom in the vicinity of the stem. To withstand the static and dynamic loads imposed by the rudders, the stem structure is strengthened in the vicinity of the rudder post by a structure known as the rudder bearing housing.

PLATING

The outer bottom and side plating forms a strong, watertight shell. Shell plating consists of approximately rectangular steel plates arranged longitudinally in rows or courses called strakes. The strakes are lettered, beginning with the A strake, which is just outboard of the keel, and working up to the uppermost side strake.

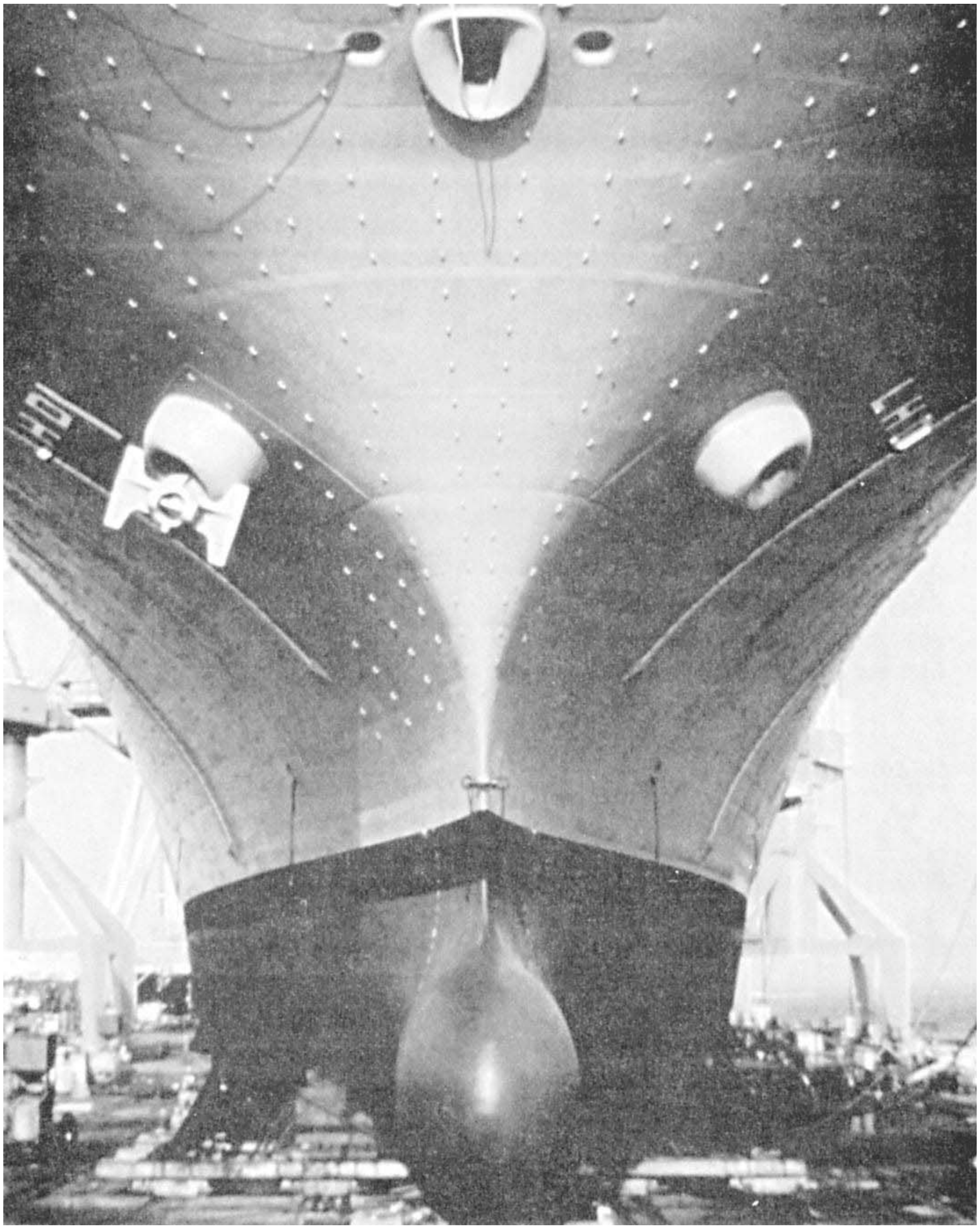


Figure 2-14.—Bulbous-bow configuration.

The end joint formed by adjoining plates in a strake is called a butt. The joint between the edges of two adjoining strakes is called a seam. Seams are also welded flush. Butts and seams are illustrated in figure 2-16.

In general, seams and butts are located so that they do not interfere with longitudinals, bulkheads, decks, and other structural members. Since the hull structure is composed of a great many individual pieces, the strength and tightness of the ship as a whole depend very much upon the strength and tightness of the connections between the individual pieces. In today's modern naval vessels, joints are welded flush together to form a smooth surface.

BILGE KEELS

Bilge keels are fitted in practically all ships at the turn of the bilge. Bilge keels extend 50 to 75 percent of the length of the hull. Bilge keels consist of two plates forming a "V" shape welded to the hull, and on large

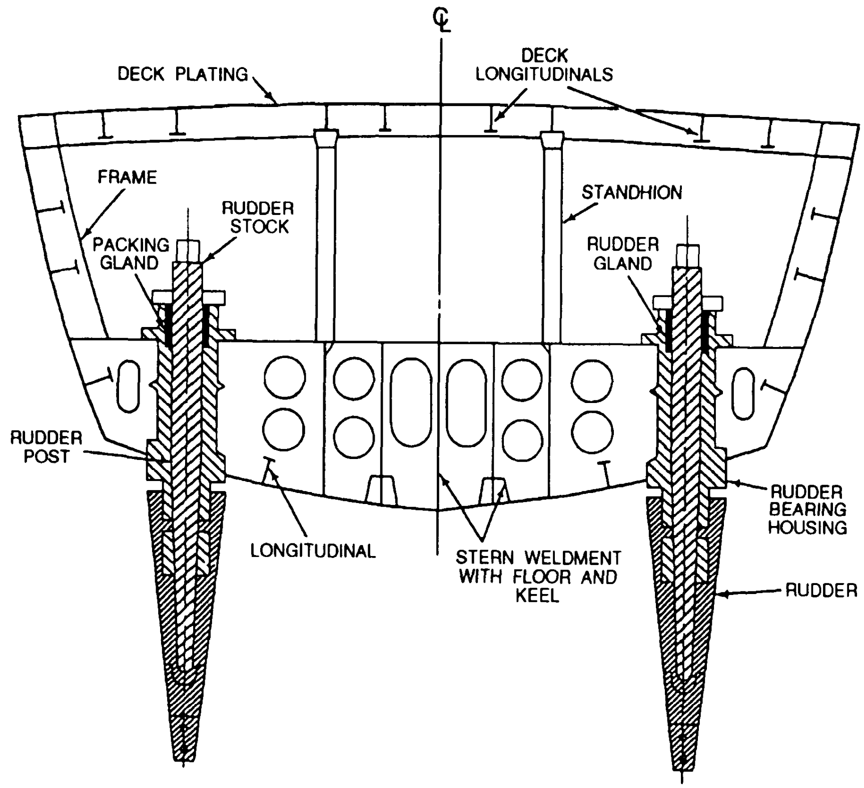


Figure 2-15.—Stern Structure.

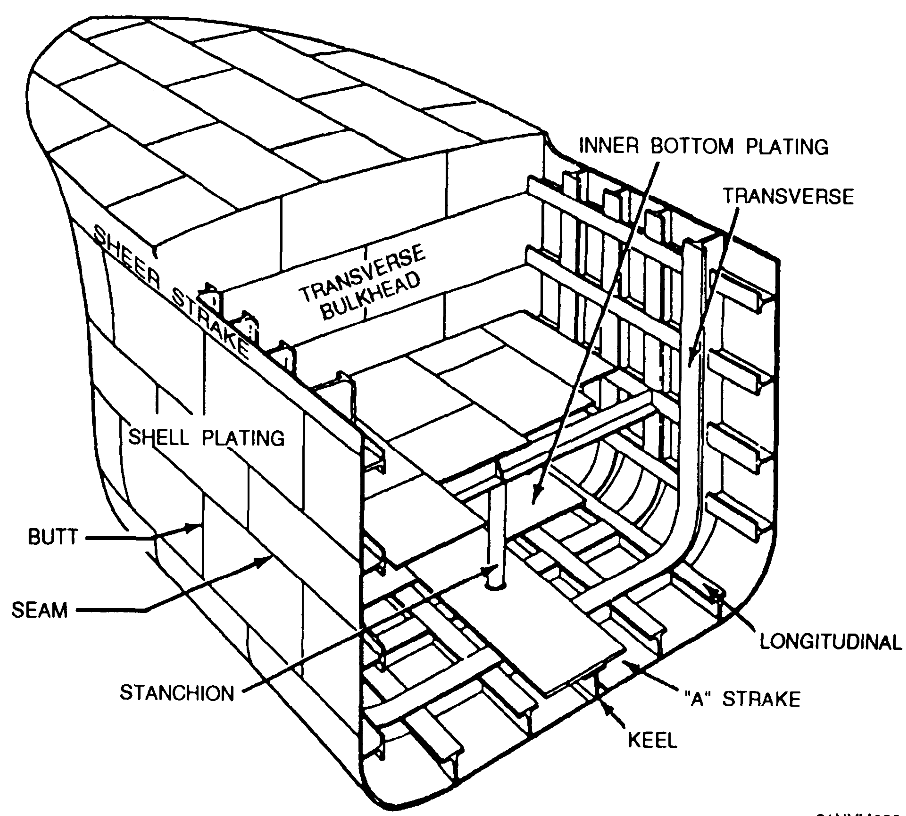


Figure 2-16.—Section of a ship, showing plating and framing.

ships may extend out from the hull nearly 3 feet. Bilge keels serve to reduce the extent of the ship's rolling.

DECKS

Decks provide both longitudinal and transverse strength to the ship. Deck plates, which are similar to the plates used in side and bottom shell plating, are supported by deck beams and deck longitudinales.

The term uppermost strength deck is applied to the deck that completes the enclosure of the box girder and the continuity of the ship's structure. It is the highest continuous deck—usually the main or weather deck. The term strength deck also applies to any continuous deck that carries some of the longitudinal load. On destroyers, frigates, and similar ships in which the main deck is the only continuous high deck, the main deck is the strength deck. The flight deck is the uppermost strength deck on aircraft carriers (CVs and LHDs) that carry helicopters, but the main or hangar deck is the strength deck on older types of carriers.

The main deck is supported by deck transverses and deck longitudinales. Deck transverses are the transverse members of the framing structure. The transverse beams are attached to and supported by the frames at the sides, as shown in figure 2-17. Deck girders are similar to longitudinales in the bottom structure in that they run fore and aft and intersect the transverse beams at right angles.

The outboard strake of deck plating that connects with the shell plating is called the stringer strake. The stringer strake is usually heavier than the other deck strakes, and it serves as a continuous longitudinal stringer, providing longitudinal strength to the ship's structure.

STANCHIONS

To reinforce the deck transverses and to keep the deck transverse brackets and side frames from carrying the total load, vertical stanchions or columns are fitted between decks. Stanchions are constructed in various ways of various materials. Some are made of pipe or rolled shapes. The stanchion shown in figure 2-18 is in fairly common use; this pipe stanchion consists of a steel tube that is fitted with special pieces for securing it at the upper end (head) and at the lower end (heel).

BULKHEADS

Bulkheads are the vertical partitions that, extending athwartships and fore and aft, provide compartmentation to the interior of the ship. Bulkheads may be either structural or nonstructural. Structural bulkheads, which tie the shell plating, framing, and decks together, are capable of withstanding fluid pressure; these bulkheads usually provide watertight compartmentation. Nonstructural bulkheads are lighter; they are used chiefly for separating activities aboard ship.

Bulkheads consist of plating and reinforcing beams. The reinforcing beams are known as bulkhead stiffeners (fig. 2-19). Bulkhead stiffeners are usually placed in the

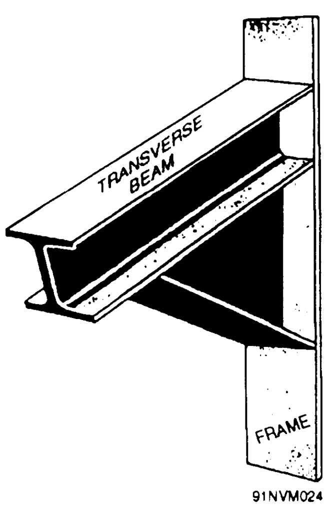


Figure 2-17.—Transverse beam and frame.

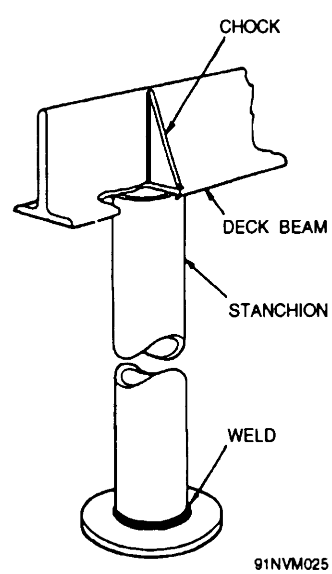


Figure 2-18.—Pipe stanchion.

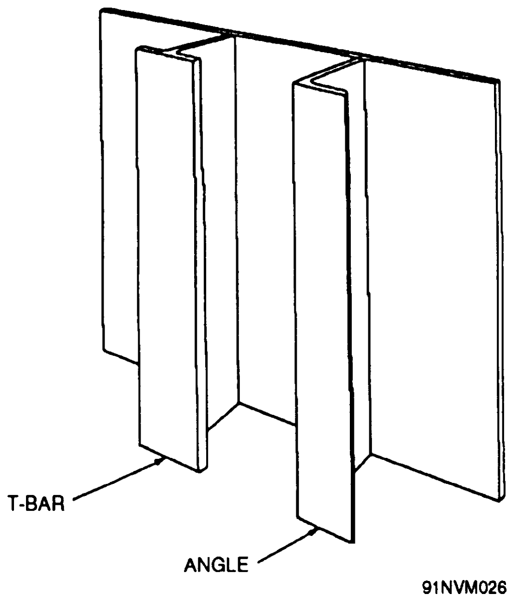


Figure 2-19.—Bulkhead stiffeners.

vertical plane and aligned with deck longitudinales; the stiffeners are secured at top and bottom to any intermediate deck by brackets attached to deck plating. The size of the stiffeners depends upon their spacing, the height of the bulkhead, and the hydrostatic pressure that the bulkhead is designed to withstand.

Bulkheads and bulkhead stiffeners must be strong enough to resist excessive bending or buckling in case of flooding in the compartments that they bound. To form watertight boundaries, structural bulkheads must be joined to all decks, shell plating, bulkheads, and other structural members with which they come in contact. Main subdivision bulkheads extend through the watertight volume of the ship, from the keel to the bulkhead deck, and serve as flooding boundaries in the event of damage below the waterline.

SUMMARY

Ship repair is the fundamental duty of the Hull Maintenance Technician. In this chapter, you have been exposed to the basic organization of the IMA and some of the personnel assigned to this type of organization. You have also been exposed to the basics of the QA program and its link to maintenance. When assigned to your command you should study your command's organization and QA program for a greater understanding of your role in that organization. As you gain experience and advance in rate you will be given the opportunity to become a work center supervisor. The appointment as a work center supervisor carries a lot of responsibility and accountability for your actions. But the role of a work center supervisor is often a rewarding and challenging position. As a work center supervisor you will be expected to organize, plan, and supervise the completion of various tasks that met all the requirements of the QA program.

CHAPTER 3

WOODWORKING CUTS AND JOINTS

LEARNING OBJECTIVES

Upon completion of this chapter, you should be able to do the following:

- *Identify, the various characteristics of wood, and tree growth and structure.*
- *Identify the various methods used in cutting and seasoning lumber.*
- *Identify common defects and blemishes of lumber.*
- *Identify the various grades of lumber and the methods used to measure lumber.*
- *Identify types of wood joinery to include cuts, joints, fasteners, and materials.*
- *Recognize the proper method and necessary took and equipment for laying out and cutting joints.*
- *Identify applications for the various joints.*
- *Recognize the purpose and use of different types of fastening materials.*
- *Identify the types of glue and their application methods.*
- *Identify the various sanding materials and their proper uses.*

INTRODUCTION

Although Navy ships are now made largely of steel and other metals, there is still plenty of woodworking for HTs to do. Cruisers and carriers usually have a shop equipped with the necessary handtools and three or more standard woodworking machines; tenders and repair ships have large shops with all types of woodworking machines.

An HT is required to have a knowledge of the types of wood and woodworking glue, the principles of wood finishing, and to be able to solve problems dealing with the number of board feet in a piece of lumber. This chapter provides information related to these requirements.

WOOD

In the lumber industry, woods are classified as hardwoods or softwoods. These two terms are more as a matter of convenience than as an exact classification. In fact, this classification does not depend on how hard the wood is. It depends on what kind of leaves the trees have. If the tree has broad leaves that shed in winter, the wood is classified as hardwood. If the tree has needle leaves and cones, the wood is classified as softwood. These classifications are somewhat confusing because some softwoods are harder than some hardwoods, and some hardwoods are softer than most softwoods.

Hardwoods are used in construction and repair work because of their strength, durability, and ability to resist warpage. They are used to make furniture, dowels, and some patterns. Hardwoods include ash, birch, beech, white oak, poplar, walnut, and maple.

HTs prefer softwoods for most patterns because they work easily. Softwoods are also used as structural lumber, boat planking, and for shoring. Softwoods include white cedar, cypress, Douglas fir, white pine, yellow pine, and redwood.

TREE GROWTH AND STRUCTURE

Wood consists of small cells. The size and arrangement of these cells determine the grain of the wood and many of its properties. Look at a freshly cut tree stump. You will see thousands of large and small cells arranged in circular rings around the pith or center of the tree. The large cells have thin walls, and the smaller cells have thick walls (figs. 3-1 and 3-2). Rings form because of a difference in the growth rate during various seasons of the year. In spring, a tree grows rapidly and builds up a layer of soft, large cells. These cells appear in the cross section of the trunk as the light-colored rings (spring rings).

As the weather gets hotter during early summer, the growth rate slows. The summer cells form closer together and become dark rings (summer rings). The age of a tree can be determined very accurately by counting these dark rings. Some trees, such as oak and walnut, have very distinctive rings. White pine is so uniform that you can barely see the rings.

The sapwood of a tree is the outer section of the tree between the heartwood (darker center wood) and the bark (fig. 3-1). Sapwood is lighter in color than heartwood.

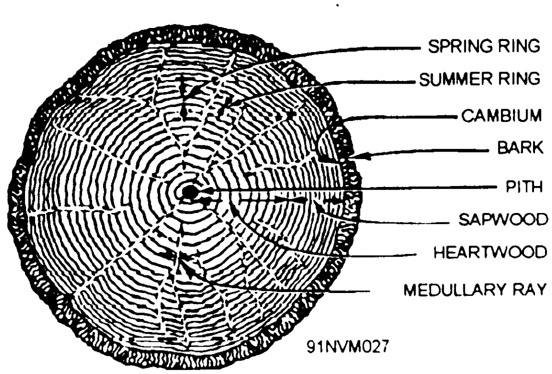


Figure 3-1.—Cross section of a tree.

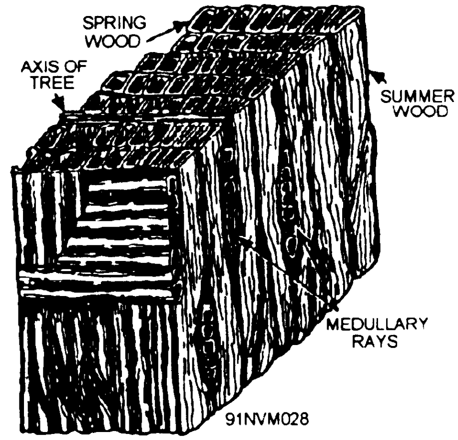


Figure 3-2.—Structure of wood.

The cambium layer (fig. 3-1) is the boundary between the sapwood and the bark. New sapwood cells form in this thin layer.

Medullary rays (fig. 3-1) are radial lines of wood cells. They are highly visible. Their function is to move cell liquids horizontally in the tree trunk. When speaking of medullary rays, we use thickness to refer to the horizontal dimension, and width to refer to the vertical dimension.

When a tree is sawed lengthwise, the annual rings form a pattern called the *grain.* Several terms describe wood grain.

- If the wood cells that form the grain are closely packed and small, the wood is *fine-grained* or *close-grained.* Maple and birch are good examples.

- If the cells are large and porous, the wood is *coarse-grained* or *open-grained.* Oak, walnut, and mahogany are examples of coarse-grained wood.

- When the wood cells are straight and parallel to the trunk of the tree, the wood is *straight-grained.*

- If the grain is crooked, slanting, or twisted, the wood is *cross-grained.*

When a log is sawed lengthwise into boards, each saw cut crosses the annual rings at an angle. If the angle between the saw cut and the rings is 45° or greater, the board has a vertical grain. If the angle is less than 45°, the board has a flat grain. If the log feeds through without turning, the first few outside boards cut off will be flat-grained. The boards cut from the center section will be vertical-grained. The last few boards cut will be flat-grained. By turning the log between saw cuts (fig. 3-3), you can produce all vertical-grained or all flat-grained lumber.

Vertical-grained wood resists wear better than flat-grained wood of the same species. Most flat-grained wood will take and hold a finish better than most vertical-grained wood. Use the term *texture* to express the relative size of the pores (cells) and fibers as coarse or fine textured and even or uneven textured.

CUTTING LUMBER

In a large lumber mill, logs are processed into lumber with huge band saws and circular saws. The two methods of sawing the logs are slash cutting and rift cutting (fig. 3-4). Slash cutting is from a series of parallel cuts. If hardwoods are cut, the process is termed *plain sawing.* If softwoods are cut, the process is termed *flat-grain sawing.*

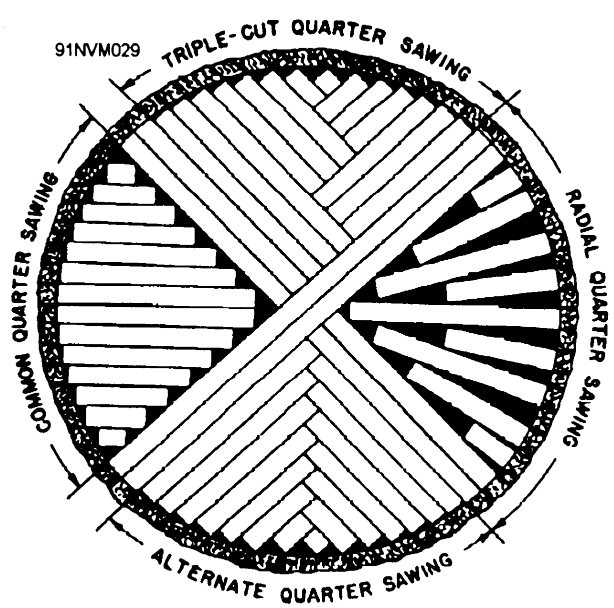


Figure 3-3.—Four methods of quarter sawing.

Slash cutting is the easier, quicker, and less wasteful of the two methods. The surface knots that appear in slash-cut lumber affect the strength of the lumber much less than the knots that appear in rift-cut lumber. However, if a log is sawed to produce all slash-cut lumber, more boards will have knots than if the log were all rift cut.

Rift-cut lumber provides edge grain on both faces. If hardwood is rift cut, it is quarter-sawed lumber. If softwood is rift cut, it is edge-grain lumber. When an entire log is slash cut, several boards near the center of the log will actually be rift cut.

Getting as many edge-grained boards as possible from a tree requires that the logs first be sawed into quarters (fig. 3-3). Then, each quarter is sawed into planks by one of the four methods shown. The method used depends on the intended use for the lumber. Radial quarter sawing will yield lumber that is stronger and will warp less than that gotten by any other method of sawing. The disadvantages, however, are that this method is more costly, takes longer, and is more wasteful of material.

SEASONING LUMBER

Once lumber has been sawed, it must be seasoned (dried). The purpose of seasoning is to remove the moisture from the cells. Moisture (water or sap) occurs in two separate forms—free water and imbibed water. Free water is the moisture the individual cells contain internally. Imbibed water is the moisture contained by the cell walls. During drying or seasoning, the free water evaporates until a minimum remains. The amount of moisture remaining is the fiber-saturation point.

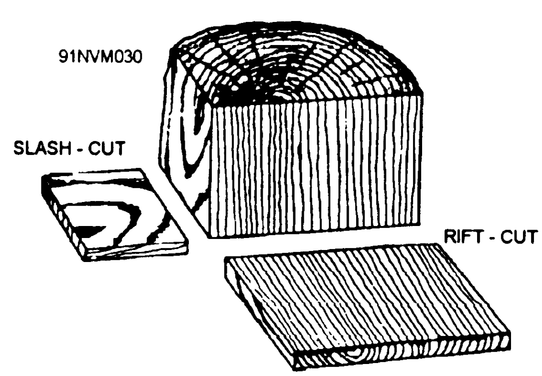


Figure 3-4.—Slash cutting and rift cutting.

The fiber-saturation point varies from 25 to 30 percent, but for general purposes is accepted as 30 percent. Below the fiber-saturation point, the imbibed water extracts from the cell walls, causing a reduction in the thickness of the walls.

Wood shrinks across the grain when the moisture content lowers below the fiber-saturation point. Evaporation or absorption of moisture causes shrinking and swelling of the wood cells, changing the size of the cells. Therefore, the lowering or raising of the moisture content causes lumber to shrink or swell.

The loss of moisture during seasoning causes wood to be (1) harder, (2) stronger, (3) stiffer, and (4) lighter in weight. There are two methods for seasoning lumber—air drying and kiln drying.

Air-dried lumber is exactly what the name implies. It is wood placed in a shed or in the open to dry. This method takes up to 7 years to season some woods.

A faster method of drying is known as kiln drying. The wood is placed in a kiln and treated with steam. The time required for drying varies from 2 or 3 days to several weeks. Often a combination of air-dried and kiln-dried methods is used to dry lumber.

Lumber is dry enough for most uses when the moisture content reduces to about 12 or 15 percent. However, lumber used for patterns should be drier. The moisture content should be 8 or 10 percent for hardwoods and 10 to 12 percent for softwoods. As an HT, you will learn to judge the dryness of a wood by its color, weight, smell, and feel. Looking at the shavings and chips also helps identify wood.

LUMBER DEFECTS AND BLEMISHES

A defect in lumber is any flaw that affects the strength, durability, or utility value of the lumber. A blemish is a flaw that mars only the appearance of the lumber. A blemish that affects the utility value of the lumber (such as a blemish in wood intended for fine furniture or cabinet work) is also a defect.

You will seldom find a piece of lumber that does not have a defect or blemish of some sort. Some defects and blemishes are the result of decay in the growing tree. Others are the result of insects, worms, and fungi, which can cause defects either before or after the lumber is cut. Improper seasoning causes other defects and blemishes.

The most common defects are knots. Knots occur in most kinds of lumber and are the result of branch growth. An interwoven knot forms while the tree is alive. Its annual rings are interwoven with those of the trunk of the tree. Usually an *interwoven knot* is solid and is not a serious defect. If the limb dies before the tree is cut, the wood formed in the trunk of the tree makes no further connection with the limb, but grows around it. This produces a *dead knot.* This may be loose enough to drop out or may be tight enough to hold its shape and position when the tree is being sawed into lumber. A *spike knot* is a long, thin knot caused by the way the tree was sawed. Small, solid knots are not objectionable in most of the lumber used aboard ship. If lumber has loose or large knots, you should cut it into smaller pieces to eliminate these defects.

Heartshake and windshake (fig. 3-5) are other lumber defects. Heartshake is caused by the action of the wind and is a lengthwise separation of the annual rings. Windshake is also a defect caused by the action of the wind, which causes the tree to twist.

A CHECK is a crack or separation, usually short, caused by the uneven shrinking of the wood cells in seasoning. Do not confuse these with pitch pockets. Pitch pockets are small enclosed spaces in the wood filled with sap or pitch (rosin).

WARP or WARPAGE is a lumber defect in which a board distorts from a true, flat surface; it is twisted, bowed, or cupped warped. The varying amount of moisture in the wood changes the diameter of the cells. This causes the board to shrink or swell in width as well as in thickness, but not in length. Redwood is an exception because it will swell or shrink in all three dimensions.

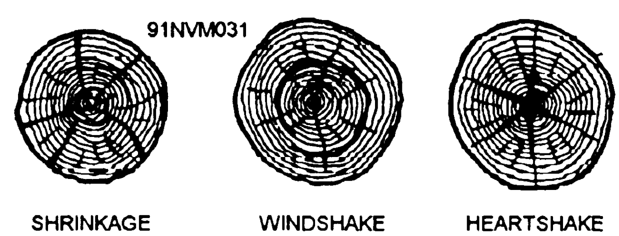


Figure 3-5.—Defects in logs.

WANE is a term that identifies a board that is not full or true to size. It lacks wood along corners, edges, or ends, or is partially composed of bark.

BLUE STAIN is a blemish caused by a mold fungus. It does not weaken the wood.

A BARK POCKET is a patch of bark that has had the tree grow over. It is entirely or almost entirely enclosed.

CROSS-GRAINED LUMBER has grain that is not parallel to the length of the lumber.

There are several lumber defects caused by improper seasoning. One common one is honeycombing. Honeycombing is a series of checks or cracks on the surface or in the center of the lumber caused by drying stresses. If the stress is not relieved by the addition of moisture during the seasoning process, honeycombing will result.

LUMBER SIZES

Lumber is sized according to how thick it is. Boards are pieces of lumber less than 2 inches thick. Planks or dimension lumber are pieces of lumber from 2 to 5 inches thick. Timbers are heavier pieces. Softwoods are usually cut to standard thicknesses, widths, and lengths.

The dressed dimensions of lumber are always smaller than the specified size (nominal size) (table 3-1). The nominal size is the size of the lumber in its rough form as it comes from the saw mill. Dressed lumber has been surfaced (planed smooth) on two or four sides. Lumber surfaced on two sides is S2S (surfaced on two sides). Lumber surfaced on four sides is S4S (surfaced on four sides).

Table 3-1.—Nominal and Dressed Lumber Sizes

Nominal Size	Dressed Dimensions
2 × 2	1 5/8 × 1 5/8
2 × 4	1 5/8 × 3 5/8
2 × 6	1 5/8 × 5 5/8
2 × 8	1 5/8 × 7 1/2
2 × 10	1 5/8 × 8 1/2
2 × 12	1 5/8 × 11 1/2
4 × 4	3 5/8 × 3 5/8

All softwood framing lumber, and most other softwood lumber, is cut to even-numbered foot lengths, such as 10 feet, 12 feet, and 14 feet. Hardwood is sometimes cut to odd-numbered as well as even-numbered foot lengths.

Hardwoods used for cabinets, furniture, and other finish work are cut to specific thicknesses (in graduations of 1/4 inch). They are cut to random widths and lengths (RWL) with a specified minimum. For example, a written order for walnut would be 4/4x4x6 RWL. This would tell the supplier that you require material 1 inch thick (4/4), at least 4 inches wide, and at least 6 feet long.

LUMBER GRADES

Lumber grades are based on the type and extent of defects, size of the pieces, and seasoning condition. Softwood lumber is graded for quality according to American Lumber Standards. These standards are set by the National Bureau of Standards for the U.S. Department of Commerce. The major quality grades, in descending order of quality, are select lumber (usually used for interior finish) and common lumber (usually used for house construction). Each grade has subdivisions in descending order of quality as follows:

1. Select lumber

Grade A lumber. This lumber is select lumber that is practically free of defects and blemishes.

Grade B lumber. This is select lumber that contains a few minor blemishes.

Grade C lumber. This is finish item lumber that contains more blemishes and more significant blemishes than grade B. These blemishes must be able to be easily and thoroughly concealed with paint.

Grade D lumber. This is finish item lumber that contains more blemishes and more significant blemishes than grade C, but it is still capable of presenting a satisfactory appearance when painted.

2. Common lumber

No. 1 common lumber. This is sound, tight-knotted stock containing only a few minor defects. It must be suitable for use as watertight lumber.

No. 2 common lumber. This lumber contains a few significant defects, but no knotholes or other serious defects.

No. 3 common lumber. This lumber contains a few defects that are larger and coarser than those in No. 2 common; for example, occasional knotholes.

No. 4 common lumber. This lumber is low quality and contains serious defects like knotholes, checks, shakes, and decay.

No. 5 common lumber. This lumber is capable only of holding together under ordinary handling.

Mill-run lumber is everything that is sawed except the slabs (bark). Some associations use grades of construction known as standard, utility, and economy.

All species of lumber are covered by the grading rules and size standards of some association or grading bureau. Softwood lumber standards are set by a regional association of manufacturers. In a few cases, a softwood species growing in more than one region is graded under rules of two different associations. It is better to buy according to these association grades than to try to buy according to individualspecifications, unless the requirements are very unusual. Occasionally a departure from the standard grade provision is necessary. This is handled as an exception to a standard grade.

Hardwoods are graded as firsts, seconds, selects, No. 1 common, and No. 2 common. These grades indicate only the amount of clear usable lumber in a particular piece. They are established by the National Hardwood Manufacturers' Association. The way to buy hardwoods for any use other than construction is by personal inspection.

MEASURING LUMBER

When you are measuring lumber, *thickness* is the dimension between the two face surfaces, *Width* is the dimension between the two edges that are parallel to the wood grain. *Length* is the dimension between two ends and is parallel to the wood grain regardless of the width dimension.

It is common practice to state the thickness dimension in inches first; the width in inches second; and the length in feet last. For example, if you were told to get a 2 by 4 by 6, you would know to get a board 2 inches thick by 4 inches wide by 6 feet long.

The standard measure for lumber is a *board foot.* This is abbreviated as bf or bd ft. A board foot is simply one-twelfth of a cubic foot. A board measuring 1 inch thick, 12 inches wide, and 12 inches long contains 1 bd ft. Figure 3-6 shows different size pieces of wood. Each one contains 1 bd ft.

You may use several formulas to determine bd ft. The one most commonly used is the *inches, inches, feet* method. To use it, multiply the thickness (T) in inches by the width (W) in inches by the length (L) in feet. Next, divide the product by 12. Write the formula as follows:

$$bd\ ft = \frac{T(in.) \times W(in.) \times L(ft.)}{12}$$

Suppose you want to determine the bd ft contained in a piece of wood measuring 1 inch thick by 8 inches wide by 9 feet long. Using the formula, you would work it like this:

$$bd\ ft = \frac{T(in.) \times W(in.) \times L(ft.)}{12}$$

$$bd\ ft = \frac{1(in.) \times 8(in.) \times 9(ft.)}{12}$$

$$bd\ ft = 6$$

Therefore, a board measuring 1 inch by 8 inches by 9 feet will contain 6 bd ft.

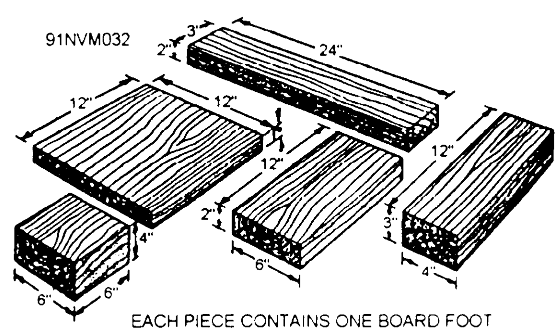


Figure 3-6.—The board foot.

A board less than 1 inch thick is figured as 1 inch when you are calculating bd ft. A board more than 1 inch thick is figured to the next larger 1/4-inch increment. Thus, a board having a thickness of 1 1/8 inches calculates as 1 1/4 inches. Board measure calculates on the basis of the nominal not the dressed dimension of the lumber.

Another common way of measuring lumber is by linear measure. Linear measure is simply the length measurement of a piece of lumber. Therefore, if you had a 2 by 4 by 6, its linear measurement would be 6 feet. This method is often used when buying dimensioned lumber for construction purposes.

COMMON TYPES OF WOODS

Before proceeding with this chapter, review the sources, uses, and characteristics of the various types of common woods provided in table 3-2.

Table 3-2.—Common Woods

TYPE	SOURCES	USES	CHARACTERISTICS
Ash	East of Rockies.	Oars, boat thwarts, benches, gratings, hammer handles, cabinets, ball bats, wagon construction, farm implements.	Strong, heavy, hard, tough, elastic, close straight grain, shrinks very little, takes excellent finish, lasts well.
Balsa	Ecuador.	Rafts, food boxes, linings of refrigerators, life reserves, loud speakers, sound-proofing, air-conditioning devices, model airplane construction.	Lightest of all woods. Very soft, strong for its weight, good heat insulating qualities, odorless.
Basswood	Eastern half of U.S. with exception of coastal regions.	Low-grade furniture, cheaply constructed buildings, interior finish, shelving, drawers, boxes, drainboards, woodenware, novelties, excelsior, general millwork.	Soft, very light, weak, brittle, not durable, shrinks considerably. Interior to poplar, but very uniform, works easily. Takes screws and nails well and does not twist or warp.
Beech	East of Mississippi River, Southeastern Canada.	Cabinetwork, imitation mahogany furniture, wood dowels, capping, boat trim, interior finish, tool handles, turnery, shoe lasts, carving, flooring.	Similar to birch but not so durable when exposed to weather. Shrinks and checks considerably. Close-grained, light or dark red color.
Birch	East of Mississippi River and north of Gulf Coast States, Southeast Canada, Newfoundland.	Cabinetwork, imitation mahogany furniture, wood dowels, capping, boat trim, interior finish, tool handles, turnery, carving.	Hard, durable, fine grain, even texture, heavy, stiff, strong, tough. Takes high polish, works easily. Forms excellent base for white enamel finish, but not durable when exposed. Heartwood is light to dark reddish brown in color.

Table 3-2.—Common Woods—Continued

TYPE	SOURCES	USES	CHARACTERISTICS
Butternut	Southern Canada, Minnesota, Eastern U.S. as far south as Alabama and Florida.	Toys, altars, woodenware, millwork, interior trim, furniture, boats, scientific instruments.	Very much like walnut in color but softer. Not so soft as white pine and basswood. Easy to work, coarse-grained, fairly strong.
Cypress	Maryland to Texas, along Mississippi Valley to Illinois.	Small boat planking, siding, shingles, sash, doors, tanks, silos, railway ties.	Many characteristics similar to white cedar. Water-resistant qualities make it excellent for use as boat planking.
Doulgas fir	Pacific Coast, British Columbia.	Patternmaking, deck planking on large ships, shores, strongbacks, plugs, filling pieces and bulkheads of small boats, building construction, dimension timber, plywood.	Excellent structural lumber. Strong, easy to work, clear straight grained, soft but brittle. Heartwood is durable in contact with ground. Best structural timber of northwest.
Elm	States east of Colorado.	Agricultural implements, wheel-stock, boats, furniture, crossties, posts, poles.	Slippery, heavy, hard, tough. Durable, difficult to split, not resistant to decay.
Hickory	Arkansas, Tennessee, Ohio, Kentucky.	Tools, handles, wagon stock, hoops, baskets, vehicles, wagon spokes.	Very heavy, hard, stronger and tougher than other native wood, but checks and shrinks. Difficult to work. Subject to decay and insect attack.
Lignum vitae	Central America.	Patternmaking, block sheaves, and pulleys, water-exposed shaft bearings of small boats and ships, tool handles, small turned articles, and mallet heads.	Dark greenish brown. Unusually hard, close-grained, very heavy, resinous. Difficult to split and work, has soapy feeling.
Live oak	Southern Atlantic and Gulf Coasts of U.S., Oregon, California.	Implements, wagons, shipbuilding.	Very heavy, hard, tough, strong, durable. Difficult to work. Light brown or yellow sap wood nearly white.
Mahogany	Honduras, Mexico, Central America, Florida, West Indies, Central Africa, other tropical sections.	Patternmaking, furniture, boats, decks, fixtures, interior trim in expensive homes, musical instruments.	Brown to red color. One of most useful of cabinet woods, hard, durable. Does not split badly. Open-grained, takes beautiful finish when grain is filled but checks, swells, shrinks, warps slightly.

Table 3-2.—Common Woods—Continued

TYPE	SOURCES	USES	CHARACTERISTICS
Maple	All states east of Colorado, Southern Canada.	Patternmaking, excellent furniture, high-grade floors, tool handles, ship construction crossties, counter tops, bowling pins.	Fine-grained, grain often curly or "bird's eyes." Heavy, tough, hard, strong. Rather easy to work, but not durable. Heartwood is light brown, sap wood is nearly white.
Norway pine	States bordering Great Lakes.	Dimension timber, masts, spars, piling, interior trim.	Light, fairly hard, strong. Not durable in contact with ground.
Philippine mahogany	Philippine Islands	Patternmaking, pleasure boats, medium-grade furntiure, interior trim.	Not a true mahogany. Shrinks, expands, splits, warps, but available in long, wide, clear boards.
Poplar	Virginias, Tennessee, Kentucky, Mississippi Valley.	Patternmaking, low-grade furniture, cheaply constructed buildings, interior finish, shelving, drawers, boxes.	Soft, cheap obtainable in wide boards. Warps, shrinks, rots easily. Light, brittle, weak, but works easily and hold nails well, fine-textured.
Red cedar	East of Colorado and north of Florida.	Mothproof chests, lining for linen closets, sills, and other uses similar to white cedar.	Very light, soft, weak, brittle, low shrinkage. Great durability, fragrant scent. Generally knotty, beautiful when finished in natural color. Easily worked.
Red oak	Virginias, Tennessee, Arkansas, Kentucky, Ohio, Missouri, Maryland.	Interior finish, furniture, cabinets, millwork, crossties when preserved.	Tends to warp. Coarse-grained. Does not last well when exposed to weather. Porous easily impregnated with preservative. Heavy, tough, strong.
Redwood	California.	Patternmaking, general construction, tanks, paneling.	Inferior to yellow pine and fir in strength. Shrinks and splits little. Extremely soft, light straight-grained. Very durable, exceptionally decay resistant.
Spruce	New York, New England, West Virginia, Central Canada, Great Lakes states, Idaho, Washington, Oregon.	Railway ties, resonance wood, piles, airplanes, oars, masts, spars, baskets.	Light, soft, low strength, fair durability, close grained, yellowish, sap wood indistinct.
Sugar pine	California, Oregon.	Same as white pine.	Very light, soft, resembles white pine.
Teak	India, Burma, Java, Thailand.	Deck planking, shaft logs for small boats.	Light brown color. Strong, easily worked, durable, resistant to damage by moisture.

Table 3-2.—Common Woods—Continued

TYPE	SOURCES	USES	CHARACTERISTICS
Walnut	Eastern half of U.S. except Southern Atlantic and Gulf Coasts, some in New Mexico, Arizona, California.	Expensive furniture, cabinets, interior woodwork, gun stocks, tool handles, airplane propellers, fine boats, musical instruments.	Fine cabinet wood. Coarse-grained but takes beautiful finish when pore closed with wood filler. Medium weight, hard, strong. Easily worked. Dark chocolate color. Does not warp or check, brittle.
White cedar	Eastern Coast of U.S. and around Great Lakes.	Boat planking, railroad ties, shingles, siding posts, poles.	Soft, light weight, close-grained. Exceptionally durable when exposed to water. Not strong enough for building construction. Brittle, low shrinkage, generally knotty.
White oak	Virginias, Tennessee, Arkansas, Kentucky, Ohio, Missouri, Maryland, Indiana.	Boat and ship stems, sternposts, knees, sheer strakes, fenders, capping, transoms, shaft logs, framing for buildings, strong furniture, tool handles, crossties, agricultural implements, fence posts.	Heavy, hard, strong. Medium coarse-grained. Tough, dense, most durable of hardwoods. Elastic, rather easy to work, but shrinks and likely to check. Light brownish grey in color with reddish tines. Medullary rays are large and outstanding and present beautiful figures when quarter sawed. Receives high polish.
White pine	Minnesota, Wisconsin, Maine, Michigan, Idaho, Montana, Washington, Oregon, California.	Patterns, any interior job or exterior job that doesn't require strength, window sash, interior trim, millwork, cabinets, cornices.	Easy to work. Fine-grained, free of knots. Takes excellent finish. Durable when exposed to water, expands when wet, shrinks when dry. Soft, white. Nails without splitting, not very strong, straight-grained.
Yellow pine	Virginia to Texas.	Most important lumber for heavy construction and exterior work, keelsons, risings, filling pieces, clamps, floors, bulkheads of small boats, shores, wedges, plugs, strongbacks, staging, joists, posts, piling, ties, paving blocks.	Hard, strong, heartwood is durable in the ground. Grain varies. Heavy, tough, reddish brown in color. resinous, medullary rays well marked.

LUMBER

Woods that have a comparatively straight, close grain, that are easy to work, and that do not warp or shrink easily are the woods you should select for pattern work. Do not select boards containing too much moisture or pitch. Such boards are difficult to work with, shrink excessively, and will not keep a smooth surface.

A board that contains excess pitch may be unusually heavy. When planed, large amounts of pitch may be seen. Excessive moisture cannot always be detected by weight. Detection comes when the board is crosscut or dressed.

Kinds of Lumber

The woods most frequently used in the carpenter shop for most projects are redwood, white pine, ponderosa pine, mahogany, and poplar.

REDWOOD is inferior to the better grades of sugar pine and white pine, but for most patterns it works well. The best grades work easily. Redwood has one peculiar property that no other wood has—it shrinks in length as well as in thickness and in width. The name redwood derives from the reddish-brown color of the wood itself. It is related to pine but is much more durable when in contact with soil or when exposed to weather.

The redwood tree grows exclusively on the West Coast. The age of these forest giants runs as high as 3,000 to 4,000 years. They frequently grow to a height of 350 feet, with a diameter of 25 feet or greater.

WHITE PINE is the best wood for making simple patterns that are used less than 30 times and that are under 2 feet in length. This softwood is smooth, straight and even-grained, light, and warps very little when properly seasoned. White pine that is free from knots is the cheapest of lumber. With sharp tools, you can cut and carve white pine almost like soap. White pine takes a good coat of lacquer or glue, but it chips or breaks easily. Its color ranges from almost white to light yellowish-brown.

In the West, the name *white pine* usually applies to the native sugar pine that grows in northern California and southern Oregon.

PONDEROSA PINE is sometimes mistakenly called sugar pine. It closely resembles the sugar pine, but it is not good for some types of work such as pattern work. It warps and shrinks a lot and has more pitch than sugar pines.

MAHOGANY is more durable and harder than pine. Use it when 30 to 100 castings are required. Also, use it for patterns having long or thin sections or projections. Mahogany is strong, coarse-grained, and warps very little. It is soft enough to cut and nail easily, yet hard enough to stand a lot of wear. Mahogany is difficult to plane or carve in the direction of the grain, but it is excellent for cross-grain carving. Mahogany will outlast pine 3 to 1.

Several varieties of mahogany are used. Spanish mahogany is from the West Indies, Honduras mahogany (also called baywood) and Mexican mahogany is from Central America and Mexico, and Senegal mahogany is from Africa. Distinguishing between varieties is difficult. Mahogany is usually reddish-brown, but it often varies in color.

POPLAR is used in many carpenter and pattern shops. It is soft with close, straight grain. Its use is limited because of brittleness and excessive warping and shrinkage. Poplar ranges in color from off-white to light yellow. The poplar tree grows in the eastern part of the United States. It goes from the Gulf of Mexico north into southern Canada.

Other woods used by HTs are discussed in the following paragraphs.

MAPLE, especially eastern maple, is very hard and is difficult to work. It varies in color from light brown to white. Oregon maple (western soft maple) is close-grained and reddish-brown in color. This wood is mostly used in the manufacture of furniture and tool handles. Oregon maple is also used for certain projects that must endure heavy wear or that are weak because of their shape or size. Maple will outlast pine 8 to 1.

WHITE ASH is open-grained, elastic, and hard. The color of the heartwood is light brown. The sapwood is almost white.

BLACK WALNUT grows in the eastern part of the United States. It is very durable and very hard. When used as pattern material, black walnut will outlast pine 5 to 1.

HICKORY is the strongest, heaviest, and toughest of all American woods. It is also flexible. The color of hickory varies from brown to white.

OREGON PINE (Douglas fir) is of two varieties, red and yellow. The yellow is the more valuable of the two, being hard, strong, and very durable—but difficult to work.

CHERRY is brown in color, close-grained, and very hard—but warps excessively. Cherry is a little difficult to carve, but when used for small patterns, it will outlast pine 5 to 1.

LIGNUM VITAE is excessively heavy, hard, and resinous. Its color varies from light yellow to dark greenish-brown—at times almost black. This wood is native to tropical America, New South Wales, and New Zealand.

TEAK is heavy, strong, and oily. It has a dark color. It does not shrink, crack, or warp. Teak comes from East India.

Care and Storage of Lumber

Lumber is a tool like the saw or plane and should be considered as such. Store and care for lumber properly. This will prevent it from becoming water-soaked, rotted, or warped. The best way to stow lumber is by stacking it on end in racks. This way air can circulate around all the boards. Circulation dries the wood evenly and reduces warping.

Room for storing lumber on end is hard to find aboard ship. Lumber usually gets stored in the next best manner. The accepted method is to store the lumber horizontally. Separate the lumber by sizes. Put the l-inch lumber together, the 1 1/2-inch lumber together, and so on. When placing the lumber in racks, you should place small strips or battens about 1 inch thick across the boards about 6 feet apart. This will separate the boards and form a space for the air to circulate around them. Air circulation is important. A dressed board laid on its flat surface without full air circulation will usually warp toward the exposed surface. The air draws more moisture from the exposed surface than from the underneath surface.

The carpenter shop usually has overhead lumber storage racks. The bulk of the lumber is stowed in other parts of the ship because of space limitations aboard a repair ship or tender.

You should maintain a careful record of the lumber used and on hand. If possible, at least 3 months' supply should be on hand.

MANUFACTURED WOOD PRODUCTS

Laminated lumber is made up of layers of wood glued face-to-face (fig. 3-7). The parts glued together to make laminated lumber may be thinly sliced sheets of veneer or they may be sawed boards.

One advantage of laminated wood is that it can be any desired thickness. Also, staggering the ends of individual layers can produce timbers that are much longer than solid timbers.

Plywood (fig. 3-8) is thin layers of wood glued face-to-face. It usually has the grain of each layer at right angles to the next layer. Plywood alternates grain each ply, and laminated wood never alternates grain. Plywood always has an odd number of plies. Veneered stock for furniture manufacture usually has five layers. A thick layer called the core is in the center. The layers that are glued on with the grain running across are called cross bands. The surface layers or faces are placed so their grain runs parallel to the length of the panel.

One-quarter inch and one-eighth inch fir plywood has only 3 plies. Plywood always has an odd number of plies—up to 15. The standard size of

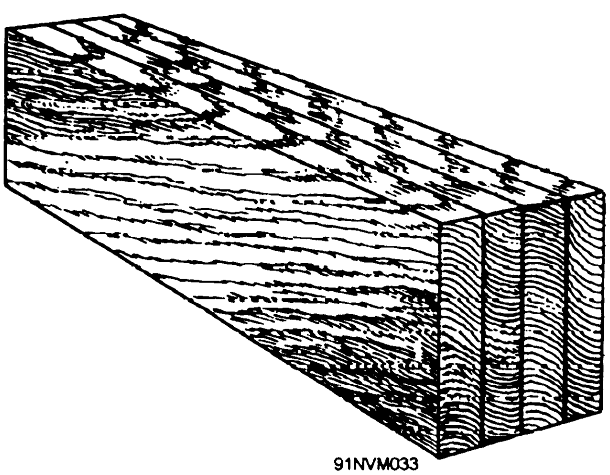


Figure 3-7.—Laminated lumber.

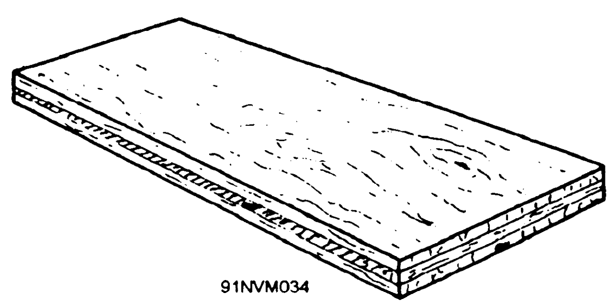


Figure 3-8.—Plywood.

plywood sheets is 4 feet wide by 8 feet long, though smaller and larger sizes are available. Because of the cross-grain effect, splitting plywood is very difficult and shrinking and swelling are rare.

The development of special glues and bonding materials has made plywood highly resistant to water. It was widely used during World War II and is still in use in the Navy.

Two basic grades of plywood are interior and exterior. Interior plywood is unreliable in wet places. Exterior plywood will keep its original form and strength when subjected to the elements. It is suitable for permanent exterior use provided it is properly protected from the elements. Most plywood is branded or stamped on the edge with the symbol EXT. or INT. More complete information is stamped on the back of the plywood sheet. A typical Douglas fir back stamp, with all symbols explained, is shown in figure 3-9.

Plywood is graded by the quality of the face veneers. Grade A is the best. Grade D is the poorest (fig. 3-9). Grading is based upon the number of defects, such as knotholes, pitch pockets, and splits. It also considers the presence of streaks, discolorations, sapwood, shims, and patches in the face of the panel. Plywood has resin-impregnated fiber faces that provide better painting surfaces and better wearing qualities.

Because of the conditions of its manufacture, plywood is dry when received. It should be stored in a closed shed. For long storage, a heated storage area is recommended.

Plywood is commonly stacked in solid piles. Under humid conditions, edges swell because of exposed end grain. This swelling causes dishing, especially in the upper panels of high piles. Reduce dishing by placing strips between sheets of stacked plywood. Use enough strips to prevent the plywood from sagging between strips. Dry l-inch strips are suitable for supporting plywood.

Hardboard is known by several trade names. It is wood fibers separated, treated, and then subjected to heat and heavy pressure. Hardboard is available in thicknesses from 1/16 inch to 5/6 inch. The most common size is 4-foot by 8-foot sheets, but other sizes are available. Hardboard comes in a plain, smooth surface or in several glossy finishes. Some finishes imitate tile or stone. Use class B treated hardboard where moisture resistance or strength is required. Otherwise, class A hardboard is satisfactory.

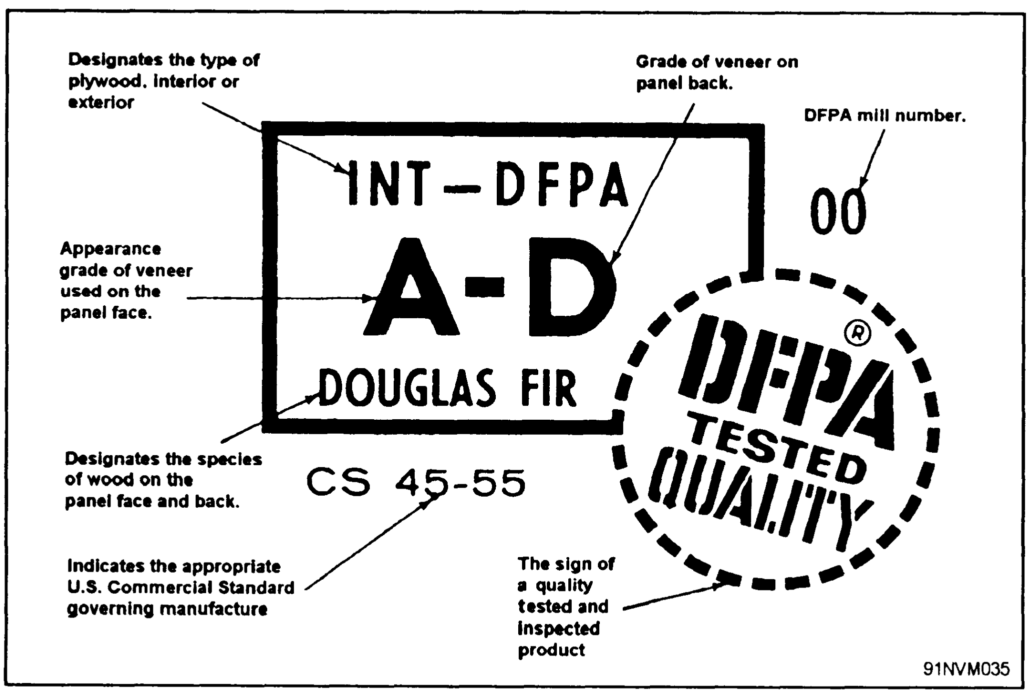


Figure 3-9.—Typical Douglas fir back stamp.

WOOD JOINERY

An important skill to master is wood joinery. In woodworking, joinery is the art of combining two or more pieces of material into one. The purpose for this procedure is to increase dimensions, strength, or material alignment. Wood joinery includes the manufacture of wood joints and the various devices or methods used to fasten them together. These methods include glue, screws, and brads.

A joint is only as strong as its weakest point. This can be the joints if they are incorrectly made or if you use the wrong joint. Correct joint usage and proper construction can make the joint the strongest point of the project.

STANDARD JOINTS

There are four standard methods for joining wood stock edge-to-edge. These methods are the plain butt, dowel, tongue-and-groove, and splined edge joints shown in figure 3-10.

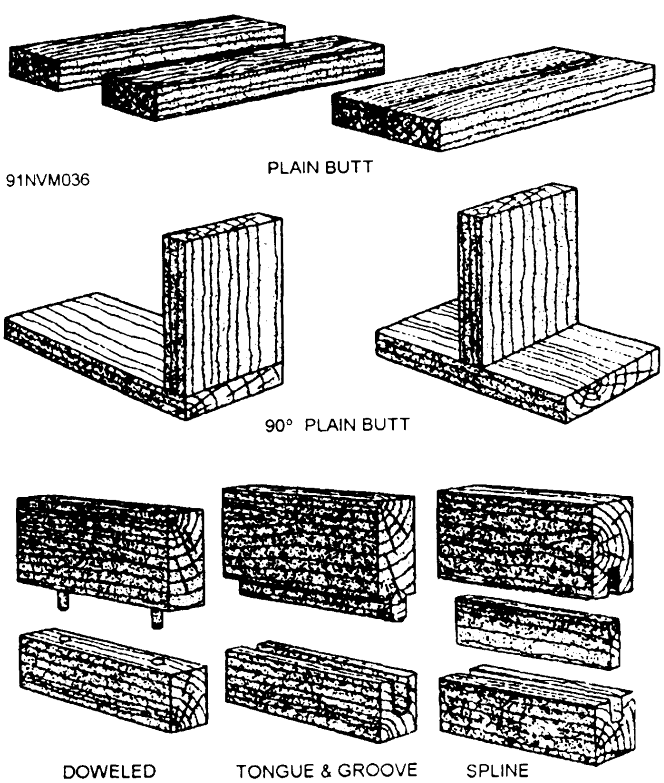


Figure 3-10.—Edge joints.

The plain butt joint is the simplest and the one most used by the HT.

The doweled joint is usually a plain butt joint that has been given greater strength with wooden dowels. Dowels also reinforce other joints such as the miter and half lap.

When choosing a dowel for edge-to-edge use, the dowel diameter should be one-third the thickness of the stock you are jointing. Thus, 3/4-inch thick stock would require a 1/4-inch dowel.

The tongue-and-groove joint is stronger than the butt or dowel joint. It is used for wood flooring.

The splined edge joint is a variation of the tongue-and-groove joint. It is easier to make because two matching grooves and a separate spline replace the tongue. Minimal strength is gained if the grain direction of the spline is parallel to the edges, as shown in figure 3-11. A significant strength gain results when the grain direction of the spline is perpendicular to the edges.

The thickness of both the spline and tongue should be one-third of the material thickness. The width of the spline should be equal to twice the material thickness, while the tongue width should be the same as the thickness. For example, 3/4-inch stock would require a spline measuring 1/4 inch thick and 1 1/2 inches wide or a tongue measuring 1/4 inch thick and 3/4 inch wide (fig. 3-11).

Lap Joints

Lap joints are shown in figure 3-12. Plain lap joints are used in all kinds of construction, particularly if appearance is not a factor. The end butt half lap is not as strong as the plain lap joint, but it looks better and requires less space. The corner half lap works well for framing buildings, boxes, and cabinets. The cross lap joint joins the spokes of a wheel pattern.

The scarf joint (fig. 3-13) is a special type of lap joint that is used to join heavy timbers. For repair purposes, the recommended slope is 1 in 12. The cut should slant through the length of a piece of wood 12 inches for every inch of depth or width.

The end butt joint with fishplates (fig. 3-14) is useful for joining short members to make long pieces. Secure the fishplates with nails, screws,

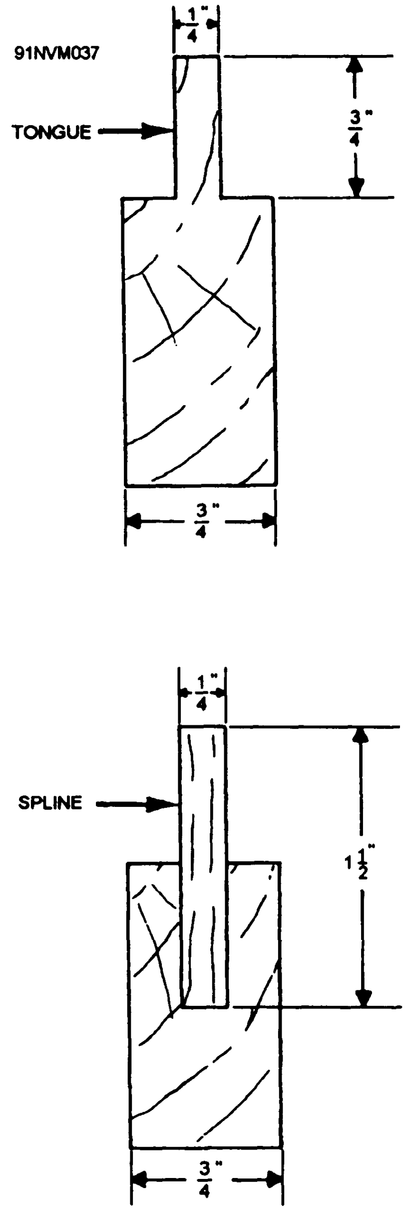


Figure 3-11.—Tongue and spline joints.

rivets, or bolts. Its main disadvantage is that it is bulky.

Dado, Gain, and Rabbet Joints

You would use the plain dado joint (fig. 3-15) to make cabinets and shelves. You would usually cut this joint with a dado head (cutters), which fits on a circular saw. You also can make this cut by hand using a backsaw or tenon saw and finish it with chisels. Fasten this joint with glue, nails, or screws.

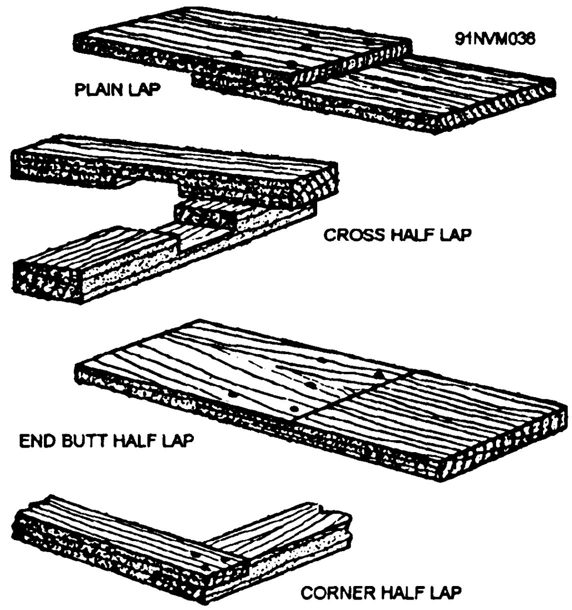


Figure 3-12.—Lap joints.

The gain joint (fig. 3-15) is a special kind of dado joint. You use it when appearance is a factor.

Rabbet joints are often used with dadoes. They are cut across or with the grain (fig. 3-16). Cut rabbets with the circular saw dado head or with the jointer. They can be cut by hand using special rabbeting planes.

Dovetail Joints

Cabinetmakers and other skilled woodworkers often use the dovetail joint (fig. 3-17). It is used most often in joining the corners of furniture drawers and chests because of its locking features. Such joints are usually made with blind dovetails so

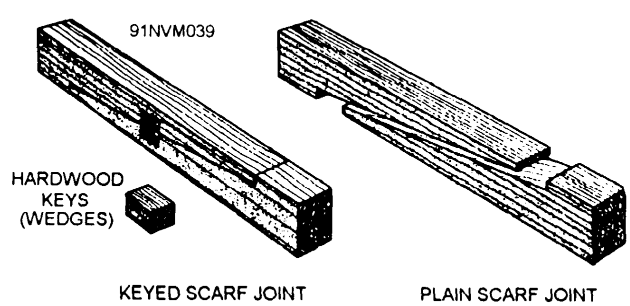


Figure 3-13.—Typical scarf joints.

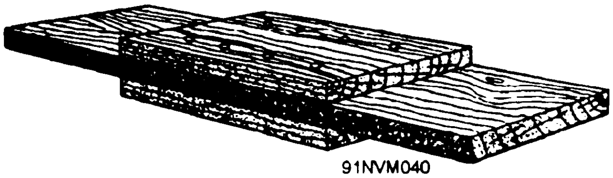


Figure 3-14.—End butt joint with fishplates.

they cannot be seen from the outside of the furniture.

Heavier construction that requires locking joints call for single dovetails and half dovetails. The single dovetail (dovetail key) is a good joint for attaching a loose piece to a pattern. Dove tails require accurate layout. Use a sharp knife edge to mark the layout, not a pencil. Use a T-bevel to lay out the angles. You can use the tenon saw to saw out most of the waste and then finish the work with a chisel.

Box Corner and Miter Joints

Many commercial packing boxes are made with the box corner joint (fig. 3-18). It cuts easily on the circular saw with special dado heads.

The miter joint (fig. 3-19) is used for picture frames, boxes, panel frames, and other frames. Glue the joints, and then fasten miter joints with nails, brads, and corrugated fasteners.

The spline miter is better than the plain miter. Cut it with the table saw and jig. Other miters require more work and are used only on special jobs.

Coping Joints

When matching inside corner joints between molding trim members, use the coping joint (fig.

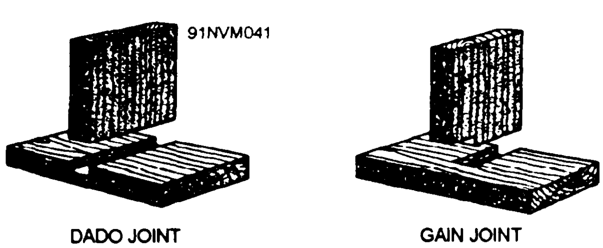


Figure 3-15.—Dado and gain joints.

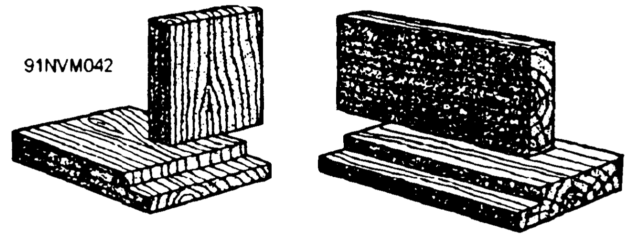


Figure 3-16.—Rabbet joints.

3-20) to shape the end of the abutting member to fit the face of the first member.

Mortise-and-Tenon Joints

Good furniture has several mortise-and-tenon joints (fig. 3-21). This joint appears weak, but when glued it is very strong. It can be wedged, split, or offset. You can't go wrong with properly designed and fitted mortise-and-tenon joints. Use the slip-tenon joint the same way as a miter or corner half-lap joint. Secure it with dowels, screws, bolts, or nails and then glue it.

LAYING OUT AND CUTTING JOINTS

One of the basic skills you must learn in woodworking is to join pieces of wood to form tight, strong joints. The two joined pieces are members. The two major steps in joining members are layout and cutting. Lay out the joints on the ends, edges, or faces of the members. Then cut the members to the required shapes for joining.

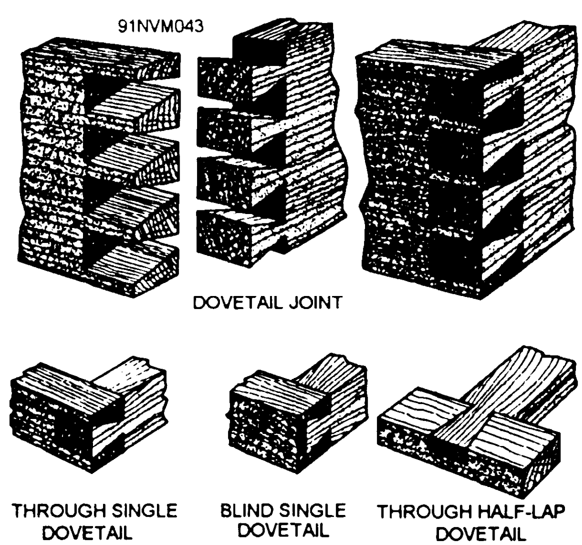


Figure 3-17.—Dovetail joints.

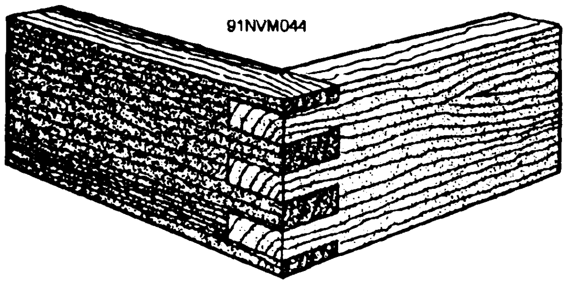


Figure 3-18.—Box corner joint.

Cutting accurate joints requires square and true stock. To square and true stock, you use a jointer for trueing the edges and a surface planer to get uniform thickness. Use a table or radial saw for squaring the ends and cutting stock to the desired length. Often, you will have to perform these operations by hand. Therefore, planing and squaring a small board to dimensions by hand should be the first lesson in woodworking. The six major steps in the process are shown in figure 3-22. Practice them until you learn to make a smooth, square board with minimum planing.

Instruments used for laying out joints are the combination square, the T-bevel, the marking gauge, and a bench knife for scoring lines. For hand cutting joints, use the backsaw, dovetail saw, coping saw, and various chisels and planes.

You can cut all joints mentioned in this chapter by hand or machine. Whatever the method you use and whatever the type of joint, always remember the following rule: To ensure a tight joint, always cut on the waste side of the line, never on the line itself. Cutting a groove on the waste side of the line with a knife or chisel will help a backsaw get a smooth start.

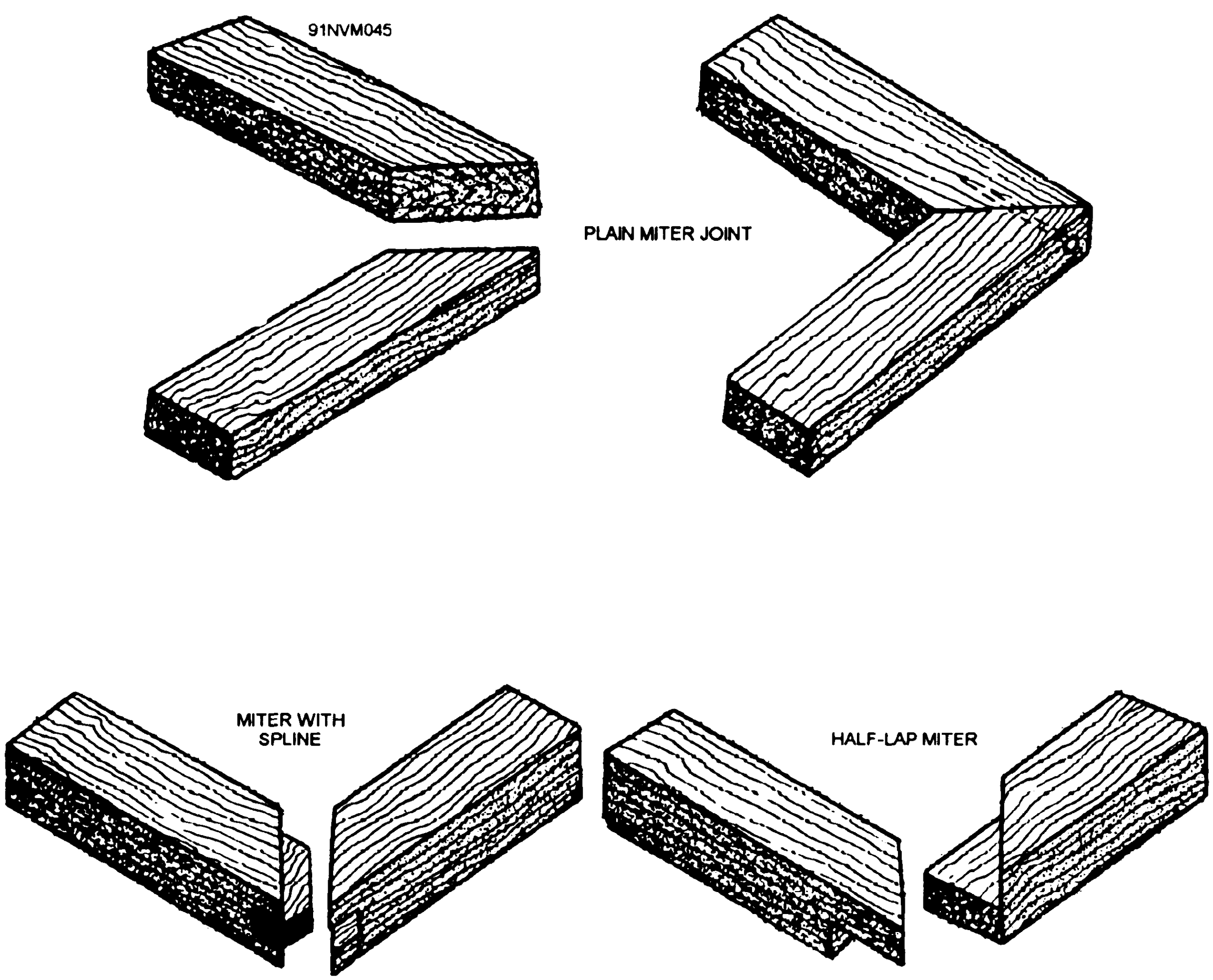


Figure 3-19.—Miter joints.

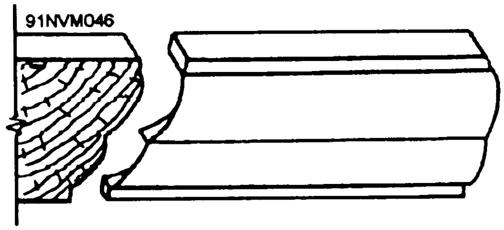


Figure 3-20.—A coping joint.

Half-Lap Joints

For half-lap joints (fig. 3-23), the joining members are usually the same thickness. For the end butt half lap, measure off the desired amount of lap from the end of each member. At this point, use a combination square to guide and to score a line all the way around the member. This is squaring a line. For the corner half lap, measure off the width of a member from the end of each member. Square a line all the way around. These are shoulder lines.

Next, you should select the best surface of each member and place it facing up. This is the face of the member. The opposite surface is the back. Mark the face of each member plainly. Next, set the marking gauge to one-half the thickness of the member. Score a line (called the cheek line) on the edges and end of each member. This line will extend from the shoulder line on one edge to the shoulder line on the opposite edge (fig. 3-23). Be sure to gauge the cheek line from the face of each member. If you gauge from both faces, the faces will be flush after cutting the joint. The faces must be flush regardless of whether or not the gauge was set to exactly one-half the thickness. Too much waste cut from one member offsets a lesser cut from the other.

If you gauge from the face of one member and the back of the other, and the gauge is not set to one-half the thickness, the faces will be out of flush by the amount of the error. A rule you should use for half-lap joints is to *always gauge the cheek line from the face of the member.*

Next, make the shoulder cuts by sawing along the shoulder line down to the cheek line. Saw from the back of the lapping member and from the face of the lapped member (fig. 3-23). Clamp a piece of wood along the starting groove to steady the saw.

The cheek cuts (sometimes called the side cuts) are next. Cut them along the waste side of the cheek line. Clamp the member in the vise so it leans diagonally away from you. With the member in this position, you can see the end and the upper edge. When the saw reaches the shoulder line on

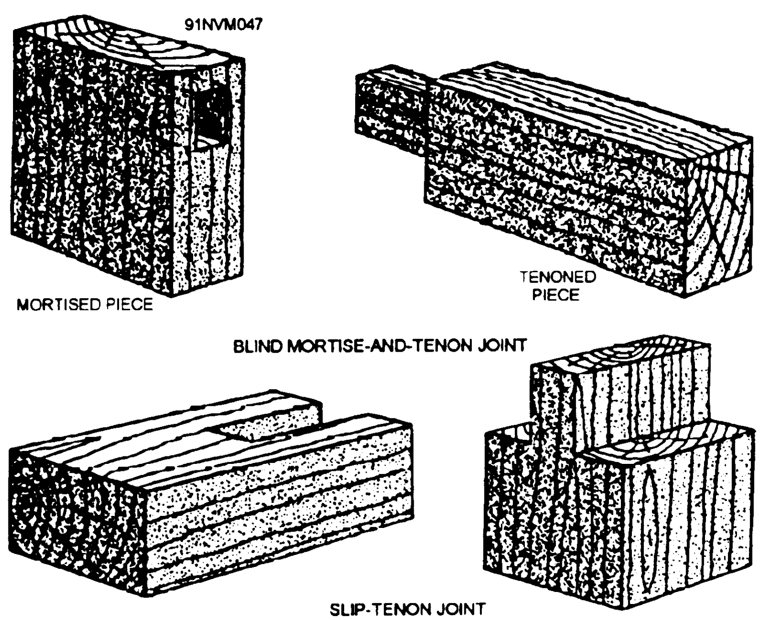


Figure 3-21.—Mortise-and-tongue and slip-tenon joints.

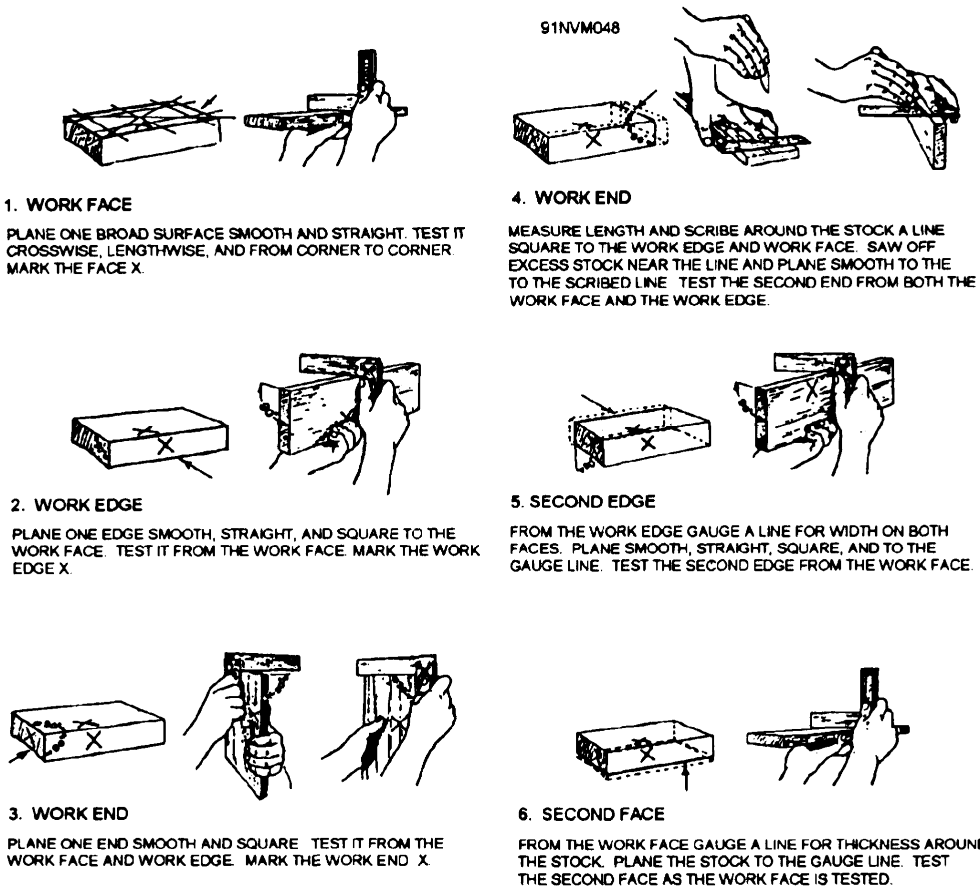


Figure 3-22.—Planing and squaring to dimension.

the upper edge, it will still be some distance away from the shoulder line on the edge you can't see. Reverse the member in the vise, and saw exactly to the shoulder line on that edge.

Completing the shoulder cut will detach the waste. The members should fit together with faces, ends, and edges flush, or near enough to make flush by a little paring with the chisel.

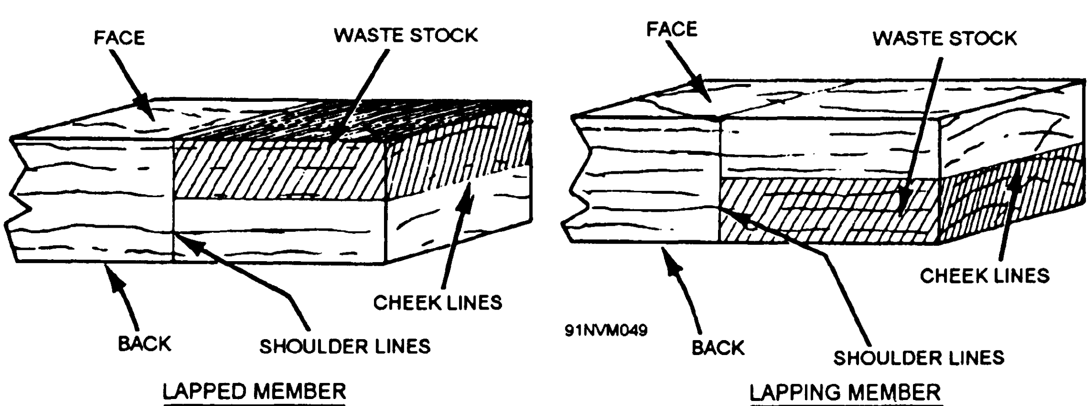


Figure 3-23.—End butt half-lap or comer half-lap joint.

A cross half-lap joint (fig. 3-24) between members of equal cross-section dimensions is laid out and cut as follows: If the members are of the same length and they are to lap each other at the midpoint, place them face-to-face with ends flush. Then square a center line all the way around. To test the accuracy of the center calculation, turn one of the members end for end. If the center lines still meet, the center location is correct.

When making a cross half-lap joint, you should put the best wide surfaces up and mark each face plainly. Lay off one-half the width of a member on either side of the center lines; then, square the shoulder lines all the way around. Again check for accuracy by turning a member end for end. If the shoulder lines meet, the layout is accurate. Next, gauge one-half the thickness of a member. Do this from the face of each member and score check lines on the edges between the shoulder lines. Next, make the shoulder cuts, sawing from the back of the lapping member and from the face of the lapped member.

In the cross half-lap joint, you should chisel the waste out rather than saw it out. To make the chiseling easier, remove as much stock as possible with the saw first. Saw a series of kerfs between the shoulder cuts. In chiseling, make a roughing cut down to just above the cheek line with a firmer chisel and mallet. Hold the chisel bevel down. Finish off the bottom with a paring chisel while holding the chisel bevel up.

You can use a circular saw to cut half-lap recesses and cross half-lap recesses. For an end half-lap recess, set the table saw blade above the table a distance equal to one-half the thickness of a member. Place the member against the miter gauge, set it at 90° to the saw blade, and make the shoulder cut. Take out the remaining waste by making as many recuts as necessary.

For a cross half-lap recess, you should proceed as follows: Set the table saw blade or dado head so its height above the table is equal to one-half the thickness of a member. Then, place the member against the miter gauge set at 90° to the saw blade

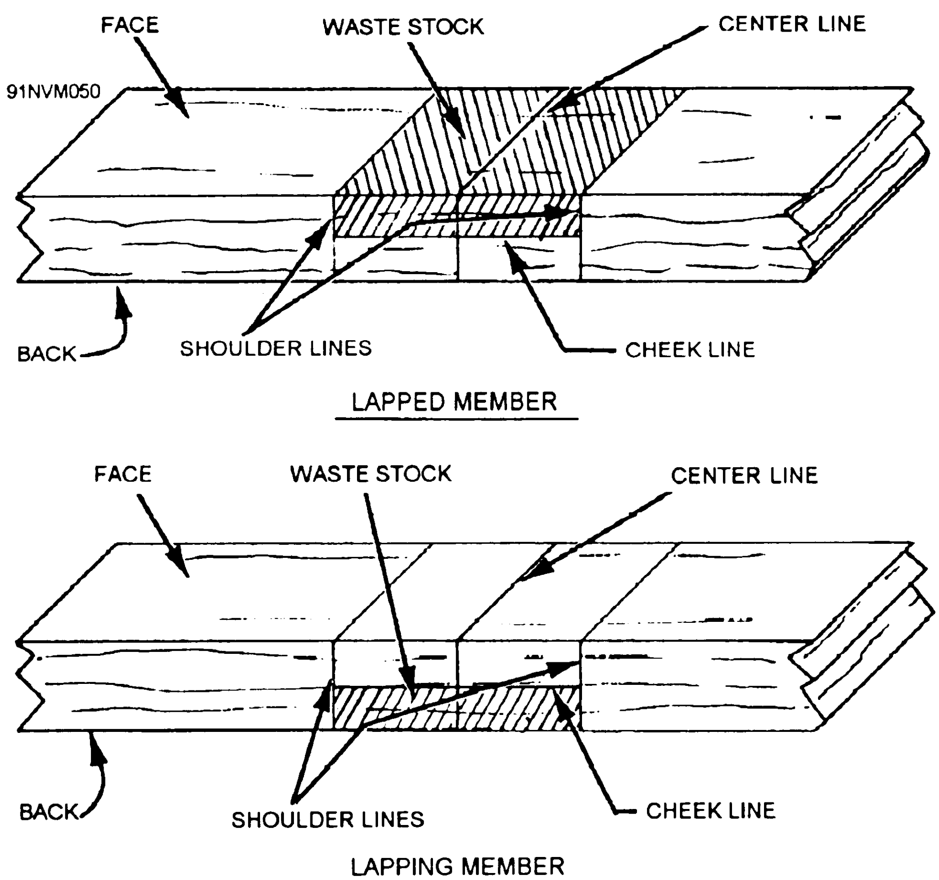


Figure 3-24.—Gross half-lap joint.

and make the shoulder cut. Then, reverse the piece end for end and repeat the procedure to make the opposite shoulder cut. Take out the remaining waste between the shoulder cuts by making as many recuts as necessary.

Grooved Joints

A groove is a three-sided recess running with the grain. A similar recess running across the grain is a dado. A groove or dado that does not extend all the way across the piece is a stopped groove or a stopped dado. A stopped dado is also known as a gain (refer to fig. 3-15).

A two-sided recess running along an edge is a rabbet (refer to fig. 3-16). Dadoes, gains, and rabbets are not actually grooves, but the joints are called grooved joints.

Grooves on edges and grooves on faces of narrow stock can be cut by hand with the plow plane. The matching plane will cut a groove on the edge of one piece. It also cuts a tongue to match it on the edge of another. You can cut a dado by hand with the backsaw and chisel. Use the same method used to cut a cross half-lap joint by hand. Saw rabbets on short ends or edges by hand with the backsaw.

Cut a long rabbet by hand with the rabbet-and-fillister plane by using the following procedure: First, be sure that the side of the plane iron is exactly in line with the machined side of the plane. Then, set the width and depth gauges to the desired width and depth of the rabbet.

NOTE: Be sure to measure the depth from the edge of the plane iron, not from the sole of the plane. If you measure from the sole of the plane, the rabbet will be too deep by the amount that the edge of the iron extends below the sole of the plane.

Next, clamp the piece in the vise. Hold the plane perpendicular, press the width gauge against the face of the board, and plane down with even, careful strokes. Continue until the depth gauge prevents any further planing.

Cut a groove or dado on the circular saw as follows: Lay out the groove on the end of the wood. For a dado, lay out the edge. Set the saw to the depth of the groove above the table. Set the fence so the saw will cause the first cut to run on the waste side of the line. Start the saw and bring the piece into light contact with it. Then stop the saw. Look at the stock to make sure the cut will be on the waste side of the line. Adjust the fence if necessary.

When the fence position is exact, make the cut. Reverse the piece and proceed to set and test as before for the cut on the opposite side of the groove. Make as many cuts as necessary to remove the waste stock between the side kerfs.

Grooving with the dado head is the same as dadoing, with one exception. The dado head builds up to take out all or most of the waste in a single cut. The two outside cutters alone will cut a groove 1/4 inch wide. Inside cutters vary in thickness from 1/16 to 1/4 inch.

The circular saw can cut a stopped groove or stopped dado. You can use either a saw blade or a dado head as follows: Clamp a stop block to the rear of the table if the groove or dado stops at only one end. (This will stop the piece from feeding when the saw has reached the place where the groove or dado is supposed to stop.) If the groove or dado stops at both ends, clamp a stop block to the rear of the table and a starting block to the front. Place the starting block so the saw will contact the place where the groove is supposed to start when the infeed end of the piece is against the block. Start the cut by holding the piece above the saw. Place the infeed end against the starting block and the edge against the fence. Lower the piece gently onto the saw blade. When the piece contacts the tabletop, feed it through to the stop block.

When you are cutting a rabbet, the cut into the face of the piece is the shoulder cut. The cut into the edge or end is the cheek cut. Make the shoulder cut first. Set the saw to extend above the table a distance equal to the desired depth of the shoulder. Set the fence a distance away from the saw equal to the desired depth of the cheek. Be sure to measure this distance from a sawtooth set to the left of, or away from, the ripping fence. If you measure it from a tooth set to the right of, or toward, the fence, the cheek will be too deep.

Place the face of the piece that was down for the shoulder cut against the fence and make the cheek cut. Make the cheek cut with the saw at the same height as for the shoulder cut if the depth of the shoulder and the depth of the cheek are the same. Change the height of the saw if the depth of the cheek is different.

By using the dado head, you can cut most rabbets in a single cut. First, build up a dado head equal in thickness to the desired width of the cheek. Next, set the head to protrude above the table a distance equal to the desired depth of the shoulder. Clamp a l-inch board to the fence to serve as a guide for the piece. Set the fence so the edge of the board barely contacts the right side of the dado head. Set the piece against the miter gauge that is set at 90° to the saw blade. Now hold the edge or end to be rabbeted against the l-inch board and make the cut.

On jointers, a rabbeting strip on the outboard edge of the outfeed table depresses for rabbeting. The strip is outboard of the end of the cutterhead. To rabbet on a jointer, you depress the infeed table and the rabbeting strip the depth of the rabbet below the outfeed table. Set the fence the width of the rabbet away from the outboard end of the cutterhead. The unrabbeted part feeds onto the rabbeting strip when the piece feeds through.

Various combinations of the grooved joints are used in woodworking. The well-known tongue-and-groove joint is actually a combination of the groove and the rabbet. The tongued member is simply a member rabbeted on both faces. In some types of panel work, the tongue is made by rabbeting only one face. A tongue of this kind is a bare-faced tongue. The dado and rabbet joint (fig. 3-25) is another joint often used in making boxes, drawers, and cabinets.

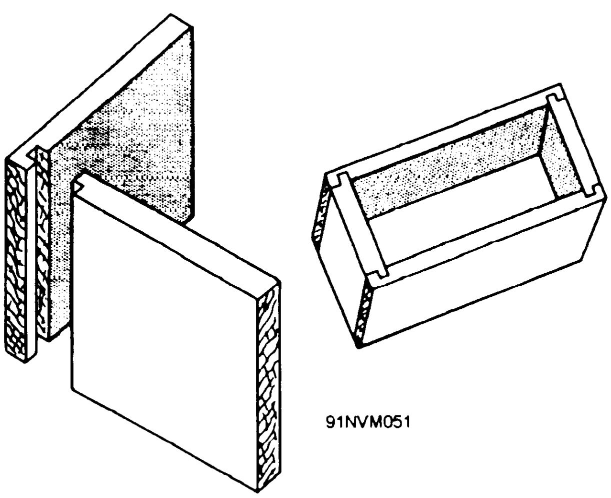


Figure 3-25.—Dado and rabbet joint.

The housed lock-joint (fig. 3-26) is a type of dado and rabbet joint. Note that the rabbeted piece is reversed. The dadoed piece extends beyond the rabbeted piece. This joint is used extensively in the pattern shop for manufacturing special wooden foundry flasks. The dadoed piece extends to form handles for the flask.

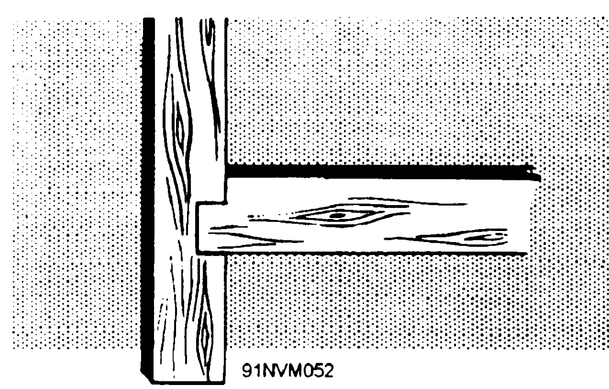


Figure 3-26.—Housed lock-joint.

Dovetail Joints

The dovetail joint (refer to fig. 3-17) is the strongest of all the woodworking joints. However, its construction requires a lot of work; therefore, you will use dovetail joints only when working on finer grades of furniture and cabinet work.

A joint containing only a single pin is a single dovetail joint. A joint containing two or more pins is a multiple dovetail joint. A joint in which the pins pass all the way through the tail member is a through dovetail joint. A joint in which they pass only part way through is a blind dovetail.

The simplest dovetail joints is the half-lap dovetail joint (fig. 3-27). This joint is first laid out and cut like an ordinary end half lap. The end of the lapping member is laid out for shaping into a dove tail as follows:

- Set the T-bevel to 10°. This is the correct angle between the vertical axis and the sides of a dovetail pin or tail. You can set the bevel with a protractor or with the protractor head on the

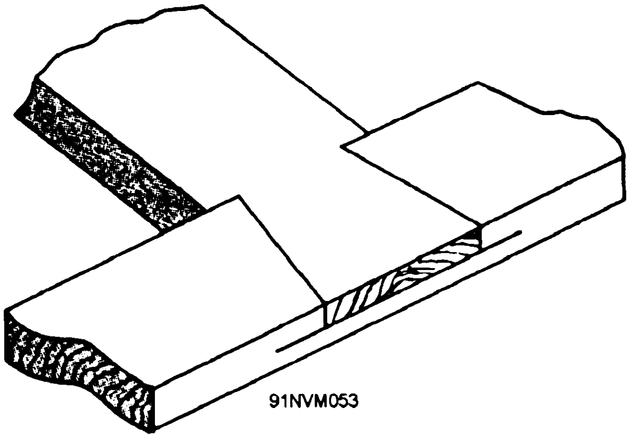


Figure 3-27.—Dovetail half-lap joint.

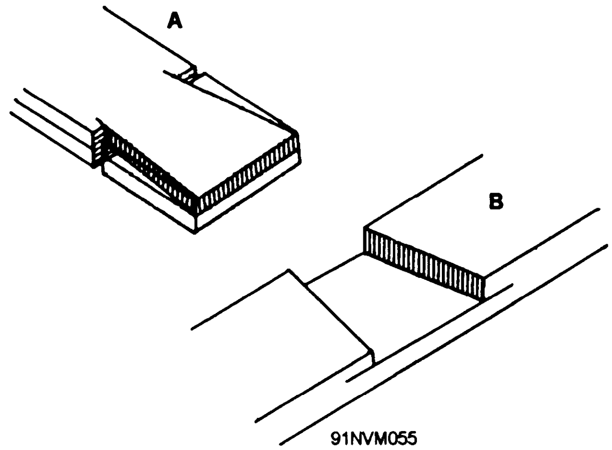


Figure 3-29.—Making a half-dovetail joint.

combination square. If you don't have either of these, use the method shown in figure 3-28.

● Select a board with a straight edge, square a line across it, and lay off six equal lengths on the line as shown. From the sixth mark, lay off one length perpendicular to the right. A line drawn from this point to the starting point of the first line drawn will form a lo-degree angle with that line.

● Lay off this angle from the end corners of the lapping member to the shoulder line (fig. 3-29). Saw out the waste as shown. The lapping member now has a dovetail on it. Place this dovetail over the other member, in the position it is supposed to occupy, and score the outline of the recess. Then saw and chisel out the recess. Remember to saw on the waste side of all lines.

To make a multiple-dovetail joint, you lay out the end of the tail member as shown in figure 3-30. The strongest type of dovetail joint is one in which the pins and tails are the same size. For ease in cutting, the pins are usually somewhat smaller than the tails (as shown). To make a multiple-dovetail joint, you first determine the number of pins and the size you want to make each pin. Then, lay off a half-pin from each edge of the member. Next, locate the center lines of the other pins at equal intervals across the end of the piece. Then, you lay

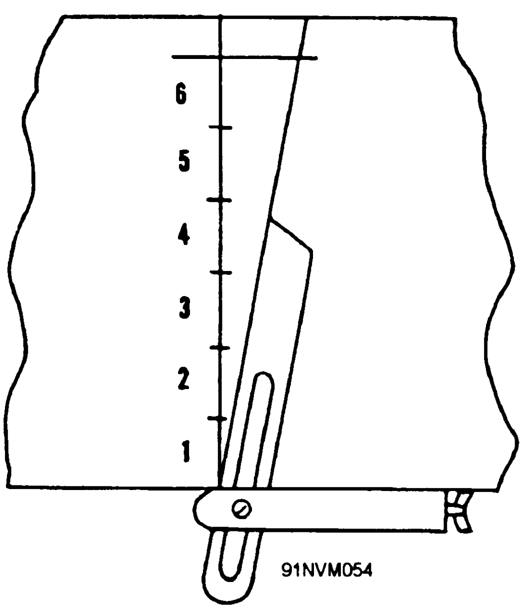


Figure 3-28.—Laying off a 10-degree angle for a dovetail joint.

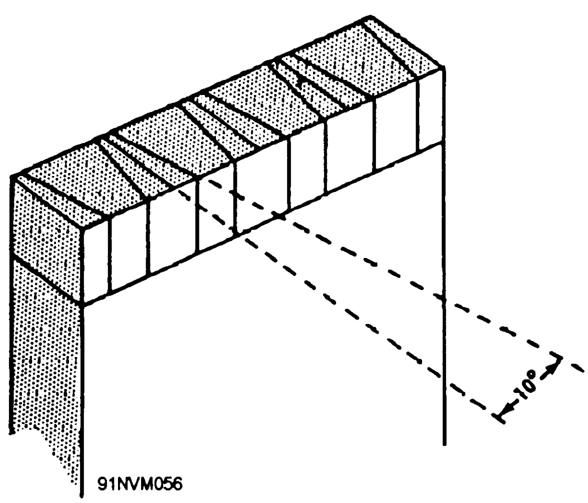


Figure 3-30.—Laying out pin member for through multiple-dovetail joint.

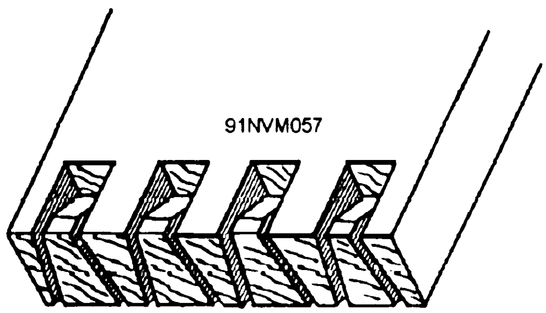


Figure 3-31.—Chiseling out waste in a through multiple-dovetail joint.

off the outlines of the pins at 10° to the center lines. Determine the depth of the shoulder line by the thickness of the tail member.

You cut out the pins by sawing on the waste sides of the lines and then chisel out the waste. You should chisel halfway through from one side, as shown in figure 3-31. Then turn the member over and chisel through from the other side.

When you have finished cutting out the pins, lay the tail member flat. Set the ends of the pins in exactly the position they are to occupy (fig. 3-32). Score the outlines of the pins, which will, of course, also be the outlines of the tails. Square lines across the end of the tail member. Saw and chisel out the waste between the tails.

Box Corner and Miter Joints

The box corner joint is the same as a multiple dovetail with one exception—the 10-degree angle (refer to fig. 3-18). A miter joint (refer to fig. 3-19) is made by mitering the ends or edges of the members that are to be joined. The angle of the miter cut is one-half of the angle formed by the joined members. In rectangular frames, door casings, boxes, and the like, adjacent members form a 90-degree angle. The correct angle for mitering is 45°. For members that will form an equal-sided figure with other than four sides (such as an octagon or a pentagon), you need to calculate the correct mitering angle. Do this by dividing the number of sides the figure will have into 180, as shown in figure 3-33.

You can miter members in a wooden or metal miter box or on the circular saw by setting the miter gauge to the desired angle. You can edge miter members to any angle on the circular saw by tilting the saw.

Abutting surfaces of end-mitered members do not hold well when merely glued. You need to reinforce them. A good reinforcement for a joint between end-mitered members is the slip feather. This joint is a thin piece of wood or veneer glued into a kerf cut in the thickness dimension of the

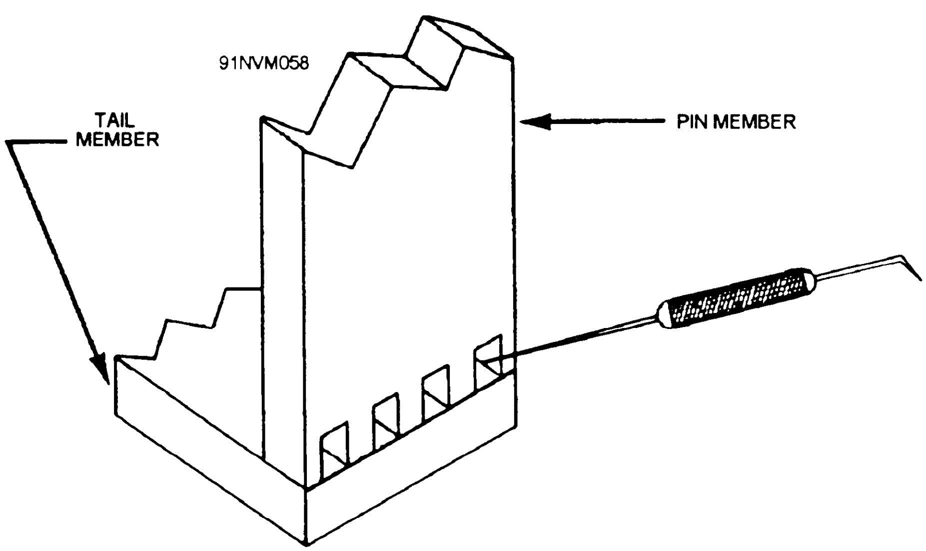


Figure 3-32.—Marking the tail member.

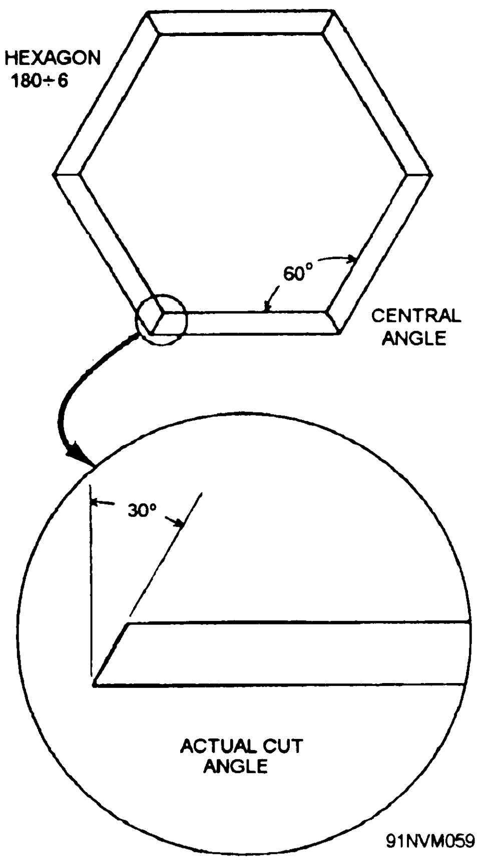


Figure 3-33.—Mitering angles.

joint. (See fig. 3-34 for a simple jig to use when making the kerf cut.) Saw about halfway through from the outer to the inner corner. Apply glue to both sides of the slip feather, and push the slip feather into the kerf (fig. 3-35). Clamp it tight and allow the glue to dry. After it has dried, remove the clamp and chisel off the protruding portion of the slip feather.

Coping Joints

Inside corner joints between molding trim members are usually made by placing the end of one member against the face of the other. Figure 3-36 shows the method of shaping the end of the abutting member to fit the face of the other members. First, saw the end of the abutting member square. Do this as you would an ordinary butt joint between ordinary flat-faced members. Then, miter the end to 45°, as shown by views A and B of figure 3-36. Set the coping saw at the top of the line of the miter cut. Hold the saw at 90° to the lengthwise axis of the piece. Saw off the segment as shown in view C. Closely follow the face line left by the 45-degree miter cut. The ends of the abutting members will then match the face of the other member as shown in view D.

Mortise-and-Tenon Joints

The mortise-and-tenon joint is mostly used in furniture and cabinet work. In the blind mortise-and-tenon joint (refer to fig. 3-21), the tenon does not penetrate all the way through the mortised member. When the tenon penetrates all the way through, it is a through mortise-and-tenon joint. Besides the ordinary stub joint (fig. 3-37, view A), there are haunched joints (view B) and table-haunched joints (view C). Haunching and table-haunching increase the strength and rigidity of the joint.

MORTISE-AND-TENON LAYOUT.—You can lay out an ordinary stub mortise-and-tenon joint using the following steps:

1. Mark the faces of the members plainly.

2. Lay off the desired length of the tenon.

3. Square the shoulder line all the way around.

4. Then, lay off the total width of the tenon member on the mortise member, as shown in figure 3-38.

5. Determine the thickness of the tenon. It is usually between one-third and one-half the thickness of the mortise member.

6. Use a marking gauge to mark two lines (fig. 3-38). If the faces of the members are to be flush, use the same gauge setting to score a double line on the mortise member. Remember to gauge from the face of the member. If the face of the tenon member is to be set back from the face of the mortise member, you should increase the mortising gauge setting by the amount of the setback.

7. Last, lay off from the end of the mortise member and from the matching edge of the tenon member. Lay off by the amount of end stock that is to remain above the mortise.

NOTE: You wouldn't need this last step of the layout for a slip-tenon joint, like the one shown in figure 3-21.

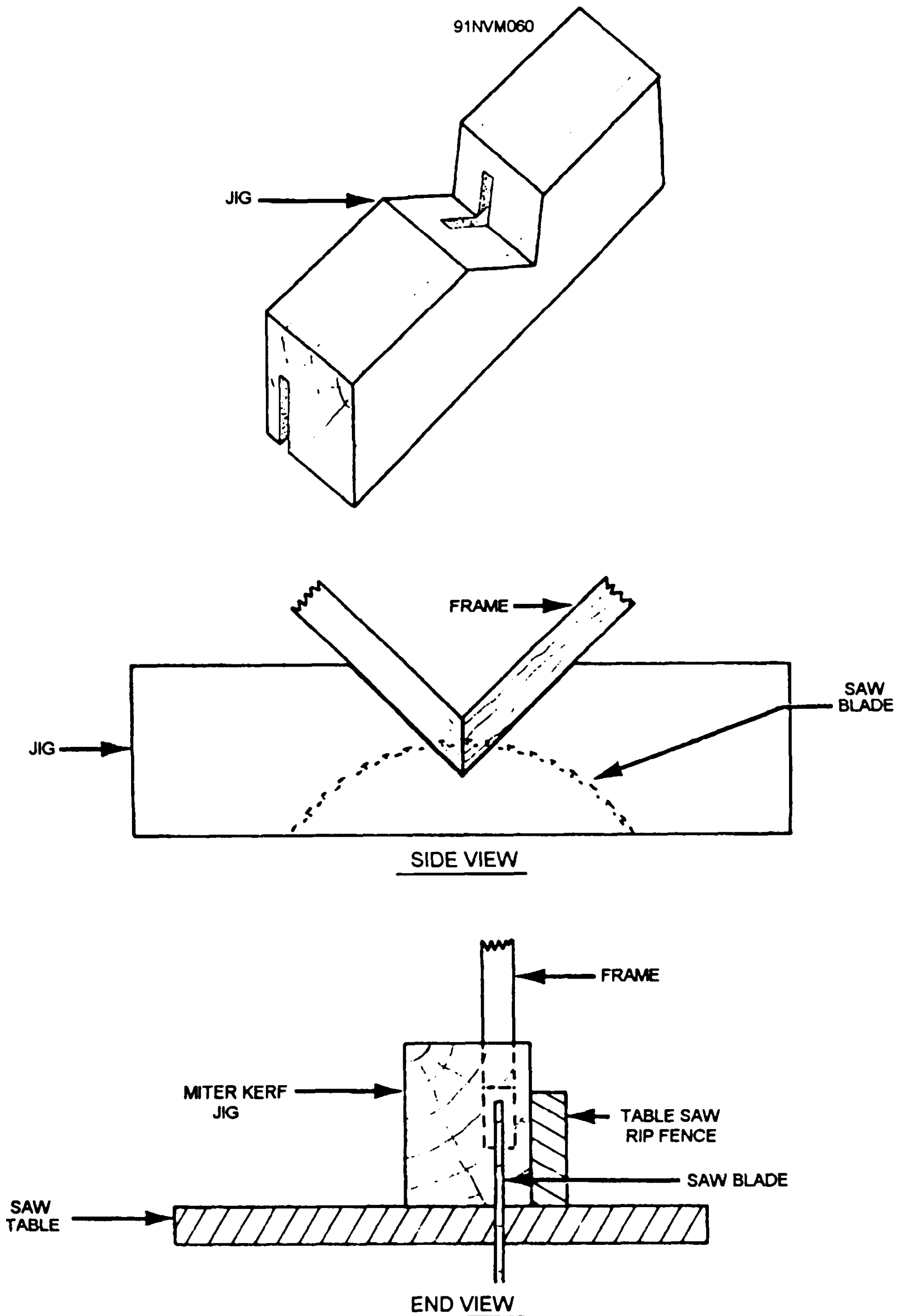


Figure 3-34.—Kerf jig for mitered joints.

CUTTING MORTISE-AND-TENON JOINTS.—You can cut tenons by hand with the backsaw by using the same method described for cutting corner and end half-lap joints. You can cut mortises by boring a series of holes slightly smaller than the width of the mortise. Then, you chisel out the remaining waste. For a blind mortise-and-tenon joint, use a depth gauge. Use of the depth gauge prevents the drill from boring below the correct depth of the mortise.

Look at figures 3-39 and 3-40 as you read the following steps on using a circular saw to cut tenons.

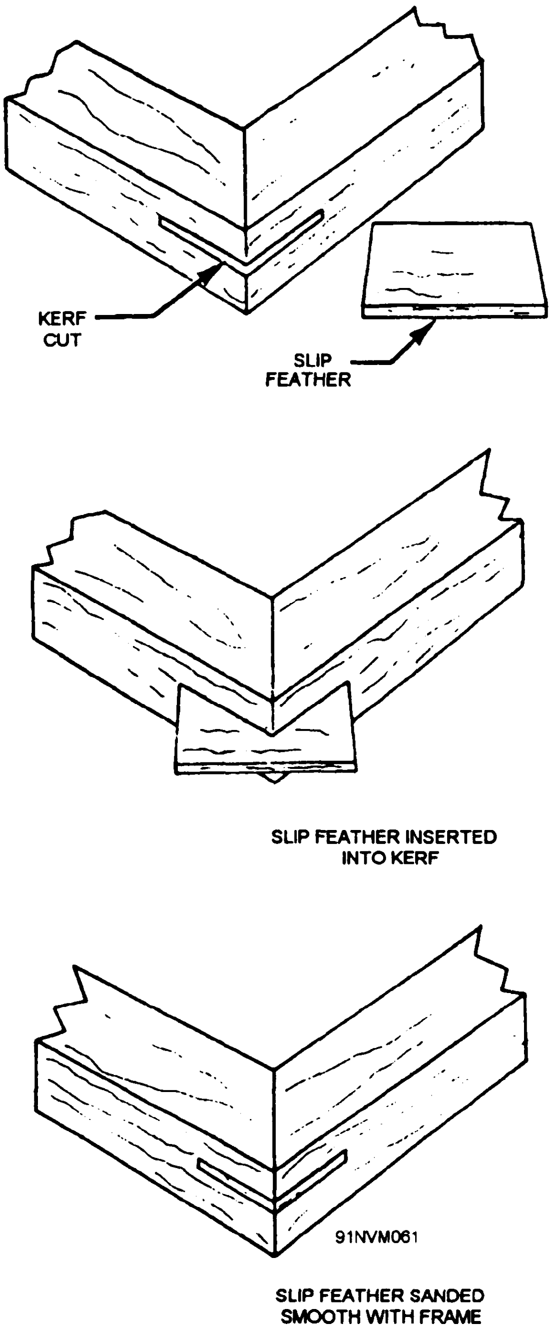


Figure 3-35.—Slip feather reinforcement.

1. Make the shoulder cuts first.

2. Set the saw the depth of the shoulder above the table.

3. Set the rip fence the length of the tenon away from the saw. Remember to measure from a sawtooth set to the left. Make the shoulder cuts, as shown in figure 3-39.

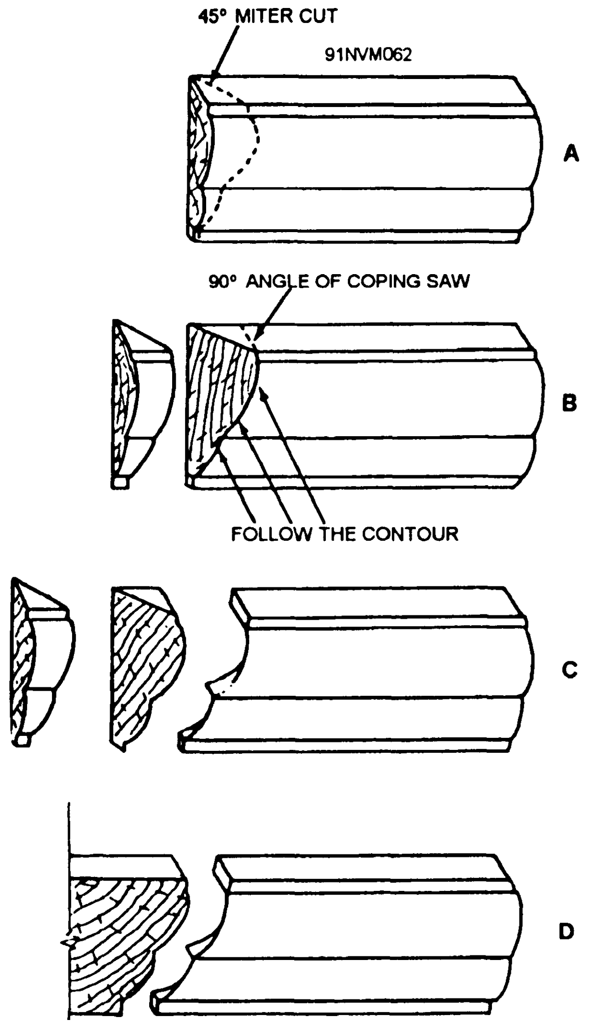


Figure 3-36.—Making a coping joint.

4. Set the saw the depth of the cheek above the table.

5. Set the fence the width of the shoulder away from the saw. Then make the cheek cuts, as shown in figure 3-40. To steady the stock against the fence, use a feather board like the one shown clamped to the table. To maintain the stock upright, use a push board, like the one shown in figure 3-40.

You can also use a dado head to cut tenons. Use the same method described before for cutting end half-lap joints.

A hollow-chisel mortising machine cuts mortises mechanically. The cutting mechanism on this machine consists of a boring bit encased in a square hollow steel chisel. As the mechanism presses into

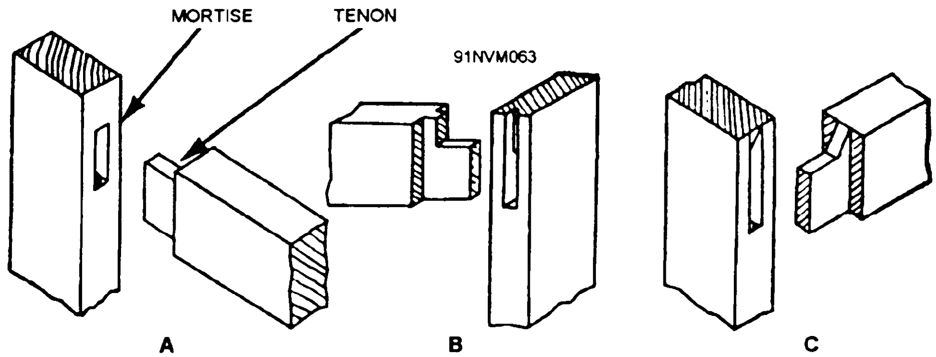


Figure 3-37.—Mortise-and-tenon joints. A. Stub. B. Haunched. C. Table-haunched.

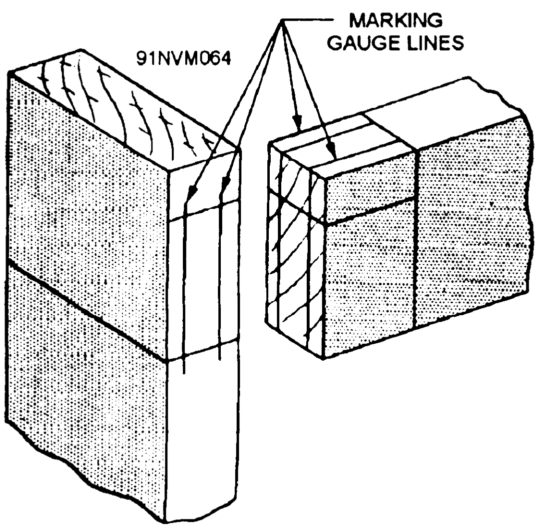


Figure 3-38.—Layout of a stub mortise-and-tenon joint.

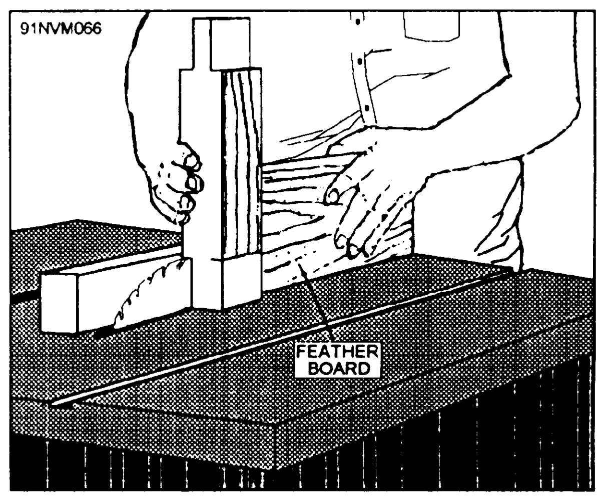


Figure 3-40.—Using a feather board and push board to steady stock when cutting a tenon cheek.

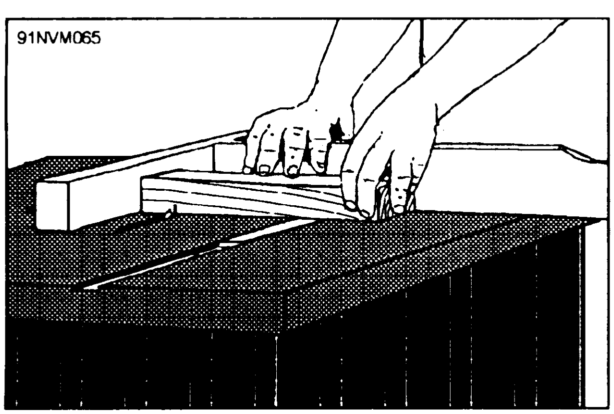


Figure 3-39.—Gutting a square-shouldered tenon.

the wood, the bit takes out most of the waste. The chisel pares the sides of the mortise square. Chisels come in various sizes with bits to match.

Fasten mortise-and-tenon joints with glue and additional fasteners as required. One or more wood or metal dowels may be driven through the joint to give strength to the joint.

JOINT APPLICATIONS

Plywood panels are installed in frames to make parts of doors, partitions, bulkheads, and many other items. The panels can be installed by several methods. Four commonly used methods are shown in figure 3-41. Notice in figure 3-41, views A and B,

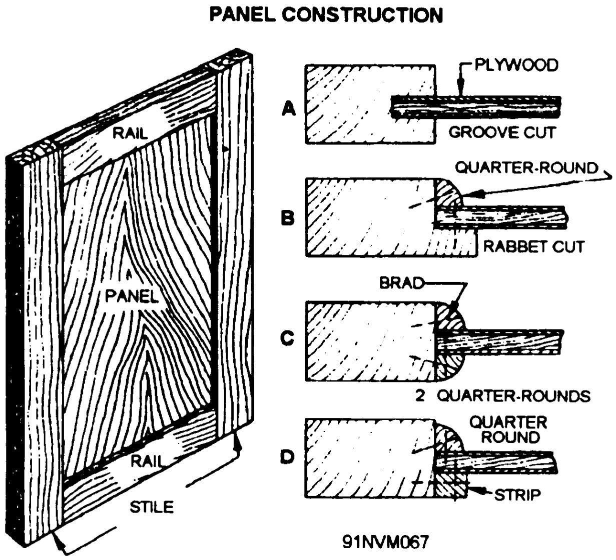


Figure 3-41.—Panel construction.

how a groove and rabbet set the panel into the rails and stiles. Join the rails and stiles by using dowels, miter joints, half-lap joints, or mortise-and-tenon joints.

Standard methods of making a table are shown in figures 3-42 through 3-46. Make desks in much the same manner but with the addition of panels and more drawers.

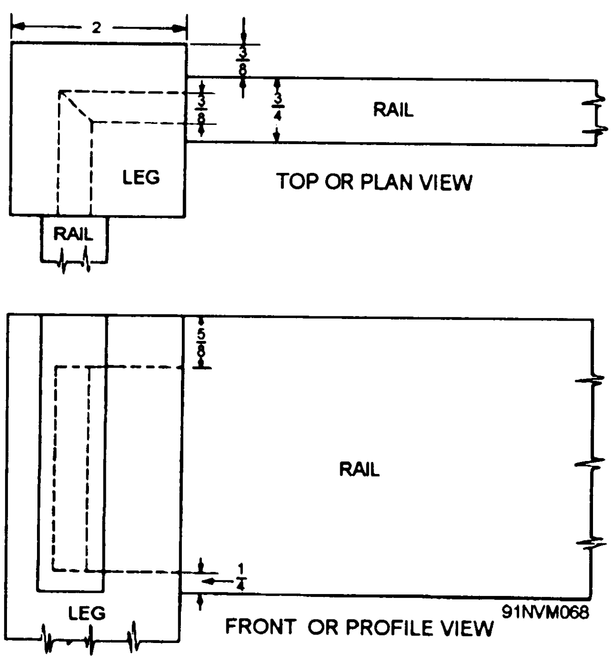


Figure 3-42.—Mortise-tenon layout and design.

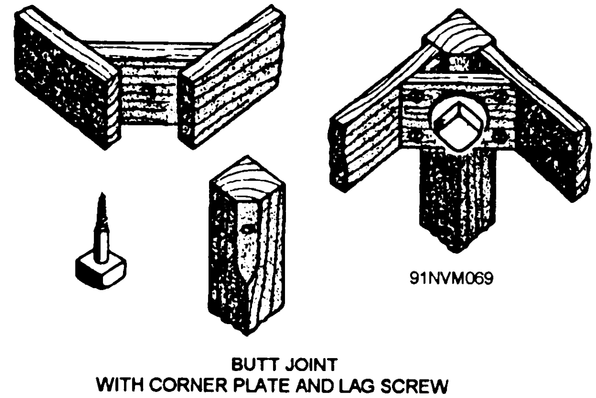


Figure 3-43.—Comer butt joint for table legs.

Figure 3-42 shows the layout and design for mortise-and-tenon joints. Mortise-and-tenon joints join the table rails to the legs (fig. 3-43) and secure the stretcher to the lower end rails. An alternate method of securing the legs to the rails is by corner plates and lag screws. Using this method, the legs tighten easily when they become loose. They also remove easily for storage or moving.

Make drawers for tables and desks by the method shown in figure 3-44. You will find it easier to make drawers by this method than by making them with dovetail joints. However, dovetail joints are better and should be used on jobs made of fine cabinet woods. Use blind dovetails for the front corners of drawers made for such furniture.

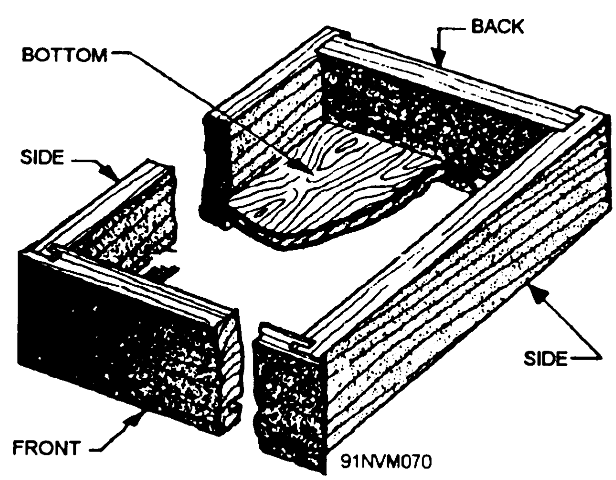


Figure 3-44.—Simple drawer construction.

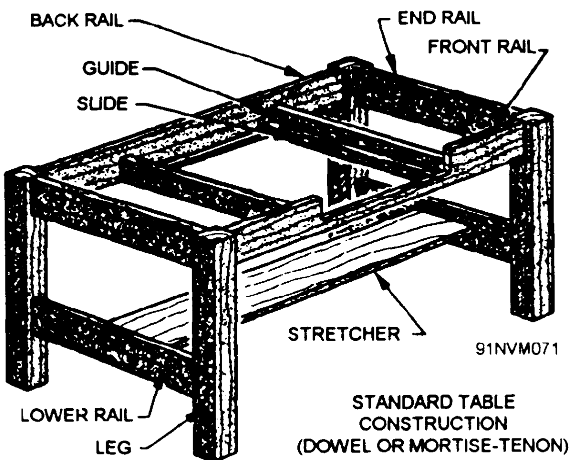


Figure 3-45.—Standard table construction.

Tabletops usually fasten to the upper rails (fig. 3-45) by one of the six standard methods shown in figure 3-46. You will probably use the cleat more than any of the others. Fasten the cleat screws to the rail first so it is about 1/16 inch below flush. Then, the screws going into the top will pull the top down tight and snug.

FASTENING MATERIALS

Many kinds of fasteners hold wood together. These include glue, nails, screws, bolts, and special fasteners.

TYPES OF GLUE

The two most commonly used glues in today's pattern shop are urea resin glue and vinyl resin (white) glue.

Urea resin glue is a synthetic compound that comes either in a powder mixed with water or a

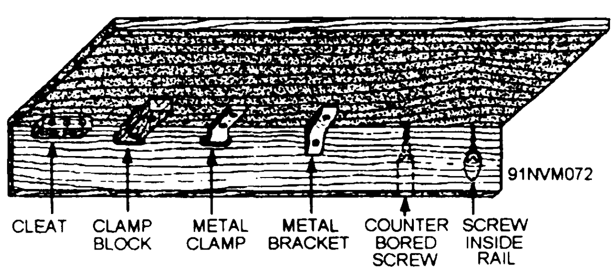


Figure 3-46.—Securing rails to tabletops.

powder mixed with another solution. It is a water-resistant glue that works well on hardwoods. It is a cold-working glue that sets within 24 hours at room temperature (70°F). Urea resin glues set and harden by the condensation of the resin.

Vinyl resin glue is a synthetic thermoplastic white liquid. It requires no mixing or heating before use. This glue comes ready to use and can be applied at temperatures above 50°F. The initial setting of the glue takes less than 30 minutes. A strong bond will occur in less than 1 hour for ordinary work. In addition, this glue is compounded to reduce wear on cutting tools. It also has a glue line that is practically colorless. For general construction, vinyl resin glue has replaced all glues that require heating, cooking, or mixing.

Pointers on Using Glue

Prepare and use each type of glue in a specific manner. Instructions and safety precautions are always given on the label of the container, or on the MSDS for the glue. You should study these carefully before trying to use any glue. Certain rules should be followed in the application of all glues.

The wood should be room temperature (70°F). If the wood is cold, the glue next to the wood chills and sets before it has penetrated the pores of the joint. If the wood is hot, the water in the wood will expel, causing the joint to warp. Glues give best results when the wood is at room temperature.

Squeeze or rub excess glue out of a joint before applying pressure. Always apply pressure as quickly as possible after spreading the glue. This prevents the glue from setting before the excess can be squeezed out. The greater the pressure applied, the stronger the joint will be.

NOTE: Do not apply so much pressure that the wood crushes.

If possible, the pressure should be at least 100 psi. Squeezing out too much glue is impossible. Clamps alone produce this pressure, but they do not distribute the pressure evenly. To get a joint with maximum strength, you should use plates between the clamps and the wood.

Methods of Applying Glue

When you need thicker or wider material but it is not available, you will have to glue several pieces of material together. The two principal methods used for gluing wood stock are face-to-face gluing and edge-to-edge gluing.

In face-to-face gluing, first determine the sizes of stock needed. Then, you should decide what available stock can be glued up to produce the required size. Remove enough lumber from the rack to do the job. Saw the lumber to the required lengths. Dress one face and one edge of each piece of material on the jointer. Dress the material to the proper thickness in the planer. Rip the pieces to the proper width in the circular saw. Adjust the hand clamps to an approximate jaw opening. Lay the stock on the bench and fit each clamp loosely over the stock. Then place them in a spot where they can be easily reached.

Place the stock in the desired gluing position. Alternate in relation to the growth rings. The warpage of each piece offsets the warpage of the one next to it if this arrangement is followed. Also, arrange the pieces so the grain of their respective surfaces runs in the same direction. Otherwise, difficulties may arise later when dressing the job to proper thickness. Planing with the grain on one part of the surface may prove to be the wrong direction for an adjacent area.

After proper arrangement, use some system of marking the pieces of stock. This is so they will not be disarranged during the gluing-up process. Apply a good coat of glue to the surface of the piece of stock lying face up. Place one of the other pieces of stock face-to-face with the glued surface. Rub back and forth or in a circular motion. Exert as much down pressure as possible. This spreads the glue evenly throughout the joint and helps prevent air bubbles. In addition, a certain amount of glue is driven into the pores of the wood. The glued surfaces are pulled closer together. Repeat the preceding gluing operations until all pieces are assembled

Position clamps and tighten glued-up stock as shown in figure 3-47. Place clamp A in a position so that when the clamps are all in place, the space between them will be somewhat equal throughout the length of the material. Keep lower clamp spindle M at least 1/2 inch above the surface of the material. Tighten up on spindle M and release spindle N until a fair amount of pressure is on that part of the jaws near M. Next, turn spindles M and N until the entire face of jaw F is exerting an even pressure on the face of the material. Use enough force to squeeze excess glue from the joints of the glued-up stock and draw all surfaces tightly together.

Adjust and tighten clamp B just like clamp A. As each clamp is added, the glue is forced along, as well as out of, the joint. If the ends are clamped first, a large amount of glue is trapped in the

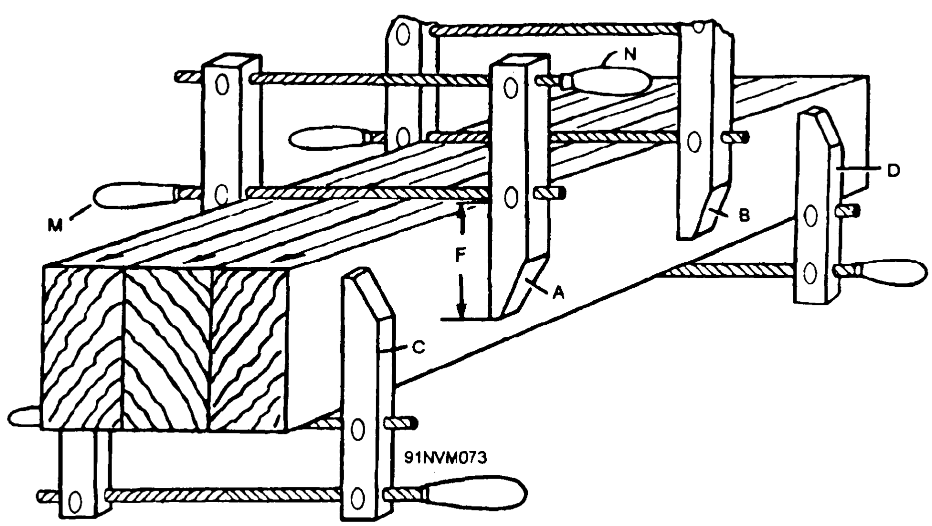


Figure 3-47.—Face-to-face gluing.

middle. This is especially true when you are gluing up wide pieces of material. Next, turn the stock completely over on a table or bench so it rests on the ends of clamps A and B. Place clamps C and D, and adjust the same as clamps A and B.

NOTE: Clamping the midsection of the material first will give the excess glue squeezed out of the joint more outlets.

Now examine the job carefully to see that all the clamps are properly set and that all the glued joints have been properly drawn up. Remove the job to a convenient spot where it will be out of the way until needed. If the job stays on the bench, excess glue squeezed from the joint will stick to the bench top. You should clean all waste glue from the top of the bench.

When the glue has jelled, remove it with a glue scraper. Then wipe the surface with a piece of cloth dipped in hot water. If it is a rush job, the clamps may be removed in 4 hours. However, the joints cannot be guaranteed to hold if the clamps are removed too soon. Best results will result from clamps left on for 12 hours. You should plan construction of the job to provide time for good results in gluing operations.

The edge-to-edge method of gluing up stock has two purposes. It is used most often to get material that will be thin in comparison with its width. Use this method to glue up material that has to be wider than any on hand.

In edge-to-edge gluing, select, dress, and rip the material the same way as you did for face-to-face gluing. Set the clamp jaw openings to suit the width of the assembled pieces of stock. Allow for blocks on the edges of the material to prevent marring. Make two jig blocks for each of the bottom clamps (fig. 3-48) to hold the clamps upright during the gluing operations. Again, note the arrangement of pieces so the annual ring growth will tend to offset warpage. Be sure the direction of the grain is the same in all the pieces to be glued.

Place glue on the edges of the boards you are joining. Rub the stock together to spread the glue evenly and force out any air bubbles. If the ends of the joints come apart before tightening the clamps, use pinch dogs to hold the boards together temporarily. Put the middle clamps in place with the blocks in front of the jaws. Adjust and tighten them. Then adjust and tighten the clamps on the ends, squeezing out all excess glue.

Inspect the clamps every few hours to make sure the stock is not warping. If any of the edges pull apart before the glue has dried, adjust the clamps to apply equal tension throughout.

NAILS, BRADS, DOWELS, AND CORRUGATED FASTENERS

Fastening materials such as nails, brads, dowels, and corrugated fasteners work in combination with glue in pattern construction. Many of the materials used in the HT rating are the same as those found in other woodworking trades. Nails provide the least holding power, screws provide better, and bolts provide the best holding power of all. Wood screws may be combined with glue and paper in parted pattern turning. Use dowels for the alignment of

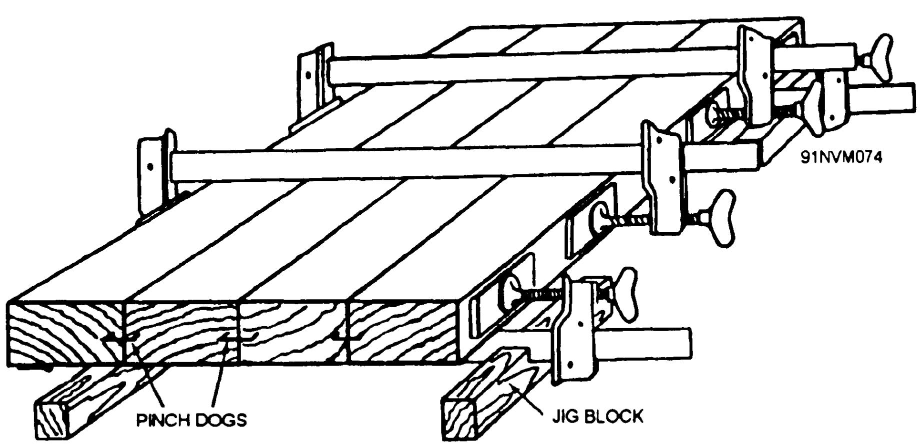
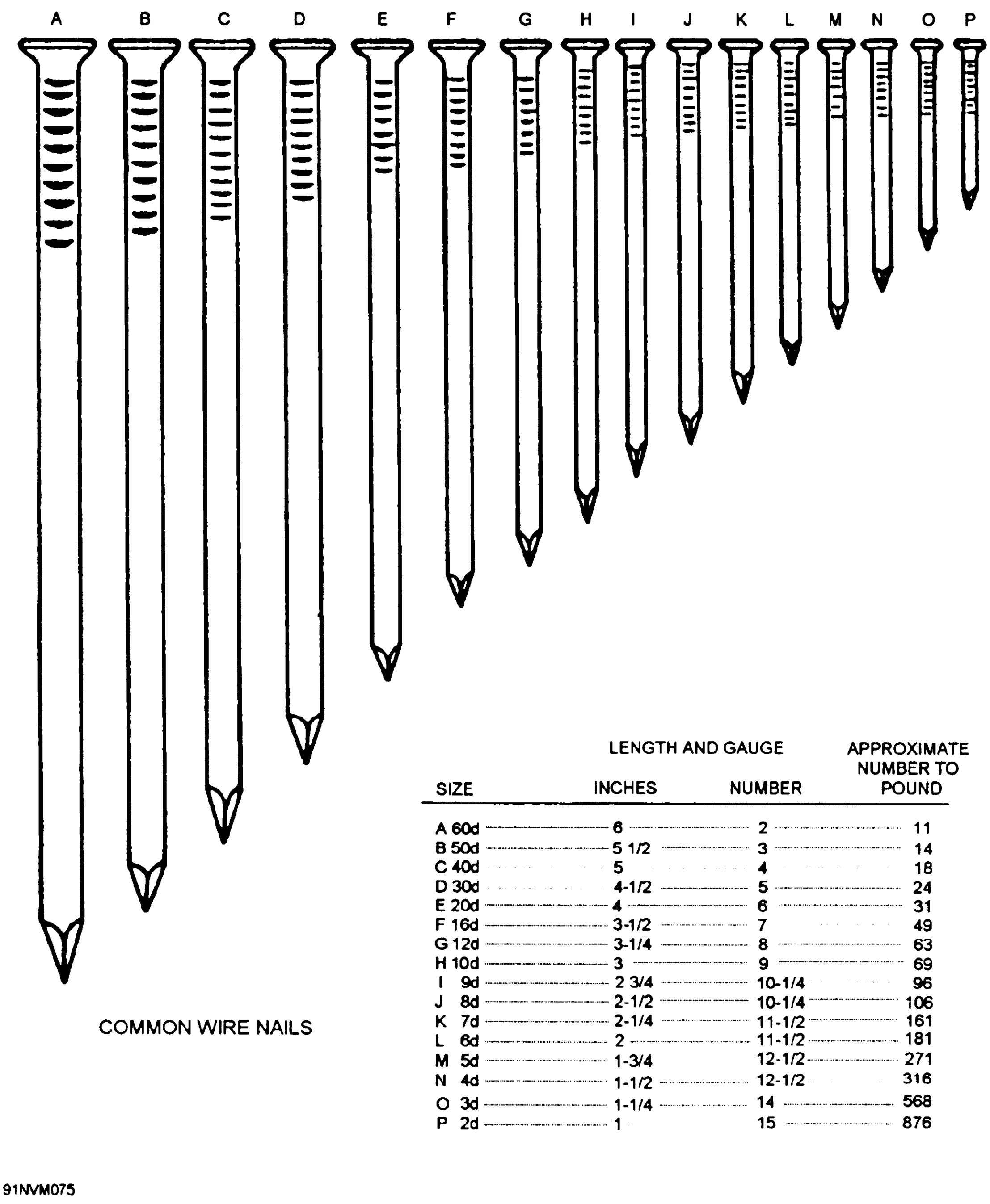


Figure 3-48.—Edge-to-edge gluing.

parted patterns and of loose pattern parts. A description of these fasteners is given in the following paragraphs.

Nails and Brads

There are many types of nails, which are classified according to use and form. They vary in size, shape of head, type of point, and finish. Nail sizes are described by the term *penny*. The penny sets the length of the nail (one penny, two penny, and so on) and is the same for all types. The approximate number of nails per pound varies with the type and size. The wire gauge number varies with type. Figure 3-49 provides the information related to the term *penny* for each nail type



SIZE	LENGTH AND GAUGE INCHES	NUMBER	APPROXIMATE NUMBER TO POUND
A 60d	6	2	11
B 50d	5 1/2	3	14
C 40d	5	4	18
D 30d	4-1/2	5	24
E 20d	4	6	31
F 16d	3-1/2	7	49
G 12d	3-1/4	8	63
H 10d	3	9	69
I 9d	2 3/4	10-1/4	96
J 8d	2-1/2	10-1/4	106
K 7d	2-1/4	11-1/2	161
L 6d	2	11-1/2	181
M 5d	1-3/4	12-1/2	271
N 4d	1-1/2	12-1/2	316
O 3d	1-1/4	14	568
P 2d	1	15	876

Figure 3-49.—Types of nails and nail sizes.

referenced in this section. The **d** next to the numbers in the size column is the accepted abbreviation of the word *penny,* as used in nail sizing. It reads two penny, three penny, and so on.

A few rules should be followed when you use nails. For maximum holding power, a nail should be at least three times as long as the thickness of wood it is to hold. Two-thirds of the length of the nail is driven into the second piece for proper anchorage. One-third provides the necessary anchorage of the piece being fastened. Nails should be driven at a slight angle toward each other. Place them carefully to provide the greatest holding power. Nails driven with the grain do not hold as well as nails driven across the grain. A few nails of proper type and size, properly placed and driven, will hold better than many nails poorly placed. Nails are the cheapest and easiest fasteners to use.

The common wire nail (fig. 3-50, view A) has a flat head. It ranges in size from 2d (1 inch long) to 60d (6 inches long). The box nail (fig. 3-50, view B) has the same length per penny size as the common wire nail. It has a lighter head and smaller diameter. In structural carpentry where appearance is not important, you should use both the common wire and box nail.

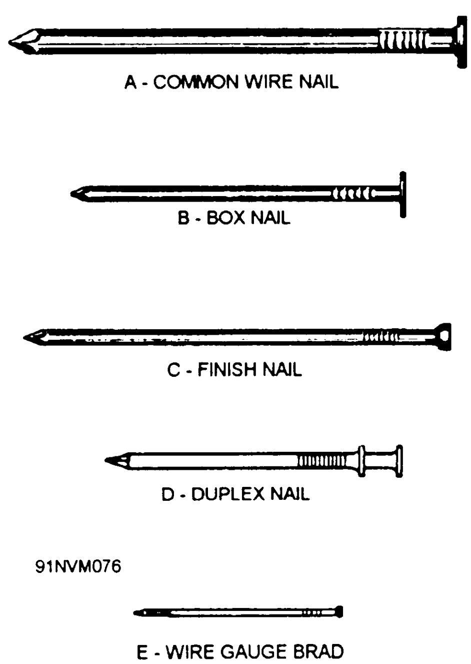


Figure 3-50.—Nails and brads.

The finish nail (fig. 3-50, view C) is made from finer wire than either the common wire or box nail. Its length per penny size is the same. The finish nail has a small head that may be set below the surface of the wood. The small hole that remains may be puttied or waxed over. You should use finish nails where appearance is important.

The duplex nail (fig. 3-50, view D) is a temporary fastener so it has two heads. The lower head, or shoulder, is driven securely home to give maximum holding power. The upper head projects above the surface of the wood to make it easy to remove.

The wire gauge brad (fig. 3-50, view E) comes in several gauges for the same length of brad. It ranges in length from 3/8 inch to 6 inches. It is the most suitable brad for pattern work. Remember that for brads, the higher the gauge number, the smaller the body diameter. Length and wire gauge identify its size. For example, 1–12 means 1 inch long and made of 12-gauge wire (0.105 inch), while 1 1/2—15 means 1 1/2 inches long and made of 15-gauge wire (0.072 inch).

Wood Screws

Several factors dictate the use of wood screws rather than nails and may include the type of material being fastened and the holding power requirements. Other factors could be the finished appearance desired and limits to the number of fasteners used. Using screws rather than nails is more expensive in time and money, but their use is often necessary to meet specifications.

The main advantages of screws are they provide more holding power and tighten easily to draw the items fastened securely together. They are also neater in appearance if properly driven and may be withdrawn without damaging the material. The common wood screw is made from unhardened steel, stainless steel, aluminum, or brass. Unhardened steel or brass screws are normally used in the pattern shop. Wood screws are threaded from a gimlet point for about two-thirds the length of the screw. They have a slotted or Phillips head designed to be driven by a screwdriver.

Wood screws (fig. 3-51) are classified according to head style. The most common types are flat head, oval head, and round head, both in slotted and Phillips heads.

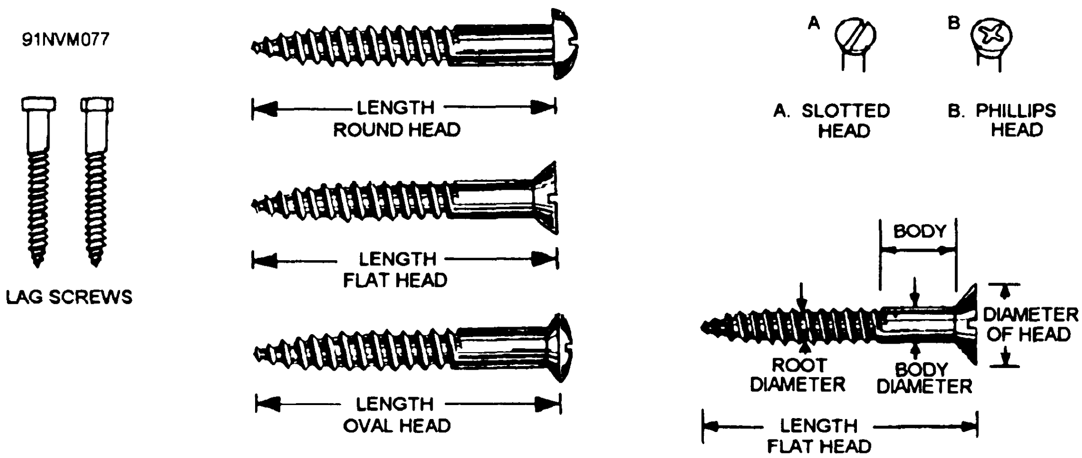


Figure 3-51.—Types of wood screws and nomenclature.

To prepare wood for receiving the screws, you bore a pilot hole the diameter of the screw in the piece of wood to be fastened (fig. 3-52). Then bore a smaller starter hole in the piece of wood that is to act as anchor to hold the threads of the screw. Drill the starter hole with a smaller diameter than the screw threads. Go to a depth one-half or two-thirds the length of the threads to be anchored. The purpose of this careful preparation is to assure accuracy in the placement of the screws. It also reduces the chance of splitting the wood and reduces the time and effort required to drive the screws.

Properly set slotted and Phillips flat-head and oval-head screws are countersunk enough to permit covering the head. Round-head screws are driven so the head is firmly flush with the surface of the wood. The slot of the round-head screw is parallel to the grain of the wood.

Wood screws come in sizes that vary from 1/3 inch to 6 inches. Screws up to 1 inch in length increase by eighths. Screws from 1 to 3 inches increase by quarters. Screws from 3 to 6 inches increase by half inches. Screws also vary in shaft size. Proper nomenclature of a screw is shown in figure 3-51. This includes the type, material, finish, length, and screw size number. The screw size number shows the wire gauge of the body, drill, or bit size for the body hole. It also shows drill or bit size for the starter hole. Tables 3-3 and 3-4 provide size, length, gauge, and applicable drill and auger bit sizes for screws.

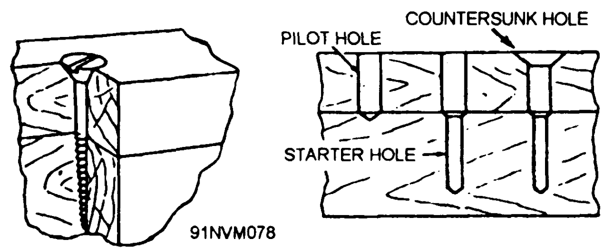


Figure 3-52.—Sinking a screw properly.

The proper name for lag screws (fig. 3-51) is lag-bolt wood screw. Building construction often requires you to use these screws. Lag-bolt wood screws are longer and much heavier than the common wood screw and have coarser threads. The threads extend from a cone or gimlet point slightly more than half the length of the screw. Square-head and hexagon-head lag screws are always externally driven, usually by a wrench. They are used when ordinary wood screws would be too short or too light.

Dowels

HTs use dowels to assemble and hold loose parts of a pattern in proper relation to each other while ramming up the pattern. Dowels often reinforce glued joints and delicate parts of a job. Wood dowels are round wooden pins made from straight-grained maple or birch. The diameters commonly used in the shop range from 1/8 to 1 inch, in 1/8-inch increments.

Table 3-3.—Screw Sizes and Dimensions

91NVM079

LENGTH (IN.)	SIZE NUMBERS																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	22	25
1/4	x	x	x	x																		
3/8	x	x	x	x	x	x	x	x	x	x												
1/2		x	x	x	x	x	x	x	x	x	x	x	x									
5/8		x	x	x	x	x	x	x	x	x	x	x	x		x							
3/4			x	x	x	x	x	x	x	x	x	x	x		x		x					
7/8			x	x	x	x	x	x	x	x	x	x	x		x		x					
1				x	x	x	x	x	x	x	x	x	x		x		x		x	x		
1-1/4					x	x	x	x	x	x	x	x	x		x		x		x	x		x
1-1/2					x	x	x	x	x	x	x	x	x		x		x		x	x		x
1-3/4						x	x	x	x	x	x	x	x		x		x		x	x		x
2						x	x	x	x	x	x	x	x		x		x		x	x		x
2-1/4						x	x	x	x	x	x	x	x		x		x		x	x		x
2-1/2						x	x	x	x	x	x	x	x		x		x		x	x		x
2-3/4							x	x	x	x	x	x	x		x		x		x	x		x
3							x	x	x	x	x	x	x		x		x		x	x		x
3-1/2									x	x	x	x	x		x		x		x	x		x
4									x	x	x	x	x		x		x		x	x		x
4-1/2													x		x		x		x	x		x
5													x		x		x		x	x		x
6															x		x		x	x		x
THREADS PER INCH	32	28	26	24	22	20	18	16	15	14	13	12	11		10		9		8	8		7
DIAMETER OF SCREW (IN.)	0.060	0.073	0.086	0.099	0.112	0.125	0.138	0.151	0.164	0.177	0.190	0.203	0.216		0.242		0.268		0.294	0.320		0.372

Metal dowels (usually brass) are sometimes used. They do not damage easily, and they do not absorb moisture from the molding sand.

Metal dowels (fig. 3-53) are self-centering. The lower portion of the threaded end locates its own center in the bored hole. It also holds the dowel to

Table 3-4.—Drill and Auger Bit Sizes for Wood Screws

SCREW SIZE NO.		1	2	3	4	5	6	7	8	9	10	12	14	16	18
NOMINAL SCREW		0.073	0.086	0.099	0.112	0.125	0.138	0.151	0.164	0.177	0.190	0.216	0.242	0.268	0.294
BODY DIAMETER		5/64	3/32	3/32	7/64	1/8	9/64	5/32	11/64	11/64	3/16	7/32	15/64	17/64	19/64
PILOT HOLE	DRILL SIZE	5/64	3/32	7/64	7/64	1/8	9/64	5/32	11/64	3/16	3/16	7/32	1/4	17/64	19/64
	BIT SIZE	---	---	---	---	---	---	---	---	---	---	4	4	5	5
STARTER HOLE	DRILL SIZE	---	1/16	1/16	5/64	5/64	3/32	7/64	7/64	1/8	1/8	9/64	5/32	3/16	13/64
	BIT SIZE	---	---	---	---	---	---	---	---	---	---	---	---	---	4

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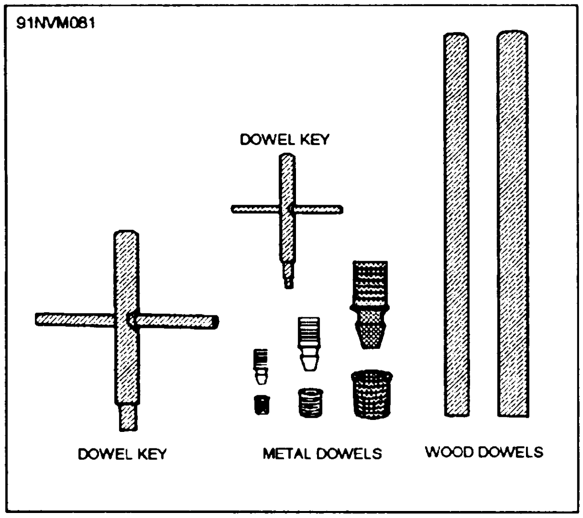


Figure 3-53.—Dowels and dowel keys.

its center as the threads cut their way into the wood. The thread depth keeps the dowel tight. The male and female parts fit within 0.001 inch.

You can easily insert or remove the metal dowel from the pattern by using a dowel key (fig. 3-53). Table 3-5 lists the dowel number size, the diameter of the dowel pin, and the recommended drill size.

Table 3-5.—Drill Sizes for Metal Dowels

Dowel No. Size	Dowel Diameter (inches)	Drill Size
0	7/64	1/8
1	11/64	3/16
2	3/16	1/4
3	7/32	5/16
4	5/16	6/16
5	13/16	9/16
6	17/32	3/4
7	13/16	1

Corrugated Fasteners

Corrugated fasteners are metal strips bent into many W shapes. These fasteners are used to butt two pieces of wood together. One- half the corrugated fastener goes on the first piece, the other half goes on the second. They are driven into the wood like a nail; but unlike a nail, they are not intended to be removed. The wood is destroyed if you try to remove a corrugated fastener. The most common application for corrugated fasteners is for holding together picture frames. The fastener is occasionally placed on the back side of the wood, but normally it is used like a slip feather.

FINISHING

The sequence of steps you should follow to complete a project is discussed in the following sections. A brief list of the steps follows. Sand the pattern to remove tool marks and ridges before it receives its final protective coating. Add fillets and include identification markings. Set rapping and lifting plates into the pattern.

SANDING MATERIALS

You need to use the correct sandpaper for the sanding job on which you are working.

Sandpaper is graded by the coarseness or fineness of the abrasive particles used on the paper. The grade is marked by a number on the back of the sandpaper. Table 3-6 shows sandpaper sizes and their suggested uses. Sandpaper usually comes in 9-inch by 11-inch sheets. For machine sanders, it comes either in rolls or cut to fit the machine.

Proper storage of sandpaper is important. Never store it in an area that is too damp or too dry. Moisture loosens the abrasive material, while excessive dryness makes the paper too brittle.

SANDING METHODS

Hand and lathe sanding are the two methods of finish sanding that you will routinely use. When you first started your pattern, you rough sanded pattern parts on power sanders made to remove large amounts of wood quickly. Finish sanding requires the careful removal of small amounts of wood in selected spots.

Table 3-6.—Abrasive Recommendations

KIND OF STOCK	STOCK REMOVAL		STOCK REMOVAL WITH FAIR FINISH		FINE FINISH	
	GRIT TYPE	GRIT SIZE	GRIT TYPE	GRIT SIZE	GRIT TYPE	GRIT SIZE
Paints and garnishes	Cabinet paper (opencoat garnet)	{ 2 1/2- 1 1/2			Wet paper "A" wight (silicon carbide)	{ 240-400
Hard tough minerals and compositions	Metal working cloth (aluminum oxide)		Metal working cloth (aluminum oxide)	{ 80-120	Finishing PaPer (aluminum oxide)	{ 150-320
Hard brittle mineral and compositions	Cabinet paper (aluminum oxide)	{ 50-80	Finishing Paper (aluminum oxide)	{ 100-180	Wet paper "A" weight (silicon carbide)	{ 220-320
Hard metals	Metal working cloth (aluminum oxide)	{ 40-60	Metal working cloth (aluminum oxide)	{ 80-120	Metal working cloth in oil (aluminum oxide)	{ 150-320 or crocus
Soft metals	Metal working cloth (aluminum oxide)	{ 36-60	Cabinet Paper (aluminum oxide)	{ 80-120	Wet paper "A" weight (silicon carbide)	{ 150-320
Hard wood Hard compositions Wallboards, etc.	Cabinet paper (aluminum oxide)	{ 36-50	Cabinet paper (aluminum oxide)	{ 60-100	Finishing PaPer (aluminum oxide)	{ 120-180
Plastics	Cabinet paper (aluminum oxide)	{ 60-100	Wet paper "C" wight (silicon carbide)	{ 120-220	Wet paper "A" wight (silicon carbide)	{ 240-600
Soft wood Soft wallboard	Cabinet Paper (garnet)	{ 2-1	Cabinet Paper (garnet)	{ 1/2-2/0	Finishing Paper (garnet)	{ 3/0-5/0

HAND SANDING

Normally, you sand the finished surfaces of cabinet and jointer work with the grain. Sanding with the grain avoids scratches that might spoil the natural appearance of the wood grain.

Redwood and some pines have a marked difference in hardness between the soft and hard portions of their growth rings. The abrasive on the sandpaper removes the softer portion of the grain quite rapidly when sanding is done with the grain on this type of wood. The harder grain portions offer more resistance to the abrasive. Instead, they tear the abrasive from the paper. This loose material, in turn, wears the softer portions of the wood. This produces a washboard surface that is not acceptable for a pattern. When the same woods are sanded across the grain, the abrasive material rapidly cuts tiny chips out of the hard fiber walls. The entire abrasive face of the sandpaper dulls evenly. It cannot remove the soft grain portion any faster than the reduction of the hard fibers will permit.

For sanding flat surfaces, you should select a sheet of sandpaper that is just coarse enough to dress the surface free of tool marks without cutting the surface too rapidly. Then, tear or cut a sheet of sandpaper into four equal parts since it is too large for the average-size job.

Make a sandpaper block and fold one of the pieces of sandpaper around it. Sand the surface by moving the block back and forth across the grain with long strokes. Move along the surface from one end of the material to the other. Do not sand in one spot. Try to remove an equal amount from all parts of the surface during each sanding motion. Brush the surface free of wood dust and loose abrasives. Examine the surface for tool marks. If they are not all removed, repeat these sanding operations until you get the desired results. Complete sanding of the surface with a fine grade of sandpaper, then brush the surface clean.

When sanding straight narrow edges, sand with the grain of the wood. Most people use a rocking motion with a sanding block when cross-grained sanding on narrow edges. The rocking motion produces a rounded surface.

When sanding concave surfaces, use a round-faced block. Do as much cross-grained sanding as you can. Start each sanding stroke at the top edge of the concave surface and push toward the bottom. Do not sand on the back stroke. You may pass over the edge and knock the corner over. Clean the surface often during sanding and look for tool marks. Finish the surface with a fine grade of sandpaper.

In sanding irregular surfaces, the usual procedure is to tear the sandpaper sheet into four equal parts. Fold each part to get three separate surfaces. As one surface of the paper becomes dull, turn the paper over until the entire piece has been used. Hold the paper as shown in figure 3-54. This method of sanding is for surfaces for which a sanding block will not work. Avoid sanding too long in one spot. This could change the dimensions of a job.

After you have finished sanding with a folded sandpaper, finish sanding by tearing off a narrow strip of sandpaper. Use it shoeshine fashion. Use a fine grade of sandpaper when you are finishing small jobs. Use coarser grades on larger work.

The principal purpose of sanding a finished or lacquered surface is to remove any roughness that may be present without removing the finish. The pressure exerted on the sandpaper should never be greater than that necessary to get satisfactory results. Also, use as fine a grade of sandpaper as the job will permit.

Look at the finished surface to see if it is fully dry before trying to sand it. Select a sheet of sandpaper of proper grade for the job to be done. Sand the surface very lightly at first. Use strokes that are as long as possible. Do no more sanding than is necessary to produce a smooth surface. Also, examine the sandpaper often to see if any part has become gummed with finish material. If it has, do not use that part of the sandpaper any longer. It will scratch the surface of the job.

LATHE SANDING

Sanding work in a lathe should be done very carefully because the dimensions of the job may alter. Carefully turn the job to a smooth finish so only minor sanding is necessary to finish the surface. Use a fine grade of sandpaper (120 or 150) on the average-size job. Always remove the tool rest from the lathe before sanding a job.

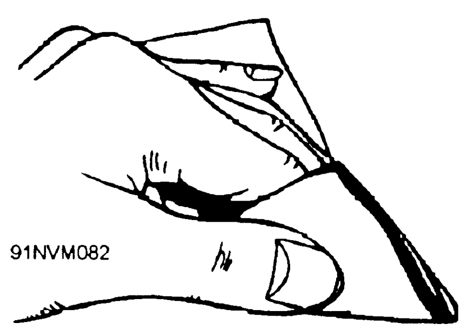


Figure 3-54.—Holding folded sandpaper.

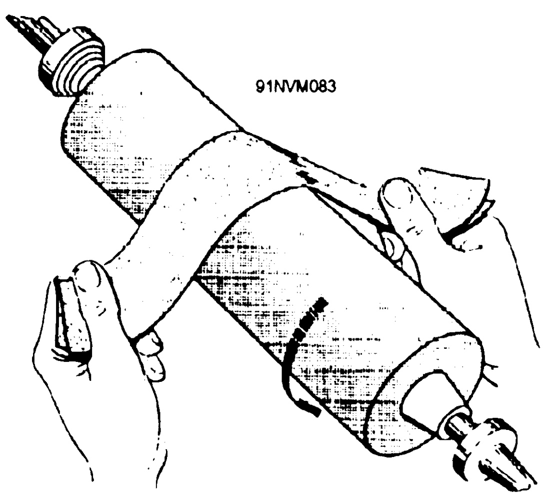


Figure 3-55.—Sanding a lathe job.

If the job is small, use a half sheet. For a large job, use the whole sheet folded twice. Apply the sandpaper lightly (fig. 3-55), moving it along the surface of the job. **Do not sand in one spot.** When sanding the ends of the job, use a narrow strip of sandpaper. Fold the sandpaper between your fingers in the shape of the sanding surface. Then hold it lightly against the stock. Rotate it at the proper angle so all angles, edges, or shoulders keep their designed shapes (fig. 3-56).

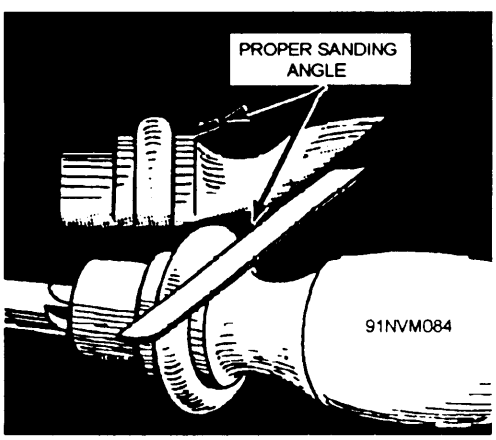


Figure 3-56.—Sanding at an angle.

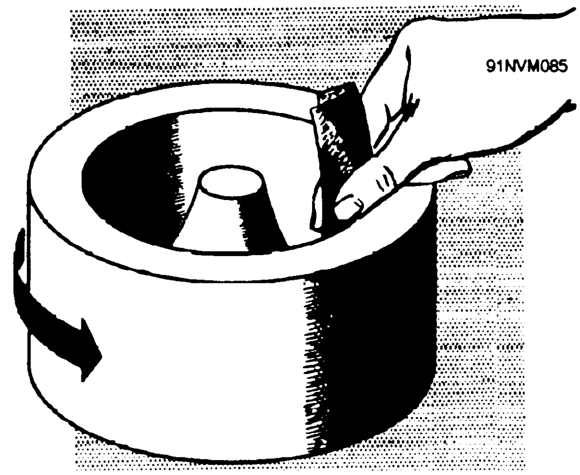


Figure 3-57.—Sanding a concave faceplate pattern.

When sanding a concave faceplate pattern, you should start by tearing a suitable piece from a sheet of sandpaper. Fold it over twice. Bend the paper a few times to make it pliable. Then, sand the job as shown in figure 3-57. Do not knock off the sharp corners on the face of the bend.

Machine sanders are useful for smoothing stock and for putting draft on the sides of patterns. Be careful when operating a machine sander so you will not cut off too much stock and ruin your work.

SUMMARY

In this chapter, you have learned about the different types of wood, wood joints, cuts, and fasteners that HTs use in their jobs. But remember when tasked with a job, no matter how small, you should take the time to pick the right material for the job. A little extra time taken before you begin may save a lot of time later.

CHAPTER 4

BOAT REPAIR AND DECK COVERINGS

LEARNING OBJECTIVES

Upon completion of this chapter; you will be able to do the following:

- *Describe the techniques and materials used to repair small craft.*
- *Describe the applications of plastic boats and the procedures used to construct and repair plastic boats.*
- *Recognize the fundamental principles of metal boat repairs and discuss the safety equipment and procedures used.*
- *Describe the preliminary preparations to be made before laying deck coverings.*
- *Describe the application and installation procedures of tiles and nonskid surfaces.*

INTRODUCTION

As a Hull Maintenance Technician aboard ship and IMAs, you must be familiar with the procedures used in making repairs to small boats, because you will be called upon to make emergency and permanent repairs on wooden, metal, and plastic boats. Each boat repair job presents a unique problem, depending on the type of boat and the nature of the damage to be repaired. In doing any repair work, the goal is to make the boat as strong and seaworthy as possible. You may also be required to repair or even replace deck coverings. We will discuss the repairs of deck coverings later in this chapter. Right now, let us look at boat repairs. The material in this chapter consists chiefly of examples of small boat repairs and cannot be taken as step-by-step directions for repairing all types of damage to all boats.

Boat repairs vary and may include repairing structural members, removing and replacing damaged planking, caulking seams, making soft patches, and making plastic repairs.

The types of boats in current use by the Navy include fast patrol boats used for inshore and riverine warfare, landing craft carried for amphibious use, motor whaleboats, utility boats, and motor boats. Figures 4-1, 4-2, 4-3, 4-4, and 4-5 show some of the boats carried aboard ship. Since inflatable boats are covered in *Basic Military Requirements,* NAVEDTRA 12043, they will not be discussed in this text.

You will be able to make repairs more intelligently if you understand the general principles of boat construction. This information will help you learn the names of the parts of boats, boat fastenings, and other terms used by boat builders.

When the construction of a boat is authorized by NAVSEA, the boat is assigned a BOAT NUMBER. You will usually find the number cut on the inboard face of the keel, apron, or keelson.

The label plate is usually secured in a conspicuous location near the steering control station. This label contains the following information:

- Length and type of boat
- Boat registry number
- Maximum capacity (number of personnel)
- Builder (usually a boat building contractor)
- NAVSEA plan number (used for construction)
- Date completed

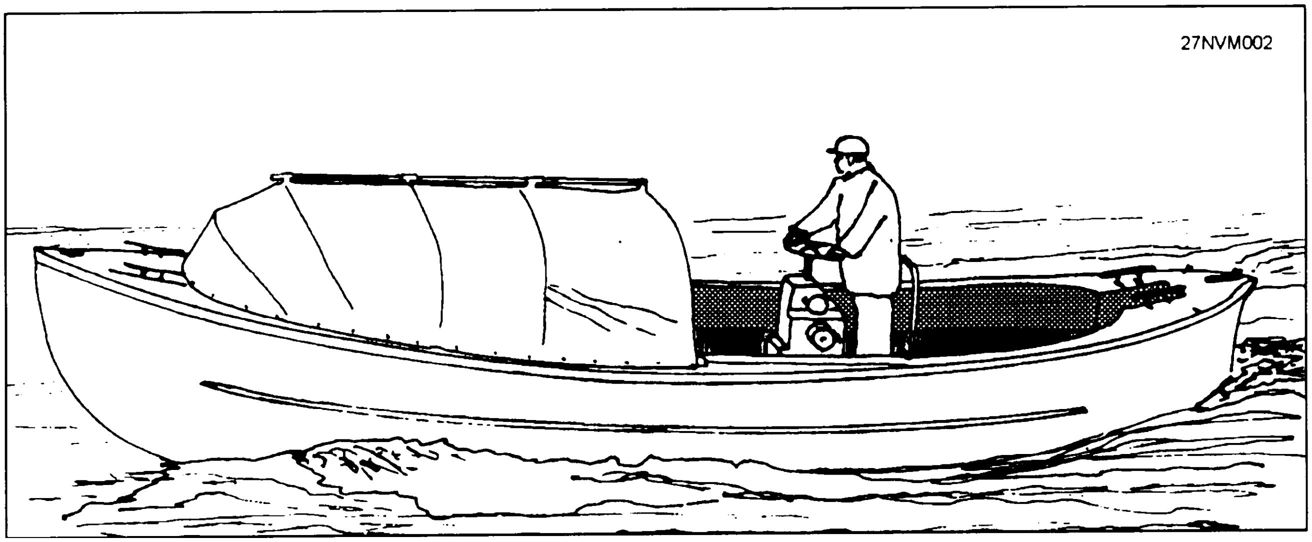


Figure 4-1.—A 26-foot Mk 10 motor whaleboat.

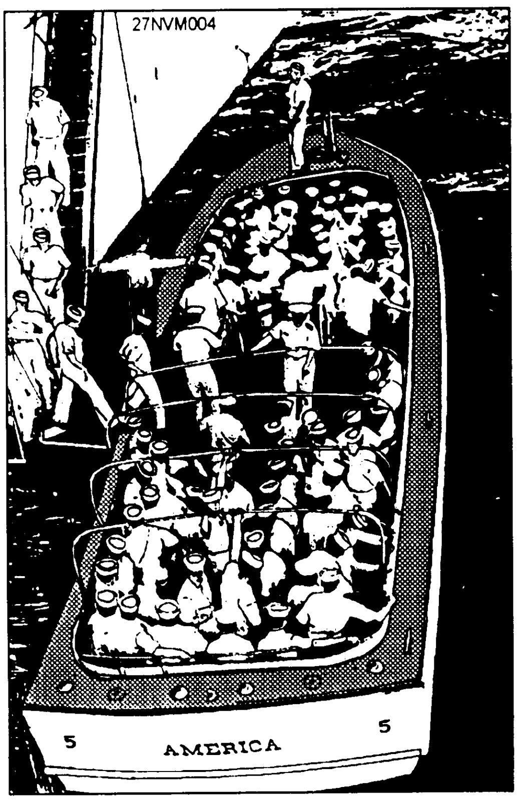


Figure 4-2.—Utility boat being used as a personnel carrier.

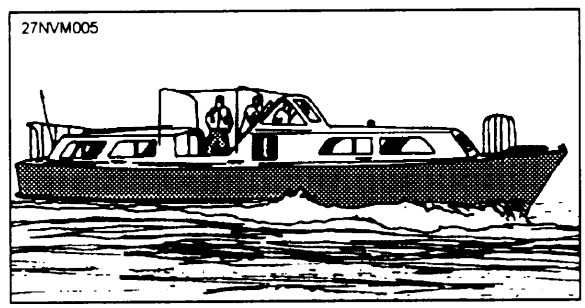


Figure 4-3.—A flag officer's barge.

INSPECTING BOAT DAMAGE

The first step in repairing a boat is to make a thorough inspection to determine the extent of the damage. It is particularly Important to determine the condition of the main strength members. A relatively slight amount of surface damage may be deceptive and may cause you to overlook deeper and more serious damage. For example, a direct blow that is heavy enough to damage the stem of a utility boat may cause severe damage to the stem apron, knee, keel, or keelson; a blow that ruptures the transom planking may break or crack a stern frame; and a broadside bump that seems to do little damage might actually loosen or damage an engine stringer or girder.

To determine the extent of the damage, you will probably have to scrape the paint away from a fairly large area. If the stem is damaged, you should remove the towing post and chafing plate. The towing post may be removed by pulling the retaining pin, which is located under the towing post partner, and lifting the post straight upward from the step or securing plate on the keel. Figure 4-6 shows a boat from which the towing post, or bitt, has been removed. On some craft, it may also be necessary to remove some of the decking to reach the stem and apron.

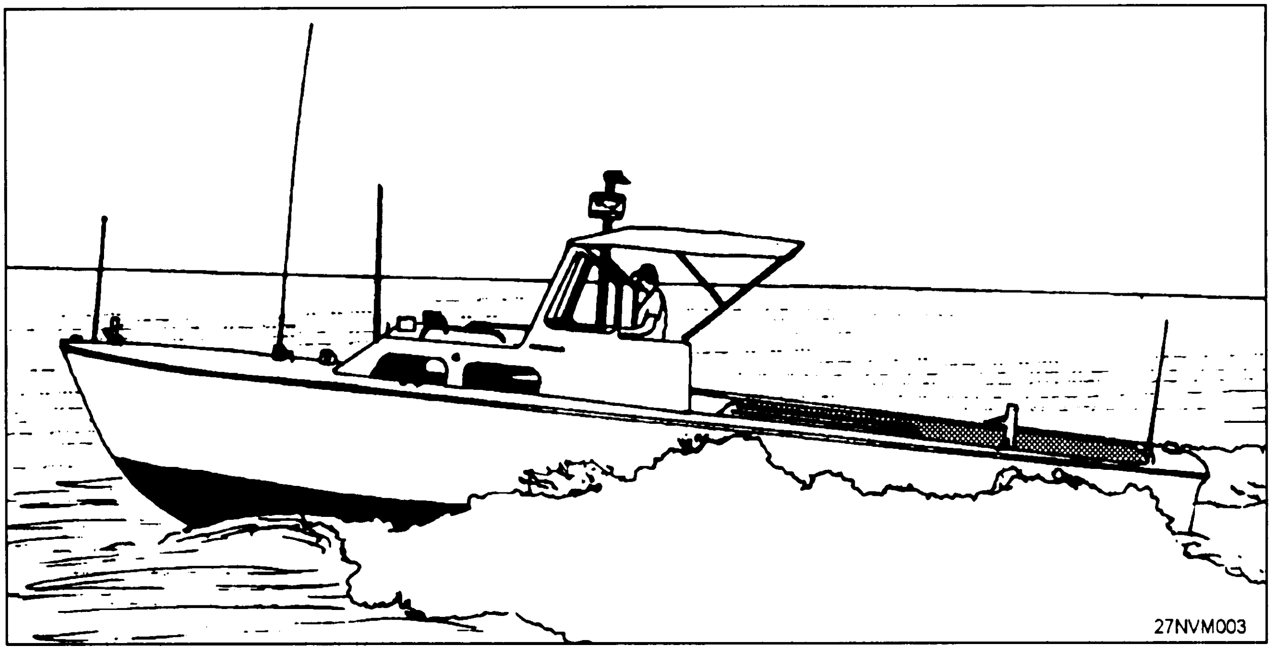


Figure 4-4.—A 36-foot Mk 11 LCPL.

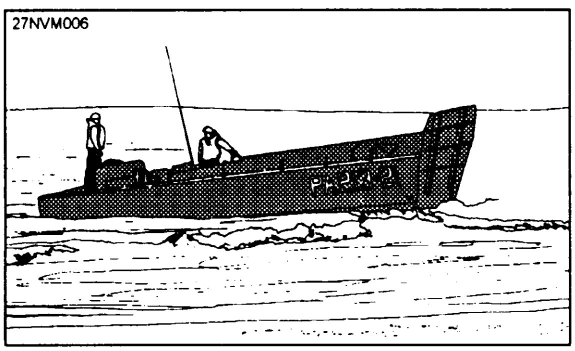


Figure 4-5.—LCVPs hitting the beach.

WOODEN BOATS

Almost all of the operational Navy small craft are now built of glass-reinforced plastic. The wooden boats that you may have occasion to repair will be odd types, kept for recreational or historic purposes. The information in this section will help you make temporary repairs to these wooden boats. They may then be operated until permanent repairs can be performed by technicians assigned to ships or shore commands with the necessary facilities and skilled ratings.

There are three causes of damage to wooden boats. The most difficult damage to repair is caused by rot. The other forms of damage are the result of fire or physical forces such as collision, grounding, broaching, or other evidences of poor seamanship.

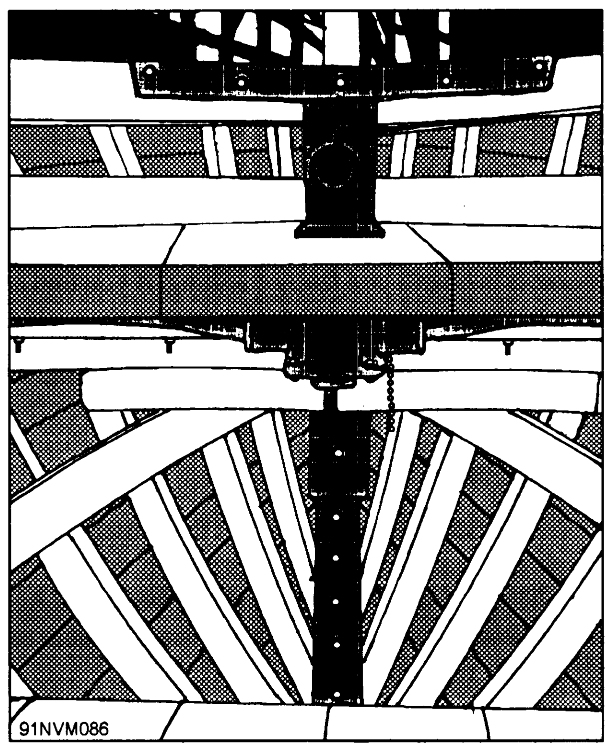


Figure 4-6.—Looking forward on a boat with the towing post removed.

There is little a Hull Maintenance Technician can do to prevent physical damage to a boat.

DECAY

Preventing rot or decay requires joint efforts with the Boatswain's Mates or other personnel who are charged with painting and caulking the boat. You should inspect boats in your charge fairly often to check the following causes of decay:

— Parts of the boat may be too dry or too wet. Strong sunlight or storage near hot machinery can dry out the wood. Dryness causes wood to shrink and crack. Water can then seep between planks and into cracks, wetting interior areas which will not dry before rotting has started. The microorganisms that cause wood to rot require a limited range of dampness to be active. Most of these organisms are fungi, and they will develop in wood having over 30 percent moisture content. They need some air, and they will not develop in wood fully saturated with water, from which comes the term *dry rot.* Once in wood, they will be dormant if the moisture content is less than 20 percent, or if the wood is saturated. Fresh water causes more decay than salt water, so inspect areas where rainwater or condensation may be trapped. Boats with closed spaces should have adequate ventilators installed or hatches opened up and interiors dried out whenever the weather permits.

— Cracks and seams are places where decay can start. Not only can dampness persist in narrow cracks, but other agents that cause decay can get in there. Look for cracks in boards and faulty caulking. If you find any, notify the boatswain's personnel to correct the problem.

— Plain iron fasteners or galvanized fittings that have lost their zinc coating will favor decay in oak frame members. Also, water may leak into the hull in the vicinity of these fasteners.

— Caustic chemicals, such as those used in cleaning, should not be allowed to stand in contact with wood. They can dissolve the wood and weaken it. Acids are less destructive; but strong acids, such as those used in batteries, will attack wood.

— A common cause of decay is destructive attacks by marine borers. This and general marine fouling are prevented by proper bottom paints and occasional overhaul. Borers are not a problem for boats kept out of the water.

Decay, particularly rot, will not start in any place where it is easy to detect. It may cause cracks and discoloration of paint, but since it is most likely to occur in bilges, behind ribs or frames, or in closed comers, it will be hard to see. Traditionally, it is found by probing with the point of a knife, chisel, or screwdriver. Press the tip of the instrument against the wood. If the wood is sound, the point will encounter increasing resistance as it penetrates deeper. In rotten wood, the resistance will seem to decrease once the paint layer is penetrated. A screwdriver tip will seem to pop through the paint and into rotten wood.

Decay may also be found in association with physical damage. Weak planks and timber will be the first to yield to stress. When inspecting collision or similar damage, look also for signs of rot.

EMERGENCY REPAIRS

Emergency repairs to boat planking can be made with sheet lead, plywood, canvas, or glass-reinforced plastic. If the patch is anchored to sound wood, it can last several weeks. If an emergency patch just covers a hole and is fastened to rot-affected wood, it should be replaced as soon as possible.

Most emergency repairs to frame members consist of reinforcing damaged timbers by backing them up and shoring them. Backup bracing can be temporarily nailed or lashed in place. Boats having serious structural damage are not seaworthy, and temporary repairs are made only to get them to a safe place where they can be repaired or surveyed.

REPAIR PROCEDURES

The first step in repairing a damaged boat is to make a general survey of the situation. Determine as best you can the extent of the damage. Having done this, consider whether you have the facilities and materials to make a repair. If work and storage space are limited, you might have to defer work on the boat until materials can be obtained. If you have adequate space, it would be best to haul out the boat for a detailed inspection and drying out before work is begun. If the boat has been sunk, the Enginemen will want to take out the engine, transmission, and electrical equipment for drying out and overhauling. If the hull is not repairable, remove the reusable parts and dispose of the hull.

As soon as a boat has been hauled out, its bottom should be cleaned. Barnacles and other marine growth are more easily removed when they are wet. They smell better then too. After the bottom is cleaned, the boat can be set up in the work area. The hull should be dried out, the bilges cleaned, and any rotten wood cut out so adjacent areas can dry out. When the boat has been cleaned and dried, you should make a careful inspection to determine the extent of damage.

Physical damage may extend far from the obviously stove-in areas. A boat may have been squeezed in a collision situation, and although there is obvious damage on one side, equal stresses have been suffered on the other side. By calculating the direction that forces were exerted on the hull, you can estimate the points where stresses were transmitted. Look in those areas for loosened fastenings or cracks in the wood.

If decay is present, either as the cause of failure or incidental to it, you must plan to remove not only the rotted wood, but also the wood into which the decay organisms are assumed to have spread. The rule in doing this is to remove sound wood for 2 feet along the grain from the soft wood and for 2 inches across the grain from the soft wood. Plywood should be removed for a 2-foot radius from the rotten area. If this is not done, decay can spread back into the repaired area.

When you remove a damaged plank, plan to take out a generous length. The new plank should butt to the end of the old one between frames, using a butt block; you should saw the ends to meet that requirement. If the plank is fastened with screws, chisel away the putty or the bung plugs and remove the screws. If boat nails are used, cut off the heads with a cold chisel. When the plank is pulled off, either pull the nail or drive it into the frame. To remove rivets, cut off the upset head and punch them out. (Rivets are usually found in lap stroke hulls, which are best sent to an expert for repair.) If the plank is fastened with drifts, pry them out by leverage on the plank, or allow the plank to break at the rib, then pull the drift or drive it flush.

To repair a sprung frame or rib where the exterior planking is sound, construct a sister frame and fasten it along the old frame. The sister frame should extend well to either side of the damaged area. Planks may be refastened to the sister frame.

If a frame has rotted, or is badly damaged, it must be replaced. To replace a curved frame section, it is easiest and best to laminate the replacement part on a template; or, if the exterior of the boat is sound, the section could be built up in place. On Vee hulls, the lower ribs should go from keel to chine, and the side ribs from the chine to the sheer strake. The ends should be joined as were the original members. Curved rib sections can be joined to the ends of the old rib if necessary. All frame member sections should be joined with a scarfjoint if at all possible. A scarf with a 12:1 pitch is best. A scarf with this pitch, glued with epoxy and secured by boat nails, bolts, or rivets, will be nearly as strong as the original member. If you use epoxy glue, you can allow some gap in the joint since epoxy has better strength in tension than regular marine glues. A good scarf can be made by overlapping the members to be joined and shaping both ends with one cut of a saw at a steep angle. Heavy timbers must be sawed and carefully planed to shape. When a rib or strake cannot be easily reached, the scarf angle will probably have to be chiseled into it. The end of the new section then is carefully fitted to this angle. Since epoxy has strength in tension, rougher faces of joints can be used than was possible with older glues.

The easiest way to lay out a replacement part is to use the old part as a template. If the old part is too badly damaged, you may be able to construct a template of scrap materials or lay out the new part by careful measurements. Experienced boatwrights have a number of techniques to form duplicate replacement parts, but for emergency repairs you can probably settle for any method that will fill the hole or provide adequate reinforcement. Plastic patch materials permit simple, quick repairs that formerly were not possible.

FERROCEMENT BOATS

Ferrocement is a material finding increased use as a low-cost material for hull construction. It is a combination of steel-reinforced mesh and portland cement binding. The reinforcement material ranges from several layers of chicken wire to a few layers of specially woven steel wire. Ferrocement hulls may also have some structural steel or steel pipe reinforcement or framing.

Repairable damage to ferrocement hulls probably will be in the form of punctures or structural damage from collisions or groundings. Other failure of these hulls will be caused by poor design, materials, or workmanship. Hull failure from these causes is not economically repairable since the seaworthiness of the entire craft is questionable.

To repair punctured areas not over about 1 foot in greatest diameter, use the plastic patching kit and basically the same techniques described later in this chapter for repairing fiberglass hulls.

Damaged ferrocement can be cut away with a masonry blade in a portable circular saw. The edges of the hole can then be scarfed with a heavy duty sander, but not to the degree of taper possible with fiberglass. Additional reinforcement can be added to the rear of the patch. Epoxies bond very well to ferrocement.

Larger damage may require some structural reinforcement. Structural steel members may be repaired by welding, and steel backing to repaired areas can be welded to structural members. Welding heat will decompose some of the surrounding cement, which should be chipped away and replaced with epoxy.

To bolt repair patches to ferrocement, use plain black iron carriage and stove bolts. Galvanized hardware does not stand up well in ferrocement.

PLASTIC BOATS

Some types of damage to plastic boats require slight deviations from the standard repair procedures, but personnel who can effectively repair a hole in the hull should have little or no trouble with other plastic repairs.

USES AND IDENTIFICATION OF PLASTICS

Plastics in naval construction have become increasingly important. Plastic patching has become standard practice aboard most ships in the Navy.

Plastics can be identified by their chemical and physical properties. For repair purposes, the most important plastic categories are the cellulose products, the protein plastics, and the synthetic resins. Physically, plastics may be divided into two basic groups: THERMOSETTING materials and THERMOPLASTIC materials. A thermosetting plastic has no melting point. Although a thermosetting material can flow and be molded, it will neither soften when heated nor return to its original liquid state. A thermoplastic material, however, will soften when heated. To illustrate, let us compare these two kinds of plastics with steel and concrete. Steel can be heated and formed, and when reheated, will soften; a thermoplastic material is like that. On the other hand, once concrete has set, it cannot be reformed; this is characteristic of a thermosetting plastic.

Polyester thermosetting resins, known as polyesters, are extensively used by the Navy. By adding various activators (catalysts and accelerators) in small quantities to the liquid polyesters, chemical reactions occur that cause the material to become rigid. This process of changing from one state to another is called curing. By varying the percentage of catalyst added, the resin can be made to cure in periods ranging from 30 minutes to over 24 hours.

REPAIRING PLASTIC BOATS

Although the use of plastics in naval construction and repair is relatively new, plastic materials and boats have become important for naval use.

The factors in favor of the plastic boat are many; it has a monolithic structure (can be cast in one piece), it can be mass produced, and it can readily be maintained and repaired. Ships are supplied with metallic pipe and general-purpose repair kits. These pipes and kits are used for emergency repairs of battle damage to piping for water, oil, gasoline, and refrigeration lines. Materials and instruction are provided not only for repairing pipes, but also for repairing damaged glass-reinforced plastic structures such as boats, floats, deck cabins, and hull and deck coverings.

Repair Kits

The metallic pipe and general-purpose repair kit are repair locker equipage. The repair kits are not to be removed from the repair lockers except in the case of an emergency and with the authorization from the leading HT or the damage control assistant (DCA), or when the shelf life date has expired and a new kit has been placed in the locker. The shelf life of a kit is 2 years. When a kit is removed from the locker because it is past its shelf life, the HT shop may keep the kit for boat repairs and training purposes. The repair kit contains epoxy resin, hardener, and glass reinforcement in the form of mats or woven cloth. Auxiliary materials include separating film, kraft paper, protective gloves, wooden spatulas, resin spreading tools, brushes, and repair instructions. Sufficient quantities of these materials are provided in a standard kit to replace about 400 square inches of damaged 1/4-inch laminate, and tubes of paste resin are provided for repairing minor surface imperfections.

The kit supplier has preweighed and packaged the resin and hardener in the proper proportions. The resin cans are only slack filled to allow the hardener to be added to the can of resin when the two are mixed.

Proper storage of plastic repair kits is important. They should be stored in a cool, dry place. Temperatures should be kept below 70°F and the relative humidity should be less than 50 percent. Kits should never be stored in temperatures below 32°F. Storage life of the resin will vary; however, under these specified storage conditions, the resin should remain stable and usable for an indefinite period of time.

Any chemicals or solvents should be handled with caution. The repair of reinforced plastics is no exception. Cutting and grinding of reinforced plastic laminates generates a fine dust that irritates the skin and eyes. Inhalation of the dust should be avoided.

The following safety precautions should be followed:

1. Wear protective gloves, goggles, and respirators provided with the kit. If available, apply a protective hand cream to all exposed skin areas.

2. Avoid contact with the eyes, skin, or clothing. If these materials contact the skin or eyes, immediately flush them with water for 15 minutes. If the eyes are involved, obtain medical attention.

3. When working in confined spaces, be sure there is adequate ventilation. Where such ventilation cannot be provided, organic respirators are required for protection against fumes.

4. If clothing becomes contaminated, remove it and wash it thoroughly before reuse.

5. Always wash exposed skin areas thoroughly when you are finished working.

6. Keep chemical containers clearly labeled and tightly covered when they are not in use. When mixing a polyester resin, NEVER mix the catalyst and accelerator directly together or an explosion may result. Always mix chemicals according to instructions.

7. Do not smoke or work near hot surfaces or open flames while using these materials.

Basic Considerations

Many factors determine how closely the strength of a reinforced plastic repair will resemble the strength of the original laminate. Workmanship, repair techniques, the glass reinforcement, and resin all play an important part in any repair. Reinforced plastics are easy to repair if you have a knowledge of materials used and proper repair techniques.

Three types of reinforcement are most frequently used—singly or in combination—in glass-reinforced plastic laminates. The cheapest and weaker type, random glass mat, consists of chopped glass fibers that are either lightly bonded together with a small amount of binder resin, or mechanically stitched into a random, jackstraw arrangement. These mats may be obtained in weights from 1/2 ounce to 3 ounces per square foot. The strongest and most expensive type is woven glass cloth. It is available in a wide range of weaves and styles, varying from a coarse, loosely woven fabric to a fine, closely woven one. Woven fabrics are usually identified by a style number that refers to a specific cloth or a certain weave, weight, and thickness. For example, style #1000 cloth identifies a plain weave cloth that weighs 10 ounces per square yard and is 0.013-inch thick. Woven fabrics are coated with a finish to improve the bond between the glass and the resin. The third type of glass reinforcement, which is gaining popularity because it is cheaper than cloth and builds up the thickness of a laminate faster, is called woven roving. This type of reinforcement resembles a hand-woven potholder both in weave and appearance. A commonly used type of roving is about 0.040-inch thick and weighs 24 ounces per square yard. Of the three types of reinforcements, the woven fabric is the easiest to handle and the most dependable for repair work.

Two types of resins are usually used for repairing reinforced plastics. The first is a polyester, which may be obtained in a wide range of viscosities. The consistency of the very high-viscosity resin resembles heavy molasses, while that of the low-viscosity resin is like water. Usually, the low-viscosity resin will saturate or "wet-out" a glass reinforcement faster, but it will also drain more rapidly on a vertical surface. This drainage may be undesirable in some applications and may be minimized by the addition of a small amount of a finely divided silica. A highly viscous resin may be thinned by the use of a small amount of styrene. Many resins are available commercially that have been specially compounded to the proper viscosity for repair use.

Polyesters are also extremely versatile in cure (hardening) characteristics. The addition of a small amount of an organic peroxide catalyst in a powder, paste, or liquid form, and an accelerator will cause a cure to occur at ambient temperatures above 50°F without the application of heat. The working life (time within which the resin remains liquid and usable) and cure time may be varied by adjusting the proportions of the catalyst and accelerator used. The resin supplier will generally provide information on resin formulations. Some resins are supplied with the accelerator already added, thus only the addition of the catalyst is required. Temperature greatly affects the cure time of polyesters; the higher the temperature, the faster they will cure. Polyesters also have a limited storage life of about 6 months to a year. Standing in storage causes them to gradually thicken until they become unusable even though the catalyst has not been added.

Epoxy, the second type of resin that may be used in reinforced plastics repair at room temperature, is widely recognized as an adhesive for a great variety of materials. Although better adhesive properties are generally claimed for epoxies, especially when heat is applied to achieve a higher strength bond, they are more costly than polyesters. Like the polyesters, epoxies are available in a variety of viscosities and with a wide range of other characteristics.

Epoxy resins are activated for room temperature cures by the addition of a recommended amount of a specific room temperature hardener. However, unlike the polyesters, the proportions of hardener should not be varied to change the cure time, since any change in concentration will adversely affect the other properties. Cure conditions can be varied only by changing hardeners or by cooling or heating the resin. There are many types of room temperature hardeners from which to choose. Users are cautioned that room temperature hardeners are alkaline in nature, so they should be handled with care. Rubber gloves and eye protection are recommended when you are handling epoxy resin and hardener. Always wash the skin immediately after any contact with the hardener.

Repair Procedures

The three types of repair patches applied to reinforced plastic laminate are shown in figure 4-7.

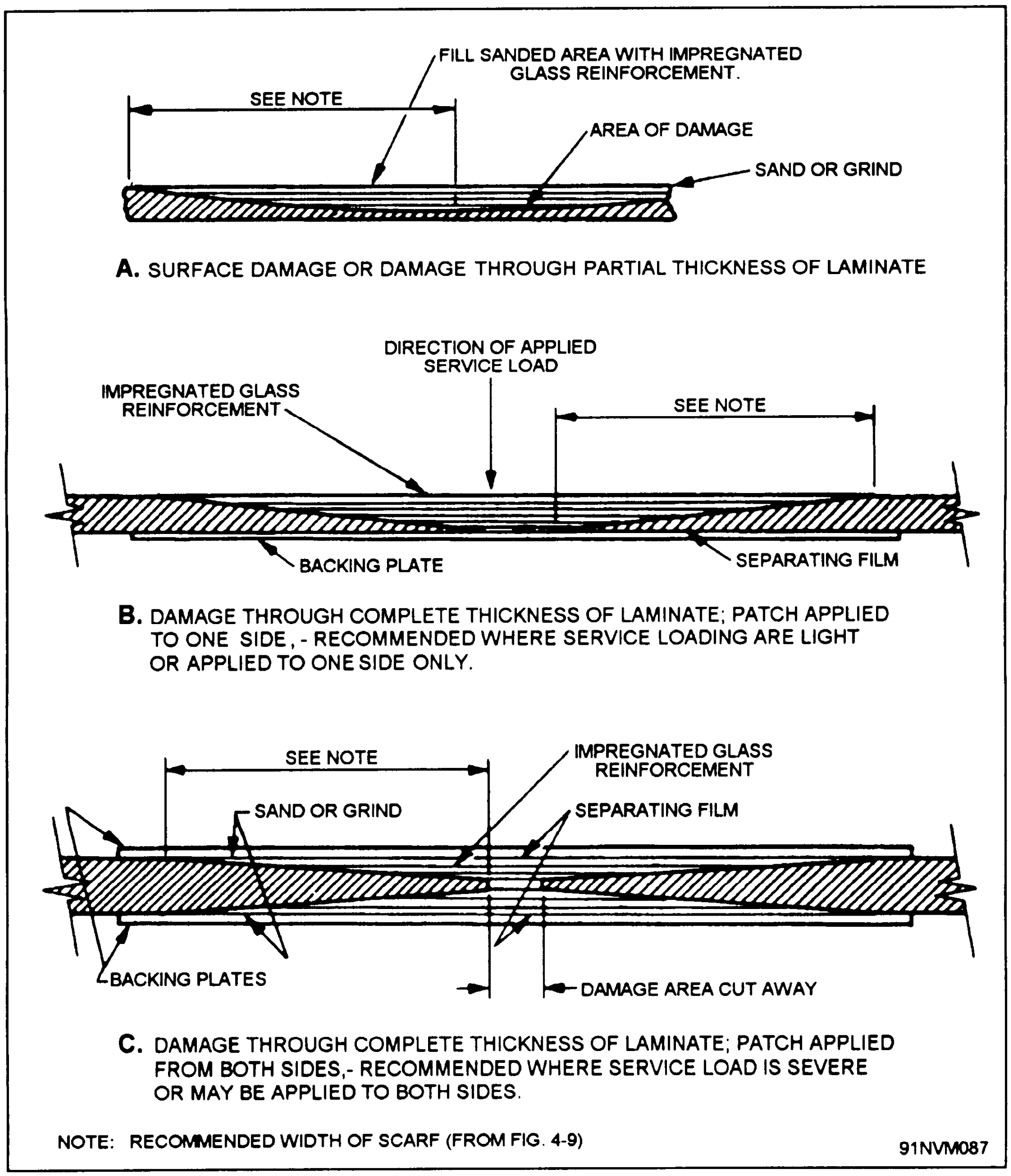


Figure 4-7.—Types of patches applied to reinforced plastic boats.

They are the surface patch, the one-sided patch, and the two-sided patch.

The basic steps are (1) planning the repair, (2) preparing the damaged area, (3) tailoring the reinforcement material, (4) preparing the resin system, (5) impregnating the reinforcement with resin, (6) applying the patch, (7) curing (hardening) the patch, and (8) finishing.

PLANNING THE REPAIR.—Before beginning the repair, several details should be checked and advance plans made to avoid later problems. If the repair is to be accomplished in an unsheltered area, check the weather. If it is cold (below 50°F), rainy, or blustery, wait for a better day or move to some indoors area away from the elements. If it is a bright, sunny day, be sure that the area is well shaded.

Assemble the necessary equipment, in the quantities required, at the repair site. This includes the materials provided in the plastic repair kit plus the following supplementary items:

- Chalk for marking the area to be repaired
- Protective equipment, such as goggles and respirator
- Ruler
- Saw (metal-cutting handsaw, holesaw, or reciprocating saw) for cutting away the damaged area
- Disk sander, cone sander, or file for grinding away the damaged portion and scarfing (beveling edge of cutout area)
- Cardboard, sheet metal, or plywood panel for use as backing and cover plates
- Tape, shoring, or bracing for attaching or supporting the backing and cover plates
- Acetone for cleaning the surface and the equipment

In determining the quantities of materials required for the repair, outline the area to be cut away and mark the area to be scarfed (beveled) with chalk (fig. 4-8). The recommended width of the scarf for

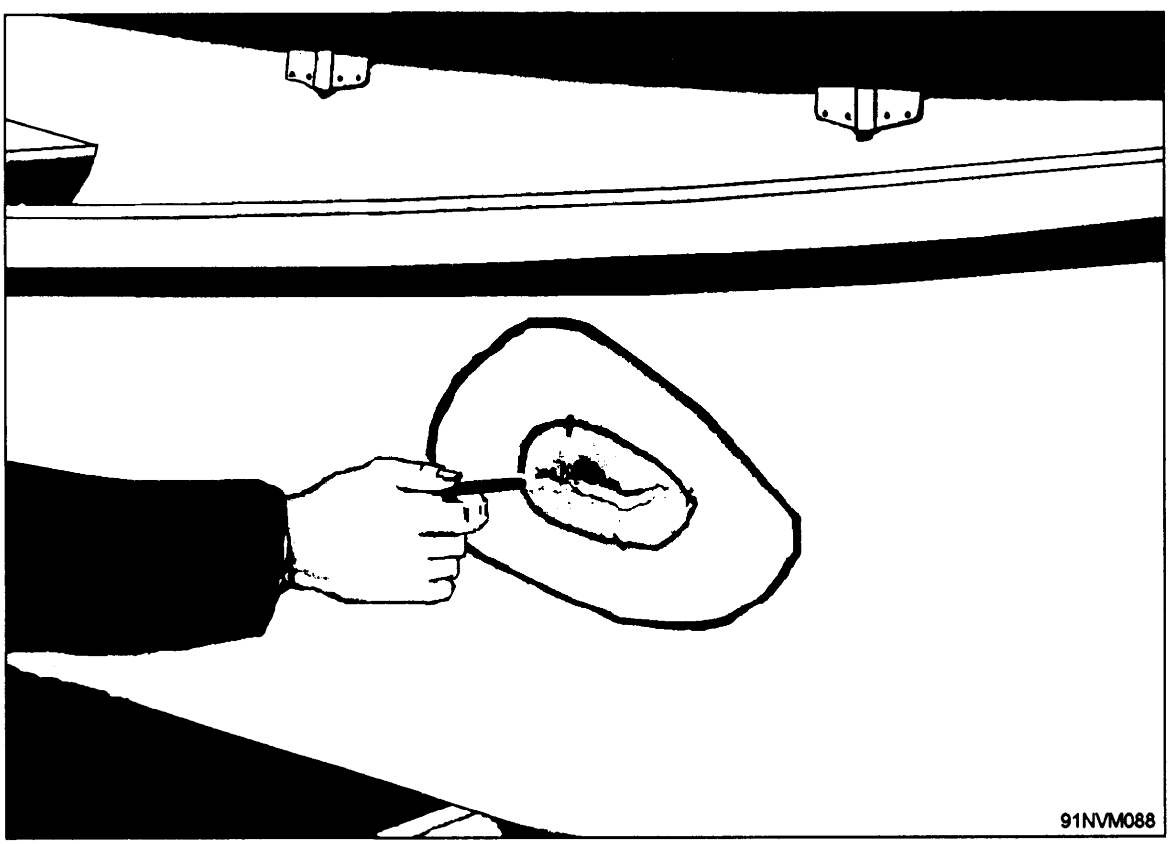


Figure 4-8.—Oval-shaped chalk marks delineate the area to be cut away (inside chalk marks) and the area to be scarfed (outside chalk mark to inside).

laminates up to three-fourths of an inch thick can be obtained from figure 4-9.

Round or oval-shaped repairs are preferable to ensure that you get a better bond and less chance of cracks in the base material. You should never use rectangular cuts with sharp comers. To estimate the amount of resin and glass reinforcement required for a round patch, determine the thickness of the laminate and the average diameter. For a rectangular or oval patch (fig. 4-10), the average area must be estimated.

Turn to the nomogram (fig. 4-9) to obtain an estimate of the materials required. Draw a straight line between scale A (average diameter and/or average area) on the left side and scale B (thickness) on the right side. Where this line intersects scale C, read the approximate amounts of cloth and resin required. Note that the estimate exceeds the actual requirement by 30 to 40 percent, particularly with respect to cloth, to allow for wastage. Select from the kit the number and size of cans of resins and hardener required. To avoid waste, open and mix the cans as they are needed.

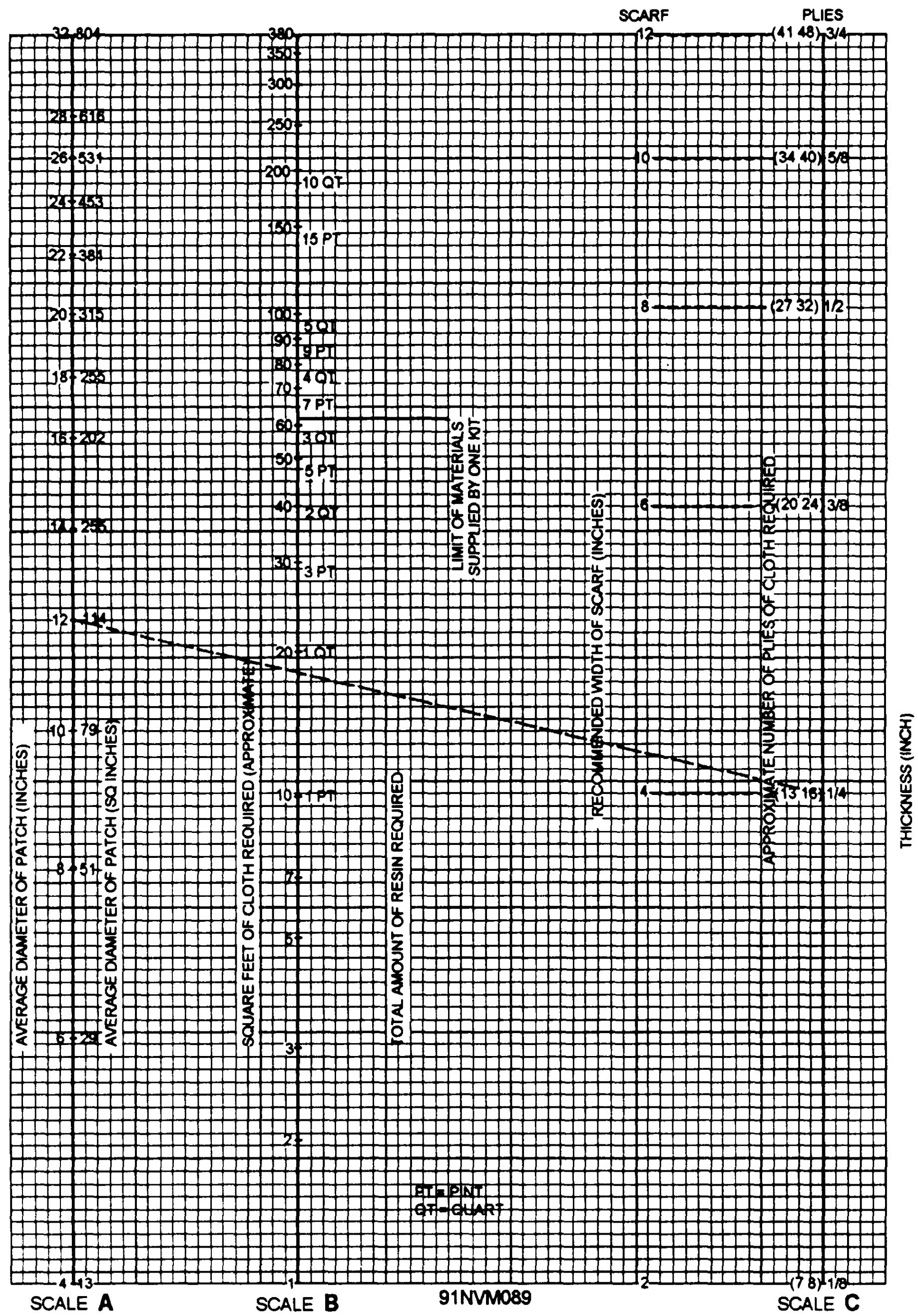


Figure 4-9.—Estimating materials.

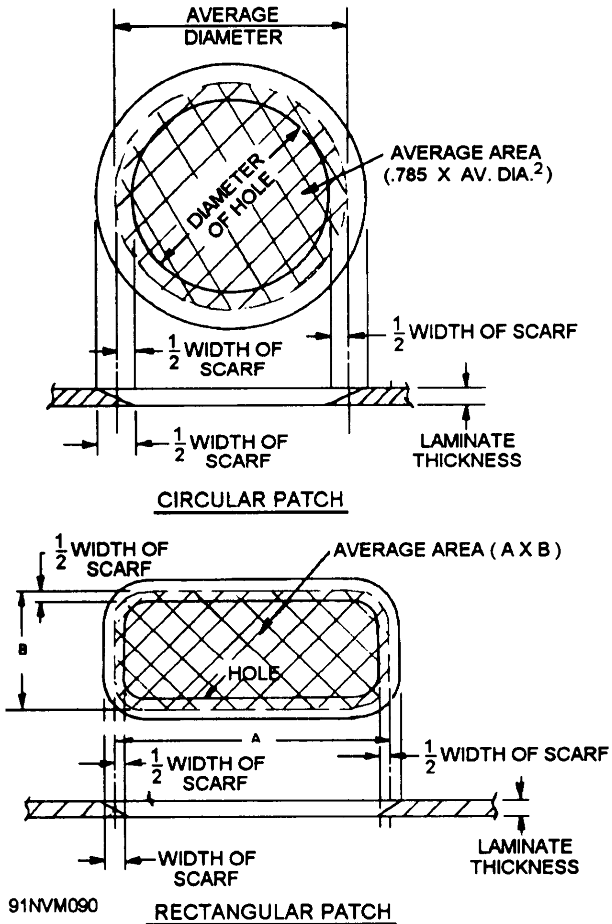


Figure 4-10.—Average diameter and area of a patch.

Scale B also indicates the recommended width of the scarf and the approximate number of plies of cloth required for any given thickness. The number of plies required is affected by the variation in the thickness of the cloth, the viscosity of the resin used (the thicker the resin, the fewer the plies), and workmanship. The amount of cloth specified on scale C is based on the maximum number of plies that might be used, and the resin estimate is based upon an approximate resin content of 60 percent.

To illustrate the use of the nomogram, assume that a repair is to be made to an 8-inch diameter hole in a 1/4-inch thick laminate. Looking at scale B, the recommended width of the scarf is 4 inches, and the approximate number of plies of style #1000 glass cloth is 13 to 16. The average diameter will be 8 inches + 4 inches (fig. 4-9) = 12 inches. Drawing a line between 12 inches on scale A and 1/4 inch on scale B (see dotted line in fig. 4-9), approximately 18 square feet of style #1000 glass cloth and 1 quart of resin are required. (As mentioned previously, the materials estimate may be 30 to 40 percent in excess of the actual requirement.)

PREPARING THE DAMAGED AREA.—The next step is to prepare the damaged area. This is accomplished in one of two ways. If the damage extends only partially through the laminate, merely grind the damaged area down to the sound laminate with a disk or cone sander using a coarse abrasive. If the break is all the way through the laminate, however, the damaged area should be cut out on the first chalk mark nearest the damage with a metal cutting handsaw or reciprocating sabre saw (fig. 4-11). Then, scarf back

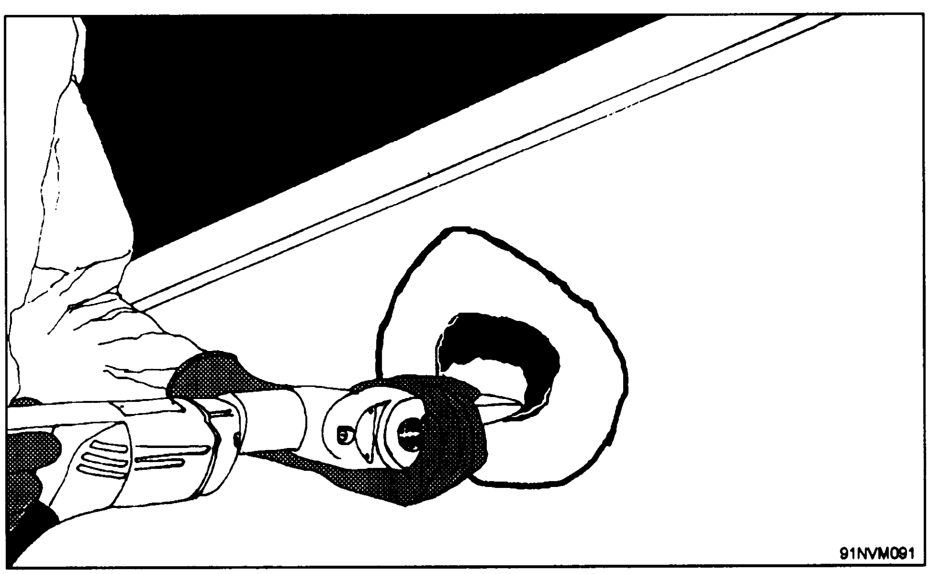


Figure 4-11.—Damaged area being cut away.

to the second chalk mark (fig. 4-12). This increases the area to which the patch will adhere so that a stronger bond may be obtained. The roughened surface caused by the coarse abrasive provides a better bond between the old surface and the patch. After the grinding has been completed, wipe away all the sanding dust and clean the entire adjacent area with acetone or lacquer thinner.

The procedure just described is for preparing a damaged area for the application of a patch on one side. The patch will generally be placed on the readily accessible external surface, because it provides greater resistance to external stresses. However, in instances where maximum strength is necessary in both directions, and both sides are readily accessible, it may be desirable to make a patch on both sides (view C of fig. 4-7). Both sides are prepared in the same manner as a repair to one side. Then, the patch must be made on both sides. Repairs of this type are especially desirable for thick laminates (three-eighths of an inch and over). Apply the temporary backing plate to support the patch while it is curing (hardening). For small repairs on flat surfaces, the backing plate can be a piece of heavy cardboard, plywood, or sheet metal. For curved areas, a formed piece of aluminum or steel sheet metal is generally preferred.

When accomplishing a repair on a vertical surface, use a plate on each side of the patch to hold the patch in place while it is curing. Cover these plates with separating film so that they may be removed easily later. Hold the plates in place by taping, shoring, or bracing them with lumber (fig. 4-13).

If the underside of the damaged area is inaccessible, apply a resin-wetted backup patch about 2 inches larger than the hole into the scarfed area on the exposed side. This patch should be allowed to cure (harden) to form a foundation for the patching material. After the backup patch has hardened, lightly sand the surface to provide a better bond between it and the material to be added later.

TAILORING THE REINFORCEMENT MATERIAL.—To cut the glass reinforcement to fit the repair, prepare paper templates for the innermost ply that are slightly larger than the hole, and for the outermost ply to barely overlap the scarfed area. Each of the intermediate plies should be cut proportionally larger than the preceding smaller ply. (See fig. 4-9 for the approximate number of plies required for a given thickness.) If the patch is being made from both sides, two sets of plies should be tailored as described, one for each side.

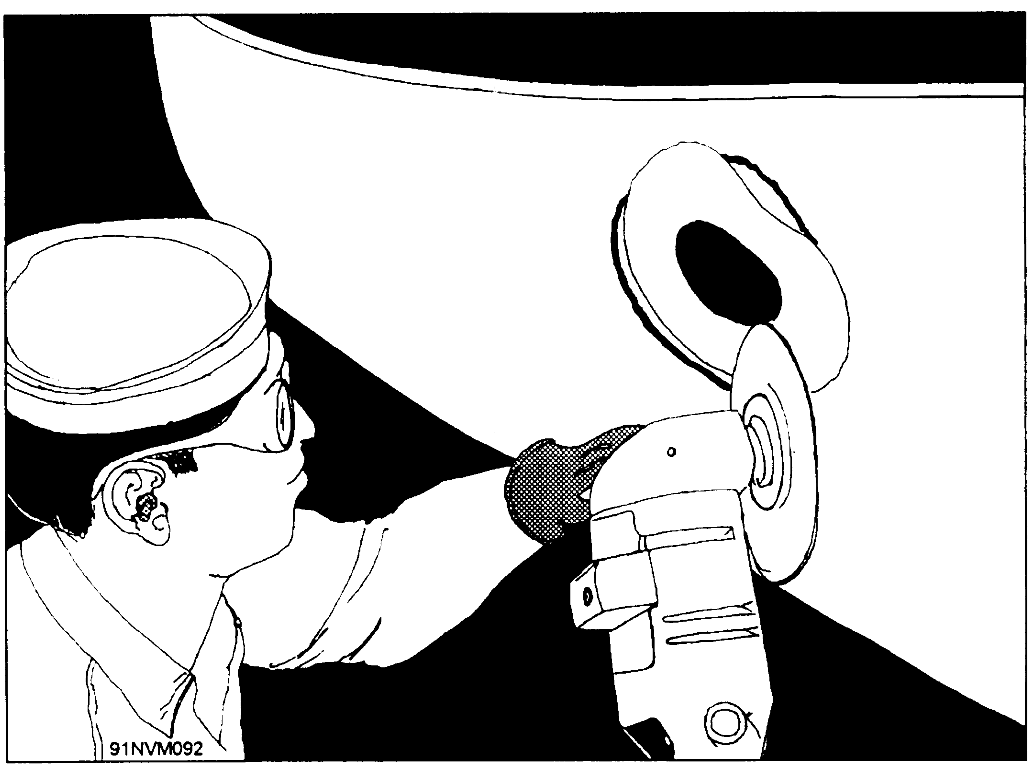


Figure 4-12.—Scarfing operation.

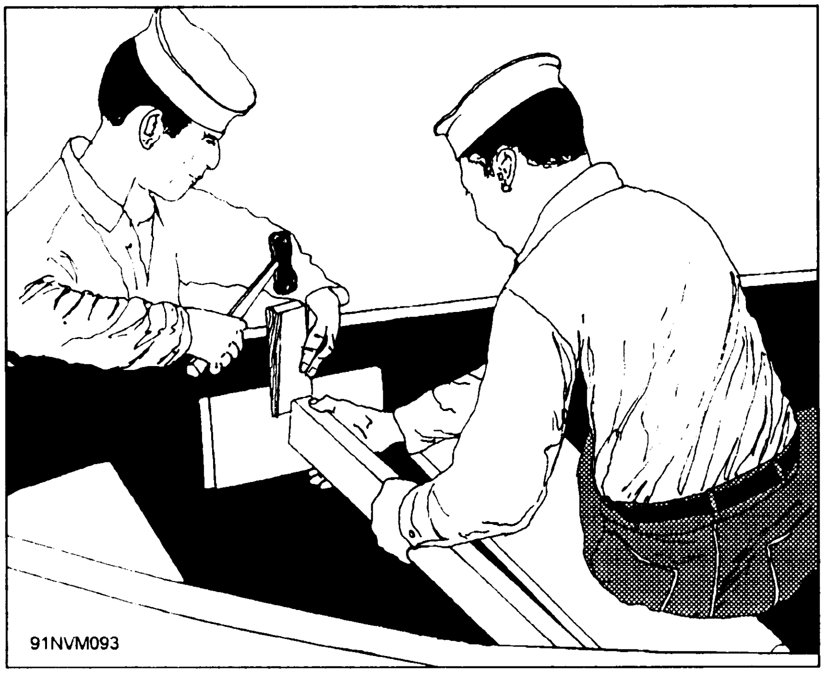


Figure 4-13.—Placing shoring over a film-covered backing plate.

Keep all glass reinforcements clean and dry. They should not be handled with dirty or greasy hands. Cut and handle the reinforcement carefully since the cut edges of some reinforcements unravel easily if handled carelessly. Glass cloth should be used for most general repairs, especially where strength is important. The glass mat may be used in fillets or for thicker buildups. alone or in combination with glass cloth.

PREPARING THE RESIN SYSTEM.—The resin and hardener in the repair kit has been preweighed and packaged in the proper proportions for mixing. If the temperature is much above 70°F, bring the resin temperature down to about 70°F, as higher temperatures will shorten the working life of the resin. Conversely, if the temperature is low, it is advisable to keep the resin indoors until used. Prior to opening the containers, clean and dry them thoroughly so that no moisture or foreign matter will get into them. NEVER mix the hardener with the resin until the preceding steps have been accomplished. The amount of resin needed for the patch may be estimated from figure 4-9.

Be sure to mix the entire contents of the hardener container thoroughly with the resin. Once the resin formulation has been thoroughly mixed, the "die is cast." Work ahead steadily to complete the repair within the working life of the resin. The resin system in the kit has a relatively short working life that depends primarily on temperature conditions.

IMPREGNATING THE MATERIAL AND APPLYING THE PATCH.—There are two methods for preparing the reinforcement material with resin for applying the patch: method one, which is particularly desirable for use with the vertical patch; and method two, which is desirable for use on horizontal surfaces where impregnated plies can be laid in place one at a time. In both methods, the first step is to brush a coat of mixed resin formulation over the area to be repaired.

Method One.—On a flat surface lay a piece of separating film larger than the largest tailored ply of reinforcement. Center the largest ply of glass cloth on the separating film and saturate it with resin mix by brushing or by pouring and spreading the mix with a wooden spatula from the repair kit. Center the second tailored ply over the first ply, then impregnate it with resin. Continue this procedure, saturating each successive smaller ply thoroughly, until all tailored plies of reinforcement are finished, with the smallest ply on top. Apportion the resin so that there is enough to uniformly saturate all plies. Then cover the saturated reinforcement with another sheet of separating film and work the air bubbles out by squeezing the wet reinforcement from the center outward with a clean spatula or spreader from the kit. Keep a close check that the time does not exceed the working life of the resin. After most of the air and excess resin have been removed, it may be desirable to apply another coat of the remaining resin to the repair area to assure that there is sufficient bonding resin.

Next, carefully feed the top layer of separating film adjacent to the smallest ply from the patch; then lift and center the patch over the hole with the separating film on the outside (fig. 4-14). This film should not be removed. With this film in place, once again work out any entrapped air and excess resin using a roller or wooden spatula. This also causes the patch to make intimate contact with the scarfed area. When the patch is being made on a vertical surface, apply a cover plate by taping, clamping, or bracing, to hold the patch firmly in place during the time needed for hardening or curing.

Method Two.—When using this procedure, you will lay individual plies of glass directly in place. One advantage this method has over method one, is that plies or reinforcements may be omitted or added in the event the calculated number of plies does not give the correct thickness buildup. A very liberal coating of resin must first be applied to the repair area. Then place the smallest ply of reinforcement in the hole and saturate it with resin. Add successively larger plies. Apply sufficient resin to each ply so that it will squeeze through the next ply, pushing out the entrapped air. Place a clean sheet of separating film over the top ply and work out the excess air and resin from the center to the edge of the patch. A cover plate may be used.

If the patch is being applied to both sides, follow the method being used for each side separately. The length of scarf and the amount of materials estimated for the repair on each side should be based on one-half of the total thickness of the laminate. Apply the patch to one side; then after it has cured, lightly sand the opposite side and apply the second patch to that side. In some applications, a patch can be applied to both sides in succession (before the first patch cures); however, this procedure requires care and skill.

CURING.—The patch should remain undisturbed at least overnight. Heat lamps may be used to speed the cure (fig. 4-15); but in using, you should not overheat the patched area as the cure reaction may “run away,” causing frothing, blisters, and porosity. Lamps should be kept at least 1 1/2 feet away. You should wait a couple of hours to permit the resin to set at room temperature and then give it a final “kick” with heat.

FINISHING.—After 12 to 24 hours, the patch is ready for finishing. The time required will be less than

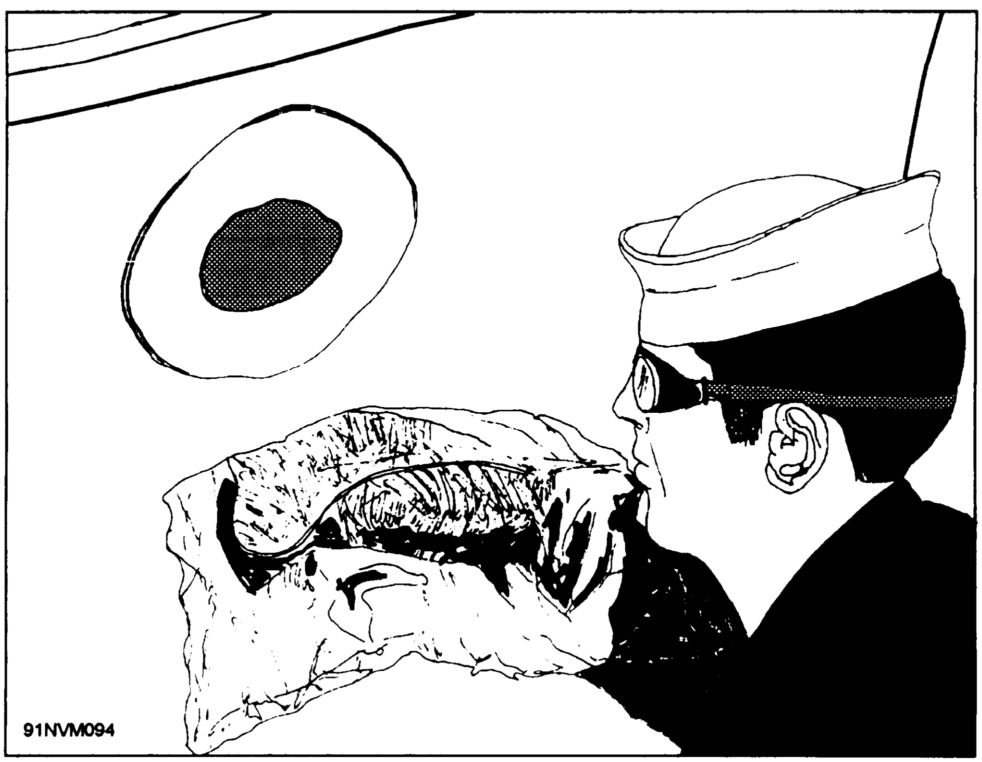


Figure 4-14.—Entire patch being put in place.

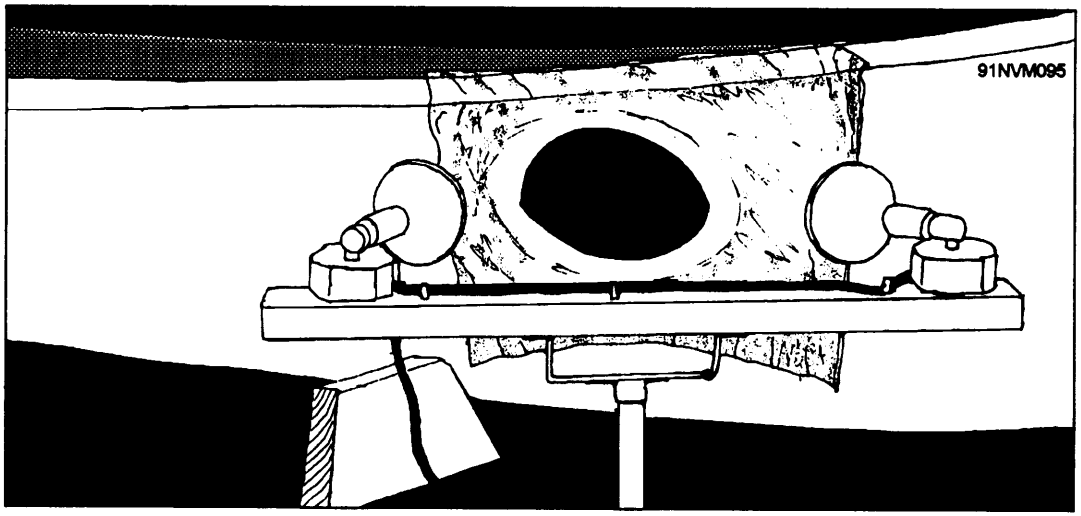


Figure 4-15.—Heat lamps in position to speed the cure.

this if heat is applied; but, in either case, the patch should be hard and cool to the touch before proceeding. Remove the cover plate and the separating film. If it is necessary to do so, fill in surface pits with the paste resin mix provided in the kit. Inspect the repair for soundness by tapping it with a coin or a metal object. A dull thud will indicate softness, poor bond (delamination) between plies, or poor bond to the original material. In the event that the patch is of poor quality, and the effectiveness of the patch is in doubt, cut out the section slightly larger than the original patch and redo the repair. Assuming the job has been done properly, lightly sand the surface (fig. 4-16). The finish may be a coat of resin or paint.

REPAIRING SURFACE DEFECTS.—The repair kit contains an epoxy-type paste resin system for making minor repairs to damaged plastic surfaces such as seams, gouges, pits, or small holes. It can also be used for filling and smoothing patches made with

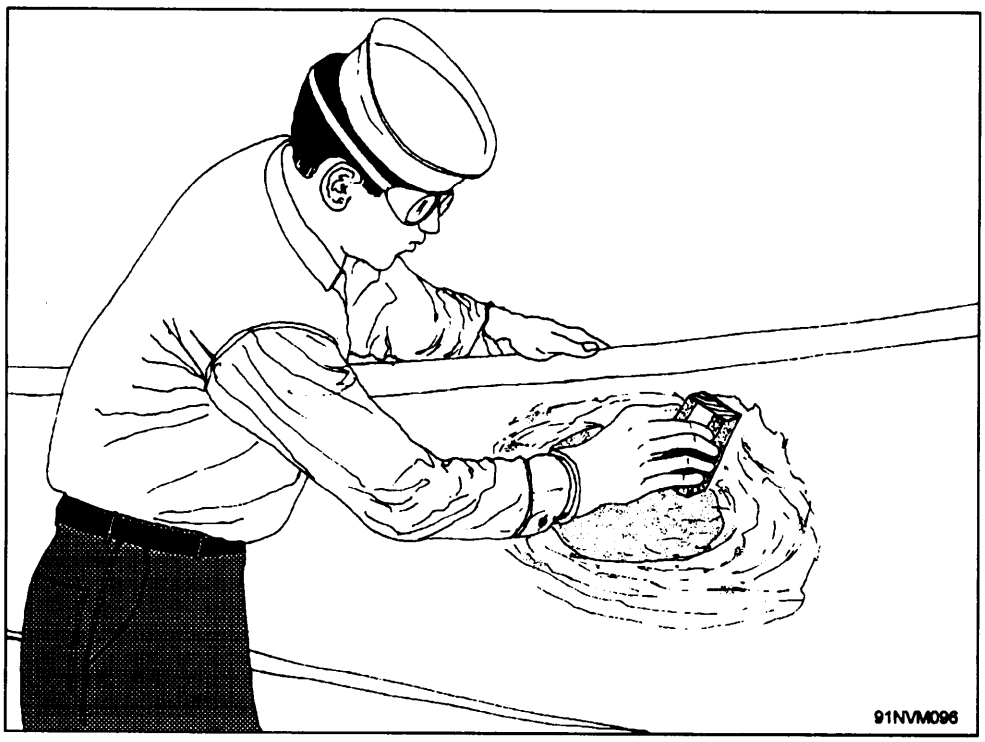


Figure 4-16.—Sanding a completed patch.

liquid resin systems and glass reinforcements, and for repairing minor damage to other materials such as wood and metals. Clean and abrade around the damaged area. Then, squeeze out the required length of paste resin from the tube. Parallel to the resin, squeeze out an equal length of hardener. This may be done on a flat surface that is covered with a piece of separating film. Mix the two materials with the small mixing stick. The resin is white and the hardener is black; when properly mixed the blend will have a uniform gray color. Spread the mixture over the damaged area with the mixing stick or a putty knife. Cover the repair with a piece of separating film and, with a clean mixing stick or spreading tool, smooth the resin from the center outward to obtain the desired contour. Finish the patch as previously described.

Bolthole Repair

To repair a slightly elongated or oval bolthole where the washer or bolthole still bears on the laminate, slightly abrade the enlarged portion of the hole with a file or sandpaper. Then fill the area of clearance around the fastener with the paste resin mix.

To repair a badly damaged bolthole, perhaps caused by a bolt pulling through the laminate, remove the bolts and separate the primary structure from any secondary member where necessary. Cut away the damaged surrounding area with a metal-cutting saw as before. From this point, follow the same plastic boat repair procedures described earlier in this chapter. Put extra plies of reinforcement in this area to provide additional strength. After the repair is completed, drill new boltholes-this time with proper clearance and bearing area. To prevent recurrence of such a failure, replace the bolts and washers with a larger size or a reinforcing plate.

Repairing a Damaged Reinforcing Member or Stiffener

The stiffeners used in reinforced plastic structures may be of various shapes that are either integrally molded with the plating or secondarily bonded to the plating. Figure 4-17 shows some typical stiffened panel constructions. Failure may be the result of poor bonding (in the case of secondarily bonded stiffeners), inadequate design, or unusual service loads. It is necessary that such failures be repaired as soon as possible to avoid further damage to the structure.

When you begin the repair, keep in mind the cause of the failure and correct any defects to prevent similar failure later on. For example, if failure is in the bond, is it the result of insufficient bond area, peeling action, or poor bonding technique? Examine the bonded area to ascertain if a uniform and sufficient amount of adhesive was applied. Compare the amount of the area that failed within the laminated part with the area that failed in adhesion at the laminate surface to see if the surfaces were improperly prepared. Surfaces should be carefully sanded and cleaned before bonding. Any repair should be aimed at preventing future failures.

If a stiffener has broken and must be replaced, the method of repair will depend on whether it has been integrally molded as shown in view A of figure 4-17 or bonded in place as shown in views B and C. In the latter cases, the entire stiffener may be completely removed by delaminating the bond, and a new stiffener fabricated by the WET LAYUP technique shown in view B of figure 4-17, or molded separately and bonded to the plating. The use of positive fasteners, at least at the ends and center of the stiffener, is often desirable where service loads are such that a possibility of peeling exists.

In the case of integral stiffeners, the damaged portion should be cut away to the extent necessary to assure stiffeners a satisfactory repair, and this area replaced, taking care that a good bond to the plating and adjacent members is obtained.

Repairs to stiffeners may be accomplished with the materials provided in the repair kit and simple wooden forms, using the repair techniques previously described. All surfaces to be bonded must be sanded and cleaned to assure good adhesion. The cross section and size of the replacement stiffener should be increased where necessary to provide additional bonding area or strength.

Repairing Glass-Reinforced Plastic Coatings

Damaged portions of glass fiber-reinforced resin coatings on wooden boats and other structures can be repaired with the resin and glass reinforcement supplied in the repair kit. The steps for this repair procedure are outlined as follows:

1. Cut away any loose or damaged sections of the glass-resin coating.

2. Repair or replace any of the wood that has been damaged. Fill seams and cracks with water-mixed wood putty or plastic wood. The resin and hardener or epoxy paste supplied in the kit may be used for filling. DO NOT use oil-base putty.

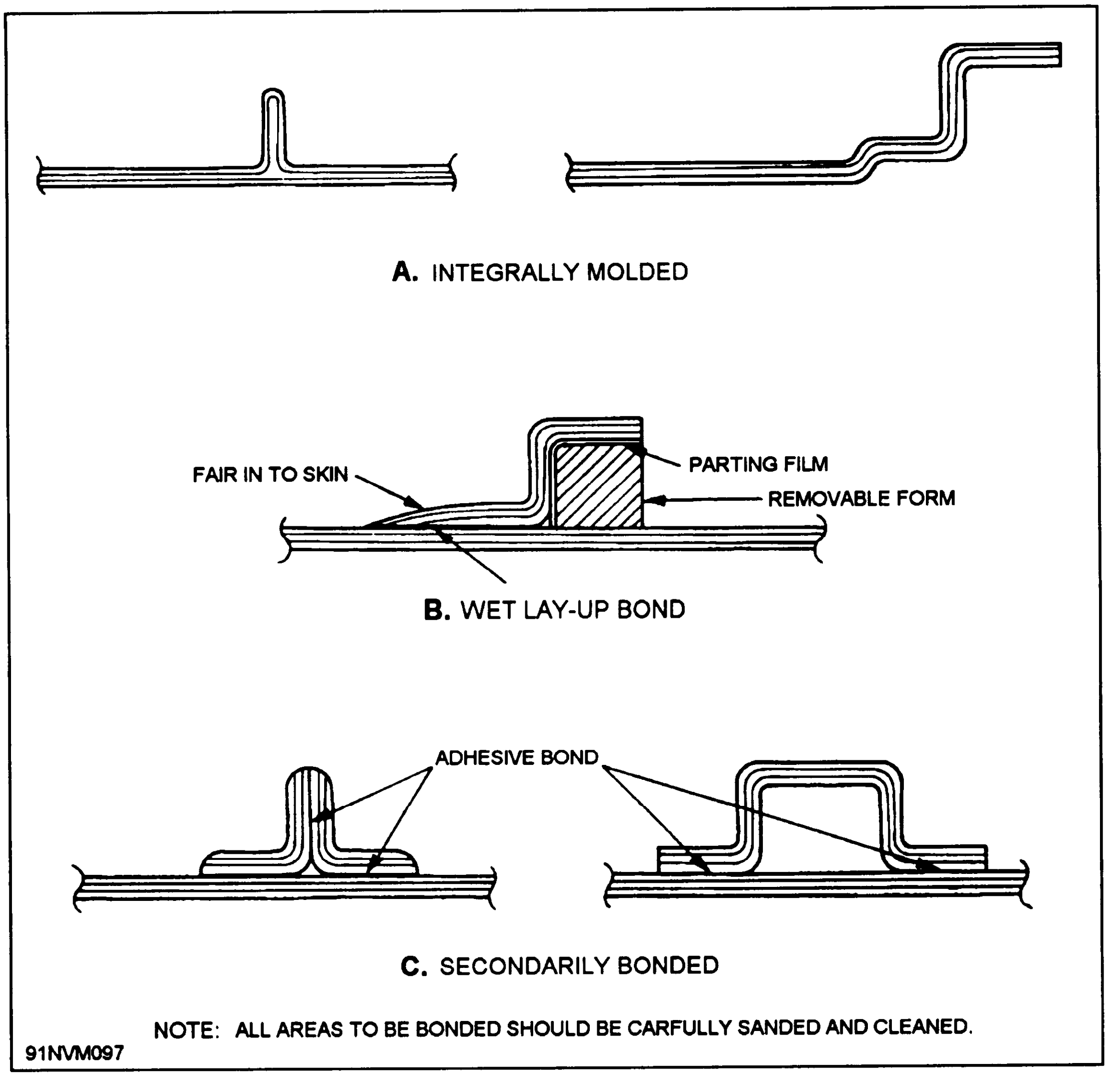


Figure 4-17.—Typical stiffeners.

3. After the putty has hardened, sand the area to be repaired down to the wood and sand the surface of the resin-coated glass to produce a 6-inch wide abraded surface around the void.

4. Cut the same number of plies used for the original coating and tailor these to fit the patch and the abraded area around it.

5. Based on the amount of cloth used for the patch, estimate the amount of resin needed. Mix the liquid resin and hardener.

6. Paint a liberal coat of the resin-hardener mixture over the abraded wood and over the abraded adjacent area.

7. Place one of the plies of cloth over the painted area and coat it with additional resin-hardener mixture. Lay up the remaining plies in the same manner. Place a sheet of separating film over the glass-resin layup and work out the entrapped air and excess resin by stroking from the center outward with the spreading tool. Tape the film in place.

8. After the patch has set, remove the separating film. Sand off any excess resin or irregularities. If the patch is to be painted, sand the surface lightly before painting.

Large Hole Repairs

In repairing large holes that completely penetrate the laminate, mark the damaged area with chalk, as shown earlier in figure 4-8. Using a reciprocating sabre saw, cut away the damaged area enclosed by the chalk mark. (See fig. 4-11.)

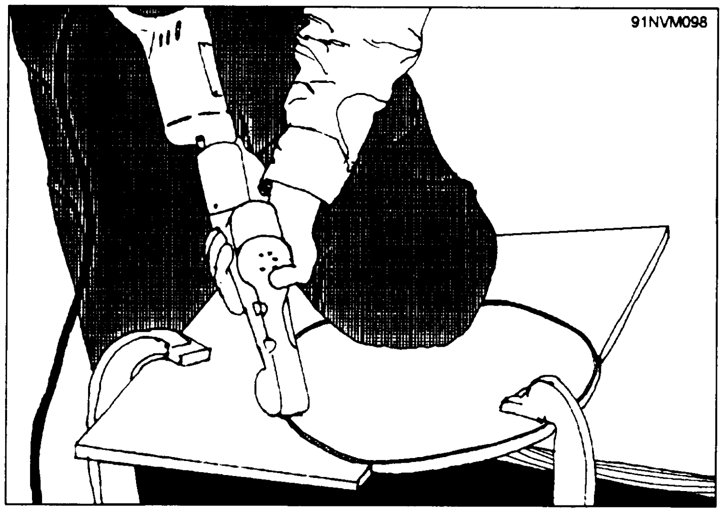


Figure 4-l8.—Cutting the patch from preformed laminate.

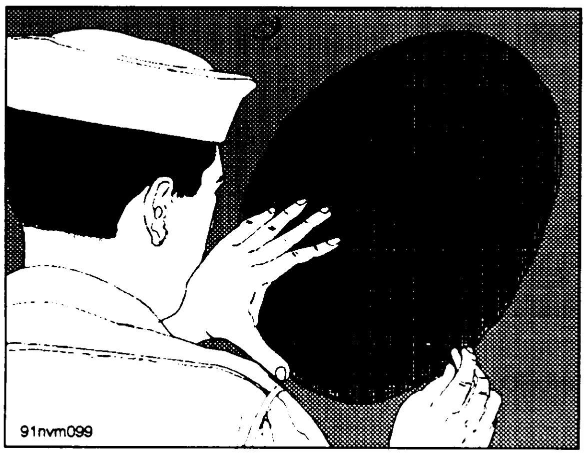


Figure 4-19.—Delineating the area where the scarf will extend on the area being repaired.

After the damaged area has been cut away, cut the patch from a section of preformed laminate of about the same thickness as the area being repaired. (See fig. 4-18.) Center the preformed laminate over the area being repaired and mark off the area to which the scarfing will extend, as shown in figure 4-19. If the opposite side of the area being repaired is accessible, make a second chalk mark conforming to the hole size on the preformed patch, as shown in figure 4-18. This delineates the extent of the scarfing to be done on the preformed patch. In case the opposite side is inaccessible, a template may be required to mark off this area to which the scarfing must extend on the patch in order for it to fit. Scarf the area around the hold so that a gradual taper extends back to the chalk mark, as shown in figure 4-12. Repeat this procedure

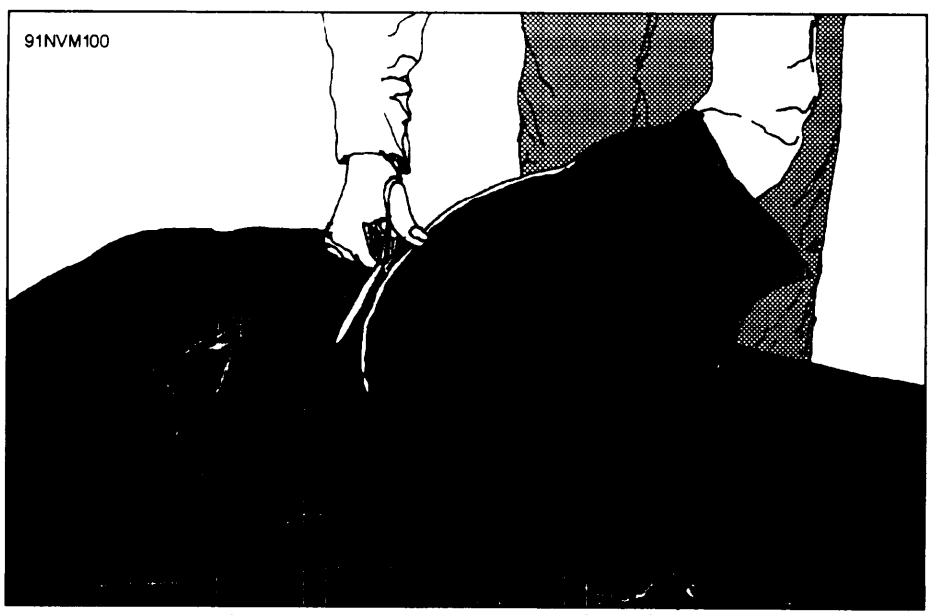


Figure 4-20.—Tailoring reinforcement. Laminate has been scarfed to fit level on the area to be repaired.

with the preformed patch. Check to be sure that the preformed laminate fits snugly over the hole. It should if the preformed patch and the damaged area have been properly scarfed. No backing plate is required when making this type of repair.

To make the reinforcement material, use the preformed patch as a pattern as shown in figure 4-20 and cut two or more bonding plies of glass cloth. The reinforcement material should be cut slightly larger than the preformed patch.

After the resin and hardener have been mixed, apply a coating to the scarfed section of the area to be repaired. (See fig. 4-21.) Then, coat the scarfed side of the patch piece with the resin mixture, as shown in figure 4-22.

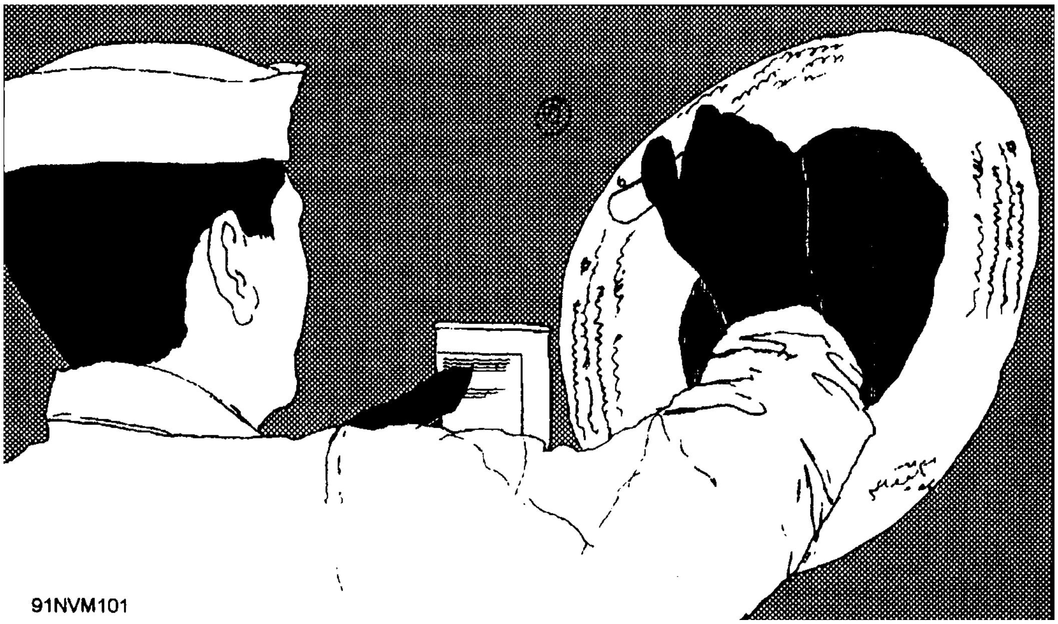


Figure 4-21.—Coating the scarfed side of a damaged boat.

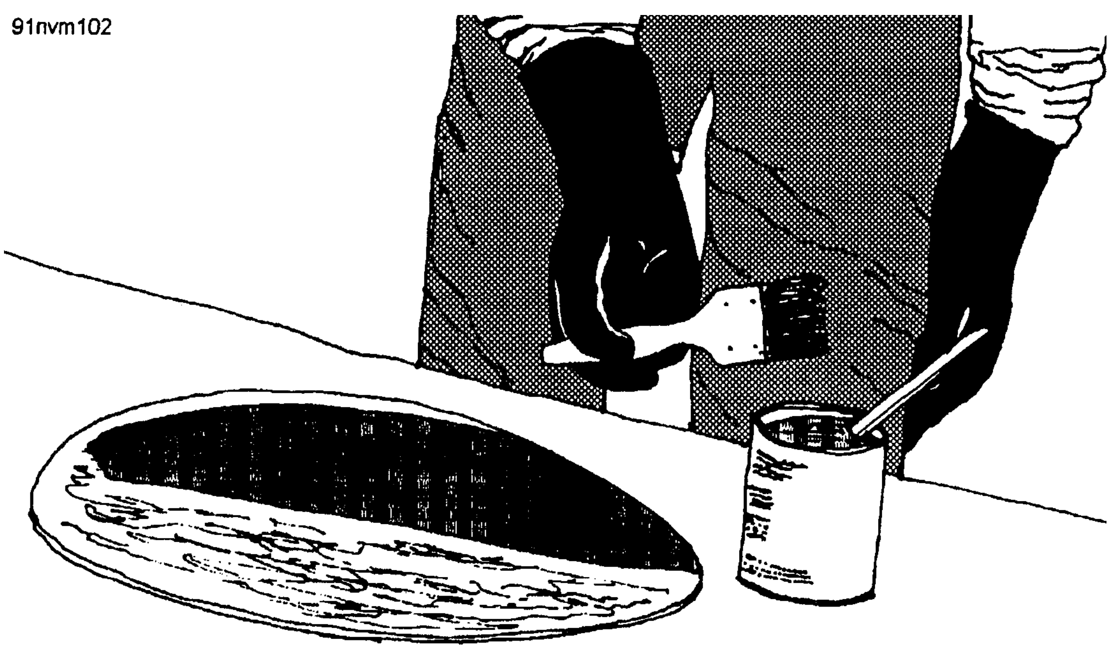


Figure 4-22.—Costing the scarfed side of the laminate patch.

Center a bonding ply over the preformed patch as shown in figure 4-23, and saturate it with resin. (See fig. 4-24.) Repeat this procedure with the other bonding plies. Position this assembly over the hole as shown earlier in figure 4-14, and cover it with a sheet of separating film. The patch can be held in place by a cover plate, or by shoring as shown earlier in figure 4-13 until the patch hardens or cures. The patch is completed in the same manner as previously described.

Repairing Double-Skin Plastic Boats

To repair damage that extends through both skins and the core section of plastic boats, follow the procedures described earlier under repair procedures. Cut out the damaged areas and prepare the skins for patching by abrading the scarfs around the holes. Patch one skin and allow it to cure. After this patch has cured, cut and fit the core section. Secure the core section with repair resin. Then, repair the second skin.

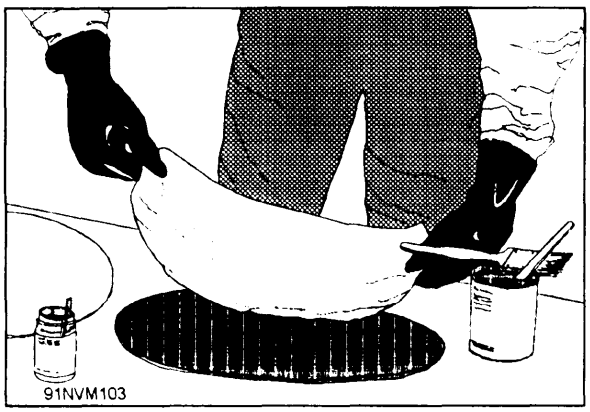


Figure 4-23.—Centering the first bonding ply.

Where damage is to only one skin and core, cut out a circle of skin with a sharp-cutting tool such as a hole saw. Cut the skin away from the core material with a knife. Damaged honeycomb core can be cut with sharp shears and pulled out with needle nose pliers. Other types of core material, such as plastic foam, can be cut out with a knife. Cut a piece of core material to fit the section that was cut out. Be careful to match the pattern, if necessary. Cement the material in place with repair resin and proceed to repair the outer skin as described previously.

Damage to the skin only can be repaired in the same way as a conventional repair to reinforced plastic.

METAL BOATS

From a wide range of aluminum alloys available for many purposes, the Navy selected those most suitable for salt water use for boat hulls. The hulls of Navy aluminum boats are usually constructed of either alloy 5086 or 5456. Both alloys contain magnesium as the primary alloying ingredient, but differ slightly in strength. In general, these two alloys are not used in combination except when emergency repairs are needed.

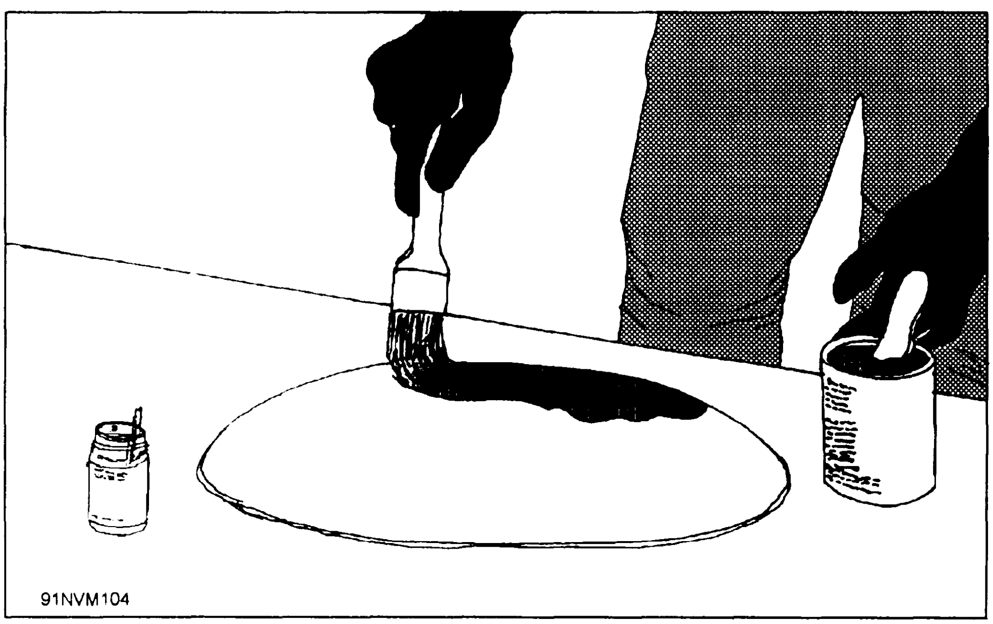


Figure 4-24.—Saturation of the bonding ply with resin.

Alloy 6061 is a general-purpose structure alloy using a combination of magnesium and silicon as the chief alloying ingredients. Its use in the Navy should be restricted to auxiliary systems, such as piping and railings, and to nonwelded structures.

Two other alloys that may be found in limited quantities are 5083 and 7039. These are used only for armor and are supplied especially for that purpose. As such, they should not be used for other structural areas of an aluminum boat.

Aluminum alloys are not identifiable by appearance and, therefore, are usually appropriately marked with alloy and temper designations. The temper designation follows the alloy number and indicates the degree of tempering. Tempering is done in two ways depending on the alloy: either by strain hardening or by the heat-treatment process. An alloy that has been strain hardened has a designator consisting of the letter *H* and a number, while an alloy that has been heat treated has a designator consisting of the letter *T* and a number. Thus, a plate labeled 5086-H116 has been strain hardened, while one marked 6061-T6 has been heat treated. Any alloy will be one or the other; for example, all tempers of 5086 begin with H. The exception is when aluminum is in the soft, or annealed, condition—indicated by the suffix 0. Thus, both 5086-9 and 6061-9 (and others) are available. The temper of material is of concern to the repairer, since it is desirable to make replacements of damaged areas with the same alloy and the proper temper.

Aluminum is a lightweight material, and it is for this reason that it is used for boats and craft. It is strong, weldable, and has excellent general corrosion resistance when proper marine alloys are employed. In the past, most interior spaces of naval boats were left unpainted in aluminum construction. There are, however, some precautions in the handling of aluminum that must be observed if the full corrosion resistance capability of aluminum is to be achieved.

As with many materials, although mild acidic solutions cause slight damage, caustic solutions of any sort such as sodium hydroxide, sodium carbonate, or sodium phosphate are particularly to be avoided; they cause severe etching of the aluminum even to the extent of resulting in perforation.

The most stringent precautions must be taken in the case of mercury. The presence of mercury even in small amounts on aluminum causes severe corrosive attack, and under no circumstances are the two metals to be permitted to come in contact with each other. Observing these precautions enables routine maintenance to be kept to aminimum.

Galvanic corrosion caused by a dissimilar metal contacting aluminum can occur. In marine applications, aluminum and its alloys are frequently the anodic metal and could corrode in preference to most other common contacting metals except zinc and magnesium. However, for galvanic corrosion to occur, the following conditions must be satisfied: a cell must be present consisting of at least two metals having different solution potentials and in electrical contact with each other (no matter how indirect), and a conductive medium (electrolyte) must be present between the metals.

Three applications account for most galvanic corrosion situations: (1) connections of aluminum deckhouse bulkheads to a steel boundary bar; (2) the attachment of steel or brass fittings to an aluminum structure; or (3) dissimilar metal appendages, such as rudders and propellers, on an aluminum hull.

Cleanliness is always important—dirty, wet bilges or accumulations of dirt and water anywhere are to be avoided. A freshwater rinse on a regular basis is generally sufficient.

ALUMINUM BOAT REPAIR

Cutting aluminum is more like cutting wood than steel. An oxyacetylene flame is not used because the excellent thermal conductivity of aluminum carries heat away too fast to get a good cut. In repair work, all cutting should be done mechanically using a circular saw, saber saw, or (in the shop) bandsaw equipment with metal-cutting blades. Use of a grease stick or lard oil will prolong blade life. Plasma arc cutting equipment is available for high-speed production work but is not needed for repair work. Shearing or punching of strained hardened alloys should be avoided.

Forming is done cold or hot. Aluminum does not change color with heat and does not glow red as does steel. Excessive heating can cause the metal to anneal to the soft condition or even melt or oxidize without any warning. Hot forming is done by carefully heating the metal to no more than 450°F. The temperature can be estimated by the use of temperature-sensitive crayons. Each crayon is formulated to melt at a different temperature; and by observing when the crayon markings on the metal melt, you can remove the heat source at the proper time.

Formed parts of a boat that have been damaged must not be re-formed using heat. When possible, it is suggested that the damaged part be replaced by new material formed for the job.

Distorted plates, whether caused by damage or the heat of welding, must not be straightened by flame-quenching (torch heating followed by spray cooling). The method does not work well and can result in overheating or melting as previously described. If the distortion does nothing more harmful than detract from appearance, it should be left alone. Otherwise, distorted shapes should be straightened cold, using jacks as necessary, while distortion in plate panels may be relieved either cold or by making a saw cut in the center of the panel and rewelding it. When you weld a saw cut, ensure that the correct alloy is used. Cracking of the weld will result if the alloy of the filler metal or authorized alternate is not used. The normal shrinkage associated with aluminum welding will tend to remove the distortion.

The light weight of aluminum will facilitate repair by making handling easier. In addition, the preparation of subassemblies or repair sections in the shop is greatly facilitated.

If welding is impractical or impossible, use bolted aluminum alloy patches. For this type of repair, the following is needed: an electric circular saw for cutting plate to size and for fairing out any jagged edges in the hull penetration, and a good metal-cutting saw blade. After the patch plate is cut to size, connect it to the hull with aluminum or stainless steel bolts or other fasteners. In an emergency, any type of bolt will do. However, this must be considered a temporary repair since dissimilar metals cause galvanic corrosion. For bolting the patch to the hull, insert a sealing material around the perimeter. If a number of repairs of this type are anticipated, then it might be wise to provide several rolls of the sealing tapes used by aluminum small boat manufacturers. Most major tape manufacturers supply these tapes in various thicknesses and widths. These are the tapes used on modem day aluminum small boats and they do a good job, not only in sealing the seam, but also in keeping the rivets and bolts from leaking. The holes for the rivets or bolts will, of course, be made by a rotary drill.

If the boat incurs damage in a remote area where there are no facilities for welding, and aluminum is not available, temporary repairs can be made with steel patches. Some type of insulation, such as neoprene, should be used between the aluminum and steel, if possible. Large, temporary hull repairs can be made in this manner. The damaged area can be cropped out. The steel repair plate, including structural framing members, can be prefabricated by welding, leaving sufficient lap for mechanical fastenings. The unit can then be bolted to the aluminum hull with insulation between them. Splices can be made across the structural members. If tapes or neoprene are not available for insulating the steel and the aluminum, material such as Butyl rubber, polysulfide, or any heavy-bodied flexible coating will do. Avoid wicking materials, such as flax or canvas, and the use of lead-pigmented compounds, such as red lead. The steel temporary repair should be replaced with the proper aluminum repair as soon as possible.

STEEL BOAT REPAIR

Permanent repairs of steel boats must be accomplished by qualified welders and nondestructive test personnel. Fabrication, welding, and inspections must be accomplished as required by the BoatAlt or applicable alteration or repair drawing. NAVSEA 0900-060-4010 and *NSTM,* chapter 074 (9920), should be used as guides.

UTILITY BOATS

In the following sections, the discussion will deal primarily with typical repairs made to utility boats.

When a boat is damaged, the HT is responsible for making the required repairs. As an HT, you must know the procedures for renewing a stem, stem frame, and engine foundation in a small boat.

In general, the procedures described for repairing utility boats are similar to those required for repairing motor boats, motor whale boats, and ships' boats for other types.

CHOCKING THE BOAT

Before beginning to work on a boat, you must get it into a safe position, retain its true form, and prevent further damage, Figure 4-25 shows a type of boat chock that you can construct aboard ship. It is simply a framework made from 4 by 4's and braced with 2 by 6 lumber. The number of chocks and other bracing should be determined so that the craft can be held reasonably rigid to a fixed position.

NOTE: When positioning chocks, ensure that they bear on the hull at structurally reinforced areas.

REMOVING DAMAGED PARTS

Remove damaged parts carefully since you will probably have to use them as patterns in making the new

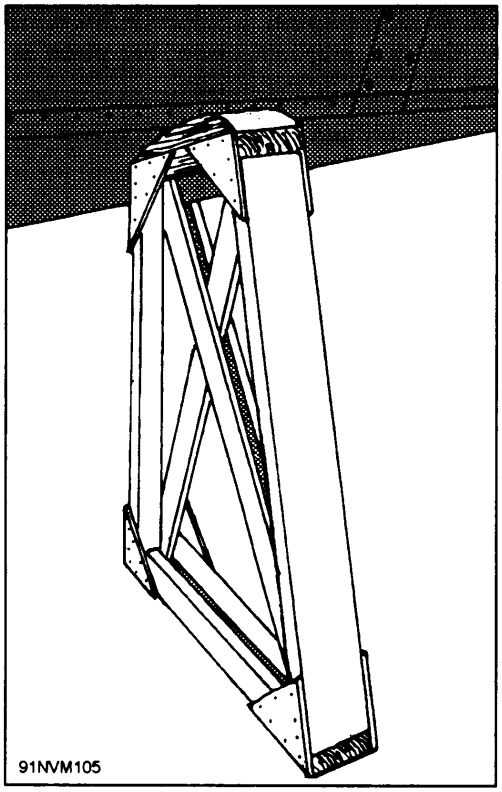
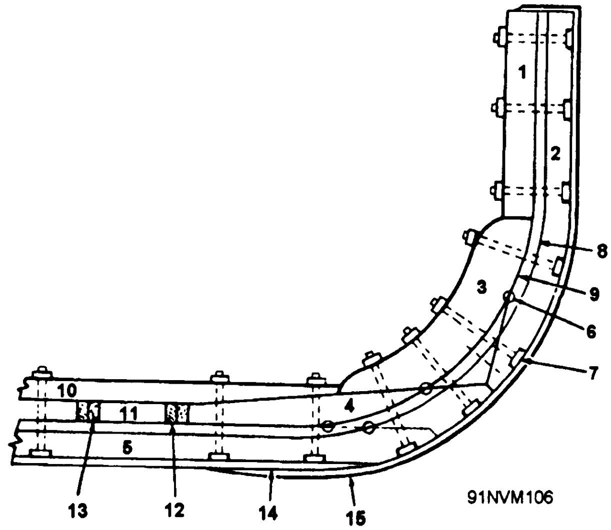


Figure 4-25.—Boat chock for shipboard use.



1. Stem Apron
2. Main Stem Piece
3. Stem Knee
4. Fore Foot
5. Keel
6. Stopwater
7. Bolts
8. Rabbet Line
9. Beading Line
10. Keelson
11. Filling Block
12. Floor Frame
13. Frame
14. False Keel
15. Stem Band

Figure 4-26.—Nomenclature of the bow structure.

parts. As an example of the procedure for removing damaged parts, a damaged stem can be removed as follows:

1. Carefully scrape the paint from the stem and from the planking as far aft as necessary, exposing the countersunk screw holes or the wood plugs over the fastenings.

2. Remove the metal stem band, chafing plate, and bow chocks. Also, remove the platform decking to clear way for work.

3. Remove the brass bolts that secure the stem to the stem apron and knee. Work from the stem apron side, and use a drift pin to drive the bolts out. When the bolts are out, check them for defects; they may require rethreading or replacing.

4. Remove the brass screw from the stem where it joins the knee. Figure 4-26 shows the stem and stem apron assembly in relation to the keel, keelson, and knee.

5. Remove plugs or putty from the screw holes, in the hull planking, and back out the screws to about one-half their length. In backing out the screws, start aft and work forward; except where hull planking is damaged, all of the damaged material should be removed. Do not remove any of the screws completely until all of them have been partially backed out and the planks have become loosened from the frames and rabbet. If the planks do not come loose immediately, remove putty and caulking cotton from the seams and tap the planking gently with a rawhide mallet, on the frame side, to help break the seal.

6. When the seal is broken and the planking comes free from the frames, run a line around each plank and fasten it to frame 2. This prevents the planking from springing out and breaking loose farther aft if it becomes necessary to remove the screws completely to pull the stem apron.

7. Pass a line through the uppermost bolthole in the stem and apron, and secure the line to a thwart. This precaution is necessary to keep the stem and apron from falling to the deck when the assembly is freed.

8. Remove the breasthook. Then, the stem assembly will be completely freed.

9. Clean the stem and remove all putty, white lead, and any foreign matter from the rabbet so that the stem will form an accurate pattern piece.

REPAIRING THE STEM

After the damaged stem has been removed and cleaned, use it as a pattern in making the template. Lay the damaged stem on a piece of 1/4-inch plywood and block it in a near-level position. Then, trace the outline with a pencil. Be sure to keep the pencil vertical so that the boundaries of the template will be the same as the boundaries of the stem. Check the boundaries by using dividers as a test gauge. Then cut the plywood on the penciled lines, and smooth the template with a plane.

To lay out the rabbet, set the dividers at the distance from the back of the damaged stem to the outside of the rabbet; then put the dividers on the template in the same relative location, and mark the template. Repeat this procedure along the entire length of the stem, at approximately l-inch intervals, so that the rabbet line will be marked all the way along the template.

Next, place the template on the lumber, as shown in figure 4-27, making sure that the maximum strength is obtained by avoiding as much cross grain as possible. Mark off the stem on both sides of the lumber, according to the template; allow 6 to 8 inches excess length above the capping.

Remove the template, and cut the new stem. Use a bandsaw to cut within 1/32 inch of the lines; then finish by planing to the lines. Lay the template on the piece again, and drive small nails through the template along the rabbet lines. Drive the nails entirely through the template and into the piece so that the rabbet lines will be marked on the piece by the small nail holes. Then, remove the template and drive small nails into the holes in the new piece. Draw pencil lines from nail to nail, and you will have the rabbet lines marked on the new stem. Figure 4-28 shows the procedure for transferring rabbet lines.

Chisel a series of notches on the rabbet lines. Be careful that you do not remove too much wood; additional paring may be done when the planks are being fitted to the stem. In cutting the rabbet, use a piece of planking as a template. Make the steam apron by copying the damaged piece. You do not have to make a template, since you can use a bevel square to get the bending lines and a rule and compass to determine the overall size. The bevels are set on the bandsaw; the cuts are then made; the piece is then trimmed to the lines on the jointer.

The new stem and the new stem apron must be very accurately fitted. It is essential to drill the lowest bolthole on the stem so that it will match up EXACTLY with the bolthole in the knee. The best way to make certain that the lowest bolthole on the stem is aligned with the bolthole in the knee is to clamp the stem to the knee (using C-clamps and blocks), and then drill through the bolthole in the knee. Be careful that you do not enlarge the bolthole in the knee while you are drilling through the stem.

After this first bolthole has been drilled in the stem, insert a bolt of the proper size and type and draw it taut. Then remove the C-clamps and the blocking. Place cabinetmakers' clamps over the stem and the knee, at each end. Then drill the second bolthole, insert the bolt, and draw it taut. The completion of the job from this point is just a matter of fairing in, fitting, white leading, shaping the stem to correspond to the width of the forefoot, tapering off to the full width at the top, and drilling holes for stopwater. Do not try to drill the holes for stopwaters until after the stem has been set in place.

Any damaged planking should be replaced at least six frames aft of the stem to ensure a substantial planking jott. If more than one plank must be replaced, be sure to stagger the after end joints of adjacent planks so that they are at least two frames apart. Figure 4-29 illustrates a completed stem repair job. Notice that the boltholes are ready for plugging, and the two new planks are ready for caulking.

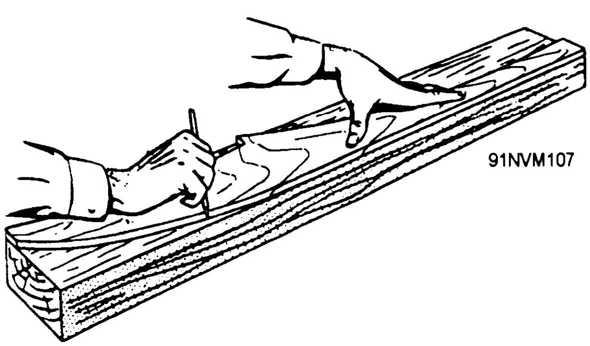


Figure 4-27.—Using the template.

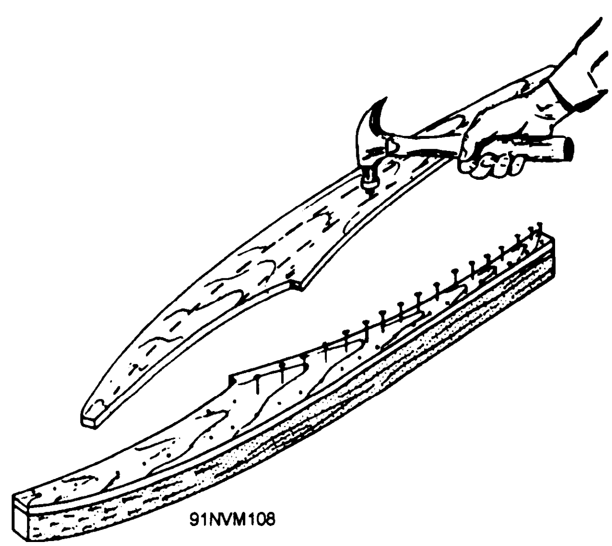


Figure 4-28.—Transfer of rabbet lines.

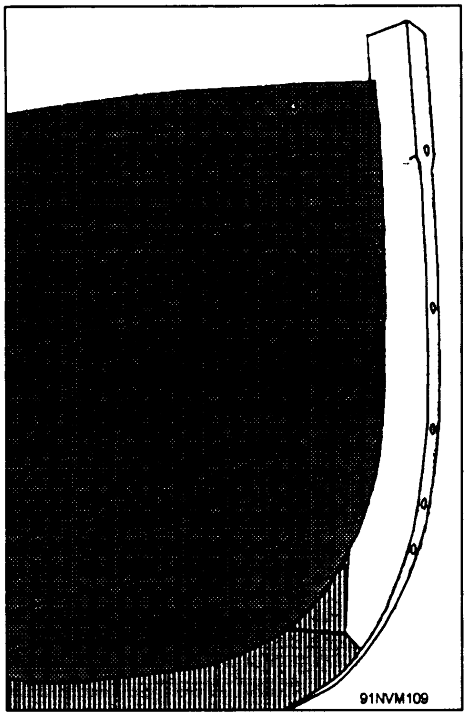


Figure 4-29.—Completed repair to a stem.

REPAIRING THE SHEER CLAMP

Suppose the sheer clamp is split from the apron to as far aft as the sixth or seventh frame. How would you proceed to repair the damage? First, remove the sheer cap as far aft as necessary to enable you to work on the sheer clamp and the sheer strake. Then remove the sheer strake by cutting the proper rivets and driving them from the frames and the clamp. Because of the twist and curvature of the damaged piece, you will have to remove the sheer clamp much farther aft than the end of the split. When you have decided where to cut the clamp, remove the clamp filling blocks for as many frames forward and aft as necessary to allow you to cut the clamp. Then saw through the clamp, and remove the damaged piece.

Select a new piece of timber for the replacement piece. Surface the piece to the correct thickness, length, and width, and lay out the scarf joint. Be sure to make the scarf joint of the proper proportions; the length should be at least six times the depth. Cut to the lines, and smooth the wood with a sharp chisel and a plane.

Make a pattern of the finished scarf, and transfer the lines to the undamaged section of the clamp. Cut and smooth the scarf on the undamaged section, as you did on the new piece.

Steam the new piece and bend it to the proper shape. Using C-clamps or cabinetmakers' draw clamps, clamp the new piece in place from the scarf end forward, and reinstall the filling blocks. Drill the scarf joint for carriage bolts, insert the bolts, and tighten the nuts over washers. Figure 4-30 shows the completed scarf on the sheer clamp.

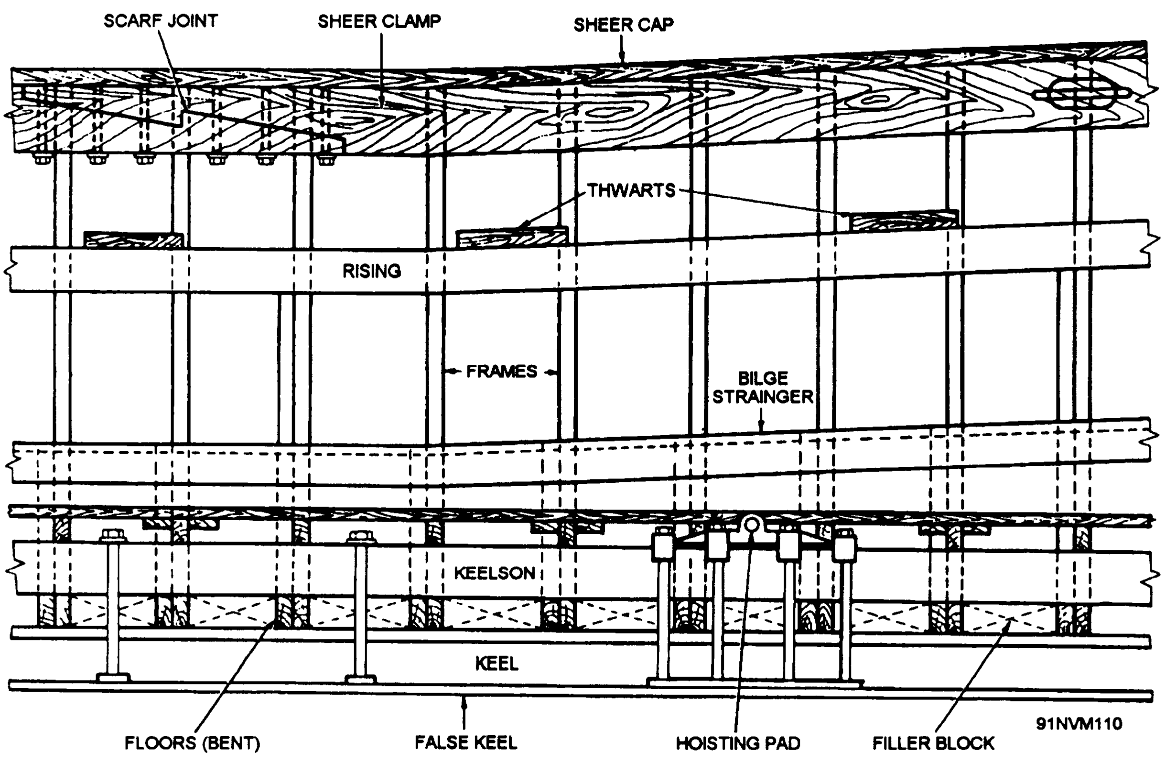


Figure 4-30.—Completed scarf joint on the shear clams.

Loosen the draw clamps and replace the sheer strake. Then put the clamps on again and draw them taut. Using the existing rivet holes in the sheer strake as a guide, drill holes for 1/4-inch copper rivets. Then rivet the clamp to the breast hook. Nail the sheer strake in place, using 4-inch copper nails, and trim the upper edges to conform with the camber. Then install the capping, and the repair job is finished except for caulking, sanding, puttying, and painting.

REPAIRING THE STERN

Let's assume that you have to renew a transom bounding frame, the stern-post knee, and deck supports on a wooden boat. Figure 4-31 shows details of transom construction. Figure 4-32 shows the outer bounding frame of the starboard transom, ready for repair. Note that the transom angles have been removed, and the paint has been scraped off.

To remove the outer bounding frame, you must also remove the inner frame. To do this, you must strip the after-deck area of the rudder assembly, taff railing, and all hardware; and then remove the decking. Figure 4-33 shows the stem with the hardware and the decking removed, but with deck supports still in place. Figure 4-34 shows the deck supports and the transom knee.

Remove all screws that join the transom planking to the inner frame, and remove the copper rivets that fasten the transom planking and the outer bounding frame to the inner bounding frame. The outer bounding frame is a filler piece, and will come free when the seal is broken. The inner frame, which is in four pieces, should be removed to the joint nearest the break. The procedure for laying out, cutting, smoothing, and fitting the replacement pieces is the same as that previously described for other members.

RENEWING ENGINE FOUNDATIONS

Procedures for renewing engine foundations vary considerably, depending upon the type of boat. In

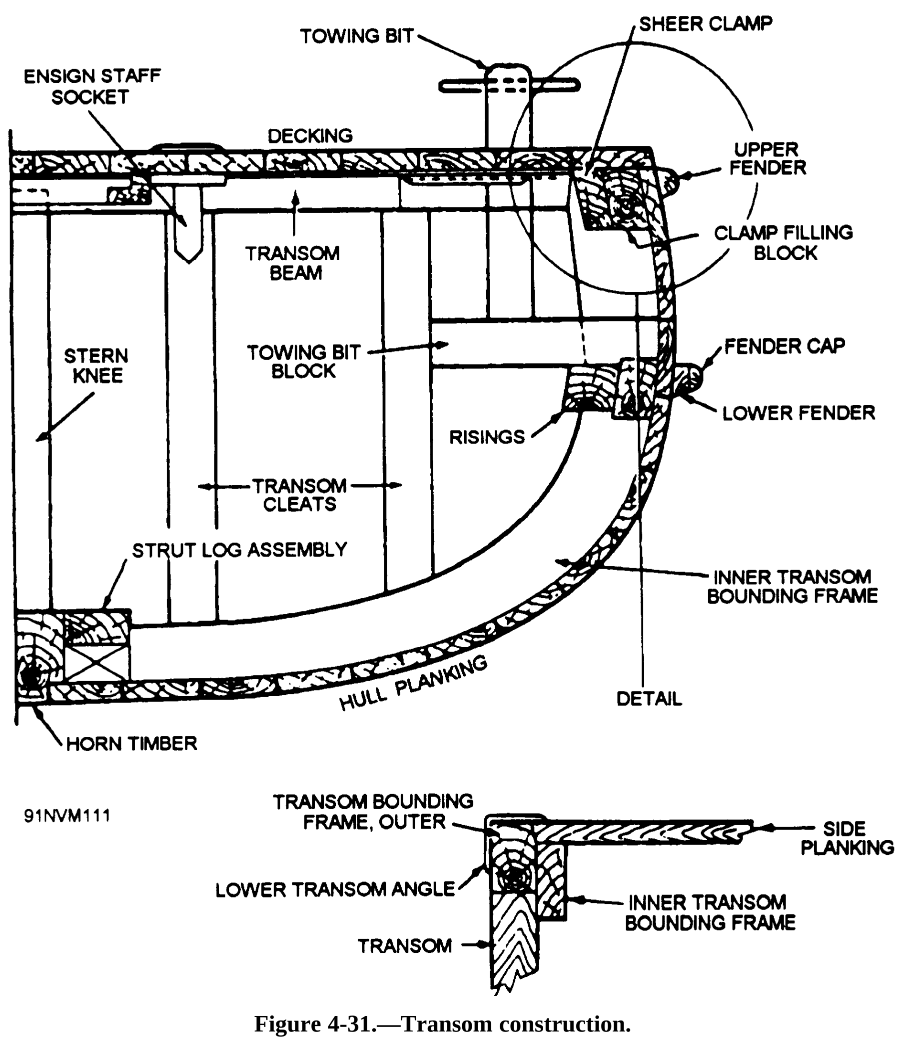


Figure 4-31.—Transom construction.

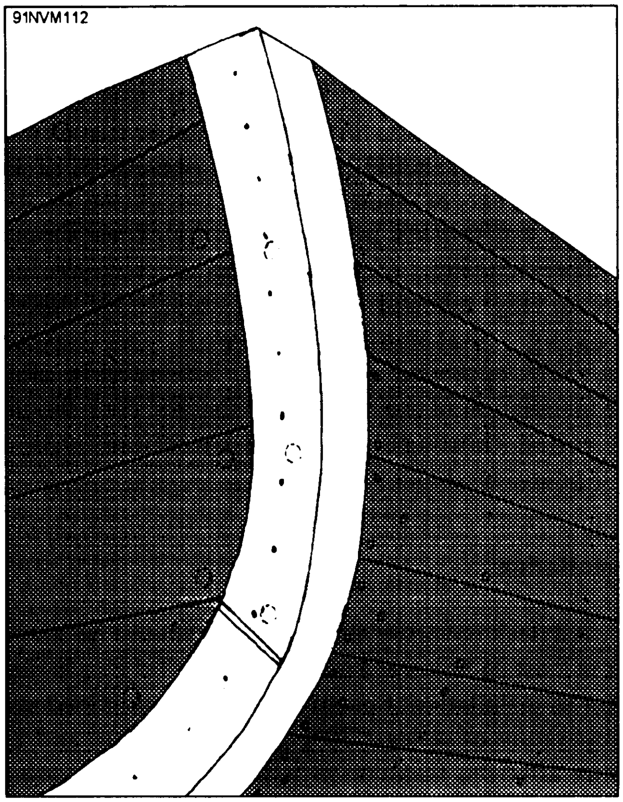


Figure 4-32.—Outer bounding frame, starboard transom.

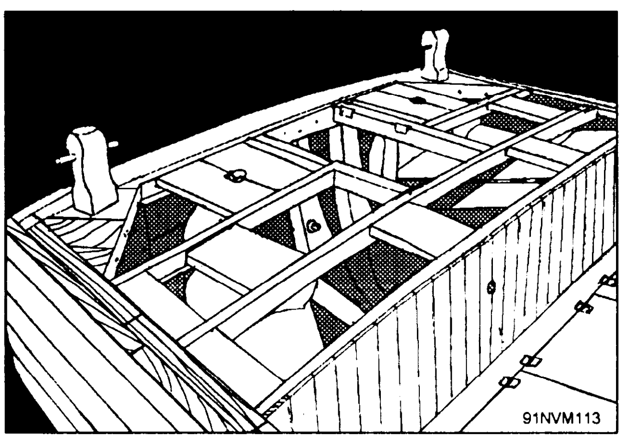


Figure 4-33.—View of stern, with decking removed.

performing this job, remove the engine and the damaged pieces carefully so that you can use them to make templates.

As a rule, the engine stringer is secured to the floor timber with rods. Since the nuts are on the face of the stringer, you must back off the underneath planking so that the rods may be removed, when necessary, to replace the stringers or defective parts. The engine bed

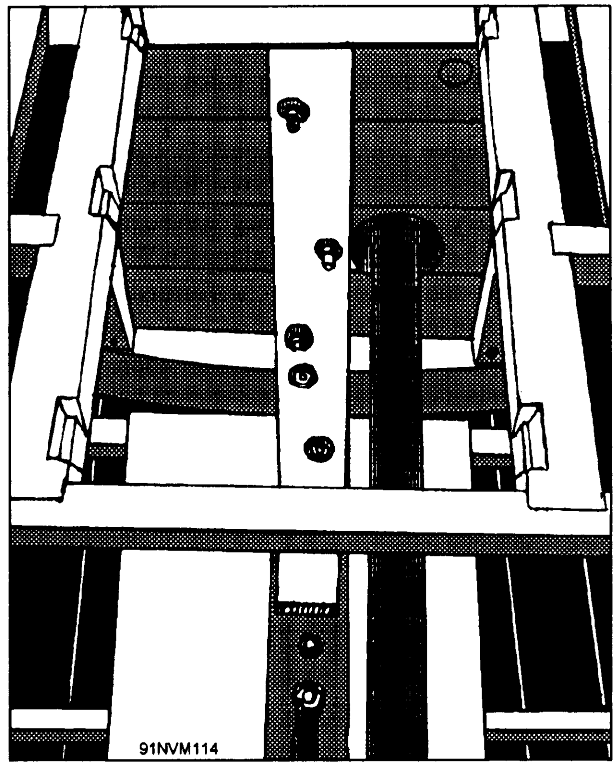


Figure 4-34.—Deck supports and transom knee.

is usually secured to the engine stringer with bolts. Engine hold-down bolts are installed with the heads at the seam between the engine bed and engine stringer. These bolts protrude upward about 2 or 3 inches above the top of the engine bed, and the engine is fitted over the protruding end. A nut is used on each of these bolts to hold the engine in place. Gaps are cut at the seam between the engine bed and the engine stringer to allow access to the heads of the hold-down bolts.

DECK COVERINGS

The qualities required in deck coverings for naval ships include nonflammability, wear resistance, lightness of weight, slip resistance, ability to protect steel decks from corrosion, good appearance, and ease of maintenance. Simplicity of application and the initial cost of the material are also important considerations.

A number of different kinds of deck coverings are available. However, deck coverings used in any area aboard ship must be according to NAVSEA instructions and specifications. Information on deck coverings that are not discussed in this chapter may be obtained from *NSTM*, chapter 634.

In general, an existing deck covering in satisfactory condition should not be replaced even if it does not agree with the materials listed for the specific space. New deck coverings should be installed only where existing authorized deck coverings are beyond economical repair. When repairs are required, they should be performed locally if possible. When complete removal and reinstallation of a new deck covering is required, an approved deck covering for the specific location should be installed.

A deck covering should cover the entire deck area of a compartment unless otherwise specified, except that it should not be installed under enclosed built-in furniture nor under equipment with enclosed foundations.

Before laying any type of deck covering, be sure that the deck is clean and free of rust, loose scale, and dirt; grease and oil should be removed with solvents and clean rags. Paint and primers that adhere strongly to the deck may be left intact unless otherwise specified.

Certain adhesives and compounds used in the application of deck coverings contain flammable solvents. Safety and health measures to be taken depend upon the flash points and toxicity of the solvents. Be sure to comply with all applicable safety precautions.

FIRE-RETARDANT DECK TILE

Marbleized fire-retardant vinyl tile, one-eighth of an inch thick, is the standard Navy deck tile approved for shipboard use. Vinyl tile is stocked in eight marbleized colors.

Deck tile should be laid over bare wood, plastic, or cleaned base metal that has been primed with formula 150 MIL-P-24441. Tile must not be installed more than two layers thick because the additional layers increase the fire hazard. In general, when laying new tile, remove tile down to base metal or wood if two layers have previously been installed. Prime the deck to prevent corrosion if it is made of metal.

Fire-retardant deck tile should conform to MIL-T-18830 or other NAVSEA-approved equivalent, and they should be installed with a latex cement, except in damp or wet areas where it is advisable to use an epoxy adhesive.

RUBBER TILE OR ROLL DECKING MATERIALS

The tile and the roll decking must meet the fire requirements of MIL-STD-1623. Rubber tile or roll deck coverings should be installed one-eighth of an inch thick, except where durability is required for the heaviest traffic areas. In this case, the thickness should be three-sixteenths of an inch. The adhesive used to cement vinyl asbestos tile may be used for the rubber decking materials, as well as other NAVSEA-approved equivalents. Immediately after the installation of the rubber decking, the deck should be rolled thoroughly in both directions with a 150-pound sectional roller.

Installation

All deck covering and adhesives should be stored for at least 24 hours at a temperature of 70°F or higher prior to installation. Spaces should be maintained at a temperature of at least 70°F prior to, during, and 24 hours after the installation is completed. A beading sealer should be used to waterproof all seams against bulkheads, stationary furniture, pipes, and other deck fittings. Where weld lines (beads) prevent the deck covering from butting tightly against the ship’s structure, caulking compound should be used to fill the gap, and painted to blend with the deck tile or bulkhead after the caulking compound skins over. Alternatively, weld lines against bulkheads may be made even by filling underlay material and the tile butted against the bulkhead. This latter method produces a better appearance. If desired, the tile may be squared off where it is in the way of vertical stiffeners and stanchions.

Preparation of Steel Decks

Steel decks must be clean, free from oil, grease, rust, and loose scale. It is not necessary to remove red lead or zinc-chromate priming paint, or deck paint if they are well bonded to the deck; otherwise, loose paint, rust, and scale should be removed by blasting, wire brushing, or any other effective method. The deck should then be washed with approved solvents to remove grease and contaminants and the steel primed with formula 150, 2- to 4-mils dry-film thickness. If possible, weld seams should be ground flush with the deck, and all low spots should be filled with underlay, MIL-D-3135, type II. All high spots should be ground down, if possible, or faired with underlay before applying the primer. The deck must be dry at the time the deck covering is installed.

Application of Deck Tile

Installation pointers for laying rubber and vinyl tile are as follows:

1. Store the tiles for 24 hours at a minimum temperature of 70°F. (At temperatures below 70°F, the material is not sufficiently flexible for satisfactory installation.) To ensure straight seams, square off the areas to be covered and, if practicable, start the installation of tile at the center of the space and work to the edges to achieve an even balance of tile around the edges of the space.

2. If a pattern of two or more colors is desired, plan this on graph paper in advance (each square of the paper can be considered one tile). For spaces with nonparallel opposite bulkheads, use a large square and chalk line at comers to square off the compartment into a rectangular or square layout. To locate the center of the space, strike a chalk line from the midpoints of opposite bulkheads after squaring off.

3. It is important that installation start at sections of the space where work can proceed to completion without kneeling on freshly laid tile. Cement should be spread with a fine-toothed trowel (approximately 1 square yard at a time) at a coverage of 100 square feet per gallon (excess cement will reduce adhesion). While the cement is tacky, force the tiles into tight contact with each other. Half tiles can be cut by scoring and cutting through with a sharp knife. Vinyl asbestos tile should be made flexible by heating before cutting. A dull or unpointed linoleum knife should not be used for cutting the tiles because uneven edges will result.

Care also should be taken that the cement does not get on the surface of the tiles. Excess cement may be cleaned off, while wet, with a damp rag. If cement is dry, a rag that has been wet with paint thinner will remove the cement. Pressure should be applied to ensure complete contact of each tile with the deck. Any high joints remaining after this operation should be rubbed even and smooth with a hand roller.

4. Travel over the newly cemented areas should be restricted until the installation is completed; then the deck can be opened to foot traffic immediately since no indentations will occur from this type of traffic However, it is recommended that heavy concentrated loads, such as legs of heavy furniture, be kept off the deck until the cement has set (approximately 18 hours). Water can affect adhesive and loosen tiles; therefore, swabbing the deck should not be done for 1 week after installation; for general cleaning, use water sparingly to prevent corrosion under tiles.

Installation of Rubber Roll, Vinyl Sheet, or Mat

When installing these materials in front of equipment only, cut the sheet to the desired length and, with a straightedge, cut off the selvedge (if applicable) before cementing the sheet. When installing sheeting material over an entire deck area, lay out the space, cutting all sheets to the desired length; then overlap edges of the sheet so all seams can be double cut, using a straightedge, to assure tight fit. After the material has been cut and fitted, roll the sheets back and cement half the space. Lay sheets down into position. Then repeat the process for the other half.

1. When cementing, use a latex-type adhesive conforming to MIL-A-21016. If a sheet has a tendency to bubble or lift after installation, it may be necessary to substitute a stronger adhesive such as an epoxy adhesive. The adhesive should be spread with a notched trowel, making certain that the entire surface is covered. When the adhesive is tacky, install the sheet. Immediately after installation thoroughly roll the deck in both directions with a 150-pound sectional roller.

2. For additional information concerning materials used to prevent electric shock, see *NSTM*, chapter 634.

Repair or Replacement of Deck Tiles

If a tile requires replacement, remove it by forcing a wide-blade paint scraper under it. Inspect for corrosion. Chip out the dried cement and corrosion products to bare steel, clean the spot with paint thinner, coat it with primer, and apply tile as previously described.

LATEX UNDERLAY

Latex underlay should conform to MIL-D-3135, type I, for use under latex terrazzo, latex, mastic, and ceramic tile.

Surface Preparation

Remove rust and paint. Clean the deck free of oil, grease, and dirt with an approved degreasing solvent. Apply one coat of epoxy primer, formula 150, MIL-P-24441, 2- to 4-mils dry-film thickness, according to *NSTM*, chapter 631.

Surface Wetting Coat

One part rubber latex mixed thoroughly with 2 parts underlay powder by weight should be brushed on in a thin coat, assuring that all of the deck is wetted thoroughly. The purpose of the wetting coat is to assure that the underlay bonds securely to the surface.

Underlay Body Coat

Mix thoroughly 1 part rubber latex, 1 1/2 parts of underlay powder, and 1 1/2 parts aggregate (all by weight). Mix only in such quantity that the material will not set up before application. Make certain there are no dry particles left. The following approximate quantities of materials are required to cover 100 square feet (one-fourth of an inch thick):

49 lb rubber latex

73 lb underlay powder

73 lb underlay aggregate

While the surface wetting coat is still wet, trowel on the underlay body coat and level off with battens. After leveling off, go over the surface with steel trowels, working down hard to flow the mix together and to blend it with the surface wetting coat. Allow the surface to dry hard (at least 2 days) before applying the deck covering. If the underlay is used in excess of one-half inch thick in one layer, it will tend to develop hairline cracks. Latex underlayment for use under deck tile and resilient sheeting should conform to MIL-D-3135, type II, and should be installed according to the manufacturer's directions. Type II can be featheredged and trowelled to a smooth finish without sanding.

INSULATION-TYPE UNDERLAY

Insulation underlay may be used to prevent condensation such as occurs on ballast tank tops and heat from the overheads of machinery spaces, especially where these surfaces form the decks of living spaces. The magnesia insulation that is used should conform to MIL-D-23134.

Surface Preparation

Remove and clean the deck free of rust, dirt, old paint, oil, and grease. Apply one coat of epoxy primer, formula 150, MIL-P-24441, 2- to 4-mils dry-film thickness, or an equivalent coating.

Installation

The on-deck magnesia insulation should be trowelled smooth, a minimum of 1 inch thick over rough finish latex underlay MIL-D-3135, type I. Apply a one-eighth inch minimum thickness of underlay. Exposed aluminum fittings should be protected from corrosive attack from the magnesia by either a coating satisfactory for aluminum (see *NSTM*, chapter 631) or a suitable covering such as a wrapping of a vinyl tape.

RUBBER TERRAZZO

Rubber terrazzo, which is used in washrooms, showers, sculleries, and water closets, is a colored material that contains chips of white and colored marble. The material is mixed at the time of application and is applied with trowels; it requires machine grinding to provide a smooth surface. The usual thickness of application is one-fourth of an inch. The material may be applied to a maximum of one-half of an inch without causing the wet mix to sag. If greater thickness must be used, apply latex underlay first.

The materials required for mixing rubber terrazzo are as follows:

- Liquid latex
- Grout powder
- Terrazzo mix (including aggregate)
- Sealer

Before rubber terrazzo is applied, the deck surface and 4 inches of vertical bounding surfaces against which the covering will abut must be cleansed by wirebrushing or similar methods. If necessary, the deck should be faired with underlay in low spots and around rivets and welds.

After the deck has been cleaned, give it a wetting coat of grout. Mix, apply, seal, and grind the terrazzo according to the manufacturer's instructions. Allow the terrazzo to dry for 72 hours before grinding it. After grinding, clean the deck with a broom or a vacuum cleaner. This should produce a smooth, durable, nonporous surface in which the marble chips are uniformly distributed and firmly embedded. Cover the deck with sealer. Allow the sealer to dry, and then apply a second coat of sealer to complete the job.

NONSKID DECK TREADS

Nonskid deck treads are similar to a coarse emery cloth. The treads, which are approximately 6 inches wide and 24 inches long, are installed at the head and foot of ladders and at each side of doors with high coarnings that are used for continuous traffic. The treads are generally placed about 2 inches apart.

The treads, which have a pressure-sensitive adhesive backing, are cut from rolls or ordered in boxes of 50 each. The comers of the treads should be rounded before installation. Nonskid deck treads may be installed over finish paint or primers and over deck tile, provided the surface is free of grease, oil, floor wax, and dirt or dust. If nonskid deck treads are applied to unpainted steel decks, all dirt, rust, and foreign matter must be removed by wire brushing. The installation of these treads over a poorly prepared steel deck can result in severe deterioration of the deck.

After the nonskid deck treads are installed, they should be rolled with a weighted roller. The edges must then be sealed with an approved beading sealer.

MAINTENANCE OF DECK COVERINGS

Deck coverings should not be washed more often than necessary.

When necessary, they should be mopped with a damp mop, using a synthetic detergent solution. Two tablespoons of cleaner per gallon of warm potable water is recommended. Deck coverings should not be flooded with detergent solution; only a limited quantity of solution should be used. Using excessive quantities of water or detergent solution is damaging to the deck covering and may cause the covering to come loose from the deck.

Deck coverings should not be cleaned with strong alkaline soaps, abrasive cleaning powders, or salt water. All water, cleaning compounds, and dirt should be removed and the deck rinsed with clean, fresh water, using a damp, clean mop. Rubber heel marks, grease, and dirt may be removed with a rag moistened with paint thinner or by using fine steel wool and soap. After washing and after the deck is completely dry, the tile may be buffed with a buffing machine or it may be given a coat of wax and allowed to dry without polishing. A slip-resistant water emulsion type of floor wax is available and should be used when possible.

If a high gloss is desired, the dried wax may be buffed with a polishing machine. To conserve wax and reduce maintenance, a deck should be buffed several times before it is rewaxed. The deck may only require rewaxing in the traffic lanes once a week. If dirty spots are wiped up promptly with a damp rag and the areas are immediately repolished, a complete refinishing job may be deferred for a long time.

Do not apply lacquer, plastic, or other hard finishes to deck coverings. These finishes tend to become yellow and to wear off in traffic.

The most painstaking and careful maintenance of deck coverings may be wasted through careless treatment. The legs of furniture, especially chairs and other movable pieces, should be properly fitted with rubber tips to prevent scratching and denting of the deck covering. Nonslip rubber tips are available. Heavy objects should not be dragged across resilient deck coverings unless they are protected. Also, deck coverings should be protected with cover cloths and scrap materials during painting and during shipyard overhauls.

SUMMARY

With the knowledge gained on emergency repairs of small boats and the assistance of experienced personnel, you should be able to keep your craft operational until permanent repairs can be made. And if the need arises, the repair or replacement of the various types of deck coverings may be made, provided that the proper materials and equipment are available to complete the job.

CHAPTER 5

TOOLS AND EQUIPMENT

LEARNING OBJECTIVES

Upon completion of this chapter; you will be able to do the following:

- *Describe the characteristics and use of some special tools used by Hull Technicians in the performance of their duties.*
- *Point out the features, purpose, and techniques of using calipers, torque wrenches, gauges, and squares.*
- *Describe the setup, operation, and maintenance of various portable shop tools and machine power tools, and identify some of the safety precautions to observe when using them.*
- *Describe the construction and safety devices of compressed gas cylinders and the safety precautions to observe when handling them.*
- *Identify the color codes, test and repair procedures, and handling and stowage requirements of compressed gas cylinders.*

INTRODUCTION

Tools are designed to make a job easier and enable you to work more efficiently. Regardless of the type of work to be done, Hull Maintenance Technicians must have, choose, and use the correct tools to do their work quickly, accurately, and safely. Without the proper tools and the knowledge of how to use them, they waste time, reduce their efficiency, and may even injure themselves or cause others to be injured.

This chapter explains the specific purposes, correct use, and proper care of some of the specialty tools you may use, such as portable shop tools, machine tools, compressed gas cylinders pneumatic tools, portable power tools, and some installed shop equipment. The various tools discussed here are by no means all the tools that exist in this group. They are the specialty tools you will normally find in an HT shop. Equipment that is used only for one purpose, or in connection with one particular skill, is covered in the appropriate chapter or chapters of this training manual. It is not the intent of this chapter to introduce or instruct you on the use of every tool or piece of equipment you may encounter in the workshop. The material in this chapter is intended to supplement, rather than repeat, the information in *Use and Care of Hand Tools and Measuring Tools,* NAVEDTRA 12085, and the manufacturer's operating manual. You should qualify on each piece of equipment in your specific work center according to the manufacturer’s technical manual and any locally written instruction prior to the setup and operation of any tool or equipment.

As a HT, you will be required to use many different handtools and instruments. Each tool does a specific job. To become a skilled craftsman, you should learn what each tool can do and select the proper tool for the job. The proper use and care of tools enable you to turn out quality work and help you develop safe work habits.

MEASURING AND MARKING TOOLS

The measuring tools found in a shop include various types of rules, calipers, squares, and gauges. They are used to measure lengths, diameters, angles, and radii. *Use and Care of Hand Tools and Measuring Tools,* NAVEDTRA 12085, and *Machinery Repairman,* NAVEDTRA 12204-A, contain more information on measuring and marking tools. In this section we will cover the use of specialty measuring devices such as torque wrenches, calipers, feeler gauges, metal gauges, and squares.

TORQUE WRENCHES

There are times when, for engineering reasons, a definite force must be applied to a nut or bolt head. In such cases a torque wrench must be used. For example, equal force must be applied to all the head bolts of an engine. Otherwise, one bolt may bear the brunt of the force of internal combustion and ultimately cause engine failure.

The three most commonly used torque wrenches are the deflecting-beam, dial-indicating, and micrometer-setting types (fig. 5-1). When using the deflecting beam and the dial-indicating torque wrenches, the torque is read visually on a dial or scale mounted on the handle of the wrench.

To use the micrometer-setting torque wrench, unlock the grip and adjust the handle to the desired setting on the micrometer-type scale, then relock the grip. Install the required socket or adapter to the square drive of the handle. Place the wrench assembly on the nut or bolt and pull in a clockwise direction with a smooth, steady motion. (A fast or jerky motion will result in an improperly torqued unit.) When the torque applied reaches the torque value, which is indicated on the handle setting, a signal mechanism will automatically issue an audible click, and the handle will release or "break," and move freely for a short distance. The release and free travel is easily felt, so there is no doubt about when the torquing process is complete.

Manufacturers' and technical manuals generally specify the amount of torque to be applied. To assure getting the correct amount of torque on the fasteners, the wrench must be used properly according to manufacturers' instructions.

Use that torque wrench that will read about mid-range for the amount of torque to be applied. BE SURE THAT THE TORQUE WRENCH HAS BEEN CALIBRATED BEFORE YOU USE IT. Remember, too, that the accuracy of torque measuring depends a lot on how the threads are cut and the cleanliness of the threads. Make sure you inspect and clean the threads. If the manufacturer specifies a thread lubricant, it must be used to obtain the most accurate torque reading. When using the deflecting-beam or dial-indicating wrenches, hold the torque at the desired value until the reading is steady.

Torque wrenches are delicate and expensive tools. The following precautions should be observed when using them:

- When using the micrometer-setting type, do not move the setting handle below the lowest torque setting. However, it should be placed at its lowest setting prior to returning to storage.
- Do not use the torque wrench to apply greater amounts of torque than its rated capacity.
- Do not use the torque wrench to break loose bolts that have been previously tightened.
- Do not drop the wrench. If dropped, the accuracy will be affected.

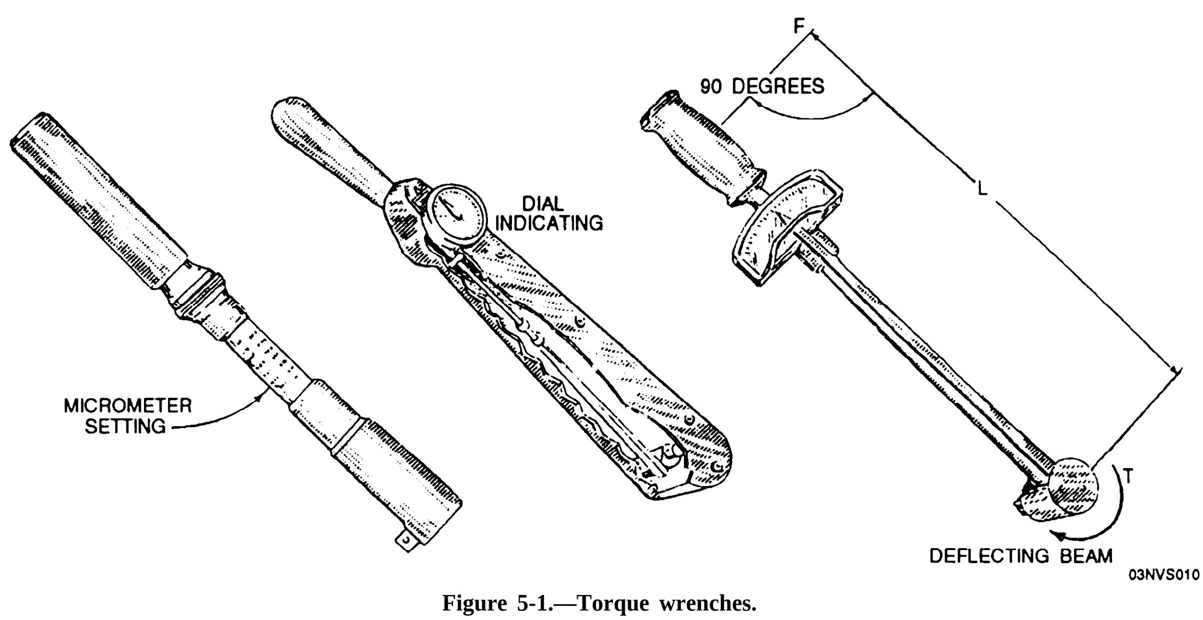


Figure 5-1.—Torque wrenches.

- Do not apply a torque wrench to a nut that has been tightened. Back off the nut one turn with a nontorque wrench and retighten to the correct torque with the indicating torque wrench.

- Calibration intervals have been established for all torque tools used in the Navy.

When a tool is calibrated by a qualified calibration activity at a shipyard, tender, or repair ship, a label showing the next calibration due date is attached to the handle. This date should be checked before a torque tool is used to ensure that it is not overdue for calibration.

CALIPERS

Calipers are precision measuring devices that measure length in thousandths of an inch. Calipers differ only in the way they are read and the types of measurements taken. The types of calipers that will be discussed in this chapter are the vernier dial caliper and the vernier.

Vernier Dial Calipers

Vernier dial calipers are the most common type of caliper found in use today. They are preferred over vernier calipers in that they are easier to read and can measure depth. They use a double set of movable and fixed measuring jaws to measure inside and outside measurements as shown in figure 5-2. Depth is measured using a depth gauge rod.

Reading the vernier dial caliper is a relatively simple and easy task involving the addition of the dial reading to the main frame scale reading. It uses a dial marked in thousandths of an inch and a main frame scale marked in inches and hundred-thousandths of an inch. As the dial is drawn across the main frame by an adjustment screw, the reading is registered on the dial face in thousandths of an inch. Before taking your measurement, always zero the dial caliper by aligning the mark on the bezel when the measuring jaws are closed. When you pass the first small numbered mark on the main frame scale, simply add one hundred thousandths to the dial reading. When you pass the first large numbered mark on the main frame scale, add one inch to your dial reading. After passing the first small numbered mark, add one inch one hundred thousandths to the dial reading. Do this wherever the reading falls on the scale.

Vernier Caliper

Vernier calipers are capable of taking measurements to the nearest thousandths of an inch using a stationary and sliding jaw assembly as shown in figure 5-2. Reading the vernier caliper is not as easy as reading the

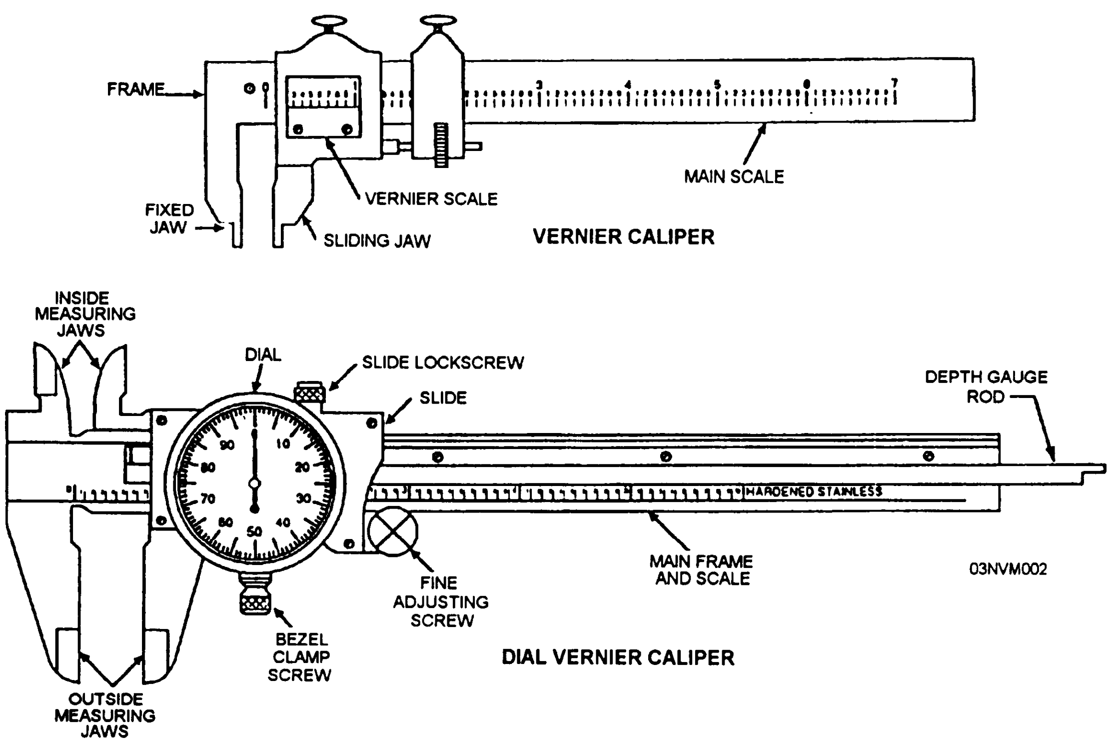


Figure 5-2.—Vernier and vernier dial caliper.

dial caliper (refer to fig. 5-3). The main frame scale (1) is graduated in 0.025 thousandths of an inch. Every fourth division (2) (representing a tenth of an inch) is numbered. The vernier scale (3). on the movable jaw, is divided into 25 parts and numbered 0, 5, 10, 15, 20, and 25. These 25 parts are equal to 24 parts on the main frame scale (1). The difference between the width of one of the 25 spaces on the vernier scale (3) and one of the 24 spaces on the main frame scale (1) is 1/1000 of an inch.

There are five steps to reading the vernier caliper as shown in figure 5-3. They are as follows:

1. Read the number of whole inches on the top scale (1) to the left of the vernier zero index (4) and record as 1.000 inch.
2. Read the number of tenths (5) to the left of the vernier zero index (4) and record as 0.400 inch.
3. Read the number of twenty-fifths (6) between the tenths mark (5) and the vernier zero index (4) and record as 3×0.025 or 0.075 inch.
4. Read the highest line on the vernier scale (3) which lines up with the lines on the top scale (7) and record as 11/25 or 0.011 inch. (Remember, 1/25 = 0.001 inch.)
5. Add the total measurement of the 4 preceding steps to find the total measured length or 1.000 + 0.400 + 0.075 + 0.011 = 1.486 inches.

Vernier calipers only take inside and outside dimensions and cannot take depth readings.

Caliper Maintenance

Since calipers are precision measuring instruments, proper care of the caliper is of great importance. Some of the more important aspects of caliper maintenance are listed as follows:

— Always store the caliper in its carrying case. Never leave calipers on work benches, table tops, weld booths, machinery or equipment, or other areas where the caliper could be knocked off, crushed, bent, or otherwise damaged.

— Calipers should always be calibrated according to the Navy's METCAL program before use.

— Keep the slide and main frame clean and free of dust, dirt, weld splatter, and metal chips.

— Never force the slide. If the slide does not move freely, check for chips or grit on the rack and remove them by cleaning.

GAUGES

There are numerous gauges in use throughout the Navy today. As an HT, you will use numerous gauges to perform your job. This section will discuss various gauges that are used in drilling, tapping, welding, and brazing operations.

Thickness (Feeler) Gauges

Feeler gauges are used for checking and measuring small openings such as root openings and narrow slots found in weld fitups and braze joints. Thickness gauges come in many shapes and sizes, as shown in figure 5-4, and can be made with multiple blades (usually have 2 to 26). Each blade is a specific number of thousandths of an inch thick. This enables the application of one tool to the measurement of a variety of thicknesses. Two or

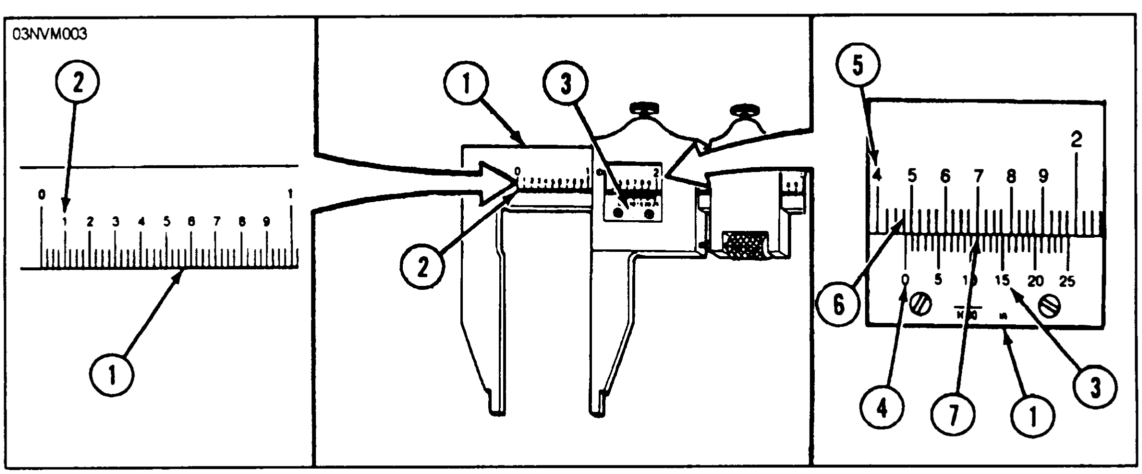


Figure 5-3.—Reading a vernier caliper.

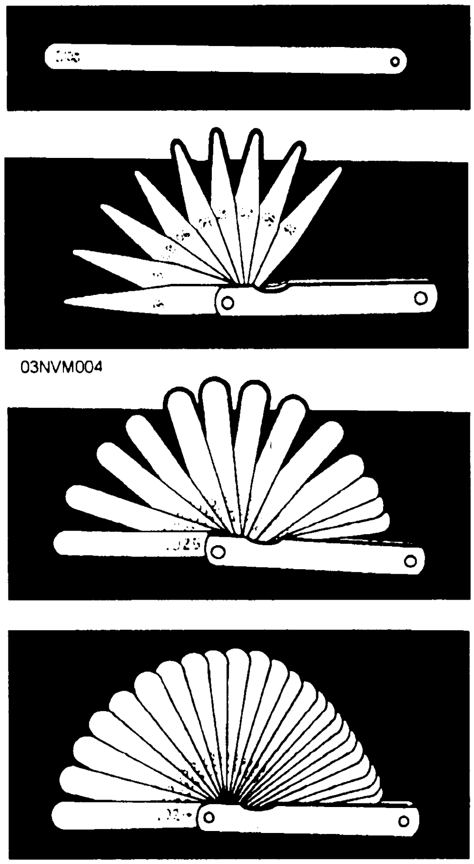


Figure 5-4.—Thickness (feeler) gauges.

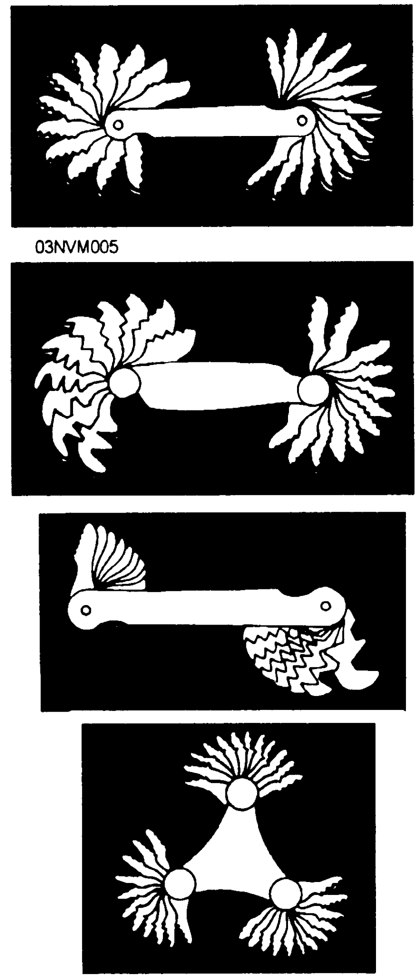


Figure 5-5.—Screw-pitch gauges.

more blades may be combined to take readings of various thicknesses.

Screw-Pitch Gauges

Screw-pitch gauges (fig. 5-5) are made for checking the pitch of U.S. Standard, Metric, National Form, and V-form cut threads. You will use them to determine the correct thread pitch of an unknown thread on a bolt, inside a nut, or in choosing the correct tap or die for threading stock or tapping a hole. Each thread gauge is marked in number of threads per inch. To take a measurement, simply lay the gauge on the thread. The correct gauge will fit the thread of the bolt perfectly with no light showing between the gauge and the threads of the bolt. The pitch of the screw thread is the distance between the center of one tooth to the center of the next tooth.

Drill Gauges

The twist drill and drill rod gauge has a series of holes with size and decimal equivalents stamped adjacent to each hole, as shown in figure 5-6. Drill gauges use either a letter, number, decimal, or fraction

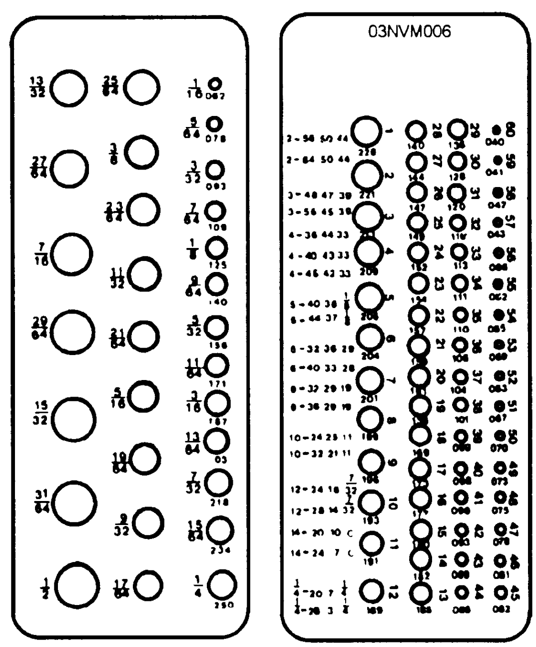
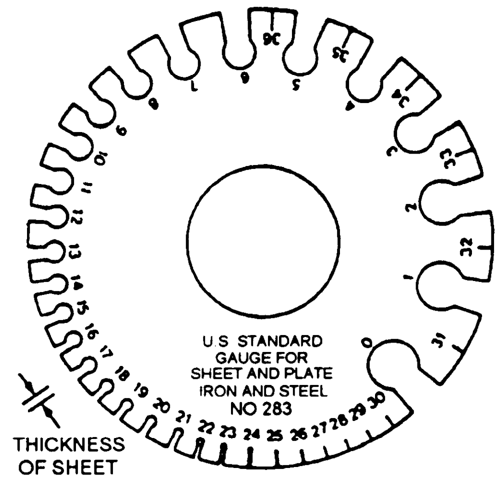


Figure 5-6.—Drill gauges.



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GAUGE NO.	BIRMINGHAM WIRE GAUGE (B.W.C.) OR STUBS IRON WIRE GAUGE, FOR IRON WIRES. HOT AND COLD ROLLED SHEET STEEL	AMERICAN WIRE GAUGE, OR BROWN & SHARPE (FOR NON-FERROUS SHEET AND WIRE)	U.S. STANDARD GAUGE FOR SHEET AND PLATE IRON AND STEEL	STEEL WIRE GAUGE, OR THE W & M (WASHBURN & MOEN) FOR STEEL WIRE
0	.340	.3249	.3125	.3065
1	.300	.2893	.2812	.2830
2	.284	.2576	.2656	.2625
3	.259	.2294	.2500	.2437
4	.238	.2043	.2343	.2253
5	.220	.1819	.2187	.2070
6	.203	.1620	.2031	.1920
7	.180	.1443	.1876	.1770
8	.165	.1285	.1718	.1620
9	.148	.1144	.1562	.1483
10.......	.134	.1019	.1406	.1350
11.......	.120	.0907	.1250	.1205
12.......	.109	.0808	.1093	.1055
13.......	.095	.0719	.0937	.0915
14.......	.083	.0640	.0781	.0800
15.......	.072	.0570	.0703	.0720
16.......	.065	.0508	.0625	.0625
17.......	.058	.0452	.0562	.0540
18.......	.049	.0403	.0500	.0475
19.......	.042	.0359	.0437	.0410
20.......	.035	.0319	.0375	.0348
21.......	.032	.0284	.0343	.0317
22.......	.028	.0253	.0312	.0286
23.......	.025	.0225	.0281	.0258
24.......	.022	.0201	.0250	.0230
25.......	.020	.0179	.0218	.0204
26.......	.018	.0159	.0187	.0181
27.......	.016	.0142	.0171	.0173
28.......	.014	.0126	.0156	.0162
29.......	.013	.0112	.0140	.0150
30.......	.012	.0100	.0125	.0140
31.......	.010	.0089	.0109	.0132
32.......	.009	.0079	.0101	.0128
33.......	.008	.0071	.0093	.0118
34.......	.007	.0063	.0085	.0104
35.......	.005	.0056	.0078	.0095
36.......	.004	.0050	.0070	.0090

Figure 5-7.—Steel plate and sheet metal gauges and thicknesses.

to designate drill size. Some drill gauges may use a combination of these designations to measure drill size. You will use these gauges when determining the correct drill size for a given tap size.

Steel Plate and Sheet Metal Gauge

Steel plate and sheet metal gauges come in various sizes and uses, as shown in figure 5-7. You will use them extensively in sheet metal and structural metal fabrication to determine metal thickness or gauge. They are simple to use and extremely accurate. Simply fit the gauge to the plate so that the metal edge slides exactly into the slot. The gauge should be snug, but do not force the gauge onto the metal. Gauge numbers are marked on the front of the gauge with the corresponding decimal reading on the back.

CIRCUMFERENCE RULE

The circumference rule is a specialty rule that is used to figure out the total length of plate needed for manufacturing cylindrical objects. The circumference rule looks similar to a regular steel rule but has two scales marked on its face as shown in figure 5-8. The top scale is an inch scale that is divided in sixteenths of an inch and represents the diameter of an object. The bottom scale is divided in eighths of an inch and represents the circumference of a cylinder. The back of the rule usually has formulas for calculating circumferences and shows areas and tables for laying out measurements.

Reading the circumference rule is a simple process that requires no special math skills. First, determine the diameter of a cylinder in inches. Next, locate the diameter on the top inch scale and read the measurement directly below on the circumference scale to determine the total length of material needed to fabricate the cylinder.

Using figure 5-8 as a guide, let's figure the total length of plate needed to manufacture a 2-inch diameter cylinder. Locate the diameter, or 2 inches, on the top inch scale, then read the circumference rule directly below that mark to get the total length of plate needed to manufacture a 2-inch diameter cylinder or 6 1/4 inches. The total length of plate needed is 6 1/4 inches.

Figure 5-8.—Circumference rule.

SQUARES

Working in an HT shop, you will use a square almost everyday. Squares are versatile instruments that can be used to lay out lines and angles, to measure distances, and for numerous other functions. There are numerous squares in use today, but only the steel square and the combination square will be discussed in this section.

Steel Square

Steel squares (fig. 5-9) are used to lay out various angles and to check squareness or straightness of an edge or surface. They are L-shaped tools that comes in 12-, 18-, and 24-inch blade length. They are marked in graduations of 1-16- or 1/8-inch divisions on the inside and outside edge. The components of the steel square are as follows:

- BLADE—the longer leg of the square
- TONGUE—the shorter leg of the square
- HEEL—the outside comer
- FACE—the inside edge of the square
- BACK—the outside edge of the blade

When using a steel square to lay out angles, place the tongue of the square on the base line with the 12-inch mark on the vertex of the desired angle. Mark the vertical distance for the desired angle along the blade edge of the square. Connect the vertex to the vertical height mark with a line. Some of the more common angles are shown in figure 5-10.

Combination Square

The combination square (fig. 5-11) is a multifunctional tool that can be used to lay out various angles, measure height and depth, bisect a 90-degree angle, and as a level. It consists of the following components:

— A 12-inch stainless steel rule (1) that is graduated in eighths, sixteenths, thirty-seconds, and sixty-fourths of an inch. The rule is slotted to accept individual tool heads. It can be used as a measuring

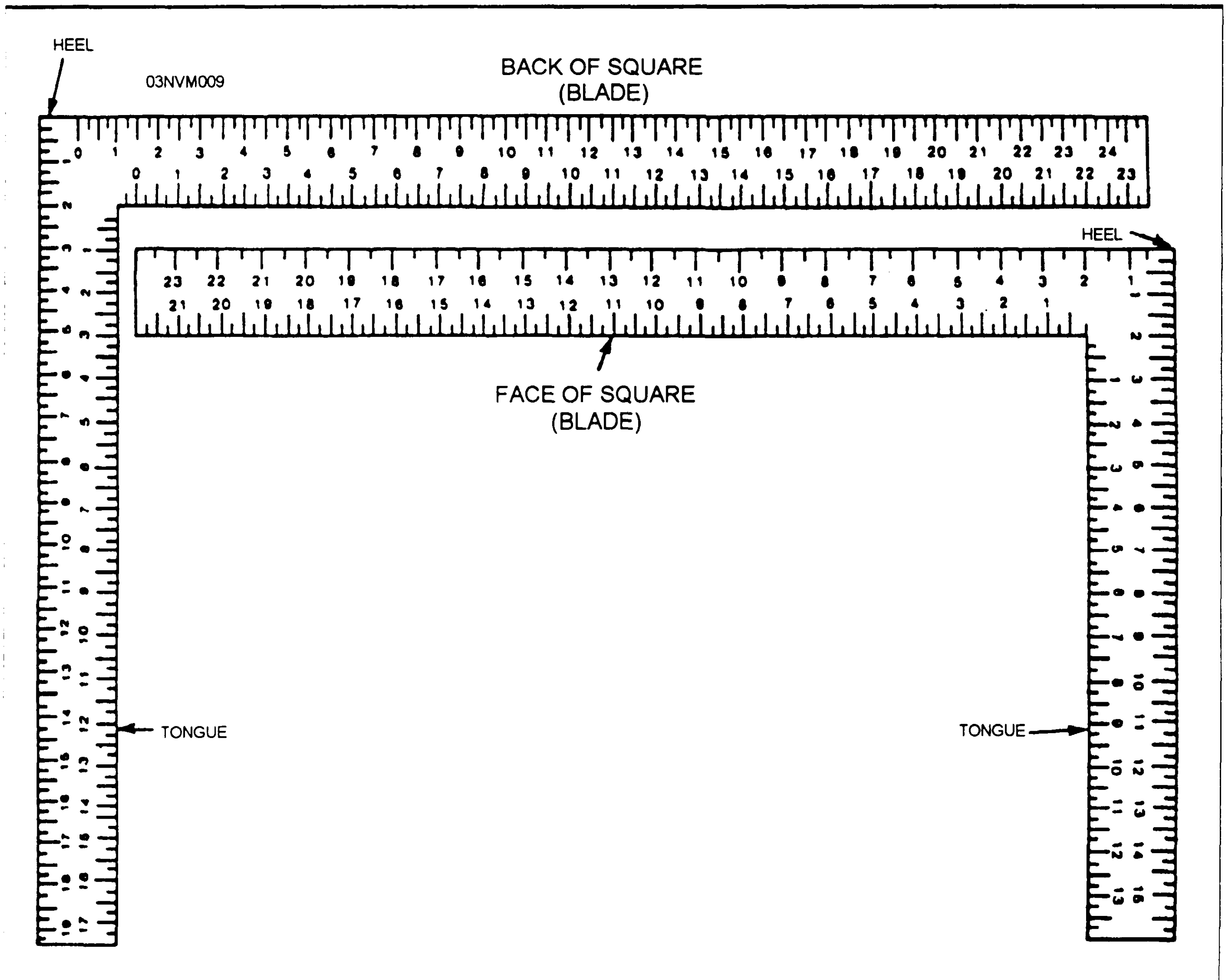


Figure 5-9.—Steel square.

ANGLE	TONGUE	BLADE
15°	12"	3-7/32"
22 1/2°	12"	4-31/32"
30°	12"	6-15/16"
45°	12"	12"
60°	12"	20-7/8"

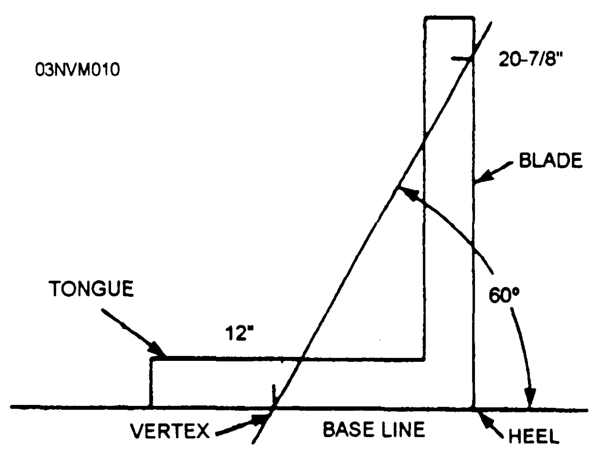


Figure 5-10.—Steel square angle layout.

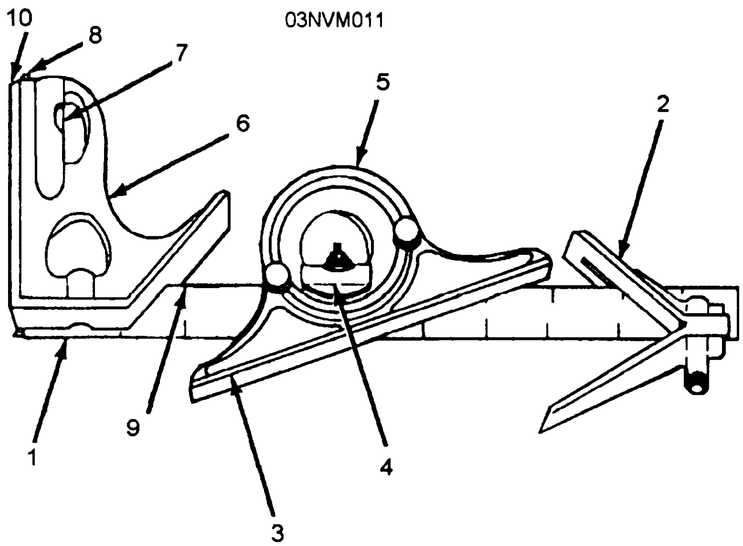


Figure 5-11.—Combination square.

scale by itself or with any one of the following components:

— The center head (2), when attached to the slotted rule, bisects a 90-degree angle. It is used to determine the center of a cylindrical object.

— The protractor head (3) has a level (4) and a revolving turret (5) that is graduated in degrees from 0 to 180 or 0 to 90 in either direction. It is used to lay out and measure angles to within one degree.

— The square head (6) has a level (7), scribe (8), and 45- (9) and 90-degree sides (10). When it is attached to the slotted steel rule, it can be used to lay out 45- and 90-degree angles and to check level. The square head may also be used as a height or depth gauge.

TRAMMELS

Trammels (fig. 5-12) measure distances beyond the range of calipers. They also can be used as calipers, if you have the auxiliary attachments.

The basic trammel consists of two heads (trams). One head has a device for fine adjustments. The wooden beam must be made by the HT as it is not provided by the manufacturer. You can attach divider points, caliper legs, and ball points to the tram. The ball points with holder are used for scribing or measuring from the center of a hole.

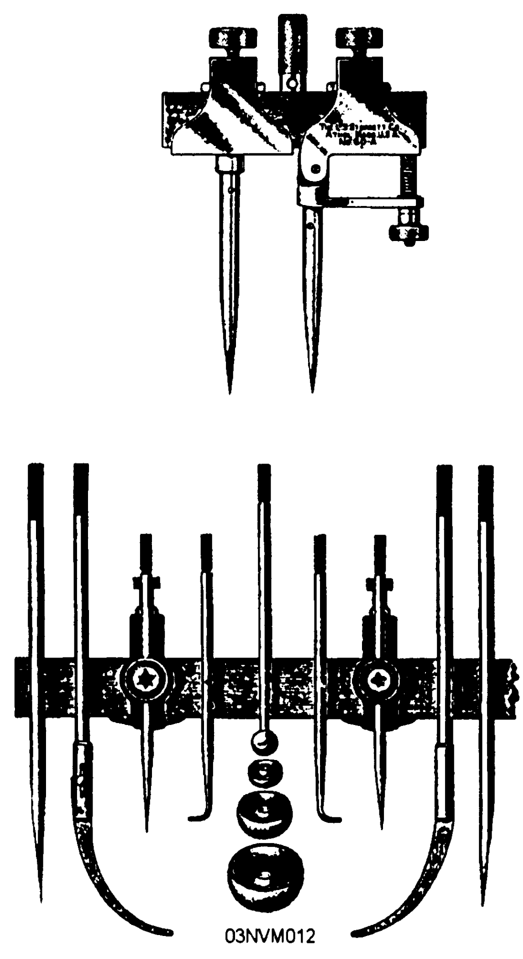


Figure 5-12.—Trammels.

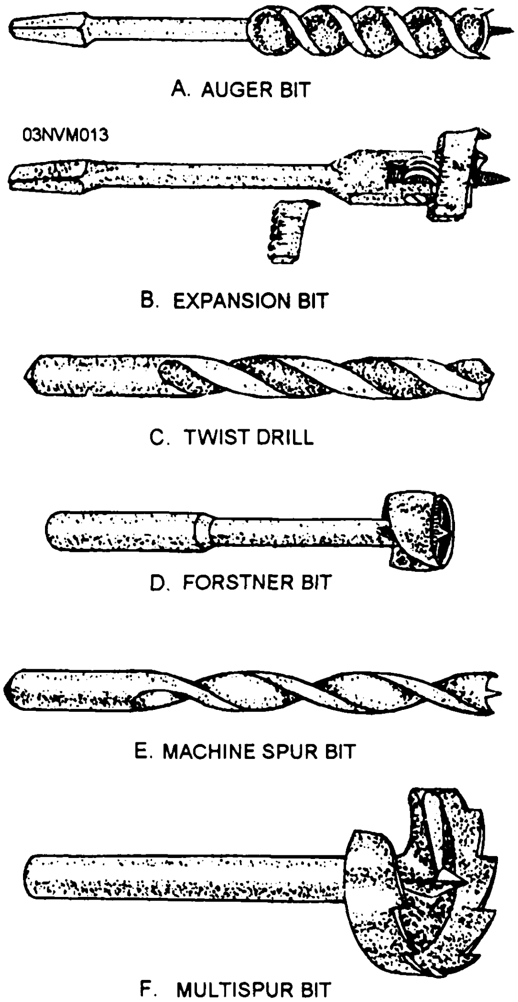


Figure 5-13.—Drill bits.

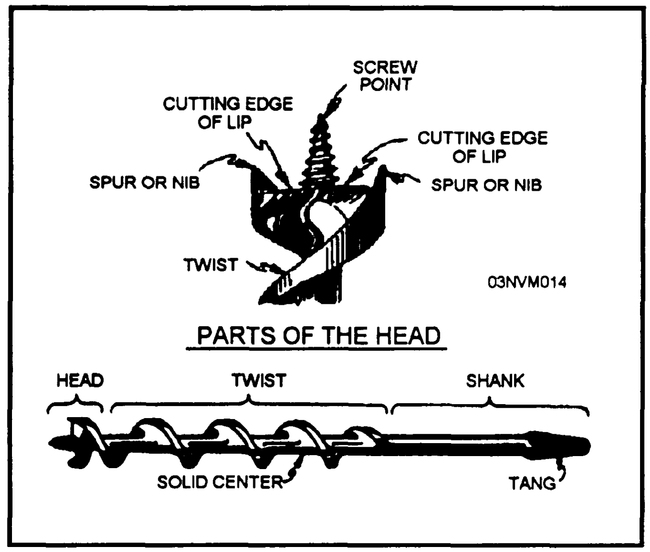


Figure 5-14.—Parts of an auger bit.

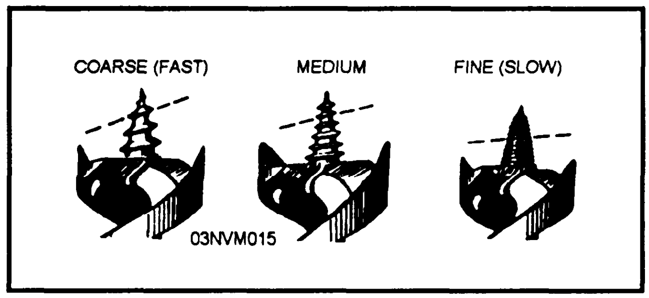


Figure 5-15.—Types of screw points.

WOOD- AND METAL-BORING BITS

The wood-boring bits and drills usually found in the HT shop are shown in figure 5-13—included are the auger bit, expansion bit, twist bit, machine spur bit, and multispur bit.

AUGER BIT

The auger bit (fig. 5-13, view A) is the most common of the wood-boring bits. It should be used with a hand brace. It consists of three parts: the head, twist, and shank, as shown in figure 5-14.

The screw point functions to center the bit and to pull the bit through the stock. The three types of screw points are coarse, medium, and fine (fig. 5-15). The coarse bit is drawn through the stock faster than a fine one, but there is more roughness because of the faster cut.

The spurs function to score the outer edge of the chip as the cutting lips chisel or cut the waste material loose. The spurs and cutting lips must be sharp to produce a smooth hole.

The twist of the auger bit is responsible for removing waste material after being cut by the spurs and cutting lips. It is slightly smaller in diameter than the head. The twist comes in three styles—single twist with solid center, single twist, and double twist.

- The single twist with solid center clears chips more rapidly, is stronger, and is more common than the single or double twist.
- The single twist has less tendency to bind in certain materials but is more fragile than the single twist with solid center.
- The double twist produces a clean, smooth, accurate hole and bores slower than other twist bits. It is the most suitable of the three to bore holes for wooden dowels.

The shank is that part of the auger bit that fits into the chuck of the brace. It has the drill size number stamped on one of the flats of the square-tapered tang. This number represents the drill size in sixteenths of an inch (fig. 5-16). For instance, if the number stamped on the flat is 12, the drill size is 12/16 inch or 3/4 inch. All bits having a tang-type shank are numbered and sized in this manner.

Auger bits usually come in sets containing 1/4-inch (#4) to 1-inch (#16) bits, but they are available up to 2 inches (#32) in diameter. Many different lengths of auger bits are available and come in three sizes. The dowel bit is about 5 inches long. The medium bit is about 8 inches long and the ship bit is from 18 to 24 inches long. The medium bit is the length most commonly used.

EXPANSION BIT

Another bit designed for use with the brace and to bore holes larger than 7/8 inch is the expansion, or expansive, bit (fig. 5-17). The expansion bit consists of a screw point, the body cutting edge, and three adjustable cutter blades. The blades let you bore holes up to 4 inches in diameter. The adjustable cutter blade adjusts by either a microdial (fig. 5-17) or a simple screw arrangement. Make a trial cut on scrap stock after adjusting an expansion bit to make sure that the bit is cutting the exact diameter desired.

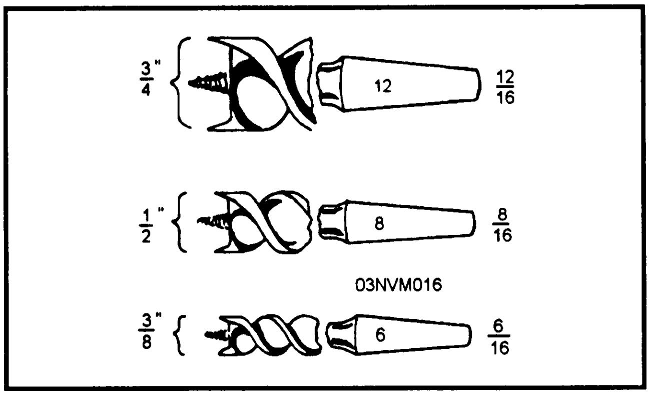


Figure 5-16.—Size markings on auger bits.

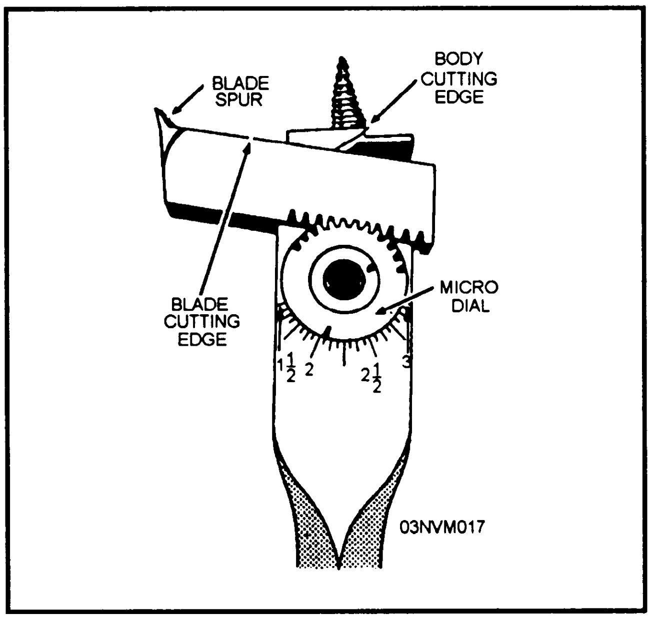


Figure 5-17.—Expansion bit.

TWIST BIT

The twist drill bit (fig. 5-13, view C) is used to bore holes 1/2 inch and under. They work with any type of drill. High-carbon or high-speed steel twist drills are used for low-speed metal boring or high-speed wood boring. The high-speed steel drill is for high-speed metal boring.

Twist drills come in several styles. The styles are differentiated by the shank. The part of the twist drill that fits into the socket, spindle, or chuck of the drill press is known as the shank. The three most common types of shanks are shown in figure 5-18.

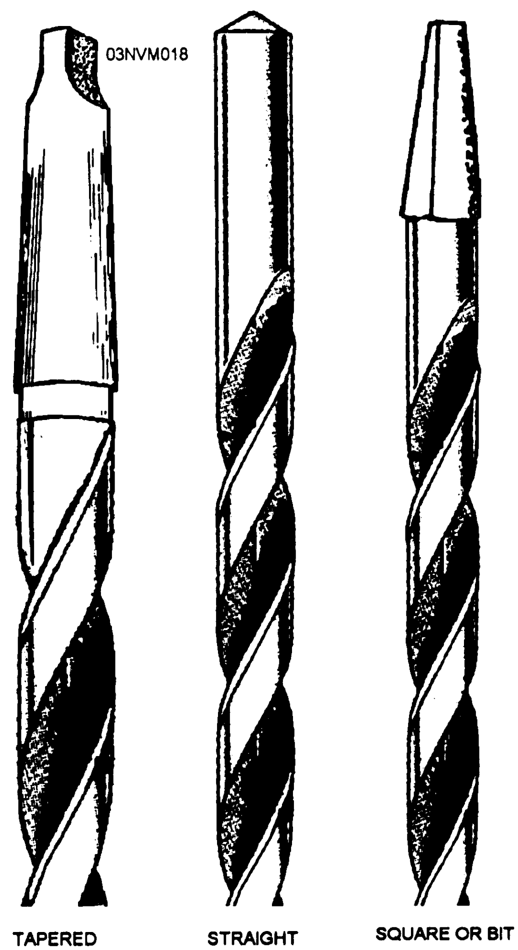


Figure 5-18.—Three most common types of shanks.

Table 5-1.—Twist Drill Sizes

SIZE	DECIMAL EQUIVALENTS	SIZE	DECIMAL EQUIVALENTS	SIZE	DECIMAL EQUIVALENTS
1/2	0.5000	C	0.2420	30	0.1285
31/64	.4844	B	.2380	1/8	.1250
15/32	.4687	15/64	.2344	31	.1200
10/64	.4531	A	.2340	32	.1160
7/16	.4375	No. 1	.2280	33	.1130
27/64	.4219	2	.2210	34	.1110
Z	.4130	7/32	.2187	35	.1100
13/32	.4062	3	.2130	7/64	.1094
Y	.4040	4	.2090	36	.1065
X	.3970	5	.2055	37	.1040
25/64	.3906	6	.2040	38	.1015
W	.3860	13/64	.2031	39	.0995
V	.3770	7	.2010	40	.0980
3/8	.3750	8	.1990	41	.0960
U	.3680	9	.1960	3/32	.0937
23/64	.3594	10	.1935	42	.0935
T	.3580	11	.1910	43	.0890
S	.3480	12	.1890	44	.0860
11/32	.3437	3/16	.1875	45	.0820
R	.3390	13	.1850	46	.0810
Q	.3320	14	.1820	47	.0785
21/64	.3281	15	.1800	5/64	.0781
P	.3230	16	.1770	48	.0760
O	.3160	17	.1730	49	.0730
5/16	.3125	11/64	.1719	50	.0700
N	3020	18	.1695	51	.0670
12/64	2969	19	.1660	52	.0635
M	.2950	20	.1610	1/16	.0625
L	.2900	21	.1590	53	.0595
7/32	.2812	22	.1570	54	.0550
K	.2810	5/32	.1562	55	.0520
J	.2770	23	.1540	3/64	.0469
I	.2720	24	.1520	56	.0465
H	.2660	25	.1495	57	.0430
17/64	.2656	26	.1470	58	.0420
G	.2610	27	.1440	59	.0410
F	.2570	9/64	.1406	60	.0400
E 1/4	.2500	28	.1405		
D	.2460	29	.1360		

Twist drills have various shank types sized by fraction, number, or letter. Fraction symbols give the actual size of the drill. Sets that include sizes from 1/16 to 1/2 inch are common in the shop. Number and letter designators only identify the drill. A drill gauge or reference chart (table 5-1) gives the actual size of the drill. Note that the letter sizes are larger and start where the number sizes stop. The most common type used in HT shops is the carbon steel drill with a straight shank.

A drill should be reground at the first sign of dullness. The increased load that dullness imposes on the cutting edges may cause a drill to break.

Twist drills are sharpened differently for boring different materials. The two common angles are the regular point (fig. 5-19) and the flat point (fig. 5-20). The regular point has an angle of 118° and is used for general boring, which includes wood and metal. The flat point has an angle of 135° and is used to bore hard and tough materials.

The general-purpose twist drill is made of high-speed steel. Figure 5-21 shows a typical plastic-cutting drill and a typical metal-cutting drill. Notice the smaller angle on the drill used for drilling plastics.

Before putting a drill away, wipe it clean and give it a light coating of oil. Do not leave drills in a place where they may be dropped or where heavy objects may fall on them. Do not place drills where they will rub against each other.

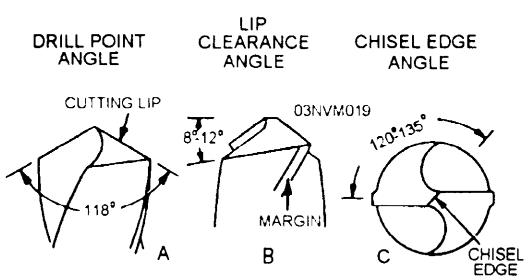


Figure 5-19—Specifications for grinding a regular point twist drill.

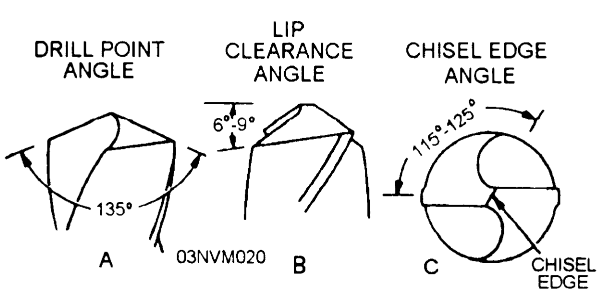


Figure 5-20.—Specifications for grinding a flat point twist drill.

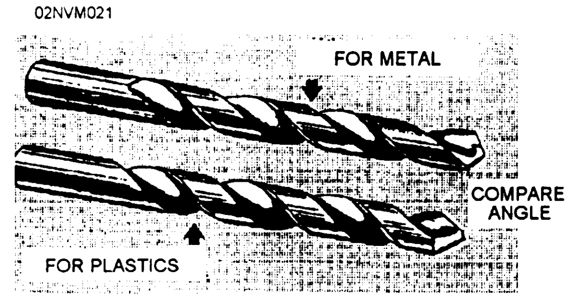


Figure 5-21.—Comparison of a twist drill for plastic and a twist drill for metal.

MACHINE SPUR BIT

The machine spur bit (fig. 5-13, view E) works only in a drill press. It is a high-speed, smooth-cutting bit for boring deep, flat-bottomed holes. It has a centering point and a twist to remove waste material and comes in sizes ranging from 1/8 to 1/2 inch in diameter.

MULTISPUR BIT

The multispur bit (fig. 5-13, view F) also works strictly in drill presses. Use it to bore flat-bottomed holes larger than the machine spur bit and ranges in size from 1/2 to 4 inches in diameter.

NOTE: As bit sizes increase, drill press speed decreases.

COUNTERSINKS

The countersink forms a seat for the head of a flat-headed wood screw and comes in three types (fig. 5-22). Type A is for use with a hand brace. Types B

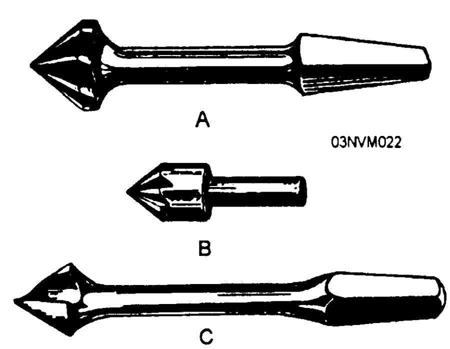


Figure 5-22.—Types of countersinks.

and C are used in either the hand drill, portable electric drill, or drill press. Type B produces a rough surface but cuts the fastest. Type C produces a smooth seat and is the countersink of choice for finish work.

There are many types of combination countersinks and counterbores, but they all perform the same function. These tools make the pilot hole, shank clearance, and countersink in one operation. The combination counterbore performs the same tasks as the combination countersink and bores a plug hole for wooden plugs. Combination countersinks and counterbores range in size from #6 to #12 and accommodate wood screw sizes #5 to #14.

The particular size of wood screw each countersink and counterbore accommodates determines the size of the countersink or counterbore. Use both with the hand drill, portable electric drill, and drill press.

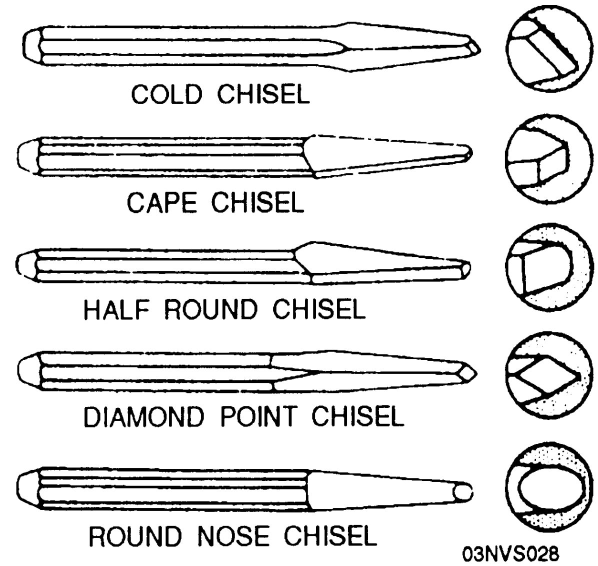


Figure 5-23.—Types of points on the metal-cutting chisel.

METAL-CUTTING TOOLS

There are many types of metal-cutting tools used by skilled mechanics of all ratings. As you become better acquainted with your rating, you will probably discover many tools that you use for cutting metal that are not described in this chapter. In this chapter, only the basic hand metal-cutting tools (chisels, hacksaws, and files) will be discussed due to their frequent but incorrect use.

CHISELS

Chisels are tools that can be used for chipping or cutting metal. They will cut any metal that is softer than the materials of which they are made. Chisels are made from a good grade tool steel and have a hardened cutting edge and beveled head. Cold chisels are classified according to the shape of their points, and the width of the cutting edge denotes their size. The most common shapes of chisels are flat (cold chisel), cape, round nose, and diamond point (fig. 5-23).

The type of chisel most commonly used is the flat cold chisel that cut rivets, split nuts, chip castings, and cut thin metal sheets. The cape chisel is used for special jobs like cutting keyways, narrow grooves, and square corners. Round-nose chisels make circular grooves and chip inside comers with a fillet. Finally, the diamond-point is used for cutting V-grooves and sharp comers.

As with other tools, there is a correct technique for using a chisel. Select a chisel that is large enough for the job. Be sure to use a hammer that matches the chisel; that is, the larger the chisel, the heavier the hammer. A heavy chisel will absorb the blows of a light hammer and will do virtually no cutting. As a general rule, you should hold the chisel in your left hand with the thumb and first finger about 1 inch from the top. You should hold it steady but not tight. Your finger muscles should be relaxed, so if the hammer strikes your hand it will permit your hand to slide down the tool and lessen the effect of the blow. Keep your eyes on the cutting edge of the chisel, not on the head, and swing the hammer in the same plane as the body of the chisel. If you have a lot of chiseling to do, slide a piece of rubber hose over the chisel. This will lessen the shock to your hand.

When using a chisel for chipping, always wear goggles to protect your eyes. If other people are working close by, see that they are protected from flying chips by erecting a screen or shield to contain the chips. Remember that the time to take these precautions is before you start the job.

After numerous blows to the head of a chisel, it will begin to deform. This deformation is called mushrooming and creates a very dangerous situation. If the head of a chisel mushrooms excessively, bits of the head will begin to fly off when struck with a hammer. These small bits of metal have the force of shrapnel from a hand grenade and could cause as much damage. Simply keep the head of a chisel ground down to remove this dangerous situation.

FILES

A tool kit for nearly every rating in the Navy is not complete unless it contains an assortment of files. There are a number of different types of files in common use, and each type may range in length from 3 to 18 inches.

Files and rasps fall into the abrading tool family. You only need the half-round file and the half-round rasp for ordinary work. The most useful sizes are 6, 8, and 10 inches.

Grades

Files are graded according to the degree of fineness, and according to whether they have single- or double-cut teeth. The difference is apparent when you compare the files in figure 5-24, view A.

Single-cut files have rows of teeth cut parallel to each other. These teeth are set at an angle of about 65 degrees with the center line. You will use single-cut files for sharpening tools, finish filing, and draw filing. They are also the best tools for smoothing the edges of sheet metal.

Files with crisscrossed rows of teeth are double-cut files. The double cut forms teeth that are diamond-shaped and fast cutting. You will use double-cut files for quick removal of metal and for rough work.

Files are also graded according to the spacing and size of their teeth, or their coarseness and fineness. Some of these grades are pictured in figure 5-24, view B. In addition to the three grades shown, you may use some DEAD SMOOTH files, which have very fine teeth, and some ROUGH files with very coarse teeth. The fineness or coarseness of file teeth is also influenced by the length of the file. (The length of a file is the distance from the tip to the heel, and does not include the tang (fig. 5-24, view C). When you have a chance, compare the actual size of the teeth of a 6-inch, single-cut smooth file and a 12-inch, single-cut smooth file; you will notice the 6-inch file has more teeth per inch than the 12-inch file.

Shapes

Files come in different shapes. Therefore, in selecting a file for a job, the shape of the finished work must be considered. Some of the cross-sectional shapes are shown in figure 5-24, view D.

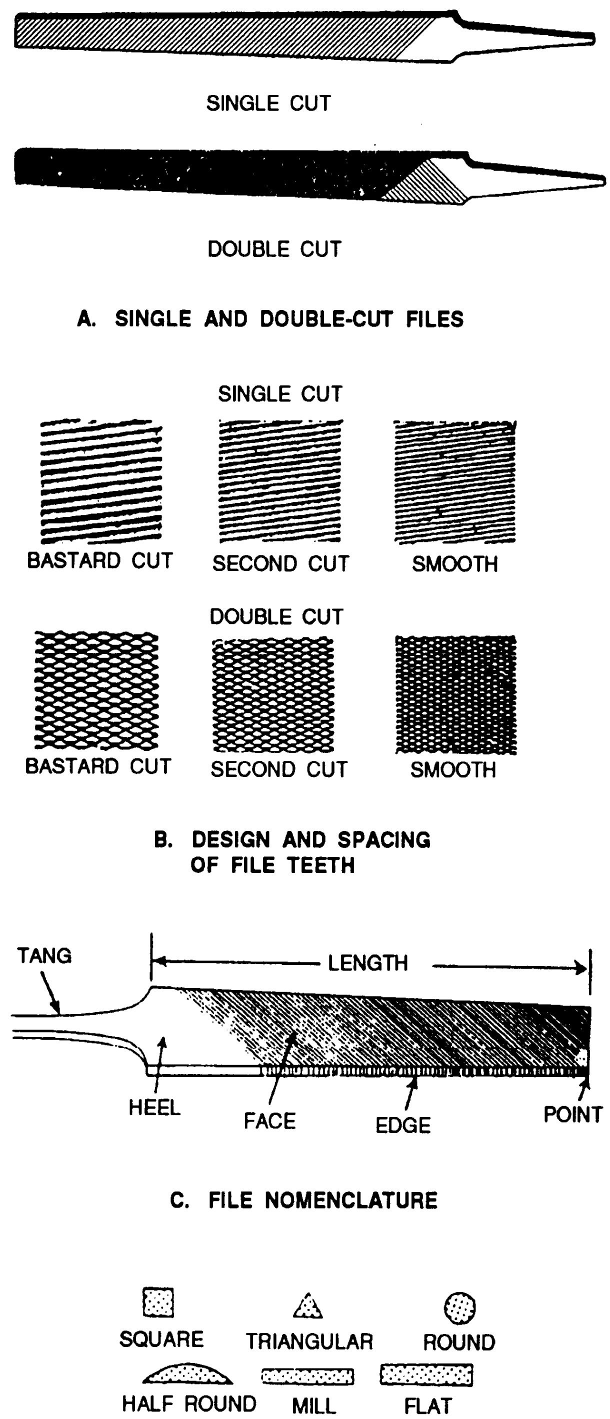


Figure 5-24.—File information.

TRIANGULAR files are tapered (longitudinally) on all three sides. They are used to file acute internal angles and to clear out square corners. Special triangular files are used to file saw teeth.

MILL files are tapered in both width and thickness. One edge has no teeth and is known as a safe edge. Mill files are used for smoothing lathe work draw filing, and other fine, precision work. Mill files are always single-cut.

FLAT files are general-purpose files and may be either single- or double-cut. They are tapered in width and thickness. HARD files, not shown, are somewhat thicker than flat files. They taper slightly in thickness, but their edges are parallel. The flat or hard files most often used are the double-cut for rough work, and the single-cut, smooth file for finish work.

SQUARE files are tapered on all four sides and are used to enlarge rectangular-shaped holes and slots.

ROUND files serve the same purpose for round openings. Small round files are often called "rattail" files.

The HALF-ROUND file is a general-purpose tool. The rounded side is used for curved surfaces and the flat face on flat surfaces. When you file an inside curve, use a round or half-round file whose curve most nearly matches the curve of the work.

Care of Files

You should break in a new file carefully by using it first on brass, bronze, or smooth cast iron. Just a few of the teeth will cut at first, so use a light pressure to prevent tooth breakage. Do not break in a new file by using it first on a narrow surface. Protect the file teeth by hanging your files in a rack when they are not in use, or by placing them in drawers with wooden partitions. Your files should not be allowed to rust—keep them away from water and moisture. Avoid getting the files oily. Oil causes a file to slide across the work and prevents fast, clean cutting. Files that you keep in your toolbox should be wrapped in paper or cloth to protect their teeth and prevent damage to other tools.

HACKSAWS

Hacksaws are used to cut metal that is too heavy for snips or bolt cutters. Thus, metal bar stock can be cut readily with hacksaws.

There are two parts to a hacksaw: the frame and the blade. Common hacksaws have either an adjustable or solid frame (fig. 5-25). Most hacksaws found in the Navy are of the adjustable frame type. Adjustable frames can be made to hold blades from 8 to 16 inches long, while those with solid frames take only the length blade for which they are made. This

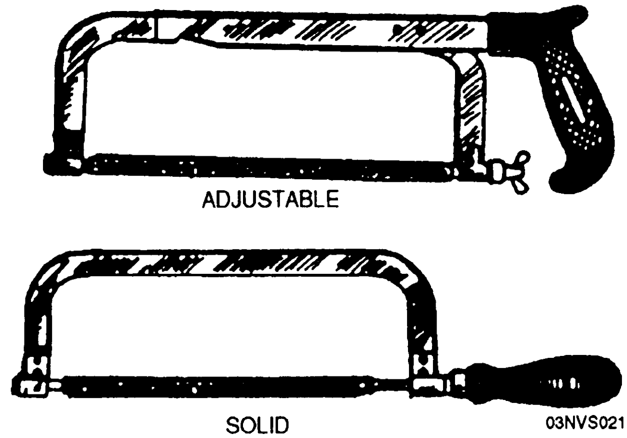


Figure 5-25.—Hacksaws.

length is the distance between the two pins that hold the blade in place.

Hacksaw blades are made of high-grade tool steel, hardened and tempered. There are two types: the all-hard and the flexible. All-hard blades are hardened throughout, whereas only the teeth of the flexible blades are hardened. Hacksaw blades are about one-half inch wide, have from 14 to 32 teeth per inch, and are from 8 to 16 inches long. The blades have a hole at each end that hooks to a pin in the frame. All hacksaw frames that hold the blades either parallel or at right angles to the frame are provided with a wingnut or screw to permit tightening or removing the blade.

The SET in a saw refers to how much the teeth are pushed out in opposite directions from the sides of the blade. The four different kinds of set are ALTERNATE set, DOUBLE ALTERNATE set, RAKER set, and WAVE set. Three of these are shown in figure 5-26.

The teeth in the alternate set are staggered, one to the left and one to the right throughout the length of the blade. On the double alternate set blade, two

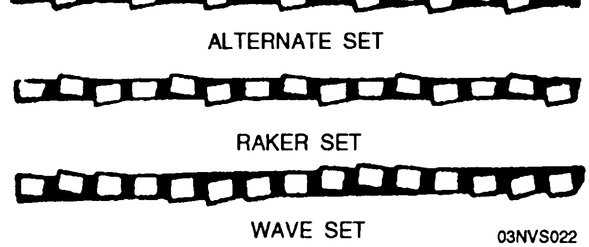


Figure 5-26.—"Set" of hacksaw blade teeth.

adjoining teeth are staggered to the right, two to the left, and so on. On the raker set blade, every third tooth remains straight and the other two are set alternately. On the wave (undulated) set blade, short sections of teeth are bent in opposite directions.

Using Hacksaws

The hacksaw is often used improperly. Although it can be used with limited success by an inexperienced person, a little thought and study given to its proper use will result in faster and better work and less dulling and breaking of blades.

Good work with a hacksaw depends not only upon the proper use of the saw, but also upon the proper selection of the blades for the work to be done. Figure 5-27 will help you select the proper blade to use when sawing metal with a hacksaw. Coarse blades with fewer teeth per inch cut faster and are less liable to choke up with chips. However, finer blades with more teeth per inch are necessary when thin sections are being cut. The selection should be made so that, as each tooth starts its cut, the tooth ahead of it will still be cutting.

To make the cut, first install the blade in the hacksaw frame (fig. 5-28) so that the teeth point away from the handle of the hacksaw (hand hacksaws cut on the push stroke.) Tighten the wingnut so that the blade is definitely under tension. This helps make straight cuts.

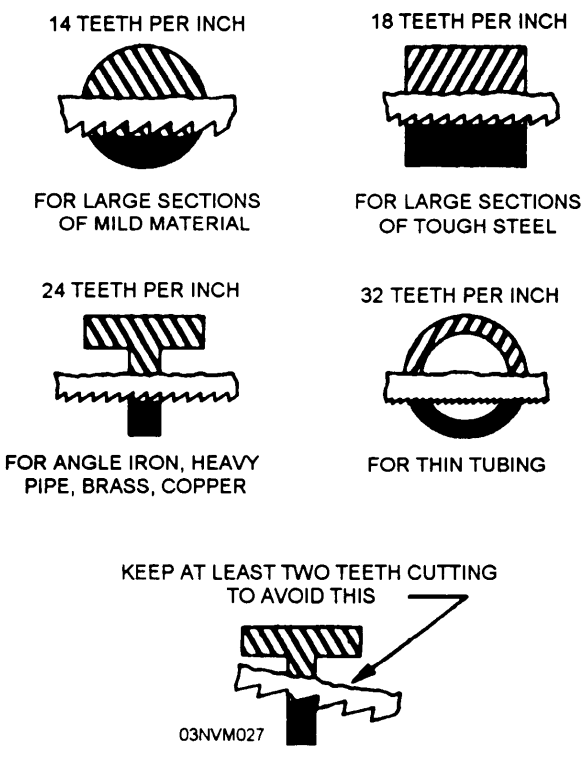


Figure 5-27.—Selecting the proper hacksaw blade.

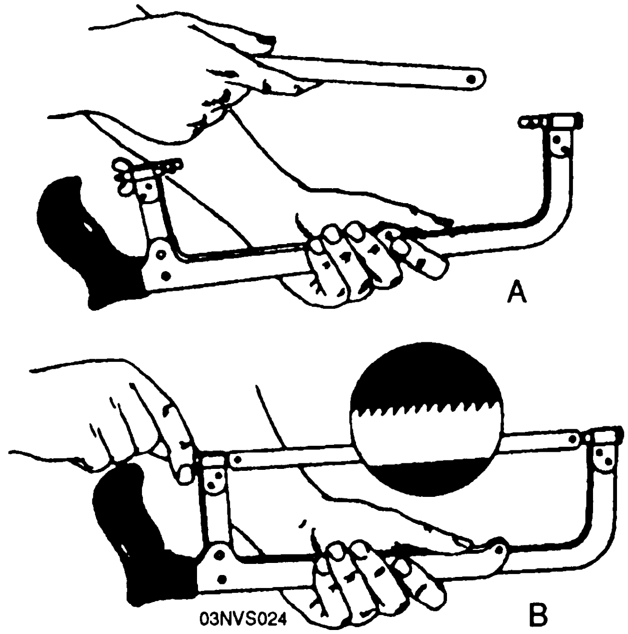


Figure 5-28.—Installing a hacksaw blade.

Place the material to be cut in a vise. A minimum of overhang will reduce vibration, give a better cut, and lengthen the life of the blade. Have the layout line outside of the vise jaw so that the line is visible while you work.

When cutting, apply pressure on the forward stroke, which is the cutting stroke, but not on the return stroke. From 40 to 50 strokes per minute is the usual speed. Long, slow, steady strokes are preferred.

For long cuts (fig. 5-29) rotate the blade in the frame so that the length of the cut is not limited by the depth of the frame. Hold the work with the layout line close to the vise jaws, raising the work in the vise as the sawing proceeds.

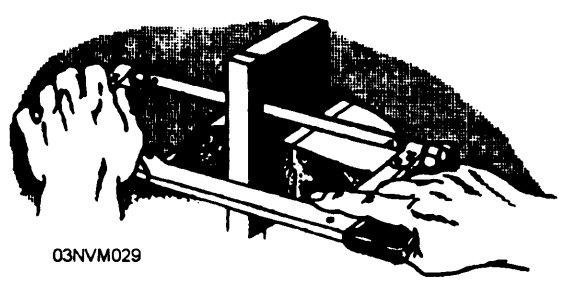


Figure 5-29.—Making a long cut near the edge of stock.

Saw thin metal as shown in figure 5-30. Notice the long angle at which the blade enters the saw groove (kerf). This permits several teeth to be cutting at the same time.

Metal that is too thin to be held, as shown in figure 5-31, can be placed between blocks of wood, as shown in figure 5-3 1. The wood provides support for several teeth as they are cutting. Without the wood, as shown in view B of figure 5-31, teeth will be broken due to excessive vibration of the stock and because individual teeth have to absorb the full power of the stroke.

Cut thin metal with layout lines on the face by using a piece of wood behind it (fig. 5-32). Hold the wood and the metal in the jaws of the vise, using a

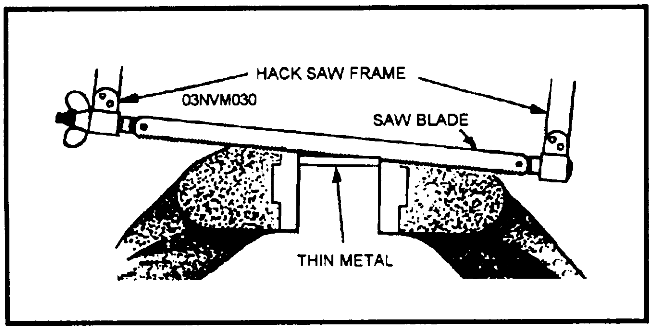


Figure 5-30.—Gutting thin metal with a hacksaw.

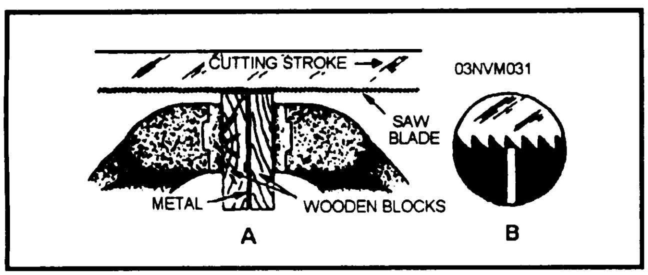


Figure 5-31.—Cutting thin metal between two wooden blocks.

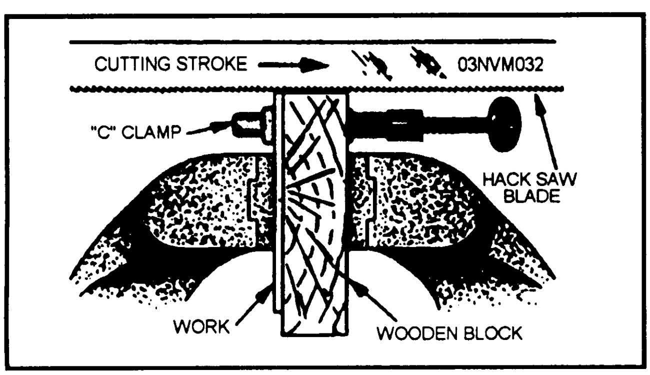


Figure 5-32.—Gutting thin metal using wood block with layout lines.

C-clamp when necessary. The wood block helps support the blade and produces a smoother cut. Using the wood only in back of the metal permits the layout lines to be seen.

Hacksaw Safety

The main danger in using hacksaws is injury to your hand if the blade breaks. The blade will break if too much pressure is applied, when the saw is twisted, when the cutting speed is too fast, or when the blade becomes loose in the frame. Additionally, if the work is not tight in the vise, it will sometimes slip, twisting the blade enough to break it.

PORTABLE POWER HANDTOOLS

You will be using portable power drills, hammers, and grinders in the shop and out on the job. You should be thoroughly familiar with the operation and care of these tools and with applicable safety precautions. Individual electrically powered hand tools are not covered in this chapter. However, it is important that you understand some important safety and operating procedures for these tools. Only the most common portable pneumatic power tools will be covered in this chapter.

Most portable power tools are driven by electricity. However, the portable power tools that you use may be powered by electric motors or by air (pneumatic) motors. Whether electric powered or air powered, the tools and the procedures for using them are basically the same. Maintenance information about portable power tools can be found in the equipment owner' s manual.

ELECTRICAL POWER TOOLS

Several safety and operating precautions must be observed when you use electrical tools. The most important of these relate to electrical shock. Electrical tools are made so all current-carrying parts, except filters, are insulated from housings and handles. The tools are laboratory tested to ensure they are safe to use when new. However, tool abuse (overload or dropping) could cause a short and you could receive an electrical shock. You can reduce the electrical shock hazard by ensuring that there is a grounding wire between the tool housing and a positive ground.

All electrically powered tools must have a three-wire cord and be double-insulated. All electrically powered hand tools are required to be stored in the electrical tool issue room so that they may be checked by an electrician prior to issue. Never use a portable electric tool that has not been electrically safety checked by shipboard electricians. Always follow approved checkout procedures for electrical tools. A 120-volt shock can kill you.

Many portable tool housings are made of special high-impact plastic that is resistant to damage. Plastic reduces the electrical shock hazard, but it does not prevent shock hazards completely. To eliminate this shock hazard when using electrically powered tools, you should wear approved electrical rubber gloves (issued with the tool by the electrician). These rubber gloves should be protected with a pair of leather gloves over them. Other safety precautions are listed as follows:

- When using an electric tool, make sure it is properly grounded. Use only three-wire grounded cords and plugs.
- When an extension cord must be used in addition to the cord on an electric tool, the extension cord must not be energized when the tool plug is inserted in or removed from the extension cord. Extension cords also must have three-wire cords and grounded plugs. Extension cords may only be 25 feet in length for shipboard use.
- All portable electrical tools and extension cords require a periodic safety check for shorts or grounds. The tool housing, cord, and plug should be checked for real or potential damage before each use.
- Ensure work is properly secured prior to operating portable equipment.

PNEUMATIC POWER TOOLS

This section deals with pneumatic drills and pneumatic grinders since these are probably the most widely used portable power tools. You will be required to maintain the portable pneumatic tools that you will be using.

Since pneumatic tools use compressed air, all low-pressure compressed air systems should have a filter, regulator, and lubricator assembly installed at the outlet. This assembly will ensure delivery of clean, regulated, mist-lubricated compressed air for the operation of pneumatic tools. The pressure must not exceed 90 psi for any pneumatic tool. **CAUTION:** Never point the air hose at another person.

Before operating a pneumatic drill, inspect the air hose and check for any leaks and damage. Blow air through the air hose to free it of foreign material before connecting it to the drill. Keep the air hoses clean and free from excessive amounts of lubricants.

The heavy duty pneumatic drill, shown in view A of figure 5-33, is reversible. Its speed can be closely controlled by the throttle valve located in the handle. The variable speed feature of this drill makes it particularly useful for heavy duty drilling in places that are hard to reach.

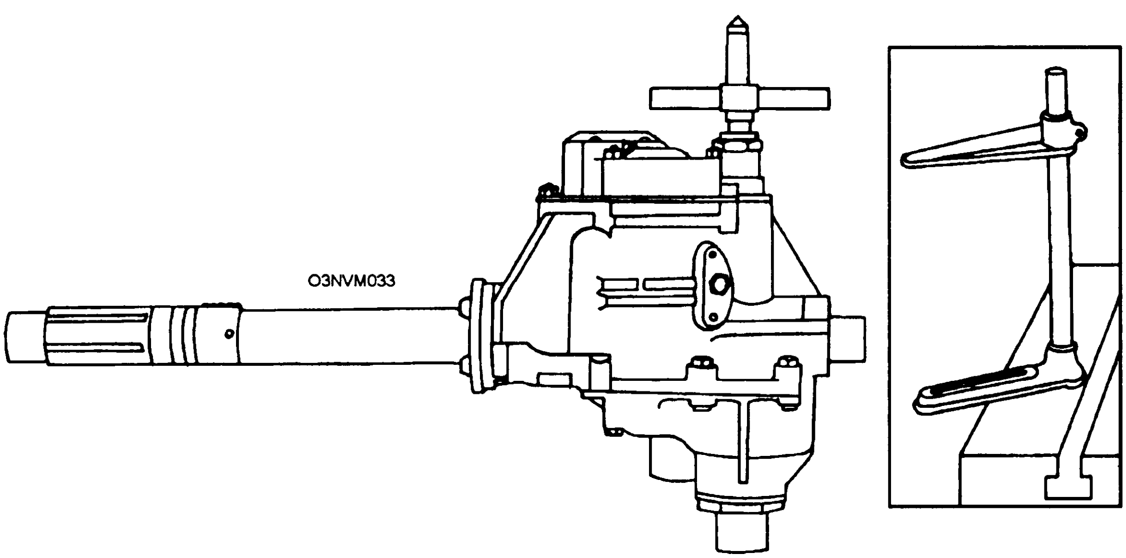


Figure 5-33.—Heavy duty pneumatic drill and stand.

Another feature of this drill is a feed screw that can be used with a special type of drill stand called an "old man." This drill stand is shown in view B of figure 5-33. To drill a hole using the "old man," first place the twist drill in the socket. Adjust the feed screw in the machine to its lowest position and place the point of the feed screw in one of the indentations in the arm. Drill the hole to the required depth. Watch the drill; when it begins to come through. decrease the speed. Hold the drill motor up by hand so that it will not drop onto the work.

The pneumatic grinder, shown in figure 5-34, operates on the same basic principle as the pneumatic drill. It can be equipped with either a grinding wheel or a wire bristle wheel. After attaching the appropriate wheel, perform the preliminary steps required to connect the pneumatic grinder. Always run this machine so that the grinding surface of the wheel is square with the surface of the material being ground. Do not grind soft nonferrous metals, such as aluminum or brass, on a wheel that is designed for carbon and alloy steels. A silicon carbide abrasive wheel is suitable for grinding soft nonferrous metals, nonmetallic materials, and cemented carbides. Make sure that the rpm rating on the wheel is greater than that of the grinder. If the rpm rating of the grinder is greater than the wheel, the wheel stands a good chance of shattering and causing personnel injury from flying particles.

In recent years, we have started using several new types of pneumatic tools that are used for the setting of rivets and fasteners. As a result, rivets and fasteners can now be set easier and faster. The tools shown in figure 5-35 are relatively easy to operate, and you need to remember only the few simple precautions described in the following paragraphs.

Pneumatic tools must have thorough lubrication. The moving parts of a pneumatic tool are very closely

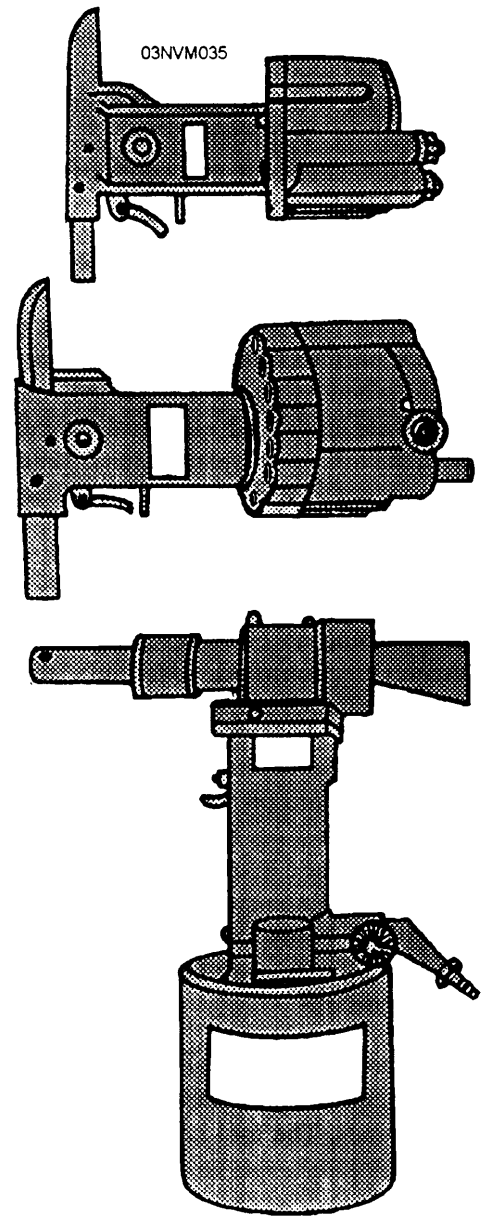


Figure 5-35.—Pneumatic rivet setting tools.

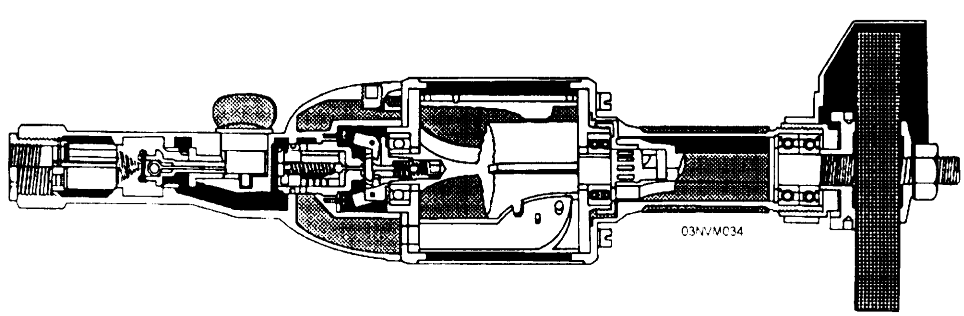


Figure 5-34.—Sectional view of a pneumatic grinder.

fitted. If proper lubrication is neglected, they wear rapidly and fail within a short time.

Valves and pistons on pneumatic hammers require a light machine oil. Since the compressed air comes directly in contact with these parts, it has a tendency to drive the lubricant out through the exhaust. Therefore, when working steadily with any pneumatic tool, you should regularly check the lubricator. Make certain there is plenty of lubricant, and empty the filter assembly when needed. On low-pressure compressed air systems that do not have the filter, regulator, and lubricator assembly, you should disconnect the air hose every hour or so and squirt a few drops of light oil into the air hose connection. Heavy oil will cause precision parts to clog up and fail. If this happens, you will have to clean your tool in cleaning solvent to loosen the gummy substance. Then blow out the tool with air, lubricate it with a light oil, and go back to work.

Keep your pneumatic tools clean and lubricated, and you will have fewer operating troubles.

When using portable pneumatic power tools, there are certain safety precautions that you must observe.

- Always wear your goggles and hearing protection when working with these tools.
- Take care not to allow any of these tools to run out of hand. The pneumatic grinder especially will want to "walk" away from the point you want to grind.
- Always stand so that your feet won't slip while you are working. Make sure that you are properly balanced.
- Apply the grinding wheel to the work with gentle pressure. Sudden forcing may cause the wheel to shatter. As you complete the work, ease up on the pressure.
- Be careful not to allow the air hose to become kinked.
- Pneumatic grinders and sanders turn at a high rpm. Use only the approved type of grinding wheel or disk. The maximum operating rpm is shown on the side of the wheel or disk. Remember the rpm rate of the wheel must be higher than the rpm rate of the grinder or sander. Using a wheel with a lower rpm rate than the tool can cause the wheel to shatter.

THREAD-CUTTING TOOLS

Internal threads are cut with taps and tap wrenches. External threads are cut with dies and die stocks. All threads are not alike. They must be designed, selected, and cut to fit the job. As an HT, you will be concerned with two types of threads: machine threads and pipe threads.

Dies and taps for cutting machine threads are now made according to three basic sets of standards: American National, American Standard, and Unified Thread Standard (also referred to as "the standard"). Knowing just what these standards are is important.

The AMERICAN NATIONAL standards were widely used for many years. There are two series of American National machine threads with which you will be concerned. These are the American National Fine (NF) and the American National Coarse (NC) series. The form of the thread is the same for both National Fine and National Coarse; the difference is in the pitch or number of threads to the inch.

The second set of standards for threads is the AMERICAN STANDARD. The American Standard threads for machine screws are based on the older American National Standard. The two sets of standards are not identical, but some of the American Standard threads are identified by the old American National designation. For example, the American Standard Fine series is designated by NF and the American Standard Coarse series by NC.

The third set of standards is the UNIFIED THREAD STANDARD. This standard was agreed to by the United States, Canada, and the United Kingdom in 1948. It is expected that the Unified Thread Standard will become the generally accepted standard for machine threads, replacing the American Standard and the American National.

Many of the machine threads using these three basic standards are interchangeable; they are either identical or very similar in general form. The major differences between the Unified Thread Standard and the earlier standards are in the application of allowances, the variation of tolerance with size, the amount of pitch diameter tolerance, and the designation of the threads. In general, the Unified Thread Standard provides more classes of fit than did the earlier standards.

Pipe taps and dies differ from machine taps and dies in that most pipe threads are tapered to provide an airtight and liquid-tight seal. Pipe diameters are measured as inside diameters; therefore, the wall thickness of the pipe must be taken into consideration. This means the pipe taps and dies are larger in diameter than the machine taps and dies. In other words, a 1/2-inch pipe tap or die is larger in diameter than a 1/2-inch machine tap or die.

The NPT, which formerly stood for National Pipe Thread, is still used as a carryover and now refers to the new name for the same thread, American Standard Taper Pipe Threads. The standard taper of pipe threads is three-fourths inch per foot. The number of threads per inch varies according to the size of pipe as follows:

- l/16- and 1/8-inch pipe have 27 threads per inch
- 1/4- and 3/8-inch pipe have 18 threads per inch
- 1/2- and 3/4-inch pipe have 14 threads per inch
- 1-, 1 1/4-, 1 1/2-, and 2-inch pipe have 11 1/2 threads per inch
- 2 1/2-inch pipe and pipe larger than 2 1/2 inches have 8 threads per inch

Hand pipe-threading tools are supplied by the Navy to cut external threads up to 4 inches and internal threads up to 4 inches. However, hand pipe-threading tools that will cut pipe up to 12 inches can be requisitioned through the supply department. Pipe over 3 inches in diameter is normally joined by oxyacetylene welding, arc welding, or by brazing with silver-base or copper-base alloys.

This section of the chapter contains instructions on how to select and use the taps and drills for the various standard thread sizes. You will also find a detailed explanation of how to use taper, plug, and bottoming taps, how to cut machine threads with taps and dies, and how to lubricate the work.

TAPS AND DIES

Taps and dies are used to cut threads in metal, plastics, or hard rubber. The taps are used for cutting internal threads, and the dies are used to cut external threads. There are many different types of taps. However, the most common are the taper, plug, bottoming, and pipe taps as shown in figure 5-36.

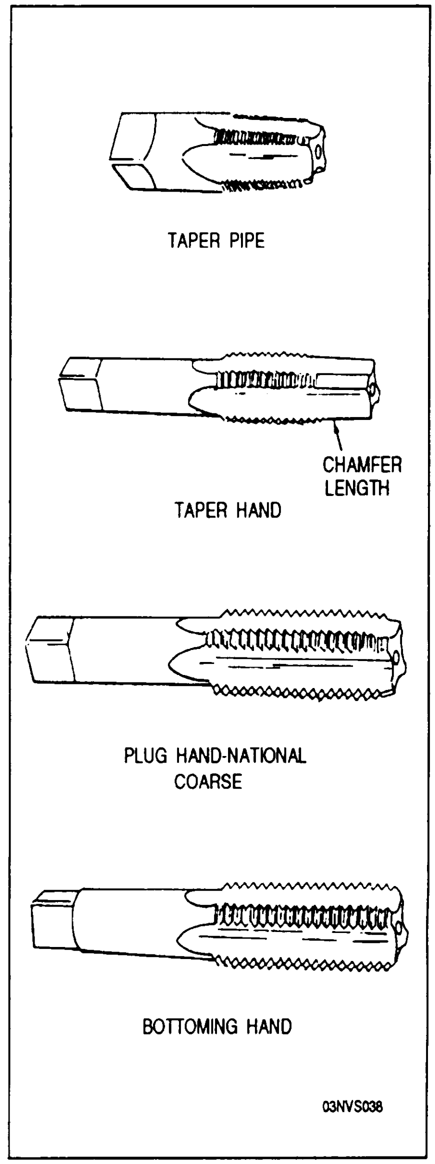


Figure 5-36.—Types of common taps.

The taper (starting) hand tap has a chamfer length of 8 to 10 threads. These taps are used when starting a tapping operation and when tapping through holes.

Plug hand taps have a chamfer length of 3 to 5 threads and are designed for use after the taper tap.

Bottoming hand taps are used for threading the bottom of a blind hole. They have a very short chamfer length of only 1 to 1 1/2 threads for this purpose. This tap is always used after the plug tap has already been used. Both the taper and plug taps should precede the use of the bottoming hand tap.

Pipe taps are used for pipe fittings and other places where extremely tight fits are necessary.

The tap diameter, from end to end of threaded portion, increases at the rate of 3/4 inch per foot. All the threads on this tap do the cutting, as compared to the straight taps where only the nonchamfered portion does the cutting.

Dies are made in several different shapes and are of the solid or adjustable type. The square pipe die (fig. 5-37) will cut American Pipe Thread only. It comes in a variety of sizes for cutting threads on pipe with diameters of 1/8 inch to 2 inches.

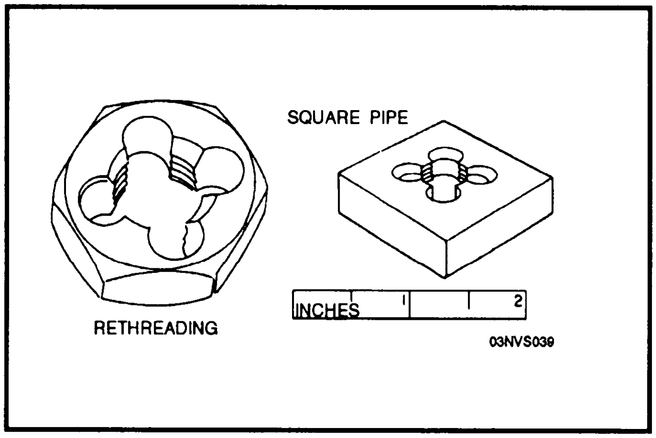


Figure 5-37.—Types of solid dies.

A rethreading die as shown (fig. 5-37) is used principally for dressing over bruised or rusty threads on screws or bolts. It is available in a variety of sizes for rethreading American Standard Coarse and Fine threads. These dies are usually hexagon in shape and can be turned with a socket, box, open-end, or any wrench that will fit. Rethreading dies are available in sets of 6, 10, 14, and 28 assorted sizes in a case.

Round split adjustable dies (fig. 5-38) are called "button" dies and can be used in either hand diestocks or machine holders. The adjustment in the screw-adjusting type is made by a fine-pitch screw that forces the sides of the die apart or allows them to spring together. The adjustment in the open adjusting types is made by three screws in the holder, one for expanding and two for compressing the dies. Round split adjustable dies are available in a variety of sizes to cut American Standard Coarse and Fine threads, special form threads, and the standard sizes of threads that are used in Britain and other European countries. For hand threading, these

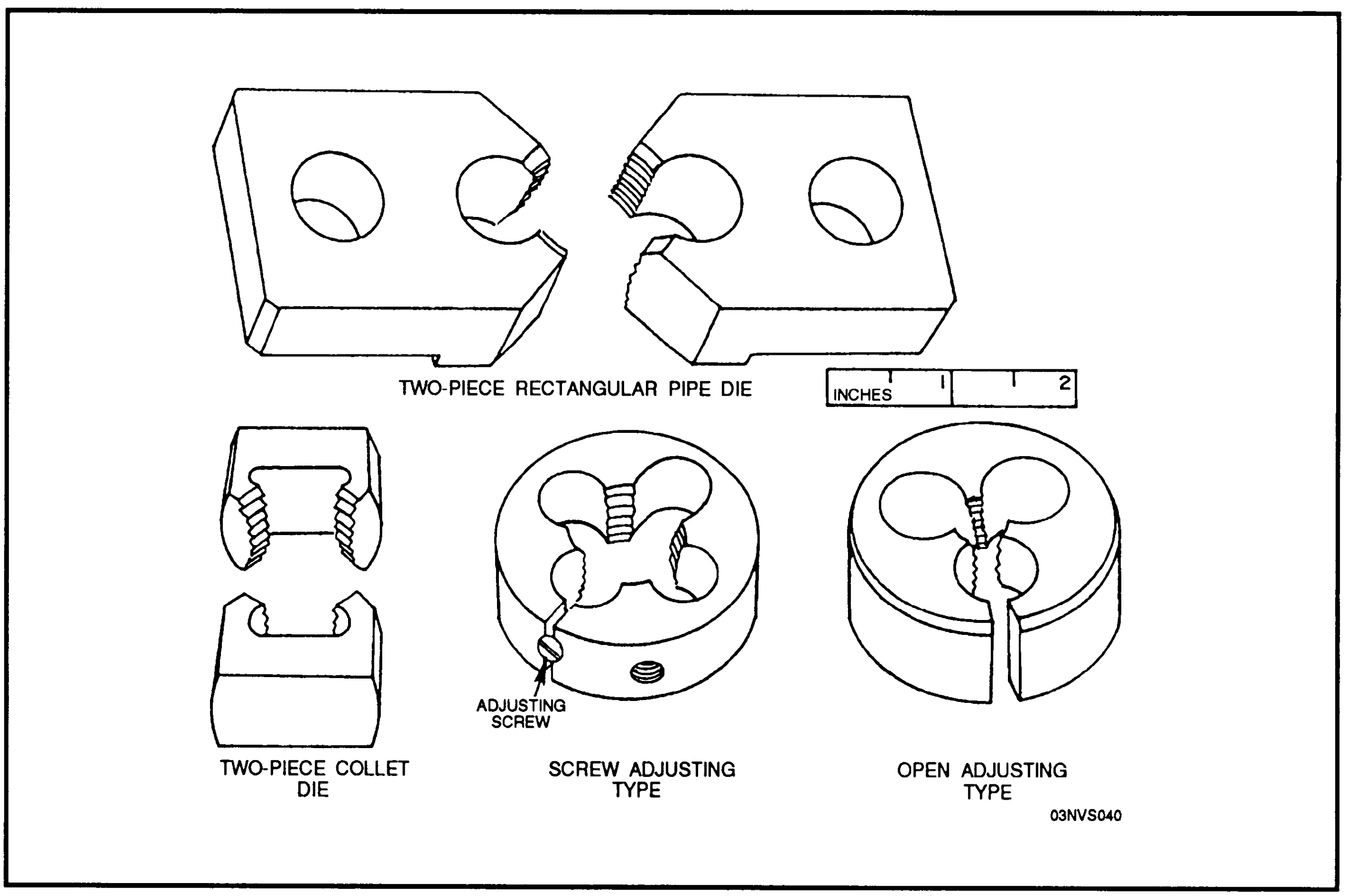


Figure 5-38.—Types of adjustable dies.

dies are held in diestocks, as shown in figure 5-39. One type of die stock has three pointed screws that will hold round dies of any construction, although it is made specifically for open adjusting-type dies.

Two-piece collet dies (fig. 5-38) are used with a collet cap (fig. 5-39) and collet guide. The die halves are placed in the cap slot and held in place by the guide that screws into the underside of the cap. The die is adjusted by setscrews at both ends of the internal slot. This type of adjustable die is issued in various sizes to cover the cutting range of American Standard Coarse, Fine, and special form threads. Diestocks to hold the dies come in three different sizes.

Two-piece rectangular pipe dies (fig. 5-38) are available to cut American Standard Pipe threads. They are held in ordinary or ratchet-type diestocks (fig. 5-40). The jaws of the dies are adjusted by setscrews. An adjustable guide keeps the pipe in alignment with respect to the dies. The smooth jaws of the guide are adjusted by a cam plate; a thumbscrew locks the jaws firmly in the desired position.

Threading sets are available in many different combinations of taps and dies, together with diestocks, tap wrenches, guides, and necessary screwdrivers and wrenches to loosen and tighten adjusting screws and

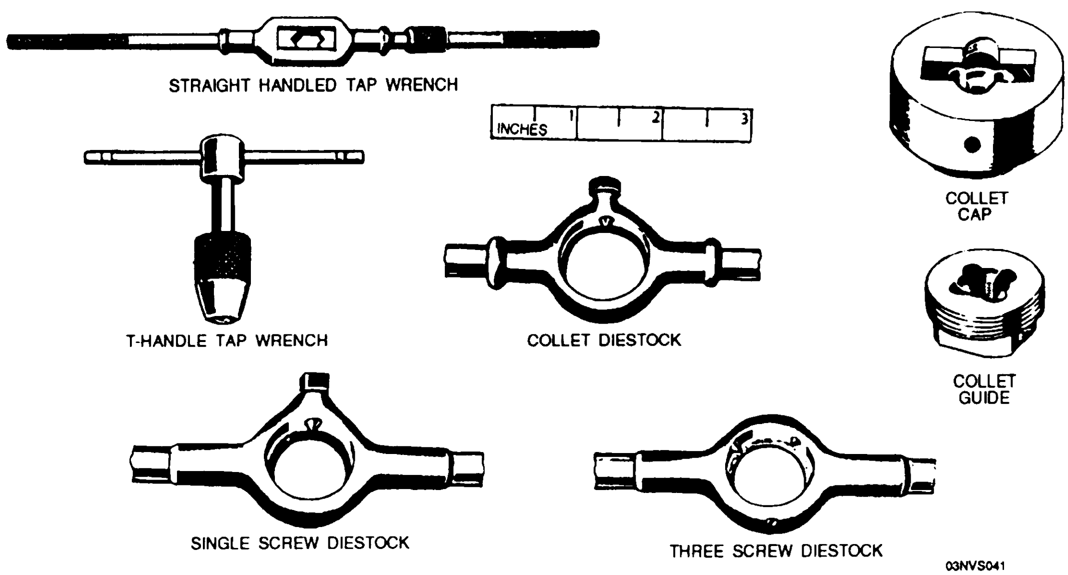


Figure 5-39.—Diestocks, diecollet, and tap wrenches.

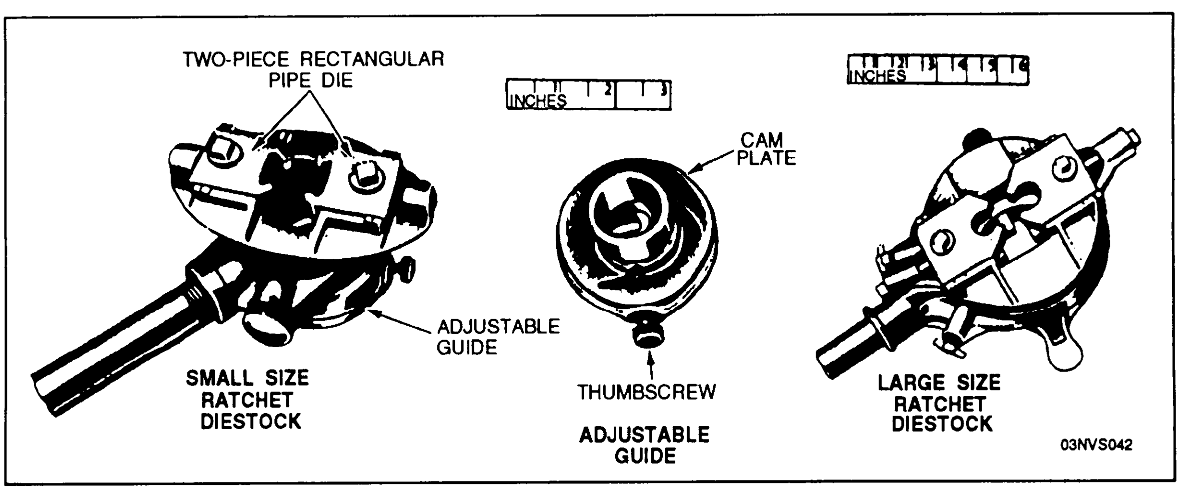


Figure 5-40.—Adjustable die guide and ratchet diestocks.

bolts. Figure 5-41 shows typical threading sets for pipe, bolts. and screws.

Never attempt to sharpen taps or dies. Sharpening of taps and dies involves several highly precise cutting processes, which involve the thread characteristics and chamfer. These sharpening procedures must be done by experienced personnel to maintain the accuracy and the cutting effectiveness of taps and dies.

Keep taps and dies clean and well oiled when not in use. Store them so that they do not contact each other or other tools. For long periods of storage, coat taps and dies with a rust preventive compound, place in individual or standard threading set boxes, and store in a dry place.

THREAD CHASERS

Thread chasers are threading tools that have several teeth and are used to rethread (chase) damaged external or internal threads, as shown in figure 5-42. These tools are available to chase standard threads. The internal thread chaser has its cutting teeth located on a side face. The external thread chaser has its cutting teeth on the end of the shaft. The handle end of the tool shaft tapers to a point.

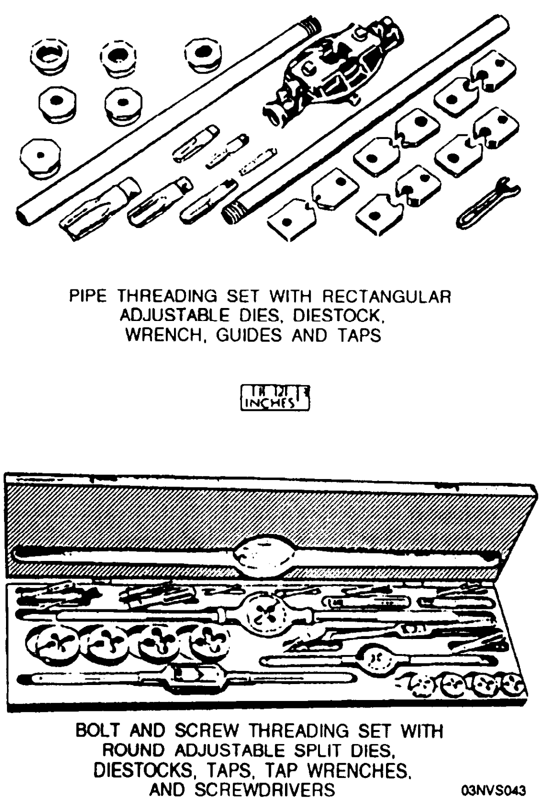


Figure 5-41.—Threading sets.

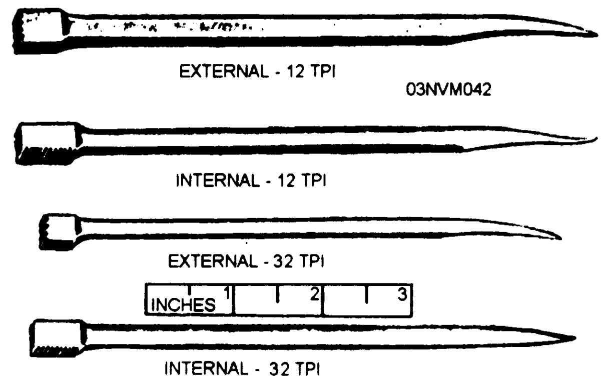


Figure 5-42.—Thread chasers.

THREADS AND THREAD CUTTING

Threads are helical ridges cut into screws, nuts, bolts, or the walls of a hole, so that the action of turning the screw, nut, or bolt gives it endwise as well as rotary motion. Many thread types exist. These types include bolt threads, machine screw threads, and pipe threads. Before we proceed with descriptions of thread-cutting procedures, we must become familiar with the terminology to be used.

Thread Terminology

Refer to figure 5-43 and note that the outside diameter of a thread is known as the MAJOR

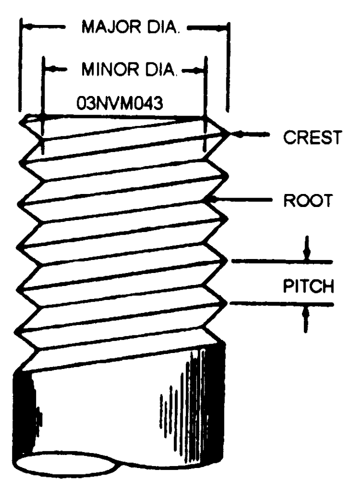


Figure 5-43.—Thread terminology.

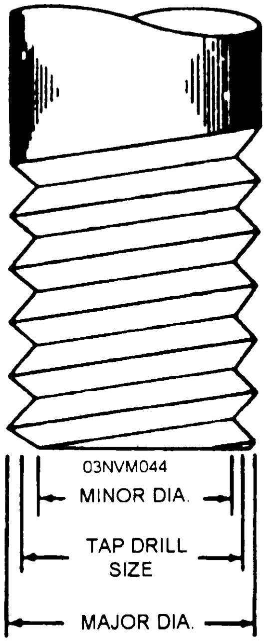


Figure 5-44.—Tap drill size determination.

DIAMETER. The diameter across the roots of the thread is called the MINOR DIAMETER. The PITCH is defined as the distance from any point on the thread of a screw to the corresponding point on an adjacent thread. It is usually measured from crest to crest and is expressed by a specific quantity of threads per inch.

Tap Drill Determination

If a threaded hole is to be made in a piece of metal, a hole of suitable size must first be drilled. The hole must be somewhat smaller than the size of the bolt to be screwed into it.

How do you determine how much smaller to drill this hole? Figure 5-44 shows the system used for figuring this. The resultant thread is known as a "75 percent thread" because the diameter of the hole is 75

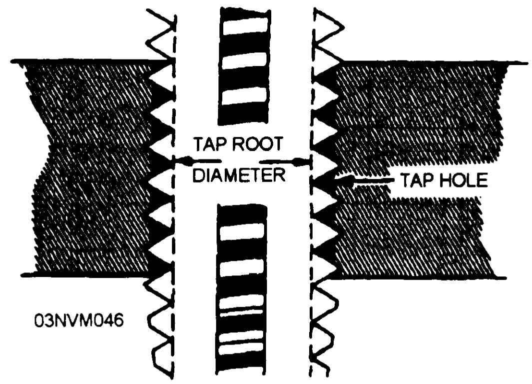


Figure 5-46.—Oversize drilled hole for tapping.

percent of the difference between the major and minor diameters, subtracted from the major diameter.

When the tap hole is the right size, it is a little larger than the root diameter of the tap, as shown in figure 5-45. The tap will cut a thread in the work which is only 75 percent as deep as the thread on the tap. The other 25 percent of the depth of thread on the tap provides clearance between the tap hole and the root diameter of the tap (see fig. 5-45). This makes tapping easier.

If the tap drill selected is oversize, the tap hole will be oversize, and the tap can cut only shallow threads in the work, as shown in figure 5-46. With less than a full 75 percent depth of thread, stud or capscrew threads usually strip.

If the tap drill selected is undersize, the tap hole will be undersize, being perhaps equal to the root diameter of the tap, as shown in figure 5-47. Then there will be no clearance, and the tap will turn hard, tear the threads, and probably break.

The best method to determine the exact size of tap drill to use is to refer to table 5-2. A chart similar to this generally is included with a set of taps and dies.

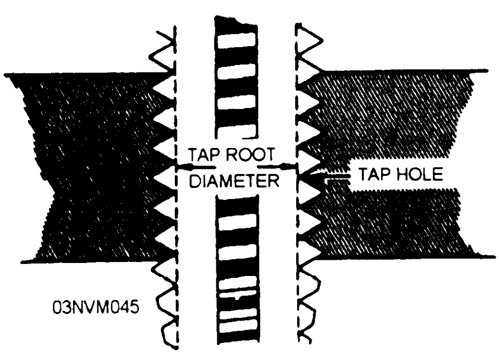


Figure 5-45.—Proper size drilled hole for tapping.

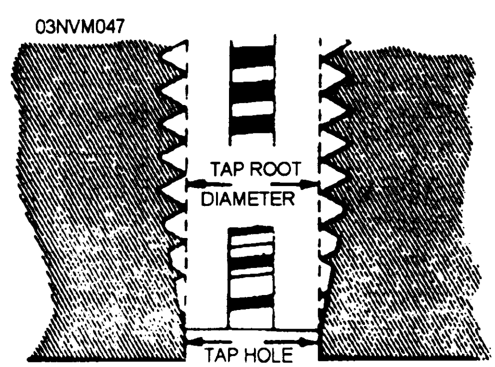


Figure 5-47.—Undersize drilled hole for tapping.

Table 5-2.—American National Form Threads

Nominal size	Thread Series	Major Diameter, inches	Root diameter, inches	Tap drill to produce approx. 75 % full thread	Decimal equivalent of tap drill
0–80	N. F.	.0600	.0438	3/64	.0469
1–64	N. C.	.0730	.0527	53	.0595
72	N. F.	.0730	.0550	53	.0595
2–56	N. C.	.0860	.0628	50	.0700
64	N. F.	.0860	.0657	50	.0700
3–18	N. C.	.0990	.0719	47	.0785
56	N. F.	.0990	.0758	45	.0820
4–10	N. C.	.1120	.0795	43	.0890
48	N. F.	.1120	.0849	42	.0935
5–40	N. C.	.1250	.0925	38	.1015
44	N. F.	.1250	.0955	37	1040
6–32	N. C.	.1380	.0974	36	.1065
40	N. F.	.1380	.1055	33	.1130
8–32	N. C.	.1640	.1234	29	.1360
36	N. F.	.1640	.1279	29	.1360
10–24	N. C.	.1900	.1359	25	.1495
32	N. F.	.1900	.1494	21	.1590
12–24	N. C.	.2160	.1619	16	.1770
28	N. F.	.2160	.1696	14	.1820
1/4–20	N. C.	.2500	.1850	7	.2010
28	N. F.	.2500	.2036	3	.2130
5/16–18	N. C.	.3125	.2403	F	.2570
24	N. F.	.3125	.2584	I	.2720
3/8–16	N. C.	.3750	.2938	5/16	.3125
24	N. F.	.3750	.3209	Q	.3320
7/16–14	N. C.	.4375	.3447	U	.3680
20	N. F.	.4375	.3726	25/64	.3906
1/2–13	N. C.	.5000	.4001	27/64	.4219
20	N. F.	.5000	.4351	29/64	.4531
9/16–12	N. C.	.5625	.4542	31/64	.4844
18	N. F.	.5625	.4903	33/64	.5156
5/8–11	N. C.	.6250	.5069	17/32	.5312
18	N. F.	.6250	.5528	27/64	.5781
3/4–10	N. C.	.7500	.6201	21/32	.6562
16	N. F.	.7500	.6688	11/16	.6875
7/8–9	N. C.	.8750	.7307	49/64	.7656
14	N. F.	.8750	.7822	13/16	.8125
1–8	N. C.	1.0000	.8376	7/8	.8750
14	N. F.	1.0000	.9072	15/16	.9375

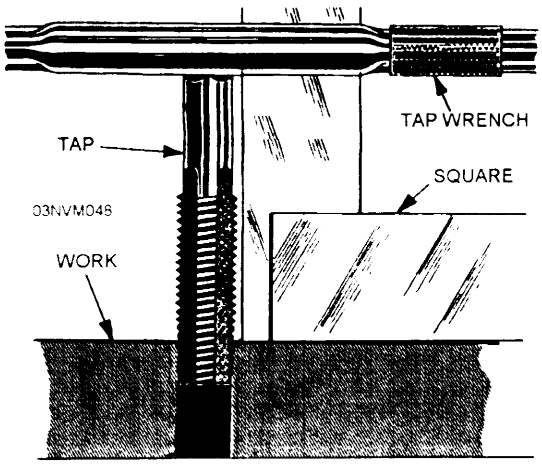


Figure 5-48.—Using a square to ascertain a tap is square with the work.

Cutting Machine Threads With Taps

Mineral lard oil, applied with a small brush, is highly recommended as a lubricant when tapping in steel. When using this lubricant, tighten the tap in the tap wrench and apply the lubricant to the tap. Start the tap carefully with its axis on the center line of the hole. The tap must be square with the surface of the work, as shown in figure 5-48.

To continue tapping, turn the tap forward two quarter turns, back it up a quarter turn to break the chips, and then turn forward again to take up the slack. Continue this sequence until the required threads are cut. After you cut for the first 2 or 3 full turns, you no longer have to exert downward pressure on the wrench. You can tell by the feel that the tap is cutting as you turn it. Don't permit chips to clog the flutes or they will prevent the tap from turning. When the tap won’t turn and you notice a springy feeling, stop trying

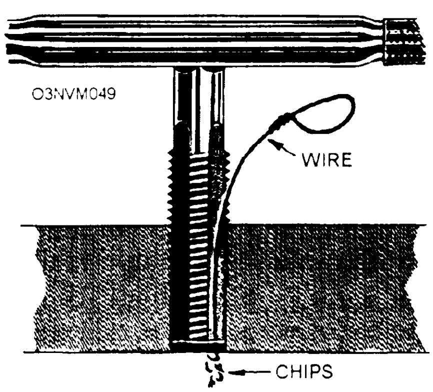


Figure 5-49.—Using a wire to clear chips from the flute of a tap.

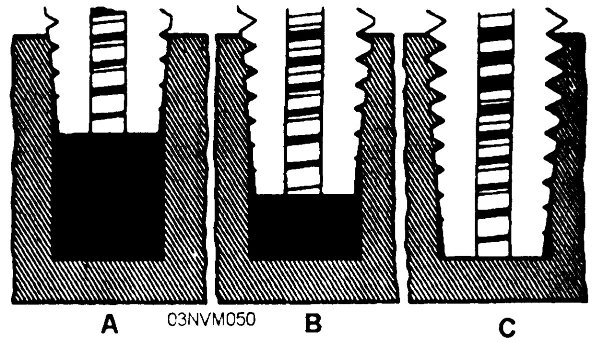


Figure 5-50.—Tapping a blind hole with a taper tap.

immediately. Back the tap up a quarter turn to break the chips, clean them out of the flutes with a wire (as shown in fig. 5-49), add some more lubricant, and continue tapping. When the tap has cut threads through the hole, the tap will turn with no resistance.

To tap a blind hole, start with the taper tap. For a blind hole you will need all three types—the taper, plug, and bottoming taps. Be sure they are the size and thread series you need, and that the tap hole is the size called for by the working drawing and table 5-2.

Begin with the taper tap. Handle it as described earlier. Figure 5-50, view A, shows the taper tap just starting to cut. In figure 5-50, view B, it has cut a little farther. In figure 5-50, view C, it has bottomed in the hole after having cut several full threads near the top of the hole. This completes the work to be done with the taper tap.

In figure 5-51, view A, the plug tap has entered the few full threads cut by the taper tap. In figure 5-51, view B, it has continued these threads a little farther down into the hole. In figure 5-51, view C, it has bottomed in the hole. This is all the work that you can do with the plug tap. It has cut full threads about halfway down the tap hole before bottoming.

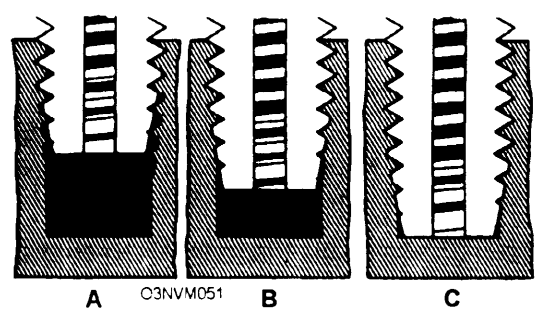


Figure 5-51.—Tapping a blind hole with a plug tap.

In figure 5-52, the bottoming tap has been substituted for the plug tap. In figure 5-52, view A, it has been run down the full threads cut by the plug tap and is ready to cut more full threads. In figure 5-52, view B, it has cut a few more threads, and in figure 5-52, view C, it has bottomed in the hole. The blind hole has now been completely tapped.

Because these threads are being tapped in a blind hole, you must remove chips differently. To remove chips, back the tap completely out of the hole very frequently, invert the stock, if possible, and jar out the chips or work them out of the hole with a wire while the stock is in the inverted position.

Chip removal in tapping blind holes is much more difficult to do and is very important because chips will fal1 ahead of the tap through the flutes and accumulate in the bottom of the blind hole. Until these chips are removed, none of the three taps can complete its work. In tapping blind holes, alternate with tapping and chip removal until each of the three taps bottom in the blind hole.

When you have finished using the three taps, brush the chips out of their teeth, oil them well with lubricating oil, wipe off the surplus oil, and replace them in the threading set.

INSTALLED MACHINE TOOLS

The Navy furnishes modern equipment to help you perform your duties. This section introduces you to some of the most common machine tools found in workshops that you should be familiar with. A machine tool is a power-driven machine that holds the material and cutting tool and brings them together so the material is drilled, cut, shaved, or ground.

The machine tools described in this chapter are found in most well-equipped shops. Other machine tools for specific types of work will be described in their appropriate chapter of this training manual.

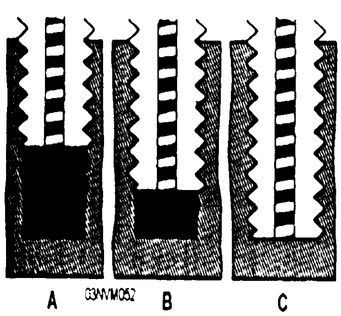


Figure 5-52.—Finish tapping a blind hole with a bottoming tap.

SAFETY PRECAUTIONS

Before using any machine tool, you must be familiar with all safety precautions pertaining to its operation. Carelessness around any moving machinery is extremely dangerous. When moving machinery is equipped with sharp cutting tools, the dangers are greatly increased. The following list includes some of the more general safety precautions for machine tools. Specific safety precautions should be posted in plain sight by every machine.

- Do not lean against any machine that is in motion. Keep clear of all gears, belts, and other moving parts. Never remove the guards from any part of an operating machine.
- Never start a machine unless you are thoroughly familiar with its operation.
- Do not attempt to clean, adjust, or repair a machine while it is in motion. NEVER attempt to clean running gears.
- PROTECT YOUR EYES. Do not hold your head too close to the cutting tool. Flying bits of metal or scale may get into your eyes. Always wear goggles when there is any danger of flying particles getting in your eyes—for example, when using a grinding or drilling machine.
- PROTECT YOUR HEARING. Always wear appropriate hearing protection. Either audio headsets or ear plugs will filter the noise from running machinery. Prolonged exposure may damage your hearing.
- Keep your fingers away from the cutting edges when the machine is in operation. Otherwise, you could lose some fingers.
- Do not wear gloves or loosely hanging clothes. They can be caught by moving parts of the shop machinery and cause serious injuries. Keep your sleeves rolled up tightly above the elbows. Do not wear neckties or loose neckerchiefs.
- In all machine work, stress SAFETY first, ACCURACY second, and SPEED last. Excessive speed is both dangerous and inefficient.

METAL-CUTTING SAWS

Metal-cutting saws are standard equipment in repair facilities. They are used for nonprecision cutting of

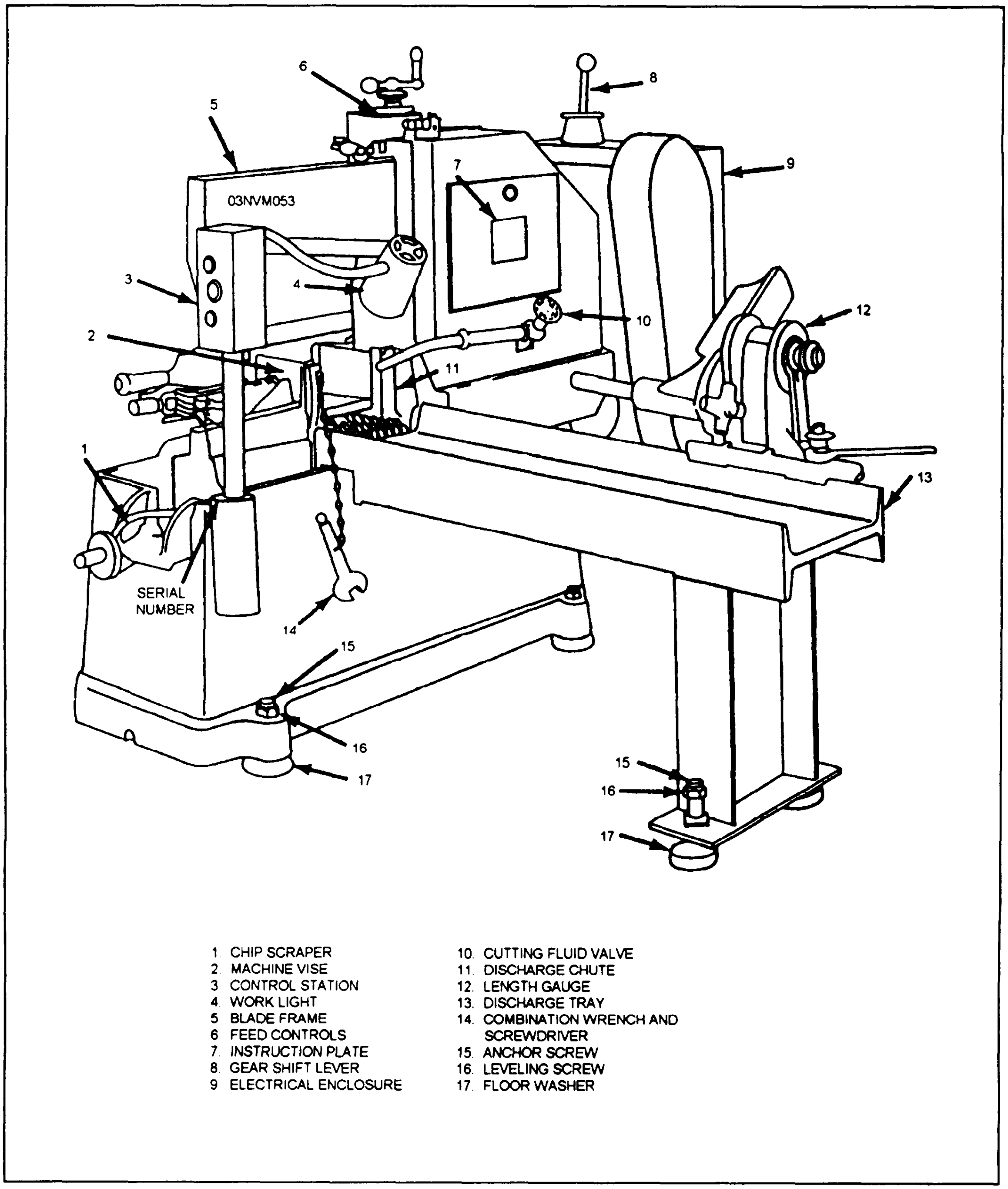


Figure 5-53.—Power hacksaw.

various metals and can cut any reasonable size or shape. In the pipe shop, bandsaws are used to cut pipe and tubing for various types and sizes at different angles. In the shipfitter shop, metal-cutting saws are used to cut angle iron, pipe, zincs, bar stock, and numerous other stock. In the carpenter shop, saws are used to cut wooden patterns, miter frames, stock, and for other similar applications. Metal-cutting saws can cut brass, bronze, aluminum, Monel, and thin sections of carbon steel casting and other types of metals.

Since the metal-cutting saw cuts materials of varying thickness, toughness, and hardness, you must select the proper blade for each job. Blade design and uses are presented later in this chapter to help you understand the differences in blades.

POWER HACKSAWS

The power hacksaw (fig. 5-53) is found in all except the smallest shops. It is used to cut bar stock, pipe, tubing, or other metal stock. It consists of a base, a mechanism for causing the saw frame to reciprocate, and a clamping vise for holding the stock while it is being sawed. There are two types of power hacksaws: the direct mechanical drive and the hydraulic drive.

The power hacksaw shown in figure 5-53 has a capacity of 4" × 4". This means it can handle material up to 4 inches wide and 4 inches high.

A power hacksaw will have one of three typos of feed mechanisms:

- Mechanical feed, which ranges from 0.001 to 0.025 inch per stroke, depending upon the class and type of material being cut
- Hydraulic feed, which normally exerts a constant pressure, but is designed so that the feed stops automatically at hard spots to decrease the pressure on the saw until the hard spot has been cut through.
- Gravity feed, in which weights are placed on the saw frame and shifted to give more or less pressure of the saw blade against the material being cut.

All three types of feed mechanisms lift the blade clear of the work during the return stroke.

Hacksaw Blades

The blade shown in figure 5-54 is especially designed for use with the power hacksaw. It is made with a tough alloy steel back and high-speed steel teeth. This combination gives both a strong blade and a cutting edge suitable for high-speed sawing.

These blades vary as to the pitch of the teeth (number of teeth per inch). The correct pitch for a particular job is determined by the size and material composition of the section and the material to be cut. Use coarse pitch teeth for wide, heavy sections to provide ample chip clearance. For thinner sections, use a blade with a pitch that will keep two or more teeth in contact with the work so that the teeth will not straddle the work and strip the teeth. In general, you should select blades according to the following information:

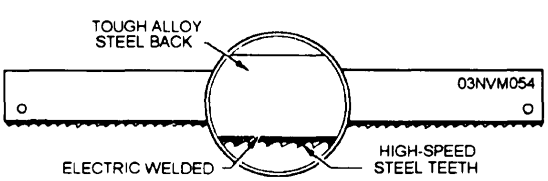


Figure 5-54.—Power hacksaw blade.

- Coarse (4 teeth per inch) for soft steel, cast iron, and bronze
- Regular (6 to 8 teeth per inch) for annealed high-carbon steel and high-speed steel
- Medium (10 teeth per inch) for solid brass stock, iron pipe, and heavy tubing
- Fine (14 teeth per inch) for thin tubing and sheet metals

speeds

Speed for hacksaws is stated in strokes-per-minute, counting only those strokes that cause the blade to make a cut on the stock are counted. A gear shift lever is used to change speeds. There may be a card attached to or near the saw giving recommended speeds for cutting various metals. However, you may use the following speeds:

— Cold-rolled or machine steel, brass, and soft metals—136 strokes per minute.

— Alloy steel, annealed tool steel, and cast iron—90 strokes per minute.

— High-speed steel, unannealed tool steel, and stainless steel—60 strokes per minute.

Coolants

You should use a coolant for most power hacksawing operations. (Cast iron should be dry when it is cut.) The coolant prevents overheating of the blade and stock along with increasing the cutting rate. A soluble oil solution with a mixture of the oil and water will be suitable for most sawing operations. The normal mixture for soluble oil is 40 parts water to 1 part oil. You also may use a synthetic coolant.

METAL-CUTTING BANDSAW MACHINES

Metal-cutting bandsaw machines are standard equipment on all repair ships and tenders. These machines can be used for nonprecision cutting similar to that performed by power hacksaws. Some types can also be used for precision cutting, filing, and polishing. A bandsaw machine is more flexible for straight cutting than a power hacksaw in that it can cut objects of any reasonable size and of regular and irregular shapes. A power hacksaw has a more limited capacity; it can only cut pieces with regular shapes. Also, the bandsaw cuts much faster than the hacksaw because the cutting action of the blade is continuous.

Figure 5-55 shows a tiltable blade bandsaw. The blade may be set either upright or at any angle up to 45 degrees from the vertical. The work is held stationary in a vise and the blade is moved into the work.

Figure 5-56 shows a tiltable table bandsaw. On the type shown, you should feed work either manually or by power to the blade, which runs in a fixed position. During recent years, the tiltable table bandsaw has been installed in most repair shops on repair ships and tenders.

A third type of bandsaw is designed for heavier work and has neither a tiltable blade nor a tiltable table. You will find this type on some ships.

Many of the new models, such as the one shown in figure 5-56, also have a job selector mounted on the machine. The names of various materials are inscribed on the outer ring of the selector. This ring is movable and can be positioned so that the name of any specific material can be brought into alignment with the window slot at the bottom of the dial. The numbers or letters that appear in the window, read in conjuction with stationary entries on the dial face, give the correct saw pitch, set and temper, saw velocity, and power feed pressure needed to cut that particular material.

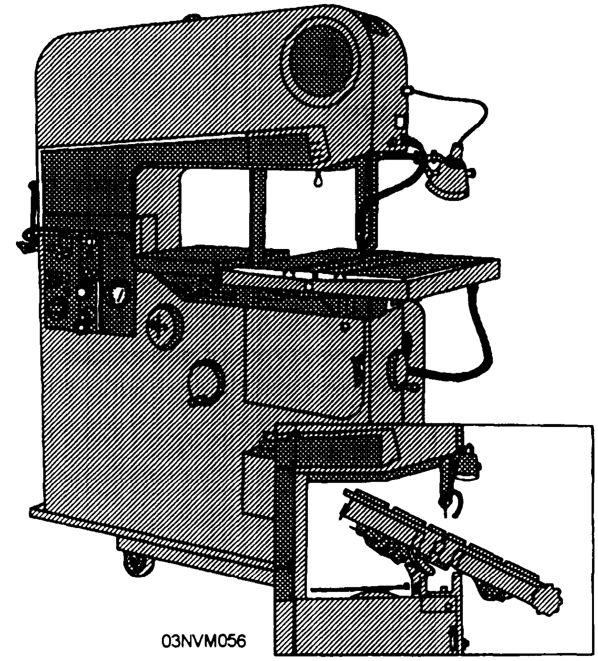


Figure 5-56.—Tiltable table-type (contour) metal-cutting bandsaw.

Another type of metal-cutting bandsaw is shown in figure 5-57. This horizontal band cutoff saw is being used in shops on some ships to replace the reciprocating-type power hacksaw. The continuous cutting action of the blade provides greater speed, accuracy, and versatility.

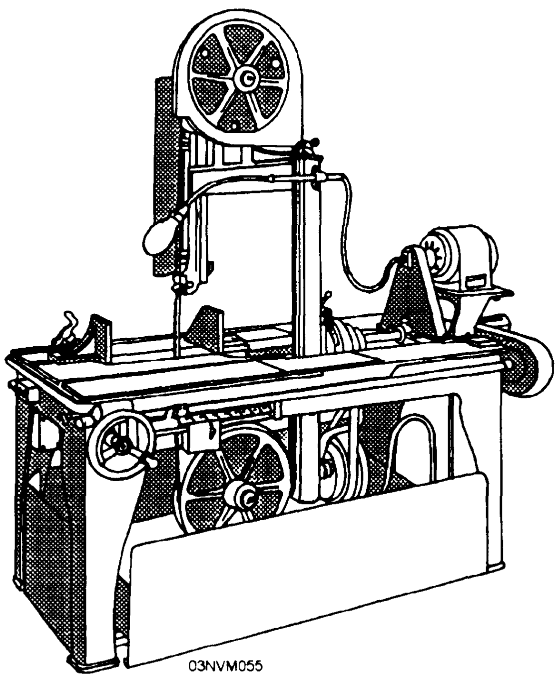


Figure 5-55.—Tiltable blade metal-cutting bandsaw.

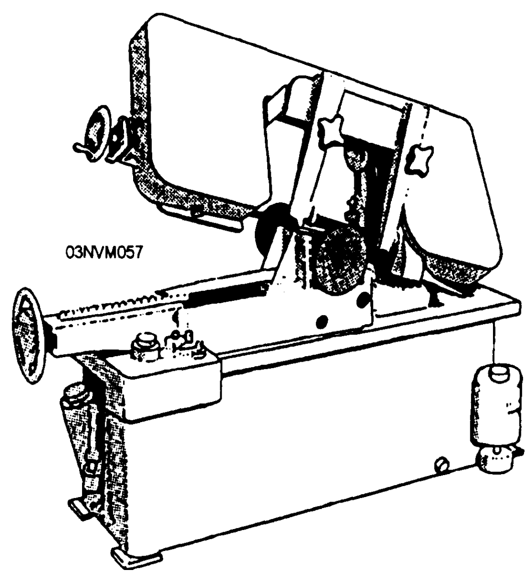


Figure 5-57.—Horizontal band cutoff saw.

Good results from the use of any metal-cutting bandsaw depends upon the careful choice of a blade. Tooth pitch should be considered in relation to the hardness and toughness of the material being worked, and the thickness of the workpiece. At least two teeth should be in contact with the work at all times during the cutting operation. When you cut thick material, select a tooth pitch that allows the smallest possible number of teeth to be in contact with the material. More teeth in contact means that a greater feed pressure is required to force them into the material. Excessive feed pressure will cause the cut to be off the mark.

Saw Bands

A saw band has the following characteristics, which are illustrated in figure 5-58.

PITCH: The number of teeth per linear inch. Every saw blade has a specific even number of teeth per linear inch. Normally this is from 6 to 32 teeth per inch of blade.

WIDTH: The distance across the flat surface of the saw band (back to the tip of the tooth). The width measurement is always expressed in inches or fractions of an inch. Blades are available in widths up to 1 inch.

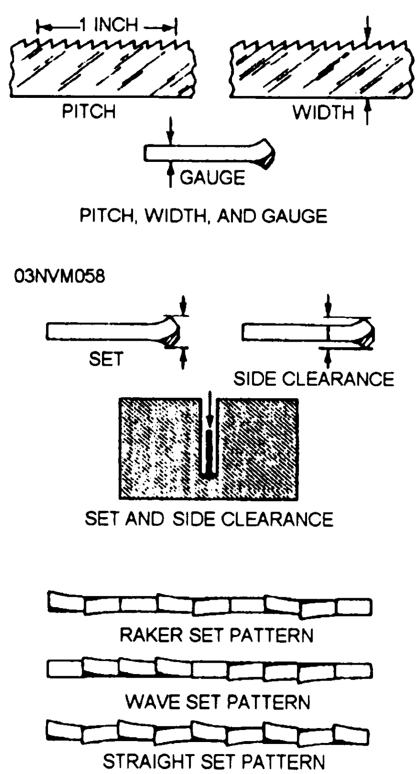


Figure 5-58.—Saw band characteristics.

GAUGE: The thickness of a blade. This measurement is expressed in thousandths of an inch. Saw bands come in three gauges—0.025, 0.032, and 0.035 inch.

SET: The bend or spread given to the teeth to provide clearance for the body of the blade when you make a cut.

SIDE CLEARANCE: The difference between the dimension of the gauge of the blade and the set of the teeth. Side clearance provides running room for the body of the blade in the kerf or cut. Without side clearance, the saw band will bind in the kerf.

SET PATTERN: One of three distinct patterns (raker, wave, and straight) in which teeth are set. The raker set pattern is used to cut solid cross-section work. The wave set pattern is used to cut hollow materials, such as pipes and tubing. The straight set pattern is not used to any great extent to cut metal.

TEMPER: The degree of hardness of the teeth, indicated by the letters *A* and *B*, with temper A being the harder. The A or B designation will only be found on the container the blade was shipped in. Temper A saw blades are used for practically all bandsaw metal-cutting work.

GRINDERS

Grinders are simple machines that allow you to reshape, form, and sharpen metal-cutting tools, or other tools. The type of grinder discussed in this chapter is the pedestal grinder.

The main parts of a pedestal grinder are as follows:

- A motor with an extended shaft for mounting grinding wheels.
- A mounting base for the motor.
- An adjustable tool rest for steadying the work piece for grinding.
- Wheel guards mounted over the grinding wheel as a safety feature.
- A shield fastened to the wheel guards to protect the operator from flying chips

The pedestal grinder is one of the most common and versatile machine found in most shops. You will probably use this piece of equipment more than any other piece of equipment found in your shop. You will use it to clean welds, remove burrs, sharpen tools, dress up torch cuts, buff sheet metal, and for numerous other functions. Not only must you be able to use a pedestal grinder, but you also must observe all important operating and safety precautions.

Grinding Safety

The grinding wheel is a fragile cutting tool that operates at high speeds. Therefore, the safe operation of pedestal grinders is as important as proper grinding techniques. Observance of posted safety precautions is mandatory for the safety of the operator and the safety of personnel in the nearby vicinity.

What are the most common sources of injury during grinding operations? Hazards leading to eye injury caused by grit generated by the grinding process are the most common and the most serious. Abrasions caused by bodily contact with the wheel are quite painful and can be serious. Cuts and bruises caused by segments of an exploded wheel, or a tool "kicked" away from the wheel are other sources of injury. Cuts and abrasions can become infected if not protected from grit and dust from grinding.

Safety in using pedestal grinders is primarily a matter of using common sense concentrating on the job at hand. Each time you start to grind a tool, stop briefly to consider how observance of safety precautions and the use of safeguards protect you from injury. Consider the complications that could be caused by your loss of sight, or loss or mutilation of an arm or hand.

The following operating instructions and safety precautions are applicable in general to all grinders and specifically to the pedestal grinders.

— Read posted safety precautions before you start to use a machine. In addition to refreshing your memory about safe grinding practices, this gets your mind on the job at hand.

— Secure all loose clothing and remove rings or other jewelry.

— Inspect the grinding wheel, wheel guards, the tool rest, and other safety devices to ensure they are in good condition and positioned properly. Set the tool rest so that it is within 1/8 inch of the wheel face and level with the center of the wheel.

— Use light pressure when you start grinding; too much pressure on a cold wheel may cause failure.

— Grind only on the face or outer circumference of a grinding wheel unless the wheel is specifically designed for side grinding.

— Use a coolant to prevent overheating the work.

— Wear goggles and respiratory filters to protect your eyes and lungs from injury by grit and dust generated by grinding operations.

— Transparent shields, if installed, should be clean and properly adjusted. Transparent shields do not preclude the use of goggles as the dust and grit may get around a shield. Goggles, however, provide full eye protection.

— When starting a grinder, push the start button and stand to one side for at least 1 minute while the machine comes up to full speed. There is always a possibility that a wheel may shatter when coming up to speed.

— Never force work against a cold wheel. Apply work gradually to give the wheel an opportunity to warm. This will minimize the possibility of breakage.

— Handle wheels carefully. Before replacing a wheel on a grinder, always sound the new wheel for cracks. To sound a wheel, tap it lightly with a piece of hard wood. A good wheel gives out a clear ringing sound, and a cracked wheel gives out a dull "thud." Make sure that a fiber or rubber gasket is in place between each side of the wheel and its retaining washer (spindle wheel flange). Tighten the spindle nut just enough to hold the wheel firmly. If the nut is tightened too much, the clamping strain may damage the wheel.

— When selecting a replacement wheel, check to be sure that the grinder rpm will not exceed the manufacturer's recommended speed for the wheel.

— When grinding, always keep the work moving across the face of the wheel. This will prevent grooves from being worn into the face of the wheel.

— Keep all wheel guards tight and in place.

— Keep the spindle bearings well oiled.

— Dress wheels frequently to keep them clean, sharp, and true, but do not remove any more material than necessary.

— Keep the tool rest adjusted so that it just clears the wheel (never more than one-sixteenth inch) and is at or just below the center line of the wheel. This will prevent accidental jamming of the work between the toolrest and the wheel.

— Do not wear gloves when operating a pedestal grinder.

— If a lot of metal is to be removed, use the coarse wheel to remove most of it.

— Use a gauge, template, or a sample for comparison, unless you are familiar with the exact finished shape of the article you are grinding.

Grinding Wheels

A grinding wheel is made up of two basic elements: (1) the abrasive grains and (2) the bending agent. The abrasive grains may be compared to many single-point tools embedded in a toolholder of bonding agent. Each of these grains removes a very small chip from the material as it makes contact on each revolution of the grinding wheel.

An ideal cutting tool is one that will sharpen itself when it becomes dull. This, in effect, is what happens to the abrasive grains. As the individual grains become dull, the pressure that is generated on them causes them to fracture and present new sharp cutting edges to the work. When the grains can fracture no more, the pressure becomes too great and they are released from the bond, allowing a new layer of sharp grains to be presented to the work.

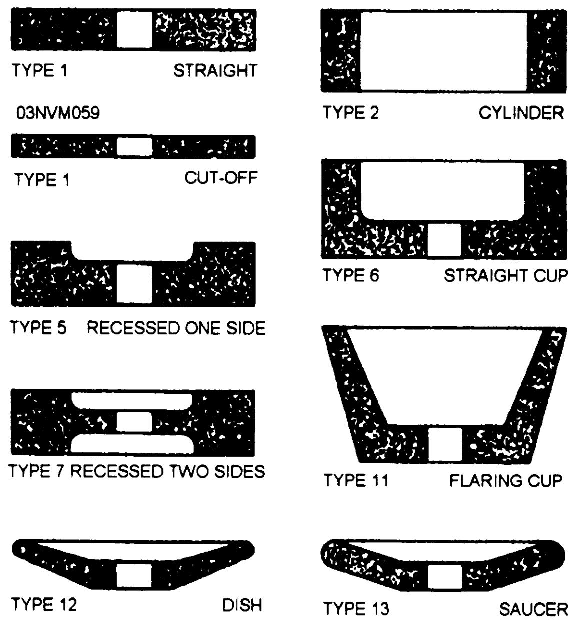


Figure 5-59.—Grinding wheel shapes.

SIZES AND SHAPES.—Grinding wheels come in various sizes and shapes. The size of a grinding wheel is given in terms of its diameter in inches, the diameter of its spindle hole, and the width of its face. Grinding wheels have too many shapes to list in this manual, however, figure 5-59 shows those used most often. The type numbers are standard and are used by all manufacturers. The shapes are shown in cross-sectional views. The specific job will dictate the shape of wheel you should use.

WHEEL MARKINGS AND COMPOSITION.—Grinding wheel markings are comprised of six sections, each of which identifies a characteristic of the wheel. The six sections are (1) type of abrasive, (2) grain size, (3) bond grade, (4) structure, (5) type of bond, (6) the manufacturer's record symbol. Figure 5-60 shows the standard marking system and possible

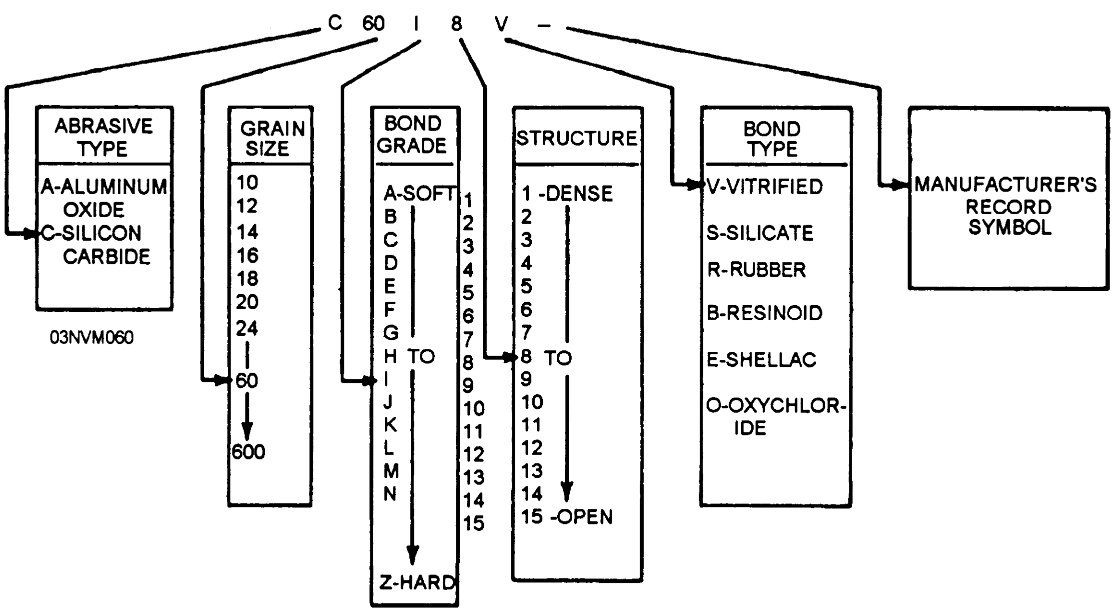
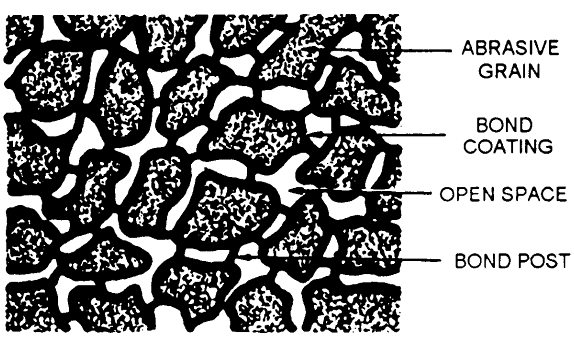


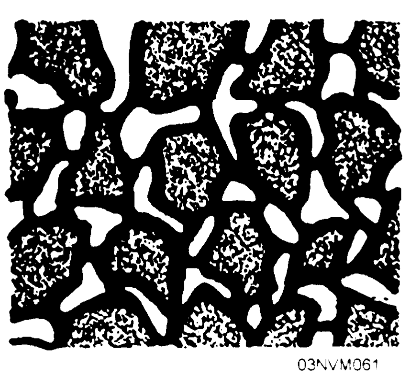
Figure 5-60.—Standard marking system for grinding wheels (except diamond).

variations that identify nearly all abrasives except diamond. The following information breaks the marking down and explains each section. Follow the sections in the figure from left to right as you read an explanation of each section in the following paragraphs. This information should be studied carefully as it will be invaluable in making the proper wheel selection for each grinding job you will attempt.

Type of Abrasive.—The first section on the grinding wheel marking shows the type of abrasive. There are two types of abrasives: natural and manufactured. Natural abrasive, such as emery, corundum, and diamond, are used only in honing stones and in special types of grinding wheels. The common manufactured abrasives are aluminum oxide and silicon carbide. They have superior qualities and are more economical than natural abrasives. Aluminum oxide (designated by the letter *A)* is used to grind steel and steel alloys, and for heavy duty work such as cleaning up steel castings. Silicon carbide (designated by the letter C), is harder but not as tough as aluminum oxide. It is used mostly for grinding nonferrous metals and carbide tools. The abrasive in a grinding wheel makes up about 40 percent of the wheel.



WHEEL A



WHEEL B

Figure 5-61.— How bond affects the grade of a wheel. Wheel

Grain Size.—The second section on the grinding wheel marking is the grain size. Grain sizes range from 10 to 600. The size is determined by the size of mesh of a sieve through which the grains can pass. Generally speaking, grain size is rated as follows: coarse: 10 through 24; medium: 30 through 60; fine: 70 through 180; and very fine: 220 through 600. Fine grain wheels are preferred for grinding hard materials, as they have more cutting edges and will cut faster than coarse grain wheels. Coarse grain wheels are generally preferred for rapid metal removal on softer materials.

Grade or Hardness.—Section three of the grinding wheel marking is the grade or hardness of the wheel. The grade is designated by a letter of the alphabet and it runs from A to Z or soft to hard. The grade of a grinding wheel is a measure of the bond's ability to retain the abrasive grains in the wheel. A soft to hard grade does not mean that the bond or the abrasive is soft or hard; it means that the wheel has either a large amount of bond (hard grade) or a small amount of bond (soft grade).

Figure 5-61 shows magnified portions of both soft-grade and hard-grade wheels. You can see that a part of the bond surrounds the abrasive grains, and the remainder of the bond forms into posts that hold the grains to the wheel and hold them apart from each other. The wheel with the larger amount of bonding material (hard grade) has thick bond posts and offers great resistance to grinding pressures. The wheel with the least amount of bond (soft grade) offers less resistance to grinding pressures.

Structure.—The fourth section of the grinding wheel marking is the structure. The structure is designated by numbers from 1 to 15. The structure of a grinding wheel refers to the open space between the grains, as shown in figure 5-61. Grains that are very closely spaced are said to be dense; when grains are wider apart, they are said to be open. Open grain wheels remove more metal faster than close-grain wheels. Also, dense, or close-grain wheels, normally produce a finer finish. Structure makes up about 20 percent of the grinding wheel.

Bond Type.—The fifth section on the grinding wheel marking is the bond type. The bond makes up the remaining 40 percent of the grinding wheel and is one of the most important parts of the wheel. The bond determines the strength of the wheel. The six basic types of bonds are vitrified, silicate, rubber, resinoid, shellac, and oxychloride. We will discuss each type in the following paragraphs.

VITRIFIED bonded wheels are designated by the letter *V*. They are not affected by oil, acid, or water. Vitrified bonded wheels are strong and porous, and rapid temperature changes have little or no effect on them. Do not run vitrified wheels faster than 6,500 surface feet per minute (sfpm).

SILICATE bonded wheels are designated by the letter *S*. Silicate bonded wheels are used mainly on large, slow rpm machines where a cooler cutting action is desired. Silicate bonded wheels are softer than vitrified wheels, and they release the grains more readily. Like the vitrified bonded wheel, do not run this wheel in excess of 6,500 sfpm.

RUBBER bonded wheels are designated by the letter *R*. These wheels are strong and elastic and they are used as thin cutoff wheels. These wheels are used extensively for regulating wheels on centerless grinders. Rubber bonded wheels produce a high finish and can be run at speeds up to 16,000 sfpm.

RESINOID bonded wheels are designated by the letter *B*. These wheels are shock resistant and strong and are used for rough grinding and cutoff wheels. Like rubber bonded wheels, you can run these wheels at speeds up to 16,000 sfpm.

SHELLAC bonded wheels are designated by the letter *E*. These wheels give a high finish and have a cool cutting action when used as cutoff wheels. Shellac bonded wheels can be run at speeds up to 12,500 sfpm.

OXYCHLORIDE bonded wheels are designated by the letter *O*. Do not run these wheels at speeds greater than 6,500 sfpm.

Manufacturer's Record.—The sixth section of the grinding wheel marking is the manufacturer's record. This may be a letter or number, or both. It is used by the manufacturer to designate bond modifications or wheel characteristics.

GRINDING WHEEL SELECTION AND USE

You should select a grinding wheel that has the proper abrasive, grain, grade, and bond for the job. You should base your selection on such factors as the physical properties of the material to be ground, the amount of stock to be removed (depth of cut), the wheel speed and work speed, and the finish required.

To grind carbon and alloy steel, high-speed steel, cast alloys, and malleable iron, you probably should use an aluminum oxide abrasive. A silicon carbide abrasive is most suitable for grinding nonferrous metals, nonmetallic materials, and cemented carbides.

Generally, you'll choose coarser-grain wheels to grind softer and more ductile the materials. Also use coarser-grain wheels to remove a large amount of material (except on very hard materials). If a good finish is required, a fine grain wheel should be used. For soft materials, small depth of cut, or high-work speed, use a soft grade wheel. If the machine you are using is worn, you may need to use a harder grade wheel to offset the effects of that wear. You also can use a harder grade wheel if you use a coolant with it. Table 5-3 lists recommended grinding wheels for

Table 5-3.—Recommendations for Selecting Grinding Wheels

OPERATION	WHEEL DESIGNATION					MATERIAL
	Abrasive	Grain size	Grade	Structure	Bond	
Cylindrical grinding	A	60	K	8	V	High-speed steel
	A	60	L	5	V	Hardened steel
	A	54	M	5	V	Soft steel
	C	36	K	5	V	Cast iron, brass, aluminum
	A	54	L	5	V	General purpose
Surface grinding	A	46	H	8	V	High-speed steel
	A	60	F	12	V	Hardened steel
	A	46	J	5	V	Soft steel
	C	36	J	8	V	Cast iron and bronze
	A	24	H	8	V	General purpose
Tool and cutter grinding	A	46	K	8	V	High-speed steel or cast alloy milling cutter
	A	54	L	5	V	Reamers
	A	60	K	8	V	Taps

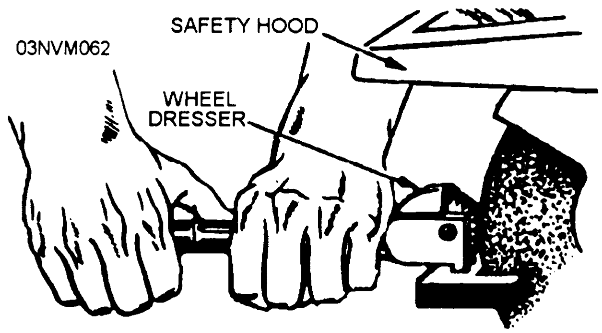


Figure 5-62.—Using a grinding wheel dresser.

various operations. However, before you perform these operations, you should be able to install and dress the wheels properly, whenever required.

WHEEL INSTALLATION.—The wheel of a pedestal grinder must be properly installed; otherwise, it will not operate properly and accidents may occur. Before you install a wheel, inspect it for visible defects and "sound" it by tapping lightly with a piece of hard wood to determine if it has invisible cracks. A good wheel will give out a clear ringing sound when tapped. If you hear a dull thud, the wheel is cracked and should not be used. When installing the wheel on the grinding machine, you should always refer to the technical manual to ensure that the wheel is correctly installed and tightened.

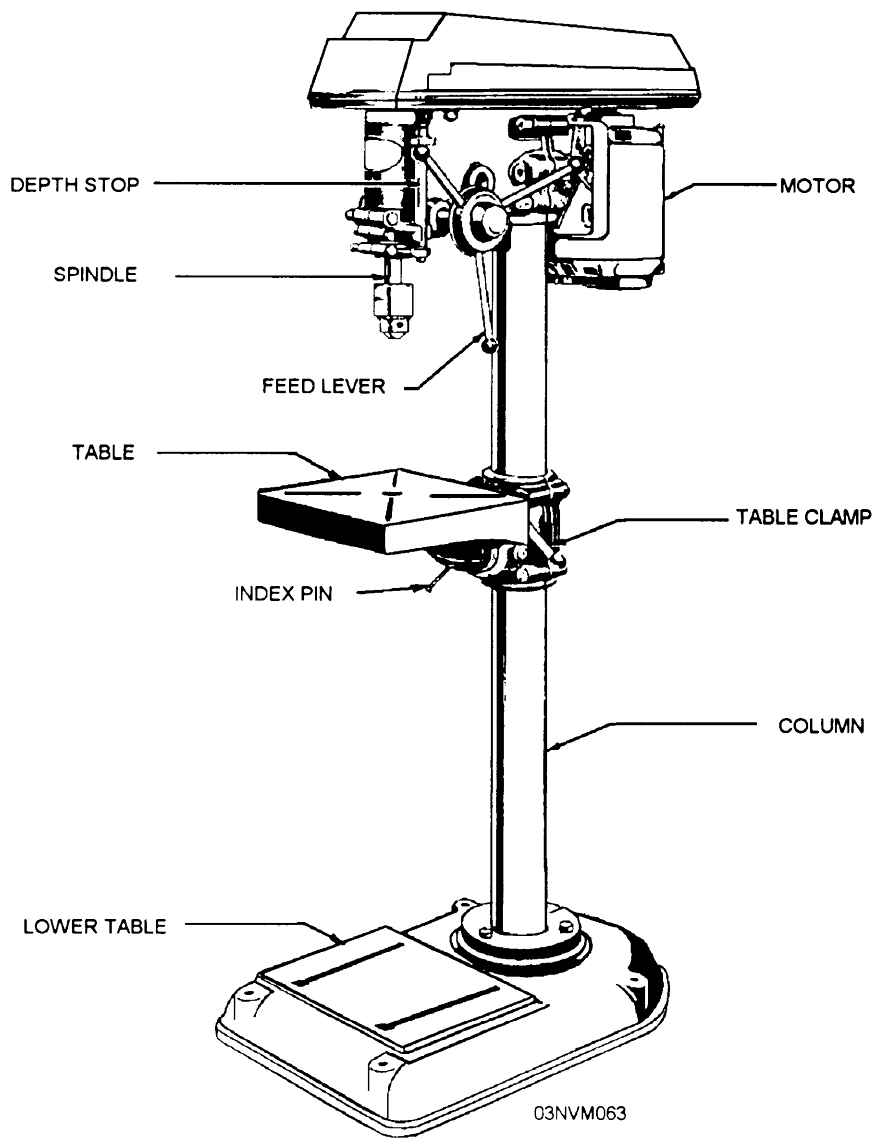


Figure 5-63.—Sensitive drill press.

TRUING AND DRESSING THE WHEEL.— Grinding wheels, like other cutting tools, require frequent reconditioning of cutting surfaces to perform efficiently. *Dressing* is the term used to describe the process of cleaning the periphery of grinding wheels. This cleaning breaks away dull abrasive grains and smooths the surface so that there are no grooves. *Truing* is the term used to describe the removal of material from the cutting face of the wheel so that the resultant surface runs absolutely true to some other surface such as the grinding wheel shaft.

The wheel dresser, shown in figure 5-62, is used for dressing grinding wheels on pedestal grinders. To dress a wheel with this tool, start the grinder and let it come up to speed. Set the wheel dresser on the rest as shown in figure 5-62 and bring it in firm contact with the wheel. Move the wheel dresser back and forth across the face of the wheel until the surface is clean and approximately square with the sides of the wheel.

Several things can get a grinding wheel out of balance. For instance, it may be out of roundness, and you can usually correct this problem by dressing the wheel. Or, it may get out of balance if part of the wheel is immersed in coolant. If this happens, remove and replace the wheel. If the wheel gets out of balance axially, it probably will not affect the efficiency of the wheel. To correct axial unbalance, simply remove the wheel and clean the shaft spindle, the spindle hole, and flanges.

Each time a wheel is dressed, you should check the clearance between the tool rest and the wheel. Reestablish the clearance at not more than 1/8 inch, as required. To preclude possible injury, make all adjustments with the machine secured.

DRILL PRESSES

There are many sizes and styles of drilling machines or drill presses, each designed for a particular type of work. Only the sensitive drill press and the radial drill press will be covered in this section.

One type of upright drill press is the sensitive drill press (fig. 5-63). It is used to drill small holes in work under conditions that make it necessary for the operator to "feel" what the cutting tool is doing. The tool is fed into the work by a very simple device-a lever, a pinion and shaft, and a rack that engages the pinion. These drills are nearly always belt-driven because the vibrations caused by gearing will reduce their sensitivity. The high-speed range of these machines and the holding devices used make them unsuitable for heavy work.

The radial drill press (fig. 5-64) has a movable spindle that can be adjusted to the work. This machine is especially useful when the workpiece is large, bulky, or heavy, or when you need to drill many holes with one setup, because the work does not have to be readjusted for each hole. The arm and spindle are designed so that the drill can be positioned easily over the layout of the workpiece.

Before operating any drill press, do a visual inspection to be certain that all parts are in the proper place, secure, and in good operating condition. Check all assemblies, such as the motor, head, pulleys, and bench for loose mountings. Check the V-belt and adjust it as necessary according to the manufacturer's technical manual. Make sure the electrical cord is securely connected and that the insulation is not damaged, chafed, or cracked.

While the drill press is operating, be alert for any sounds that signal trouble, such as squeaks or unusual noises. Report any unusual or unsatisfactory performance of the drill press to the petty officer in charge of the shop.

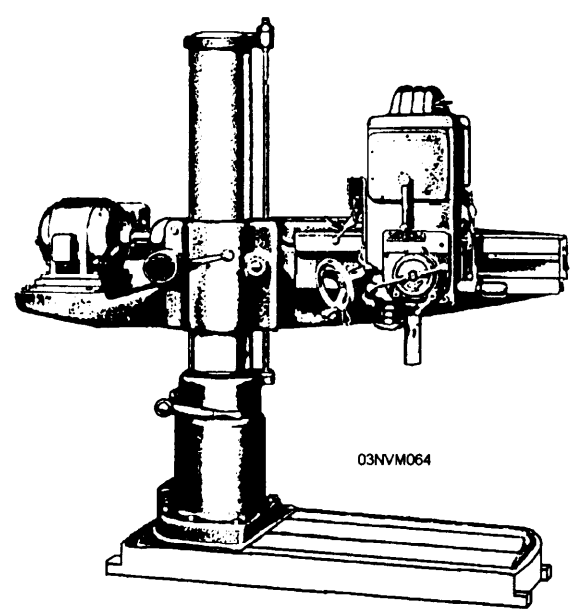


Figure 5-64.—Radial drill press.

You must use a cutting oil when drilling steel or wrought iron. Cast iron, aluminum, brass, and other metals may be drilled dry at high drilling speeds. However, you should use some medium to cool these metals. This will reduce the chances of overheating the drill bit and loss of the cutting edge. Compressed air may be used for cast iron; oleic acid for copper; sulphurized mineral oil for Monel; and water, lard, or soluble oil and soda water for ferrous metals. (Soda water reduces heat, overcomes rust, and improves the finish.)

After operating a drill press, wipe off all dirt, oil, and metal particles. Inspect the V-belt to make sure no metal chips are imbedded in the driving surfaces.

MAINTENANCE OF INSTALLED SHOP EQUIPMENT

The machines in your shop depend upon you for their care and maintenance. To keep your machines operating properly, you should perform PMS routinely. Preventive maintenance should be performed according to the Planned Maintenance System (PMS), described in *Military Requirements for Petty Officer Third Class,* NAVEDTRA 12044. PMS is minimum maintenance. If you feel more maintenance is required, refer to the technical publication and perform the necessary maintenance.

GAS CYLINDERS AND CYLINDER VALVES

You are required to know the standard Navy system for marking gas cylinders and to be able to identify the cylinder valves and cylinders of various gases. You should be familiar with the construction, design, and size of these cylinders. You should also know how to handle and stow gas cylinders in a safe and proper manner. This section will give you a few of the important facts about gas cylinders and cylinder valves. Additional information concerning compressed gases can be found in MIL-STD-101, *Color Codes for Pipelines and for Compressed Gas Cylinders.*

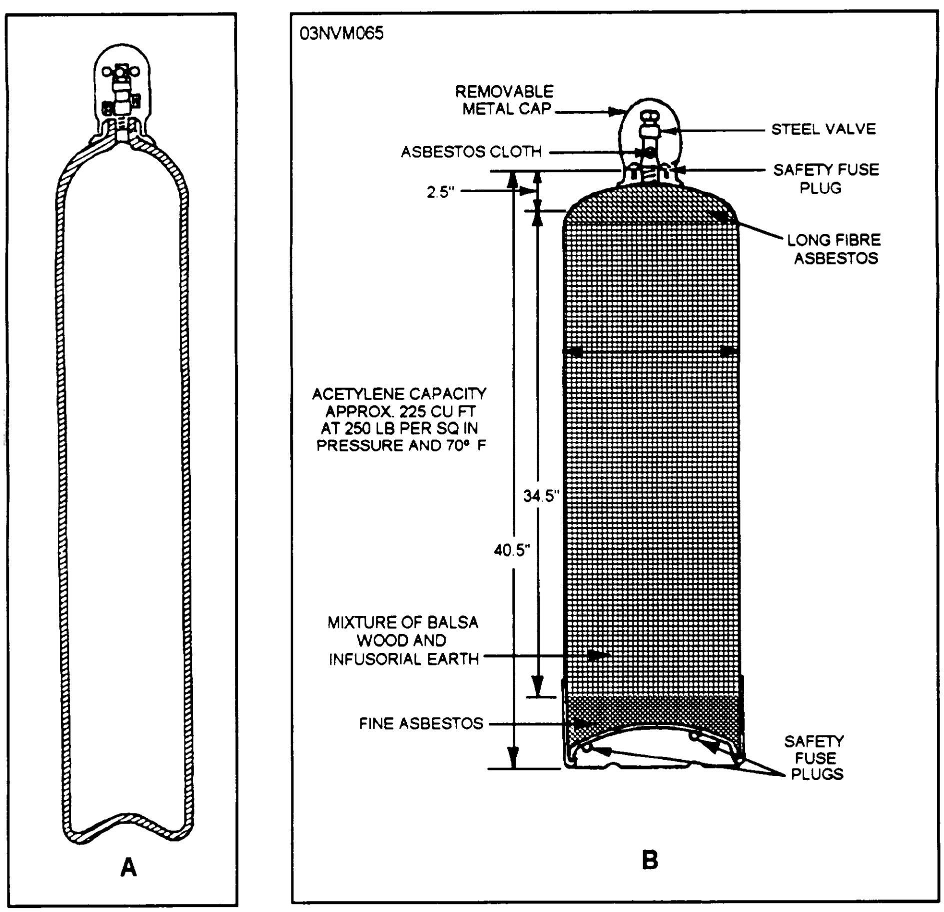


Figure 5-65.—Cutaway view of compressed gas cylinders: (A) Oxygen cylinder; (B) acetylene cylinder.

CONSTRUCTION OF CYLINDERS

Gas cylinders are made of high-quality steel. High-pressure gases, such as oxygen, hydrogen, nitrogen, and compressed air are stored in cylinders of seamless construction. Only nonshatterable high-pressure gas cylinders may be used by ships or activities operating outside the continental United States. Cylinders for low-pressure gases, such as acetylene, may be welded or brazed. All cylinders are carefully tested, either at the factory or a designated processing station, at pressures above the maximum permissible charging pressure.

The cylinders for most compressed gases are shaped alike. However, cylinders for acetylene are shorter and of a larger diameter, as shown in figure 5-65.

All gas cylinders have safety devices either in the valve, in the shoulder, in the bottom of the cylinder, or in a combination of these places. A threaded valve protection cap screws on the neck ring and protects the valve.

MARKING AND IDENTIFYING GAS CYLINDERS

Gas cylinders are manufactured and maintained according to the regulations of the Interstate Commerce Commission (ICC). The ICC stipulates that each cylinder be indented or stenciled with prescribed identification markings. Cylinders larger than 2 inches in diameter must be indented with serial numbers. Therefore, cylinders exceeding 2 inches in diameter, which are not assigned Navy serial numbers, require manufacturer's serial numbers. No more than 500 cylinders are allowed in each lot manufactured. Requirements for ICC 8 (acetylene) and ICC 9 (aerosol dispenser) cylinders are exceptions to this requirement. ICC 8 cylinders of all sizes require serial numbers and ICC 9 cylinders of all sizes are assigned lot numbers. However, an unlimited number per lot is authorized.

Navy-owned compressed-gas cylinders are indented with figures and letters. In addition to the identifications required by ICC regulations, Navy-owned cylinders for gases in the liquid state with a water capacity in excess of 15 pounds, or gases in the gaseous state with a volume in excess of 658 cubic inches, are identified by an indented Navy serial number. This number is preceded and followed by the letters USN. Acetylene cylinders contain acetylene dissolved in acetone, and are assigned Navy serial numbers on the volume basis. In other words, gases in the liquid state are measured by weight, and those in the gaseous state are measured by volume. Acetylene, though dissolved in a liquid, is measured as a gas by volume.

Since 1 August 1944, Navy serial numbers have a designated letter placed before the numerals. This letter shows the type of gas carried in the cylinder. The lettering system assigns the following letters to the gases:

A—Acetylene

M—Ammonia

D—Carbon dioxide

K—Chlorine

E—Ethylene oxide

H—Helium

N—Nitrogen

J—Nitrous oxide

G—Aerosol

X—Oxygen

P—Liquefied petroleum gas (propane, butane, and so on)

S—*Sulfur* dioxide

F—Freon

B—Carboxide

Y—Hydrogen

R—Methyl chloride

Z—Compressed air

L—Ethyl chloride

NO—Nitrogen dioxide

V—Argon

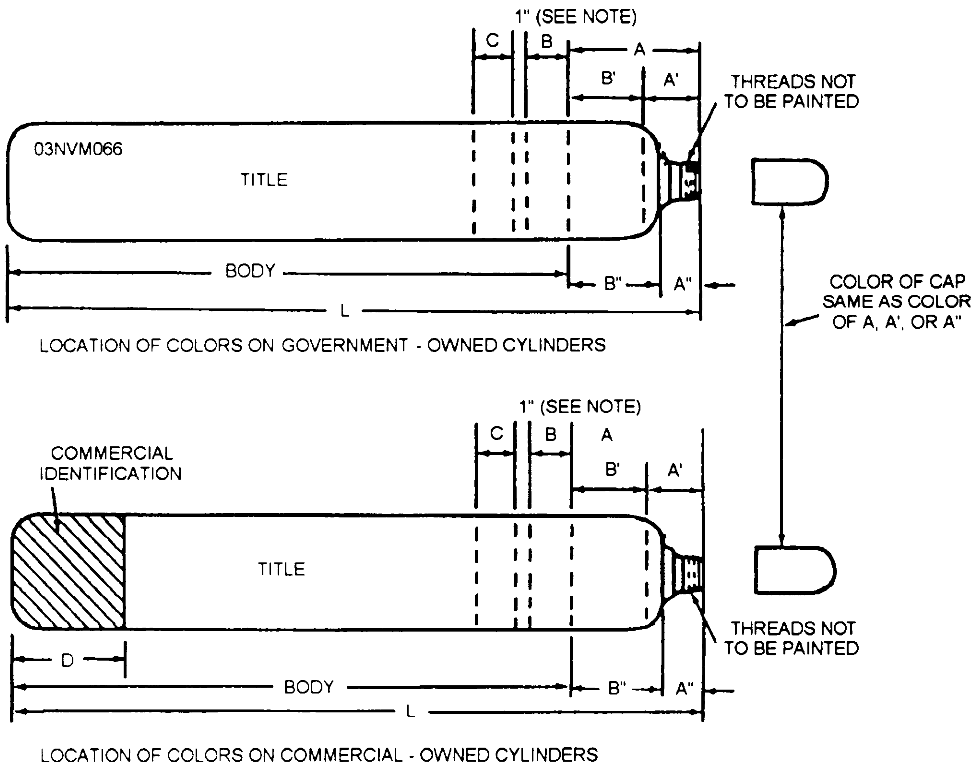
In addition to markings required by the ICC, gas cylinders used by all three services—Navy, Army, and Air Force—have certain standard identifying features. So much injury and damage can be, and has been, caused by mistaking one gas cylinder for another. Therefore, a national program has been established to make it almost impossible to confuse cylinders. The identifying features used by the Armed Forces in this program consist of using a color code for painting the cylinders, stenciling the name of the gas along two sides of the cylinder, and placing two identifying symbols (decals) on the shoulder of each cylinder. The gas cylinders must be painted as shown in figure 5-66, and the arrangement of colors will appear as shown in table 5-4.

If the color of the cylinders reduces the effectiveness of the ship's camouflage scheme, canvas covers painted with the camouflage colors should be placed over the cylinders. Do not paint the cylinders with camouflage paint.

Shatterproof cylinders are stenciled in two locations with the phrase "Non-Shat" lengthwise and 90° from the titles. Letters must be either black or white, and approximately 1 inch in size.

Color Codes for Cylinders

Color coding is mandatory for compressed-gas cylinders. Identifying colors are assigned by the Standardization Division, Office of the Assistant Secretary of Defense (Supply and Logistics).



LOCATION DIMENSIONS

ON CYLINDERS FOR MEDICAL GAS MIXTURES, 1" SPACE AND BAND C ARE LOCATED IMMEDIATELY BELOW BANDS B' OR B"

CYLINDERS FOR	OVERALL LENGTH	SHOULDER COLOR(S)			CYLINDER COLOR BAND (S)				COMMERCIAL IDENTIFICATION
		A	A'	A"	B	B'	B"	C	D
MEDICAL GAS MIXTURE	OVER 30"	L/5	3 1/2"	—	—	A LESS 3 1/2"	—	3"	L/6
OTHER GASES	"	L/5	—	—	3	—	—	3"	L/6
MEDICAL GAS MIXTURE	30" AND UNDER	L/5	—		—	—	A LESS A"	2"	L/6
OTHER GASES	"	L/5	—	—	2	—	—	2"	L/6

FROM CYLINDERS TOP TO BOTTOM OF NECK RING

NOTE: 1" SPACE TO BE OMITTED IF BANDS B & C ARE OF DIFFERENT COLORS

Figure 5-66.—Location of color codes on gas cylinders.

Table 5-4.—Cylinder Color Code

Contents of cylinder	Location of cylinder markings			
	Top A	B and B	B and C	Body
Medical anesthetic gases:				
Cyclopropane.	Orange	Yellow	Blue	Blue
Ethylene.	Yellow	Blue	Blue	Blue
Nitrous oxide	Blue	Blue	Blue	Blue
Fuel gases:				
Acetylene	Yellow	Yellow	Yellow	Yellow
Hydrogen	Yellow	Black	Yellow	Yellow
Manufactured gases.	Brown	Yellow	Yellow	Yellow
Petroleum (liquefied & nonliquefied)	Yellow	Orange	Yellow	Yellow
Industrial gases:				
Butadiene.	Yellow	White	Buff (tan)	Buff (tan)
Ethylene oxide	Yellow	Blue	Buff (tan)	Buff (tan)
Ethyl chloride	Buff	Blue	Yellow	Buff (tan)
Propylene.	Yellow	Gray	Buff	Buff (tan)
Vinyl chloride	Yellow	Orange	Buff	Buff (tan)
Vinyl methyl ether.	Yellow	Black	Buff	Buff (tan)
Aerosol insecticide.	Buff	Buff	Buff	Buff (tan)
Toxics and poisonous materials:				
Carbon monoxide.	Yellow	Brown	Brown	Brown
Hydrogen sulfide	Brown	Yellow	Brown	Brown
Methyl bromide.	Brown	Black	Brown	Brown
Boron trifluoride	Gray	Brown	Brown	Brown
Chlorine	Brown	Brown	Brown	Brown
Hydrogen chloride	Brown	White	Brown	Brown
Phosgene	Brown	Orange	Brown	Brown
Sulfur dioxide	Brown	Gray	Brown	Brown
Refrigerants:				
Ammonia	Brown	Yellow	Orange	Orange
Freons	Orange	Orange	Orange	Orange
Methyl chloride.	Yellow	Brown	Orange	Orange
Oxidizing gases:				
Oxygen, aviator's	Green	White	Green	Green
Air, oil pumped	Black	Green	Green	Black
Air, water pumped	Black	Green	Black	Black
Helium-oxygen.	Buff	White	Green	Green
Oxygen-carbon dioxide	Gray	White	Green	Green
Inert gases:				
Argon, oil pumped	Gray	White	White	Gray
Argon, water pumped.	Gray	White	Gray	Gray
Carbon dioxide.	Gray	Gray	Gray	Gray
Helium, oil pumped.	Gray	Orange	Gray	Gray
Helium, oil free	Buff	Gray	Gray	Gray
Nitrogen, oil pumped	Gray	Black	Gray	Gray
Nitrogen, water pumped.	Gray	Black	Black	Gray
Fire-fighting gases:				
Carbon dioxide.	Red	Red	Red	Red
Methyl bromide.	Red	Brown	Red	Red

Cylinders that have a background color of yellow, orange, or buff have the title stenciled in black. Cylinders that have a background color of red, brown, black, blue, gray, or green have the title stenciled in white. Figure 5-67 shows how cylinders are identified by the overall painted color code and by the stenciled name of the gas.

Decalcomanias

As a further identification measure, two decalcomanias (pronounced de-kel-ko-main-e-ah, or abbreviated as decals), are applied to the shoulder of each cylinder. The decals show the name of the gas and the precautions for its handling and use. The decals are available from general stores for each gas used in the Navy.

TESTING AND REPAIRING CYLINDERS

ICC regulations require that all gas cylinders, except acetylene cylinders, be retested every 5 years. Cylinders that are due for retesting are not to be charged and shipped until such retests have been properly made. However, cylinders that have been charged before the expiration of their retest period may be shipped and used until empty. They will then be turned in for retesting. The dates of retests are permanently and plainly marked by the stamping on the shoulder of the cylinder, directly opposite the ICC and Navy serial numbers. The stamping, for example 4-88, means that the last test was performed in April 1988.

The 5-year tests are performed by naval activities and civilian agencies under regulations of the ICC. Personnel aboard naval ships are not authorized to perform such tests. Empty cylinders with expired test periods should be returned to the nearest naval supply depot or cylinder testing activity, and marked "For Retest."

HANDLING AND STOWING CYLINDERS

You must always remember ALL compressed gases are hazardous. Many detailed precautions could be set down with regard to the handling and stowing of these gases. The more important ones are summarized in this section.

The term *stowage* as used in the following paragraphs refers to articles under the cognizance of the supply officer, in general stores, to be drawn on for the ship's own use, or articles of cargo being

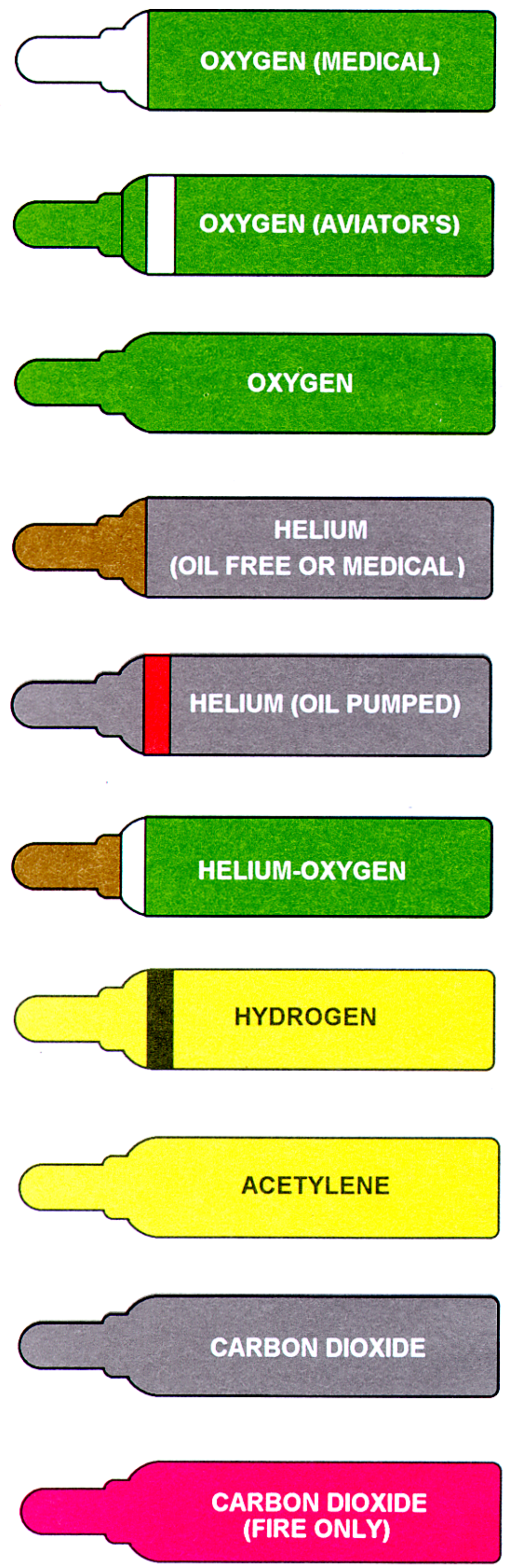


Figure 5-67.—Identifying color patterns for gas cylinders.

transported. It does not refer to cylinders that have been removed from stores or from cargo and transferred to the shops or other locations for use.

The term *ready service* refers to cylinders or other articles that have been transferred from stores and are actually located in a shop or near a place where they are to be used. It is not necessary that the articles be in actual use, but they must be ready for use.

Handling Cylinders

Cylinders that contain flammable and/or explosive gases must be handled with extreme care. Every effort should be made to avoid dropping them or allowing them to strike too hard against each other or any other object. Take every precaution to prevent bumping or striking the discharge valves.

When cylinders are being handled, the cylinder valve outlet cap and the cylinder valve protecting cap must be in place. Unless ready-service cylinders are secured in special portable racks, regulators must be removed and caps replaced before the cylinders are moved to a new location. Even then, it is best to remove the regulators and replace the caps for safety.

Be very careful when loading or transferring cylinders, especially when using a crane or derrick. The cylinders must be secured in a cradle, suitable platform, rack, or special container such as a sandbag. Electromagnets must never be used. A cylinder moved by hand should be tilted slightly and rolled on its bottom edge, without dragging or sliding. Hooks or lines through the valve protection cap must not be used for hoisting cylinders. Cylinders frozen to the deck, or otherwise fixed, must not be pried loose with crowbars or similar tools.

When gas cylinders are transported on a hand truck, they must be held securely in position. The truck should be fastened to a bulkhead or stanchion as soon as the destination is reached. The truck should be constructed as follows:

— Frame sufficiently rigid to permit handling with tackle.

— Grips or handles ending in a vertical line with the aft side of the wheels. (This facilitates fastening to a bulkhead.)

— Platform fitted with sides to prevent the cylinders from sliding off.

— Metal strap clamps provided for retaining the tops of the cylinders in place. Chains are not to be used as retainers since they normally are a little slack; the cylinders can shift and cause an accident.

Stowage of Compressed Gases

In general, weather-deck stowage will be provided for flammable and explosive gases. However, in specific cases, below-deck stowage is approved; depending on the particular type, mission, and arrangement of the ship. In such cases, these approved locations are shown on the ship's plans.

Compressed gases aboard all ships, except cargo ships, should be stowed only in compartments designated by NAVSEA, as shown in applicable plans for the ship. In such cases, the following precautions must be observed:

- Take necessary steps to keep the maximum temperature of the stowage compartment below 130°F.
- When provisions are made for mechanical ventilation, operate this ventilation according to the damage control classification assigned. The classification for closures of this system are either "Z, " "W," or "W."
- Do not install portable electric wiring and equipment in compartments designated for the stowage of flammable or explosive gases.
- Keep flammable materials, especially grease and oil, out of the stowage space.
- Securely fasten each cylinder individually, in the vertical position (valve end up), by metal collars. Other arrangements are approved for cargo ships fitted especially for cylinder transport.
- Stow oxygen and chlorine in compartments separate from flammable gases. Inert or nonflammable gases may be stowed in any compartment designated for compressed gas stowage.
- Ventilate compartments containing compressed gases for 15 minutes before entry in the event that ventilation has been closed down. A suitable sign to this effect should be posted on the outside of the access door.

When compressed gas is stowed on the weather deck, the following additional precautions must be observed:

- Do not stow oxygen and chlorine cylinders close to the fuel-gas cylinders. Normal practice is to stow gas cylinders on one side of the ship and to stow oxygen and chlorine cylinders on the other side.

- Stow cylinders containing compressed gases for the greatest possible protection. During the winter, protect cylinder valves against the accumulation of snow and ice. Use warm water (not boiling) to thaw ice accumulations in cylinder valve caps and outlets. Boiling water may melt the fusible plugs. During the summer, screen cylinders from the direct rays of the sun.

- Make every effort to prevent corrosion of threaded connections of cylinders that are stowed for extended periods of time. The use of grease, lubricants, or flammable corrosion inhibitors on oxygen cylinders is NOT permitted. Oil or grease in the presence of oxygen under pressure will ignite violently.

- The stowage area should be as far away as practical from navigation stations, fire control stations, and gun mounts.

Ready-Service Storage Rules

Cylinders in actual use, and those attached to welding, fire fighting, medical, refrigeration, or similar apparatus, ready for use, are permitted below decks outside of the stowage compartment.

The following special precautions must be taken with oxygen and fuel-gas cylinders for welding:

- The number of cylinders of gas needed to equip each authorized gas cutting and welding position may be installed in shops. The number of authorized positions will be determined from either a NAVSEA-approved plan or the machinery specifications for the shop concerned.

- Securely fasten cylinders in a rack. The rack must be securely fastened to the bulkhead, <u>and must not allow any vertical movement of cylinders.</u>

- Stow cylinders attached to NAVSEA-approved damage control equipment below decks in repair lockers. Spare cylinders used for this purpose may be stowed in the same locations.

- Remove welding units from the designated stowage location to perform work at some remote location in the ship. Return these units to the designated stowage location immediately after you complete your work. Attend to the equipment at all times while it is away from its regular stowage.

- Post a card showing the following warning at the designated stowage location of each unit:

WARNING: UNIT IS NOT SECURE WHILE PRESSURE SHOWS ON GAUGES, OR WHEN CYLINDERS ARE NOT FIRMLY FASTENED TO RACK OR TO BULKHEAD, OR WHEN RACK IS NOT FIRMLY FASTENED TO BULKHEAD. IF REMOVED FROM THIS LOCATION, THIS UNIT IS TO BE CONSTANTLY ATTENDED UNTIL RETURNED AND SECURED.

- Attach a card showing the following statement to each unit:

RETURN TO (DESIGNATED LOCATION) IMMEDIATELY ON COMPLETION OF WORK. UNIT SHALL NOT BE LEFT UNATTENDED WHILE AWAY FROM ABOVE LOCATION. UNIT IS NOT SECURE WHILE PRESSURE SHOWS ON GAUGES, OR WHEN CYLINDERS ARE NOT FIRMLY FASTENED TO RACK OR BULKHEAD, OR WHEN RACK IS NOTFIRMLY FASTENED TO BULKHEAD OR STANCHION.

See *NSTM*, chapters 550 and 074, volume 3, for detailed precautions.

DISPOSITION OF EMPTY CYLINDERS

Empty cylinders should be delivered to the nearest naval supply depot. Valves should be closed and under some positive pressure, except where the design of the valve does not permit closing, as is the case with fire extinguishers. The pressure is necessary to prevent condensation of atmospheric moisture on the internal walls. In the case of acetylene cylinders, the pressure prevents loss of the solvent (acetone) and/or entry of air, if the cylinders cool considerably below the temperature at which they were discharged.

Sometimes, cylinders used for aviator's breathing oxygen, dry nitrogen, argon, or dry air are found to have open valves and/or a positive internal pressure of less than 25 psi. These cylinders should be tagged with the explanation that they must be dried before they are refilled.

GAS CYLINDER VALVES

Navy standard gas cylinder valves are of two basic designs: packed valves and diaphragm-type packless valves.

Packed valves require a packing material around the valve stem to prevent leakage. The valve stem is packed to prevent gas from leaking out around the stem when the valve is open. MIL-V-2 covers the authorized packing material for gas cylinder valves.

Packless valves are sealed against leakage around the valve stem by flexible metallic diaphragms securely clamped to the valve bonnets. The basic packless design may be classified into two types: nonbackseating and backseating. The nonbackseating type is designed so that the metallic sealing diaphragms may not be replaced under pressure. In the backseating type the metallic diaphragms may be replaced without undue hazard or loss of contained gases if the outlet cap is in place and secure. Diaphragms in packless valves should be replaced only by activities carrying spare diaphragms specifically designed for the valves in need of reconditioning.

These diaphragms are made from materials selected for service at varying high pressures. In addition, they are often designed only for use with valves built by a given manufacturer and for a specific gas.

The Navy gas valve program (and concerned civilian agencies) provides noninterchangeable valve outlets and connections for different gases to prevent the use of the wrong gas at any time.

Construction and Identification of Valves

Valves designed to control the flow of compressed gases are forged of brass, bronze, or steel, and are made in various shapes and sizes. Figures 5-68 and 5-69 show typical gas cylinder valves. The valves are opened and closed with either hand-operated or wrench-operated spindles. When the valves are open,

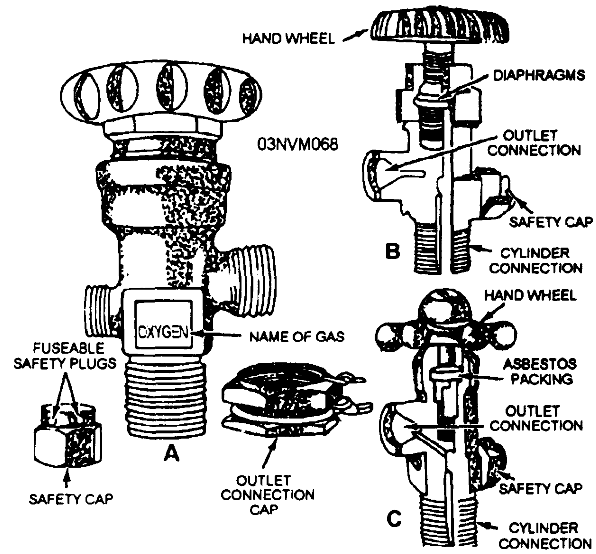


Figure 5-68.—Oxygen cylinder gas valves: (A) external view of one type of valve, with related safety and outlet connection caps; (B) cutaway view of the same valve, showing diaphragms to prevent gas leakage when the valve is opened; (C) cutaway view of another type of valve, with asbestos packing to prevent gas leakage when the valve is opened.

gas flows through a threaded male cylinder connection into the valve body and past the valve outlet connection into the pressure regulator. (Pressure regulators reduce the pressure of compressed gases from the cylinder pressure to the desired working

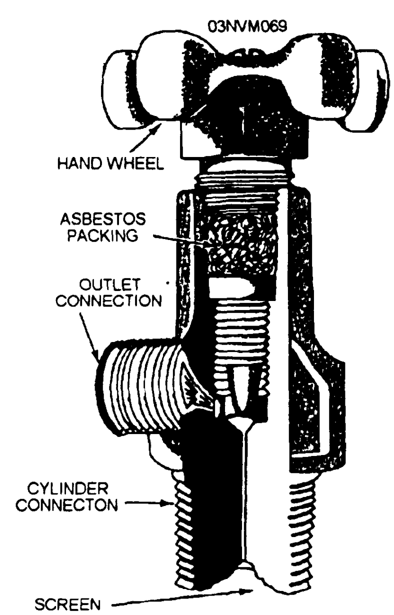


Figure 5-69.—Cutaway view of an acetylene cylinder valve showing asbestos packing.

pressure. All regulators are marked with the name of the gas for which they are intended.)

To prevent leakage of gas above the valve stem when the valve is opened, each valve is equipped with asbestos, leather, rubber packing, or metal diaphragms. Most valves have safety devices. (The safety devices for acetylene and ammonia are in the cylinders rather than in the valves.) These safety devices consist of fusible metal plugs, rupture disks, or both. Spring-loaded safety devices are used for some gases. If heat causes too much pressure, the fuse plugs melt and the disks burst, releasing the contents of the cylinder. Acetylene valves have screens in the cylinder connections; other valves do not.

Valves manufactured according to the latest military specifications have the name of the gas, or service for which they are designed. indented on at least one of the flats on the sides of the valves. Valves must be used only for the gases or fluids indicated. Otherwise, personnel may be injured or the equipment may be damaged.

Safety Devices for Valves

Military specifications and ICC regulations require that valves designed for certain services be fitted with safety devices. These devices guard against a buildup of hazardous pressures caused by heat. This can easily happen with CO_2 cylinders used for fire fighting in fire rooms and engine rooms. Pressure can also build up from overcharging or similar causes. These safety devices may be divided into four general categories based on functional design as follows:

1. FUSIBLE PLUGS—A fusible plug may be described as a threaded hex-head plug with a center filled with fusible metal. When the cylinder is overheated, the fusible metal melts and permits the gas to escape. This type of device is used on chlorine, freon, acetylene, and such gases.

2. SPRING-LOADED SAFETY DEVICE—These devices usually function as "pop" valves that open to release excess pressure when pressure in the cylinder overcomes spring tension. Devices of this sort are used on liquefied petroleum gas valves. They operate generally at about 150 percent of the cylinder's ICC-approved pressure.

3. UNBACKED SAFETY CAP WITH RUPTURE DISK—This safety device is essentially a safety cap that covers a safety port in the valve. The cap retains a breakable disk firmly over the safety port. Pressures ranging from 2,600 to 3,000 psi will rupture the safety disk and allow the gas in the cylinder to vent to the atmosphere. This type of safety device is used in carbon dioxide service.

4. BACKED SAFETY CAP WITH RUPTURE DISK—Backed safety caps with rupture disks are essentially the same as those described in paragraph 3. However, the breakable disk is supported by fusible metal contained in the safety cap thus blocking off escape ports. This cap works when the cylinder, valve, and therefore the fusible metal are heated above the melting temperature. When the pressure within the cylinder reaches 2,600 to 3,000 psi, the breakable disk ruptures and reduces the pressure. This type of device is used commonly on air, argon, helium, hydrogen, nitrogen, and oxygen valves.

Lea king Valves

Cylinders with leaking or defective valves should be tagged as such and turned in to the nearest naval supply depot for overhaul.

Safety Precautions

Cylinders, regulators, hoses, and torches are important parts of the shop equipment for heating, welding, and cutting. Learn and follow these safety rules for this type of equipment:

- Never fill a cylinder with a gas other than the gas for which it is specifically designated. Never remove or change the decals.
- Never return an empty cylinder without making sure that valves are closed and that protective caps are in place.
- Never drop the cylinders or let them strike against each other.
- Never use cylinders as rollers or supports.
- Never hammer or strike the valve wheel to open or close the valve. Use only the wrenches or tools approved for that purpose.
- If valve outlets are iced, use only warm water to free them. Never use hot or boiling water.
- Never use a cylinder that IS improperly marked; that is, where the paint color doesn't agree with the information on the decal.

- Never use a lifting magnet or a sling to raise or handle a cylinder.
- Be careful not to mix full and empty cylinders in a stowage rack.
- Never tamper with safety devices on the valves or cylinders.
- Never store oxygen and acetylene cylinders in the same immediate area.
- Be especially careful that you never strike an arc on gas cylinders or sealed metal cylinders of any kind.
- Acetylene and low-pressure fuel-gas cylinders, which have been stowed in a horizontal position, must be placed in a vertical position for at least 2 hours before you use them. This will allow the porous filler material inside the cylinder to settle.

SUMMARY

This chapter gave you a brief introduction to the handtools, power tools, and installed equipment used by HTs. The importance of caring for these tools properly cannot be stressed enough. Learn to use them correctly and protect them from loss or damage. These tools will determine how well you perform your job.

Now you also have an understanding of the operations and safety precautions of portable hand and power tools, pneumatic tools, grinders, drilling machines, bandsaws, power hacksaws, and thread-cutting tools. However, it would be to your advantage to read the manufacturers' operating manuals for all of shop tools and equipment. You should also review the section on compressed-gas cylinders and the safety precautions involved with them. You will find that you will work with some aspect of compressed-gas cylinders almost every day.

CHAPTER 6

METALLURGY

LEARNING OBJECTIVES

Upon completion of this chapter; you will be able to do the following:

- *Explain the concepts of stress and strain in metals.*
- *Describe the different properties of metals.*
- *Identify the two major classes of metals.*
- *Describe the different types offerrous and nonferrous metals.*
- *Identify different metals by color markings, surface appearance, and identification tests.*

INTRODUCTION

As an HT, you will be working with many different types of metals and alloys. The more knowledge you have of metals and alloys, the better you will be able to perform your repair and maintenance duties. You should have some accurate means of identifying metals. To intelligently solve welding problems, you should also have a good understanding of the internal structure of metals, and the effects that welding (heat input) has on metals. This chapter will start you on your way by giving you a basic understanding of metallurgy.

Can you define a metal? Chemical elements are considered to be metals if they are lustrous, hard, good conductors of heat and electricity, malleable, ductile, and heavy. Some metals are heavier than others; some are more malleable than others; and some are better conductors of heat and electricity. These properties are known as "metallic properties," and chemical elements that possess these properties to some degree are called metals. Chemical elements that do not possess these properties are called nonmetals. Oxygen, hydrogen, chlorine, and iodine are examples of nonmetallic chemical elements.

Chemical elements that behave sometimes like metals and sometimes like nonmetals are often called metalloids. Carbon, silicon, and boron are examples of metalloids.

An alloy may be defined as a substance that has metallic properties and is composed of two or more elements. The elements that are used as alloying substances are usually metals or metalloids. By combining metals and metalloids, it is possible to develop alloys that have the particular properties required for a given use.

Table 6-1 lists some common metals and metalloids and gives the chemical symbol that is used to identify each element.

Table 6-1.—Symbols of Common Metals and Metalloids

Element	Symbol
Aluminum	A1
Antimony	Sb
Cadmium	Cd
Carbon	C
Chromium	Cr
Cobalt	Co
Copper	Cu
Iron	Fe
Lead	Pb
Magnesium	Mg
Manganese	Mn
Molybdenum	Mo
Nickel	Ni
Phosphorus	P
Silicon	Si
Sulfur	S
Tin	Sn
Titanium	Ti
Tungsten	W
Vanadium	V
Zinc	Zn

IRON AND STEEL

CARBON STEEL is an alloy of iron and controlled amounts of carbon. ALLOY STEEL is a combination of carbon steel and controlled amounts of other desirable metal elements.

The percentage of carbon content determines the type of carbon steel. For example, wrought iron has 0.003 percent carbon, meaning three thousandths of one percent. Low-carbon steel contains less than 0.30 percent carbon. Medium-carbon steel varies between 0.30 and 0.55 percent carbon content. High-carbon steel contains approximately 0.55 to 0.80 percent carbon, and very-high-carbon steel contains between 0.80 and 1.70 percent carbon. Cast iron contains 1.8 to 4 percent carbon.

Carbon generally combines with the iron to form CEMENTITE, a very hard, brittle substance. Cementite is also known as IRON CARBIDE. This action means that as the carbon content of the steel increases, the hardness, the strength, and the brittleness of the steel also tend to increase.

Various heat treatments are used to enable steel to retain its strength at the higher carbon contents, and yet not have the extreme brittleness usually associated with high carbon steels. Also, certain other substances, such as nickel, chromium, manganese, vanadium, and other alloying metals, may be added to steel to improve certain physical properties.

A welder must also have an understanding of the impurities occasionally found in metals and their effect upon the weldability of the metal. Two of the detrimental impurities sometimes found in steels are phosphorus and sulphur. Their presence in steel is due to their presence in the ore, or to the method of manufacture. Both of these impurities are detrimental to the welding qualities of steel. Therefore, during the manufacturing process, extreme care must always be taken to keep the impurities at a minimum (0.05 percent or less). Sulphur improves the machining qualities of steel, but it is detrimental to its hot forming properties.

During a welding operation, sulphur or phosphorus tends to form gas in the molten metal. The resulting gas pockets in the welds cause brittleness. Another impurity is dirt or slag (iron oxide). The dirt or slag is imbedded in the metal during rolling. Some of the dirt may come from the by-products of the process of refining the metal. These impurities may also produce blow holes in the weld and reduce the physical properties of the metal in general.

STRESS AND STRAIN

When external force is applied to any solid material, the material is subjected to stress. Many of the properties of metals can best be understood in terms of the manner in which they react to stress. Therefore, before considering the properties of metals and alloys, let us examine the concepts of stress and strain.

Load, which is usually measured in pounds, is the external force applied to a material. When the load is applied, reaction forces to the load occur throughout the material. The reaction forces are stresses. Why do these forces occur when a load is applied to a material? Newton's third law of motion states that “to every force or action, there is an equal and opposite reaction.” Stress, therefore, is the “equal and opposite” reaction to the externally applied load. It is defined as the force per unit area resisting the load. Unit area is important. The unit area may be stated as a square inch, a square foot, or any other predetermined amount of area that is used to figure the amount of stress that the material will be subjected to. When the load is applied, it is distributed equally throughout the cross section of the material. For example, suppose two round metal rods with cross-sectional areas of 1 square inch and 2 square inches are each supporting a 2000-pound weight. The load or external force is the same on both, but since the cross-sectional areas are different and the load is distributed equally over the cross-sectional areas, the stresses in the two rods are also different.

You can see from the example that the stress is equal to the load divided by the cross-sectional area. That is, equal portions of the load are distributed equally over the cross-sectional area. Stress is usually measured in pounds (for load) per square inch (for area). Conversely, the load can be determined by multiplying the stress by the cross-sectional area.

Strain is the deformation or change in shape caused by the load. Some strain always occurs as a reaction to a load. The amount of strain depends on the magnitude and duration of the stress caused by the load. It also depends on the type and condition of the material. Strain is measured in inches per inch or in percentage. Thus, when a load is applied to a bar in tension, the bar will elongate (be strained) some fraction of an inch for each inch of bar (the strain will be the same in each inch of bar). If strain is being measured in percentage, the bar will be elongated a certain percentage; that is, the total length of the bar will be increased a certain amount, which will be a percentage of the original length.

Stress occurs because molecular forces within the material resist the change of shape that an applied load tends to produce. In other words, stress results from the resistance of the molecules to being shifted around, pulled apart, or squeezed together. Because stress involves molecular forces, a piece of metal that is subjected to a load develops an enormous number of stresses, rather than just one stress. If you had more than a very few molecules, you would have to draw thousands or perhaps millions of arrows to indicate all the molecular forces involved. We often speak of stress as though it were one internal force, acting in one direction; that is, the direction opposite to the direction of the applied load. In other words, we consider the TOTAL EFFECT of all the molecular stresses, rather than trying to consider each set of molecular stresses separately.

The manner in which the load is applied determines the type of stress that will develop. Applied forces are usually considered as being of three basic kinds: tension (or tensile) forces, compression forces, and shearing forces. The basic stresses, therefore, are tension (or tensile) stresses, compression stresses, and shearing stresses. Complex stresses such as bending stresses and torsional stresses are combinations of two or more of the basic stresses.

TENSION STRESS

Tension stresses develop when a material is subjected to a pulling action. If, for example, a cable is fastened to an overhead clamp and a weight is attached to the free end, tension stresses develop within the cable. The tension stresses resist the tension forces that tend to pull the cable apart. Figure 6-1 shows tension forces and the resulting “equal and opposite” tension stresses.

COMPRESSION STRESS

Compression stresses develop within a material to oppose the forces that tend to compress or crush the material. A column that supports an overhead weight is said to be in compression, and the internal stresses that develop within the column are compression stresses. Figure 6-2 shows compression forces and compression stresses.

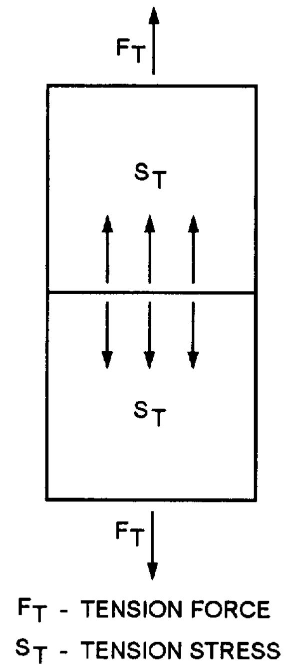


Figure 6-1.—Tension forces and tension stresses.

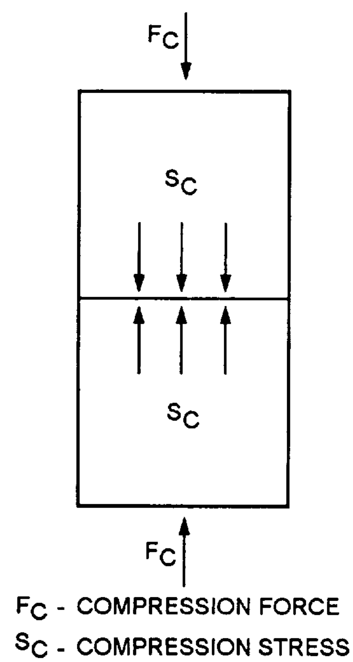


Figure 6-2.—Compression forces and compression stresses.

SHEARING STRESS

Shearing stresses develop within a material when opposite external forces are applied along parallel lines in such a way as to tend to cut the material. Shearing forces tend to separate material by sliding part of the material in the opposite direction. The action of a pair of scissors is an example of shear forces and shear stresses. The scissors apply shear forces, and the material being cut resists the shear forces by its internal shear stresses. Forces tending to produce shear in a rivet are illustrated in figure 6-3. Shear stresses are not shown, since they are considerably more complex than tension stresses and compression stresses.

BENDING STRESS

Bending stresses develop when a material is subjected to external forces that tend to bend it. When a load is applied to a beam, for example, as shown in figure 6-4, the upper surface is in compression and the lower surface is in tension. The NEUTRAL AXIS, indicated by the broken line in figure 6-4, is neither in compression nor in tension.

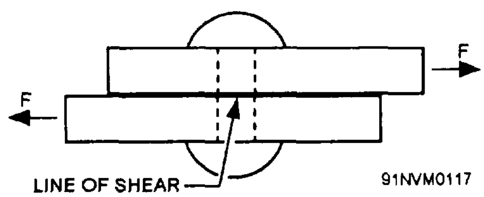


Figure 6-3.—Shearing forces applied to a rivet.

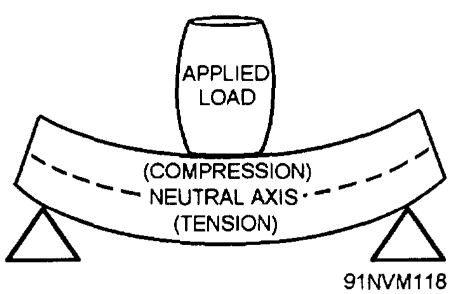


Figure 6-4.—Load applied to a beam.

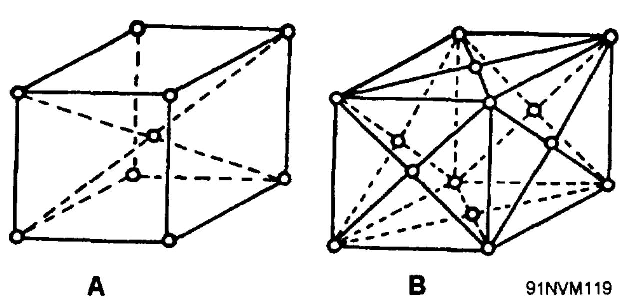


Figure 6-5.—Crystal structure of iron. A. Body-centered cubic, 9-atom space lattice. B. Face-centered cubic, 14-atom space lattice.

TORSIONAL STRESS

Torsional stresses develop in a material when external forces are applied in such a way that they tend to produce rotation. A ship's shaft, for example, rotates when the external applied forces are greater than the internal torsional stresses developed in the shaft. Torsional stress is primarily a special form of shear stress, although it may also involve some compression stress and some tension stress.

INTERNAL STRUCTURE OF METALS

The atoms in all solid metals are arranged in some definite geometric (or crystallographic) pattern. The smallest grouping of atoms that has the complete symmetrical arrangement of the crystal is called a unit cell. The regular arrangement of these atoms is called a space lattice. A unit cell is much too small to be seen. When a great many unit cells are combined, however, they form a visible crystal that has the same geometric structure as the unit cell.

A number of different geometrical arrangements of atoms are possible, but most metals have space lattices that are basically shaped like cubes, tetragons, or hexagons. Figure 6-5 shows the body-centered cubic and face-centered cubic space lattices.

How do crystals form? When the metal is in the liquid state, the atoms move freely and are not arranged in any orderly fashion. When the metal begins to cool, however, the atoms move more and more slowly. When the freezing (solidifying) temperature of the metal is reached, the atoms begin to form unit cells of the type characteristic of the particular metal. In this crystallization process, the atoms give up energy in the form of heat. As this energy flows from the metal, other atoms form around each of the original unit cells in a definite pattern. This definite and repeating pattern upon solidification is called a space lattice. Eventually all of the metal is changed from the liquid state, in which the atoms are moving freely, to the solid state, in which the atoms are arranged in a definite, orderly pattern. At this point, we say that the metal has completely solidified or frozen.

If crystallization could proceed without any interference, the result would be one large crystal with the external form of the internal space lattice. As a rule, however, the space lattices do not all line up perfectly with each other; this means that the growth of some crystals interferes with the growth of others.

In other words, space lattices that are not oriented in approximately the same way cannot join each other. As a result, the crystallization process usually results in the growth of many small crystals rather than one large one. In any given piece of solid metal, the size of the crystals will vary. The larger ones are the result of the combination of a great many space lattices that happened to line up in such a way that they could join each other.

Because the crystals interfere with each other as they grow, a piece of metal in cross section may show very few characteristic crystal shapes. Note, however, that the metal is still considered crystalline even if the crystalline forms are distorted. The crystals are there, but they are not usually perfect in shape.

When a metal crystallizes in such a way that the crystals are not perfectly formed and therefore do not have the typical shape of the space lattice, it is customary to call each visible unit a grain rather than a crystal. The areas between adjacent grains are shown as grain boundaries. The grain boundary material has somewhat different properties than the actual grains or crystals; this is partly because the space lattices are distorted at the grain boundaries and partly because the process of crystallization tends to push impurities out of the crystals and into the grain boundaries.

The term grain structure refers to the crystalline structure of the metal, often with particular reference to the shape and size of the grains. Figure 6-6 illustrates several types of gram structure, as seen under a microscope. The size of the grains depends upon a number of factors, including the nature of the metal, the temperature to which it is heated, the length of time it is held at a specified temperature, and the rate at which it is cooled from a liquid to the solid state. In general, the quicker a metal solidifies, the smaller the grain will be. The size of grain structure desired for any particular application depends upon the purpose for which the metal is to be used.

In alloys, the internal structure may be in the form of crystals of pure metals, solid solutions, intermetallic compounds, mechanical mixtures, or some combination of these structures.

In a solid solution, the elements are completely dissolved in each other, with the atoms of each element fitting into and forming part of the space lattice of the other element. Figure 6-7 illustrates two

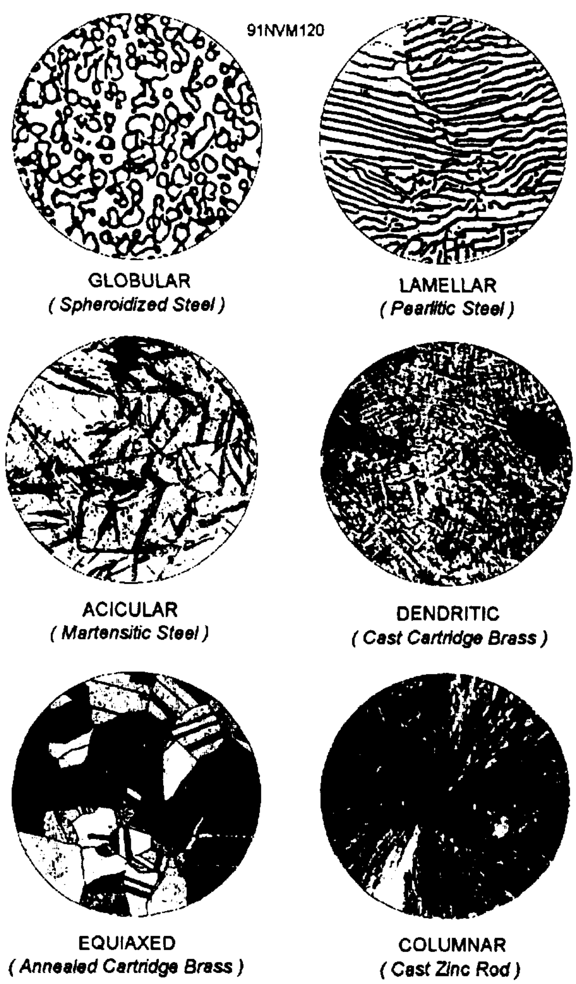


Figure 6-6.—Grain structure in metals.

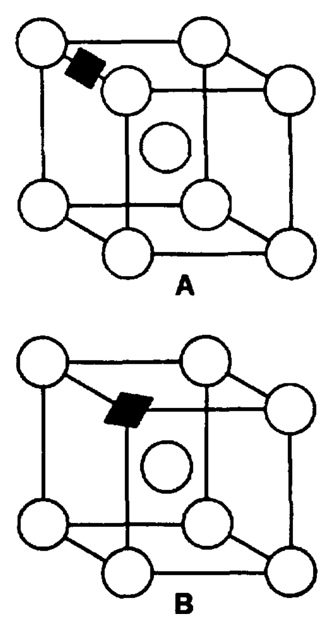


Figure 6-7.—Space lattices of two forms of solid solution. A. Atoms of one element fit between atoms of another element. B. Atoms of one element replace atoms of another element.

ways in which solid solutions may exist. The atoms of one element may fit into the spaces between the atoms of another element, as indicated in view A; or the atoms of one element may replace the atoms of another element in the space lattice, as indicated in view B.

A solid solution in a metal is similar to many solutions you are familiar with; for example, water dissolves salt. The result is a wet salty liquid. The taste of the salt and the wetness of the water have not changed. As you see, there has been no change of individual properties. However, you cannot see or distinguish which is water or which is salt. The loss of individual identity is apparent. An example of a familiar solid solution is Monel metal. You know from experience that Monel is tough, and yet, soft and plastic; the toughness of nickel and the plasticity of copper have been combined in the form of a metallic solid solution.

The individual elements lose their identity in a solid solution. A polished cross section of a material that consisted of only one solid solution would show all grains to be of the same nominal composition.

Ferrite and austenite are two solid solutions that are important constituents of steel. Ferrite is the name given to a solid solution of alpha iron and carbon. *Austenite* is the term for a solid solution of gamma iron and carbon. Carbon is only slightly soluble in alpha iron but is quite soluble in gamma iron. Alpha iron at room temperature can hold only about 0.007 percent carbon in solid solution. At a temperature of 2065°F. gamma iron can hold up to about 1.7 percent carbon in solid solution.

INTERMETALLIC COMPOUNDS are compounds formed between a metal and some other substance such as carbon or sulfur. There are many ordinary compounds that we are familiar with in everyday life; common table salt is one. The two poisonous elements, sodium and chlorine, when combined, form sodium chloride or common table salt. Salt does not resemble either sodium or chlorine, either by identity or properties. When the two elements are combined chemically, a new and different substance is created. Under certain conditions, intermetallic compounds form and a new substance with new properties is created in very much the same manner, but on a more complicated basis. Perhaps the most important thing to remember about the intermetallic compounds is the loss of identity and the change in properties. The heat treater quite often utilizes the change in properties offered by compound formations in metals.

One intermetallic compound of great importance in ferrous alloys is known as IRON CARBON or CEMENTITE. This is an extremely hard and brittle compound that is formed by the combination of iron (a metal) and carbon (a metalloid). The formula for iron carbide or cementite is Fe_3C. This formula shows that three atoms of iron combine with one atom of carbon to produce iron carbide, or cementite.

The structure of an alloy is described as being a MECHANICAL MIXTURE when two or more structural forms are mixed together but are still separately distinguishable. A mechanical mixture of an alloy is comparable, though on a smaller scale, to the mixture of sand and gravel that may be seen in concrete.

One of the most important mechanical mixtures that occurs in many steels is known as PEARLITE. Pearlite, so called because it has a pearly luster when seen under a microscope, is an intimate mechanical mixture of ferrite and cementite in alternate plates or layers. Ferrite is a solid solution, and cementite or iron carbide is an intermetallic compound; in pearlite the two are closely mixed to form a characteristic layered structure.

Pearlite is formed when steel that contains just about 0.85 percent carbon is heated to a certain temperature and then cooled slowly. When the entire structure of the alloy is in the form of pearlite, this composition of plain carbon steel (0.85 percent carbon) is often referred to as the eutectoid composition, and the completely pearlitic structure is called the EUTECTOID or the EUTECTOID STRUCTURE.

The internal structure of an alloy may show various combinations of pure metals, solid solutions, intermetallic compounds, and mechanical mixtures. Many of the combinations that are important in steels and other alloys are the result of controlled heating and cooling of the alloy; in other words, they are the result of heat treatment. Figure 6-8 shows, very much enlarged, a typical combination that occurs when plain carbon steel containing less than 0.85 percent carbon is heated to a certain temperature and then cooled slowly. As may be seen, this combination consists of the solid solution ferrite and the mechanical mixture pearlite, each in crystal form, distributed throughout the alloy. The relative proportions of ferrite and pearlite in this combination depend largely upon the carbon content of the alloy.

This combination contains no free crystals of ferrite; instead, it consists of crystals of pearlite surrounded by cementite at the grain boundaries.

PROPERTIES OF METAL

A PHYSICAL PROPERTY is a characteristic of a metal that may be observed or measured. The physical properties of steel are affected by the following:

- Carbon content
- Impurities
- Addition of various alloying metals
- Heat treatment

The particular properties that we require of any metal or alloy depend upon the use we will make of the material. For example, an anchor chain must have the property of toughness; a boiler tube must have high tensile strength, the ability to conduct heat, and the ability to resist deformation or creep at high temperatures; an electric wire must be able to conduct electricity; a knife blade must have the property of hardness; a spring must be elastic; a saltwater piping system must resist corrosion; and a piece of metal that is to be drawn out into a wire must possess the property known as ductility. The following sections deal with some important properties of metals and alloys.

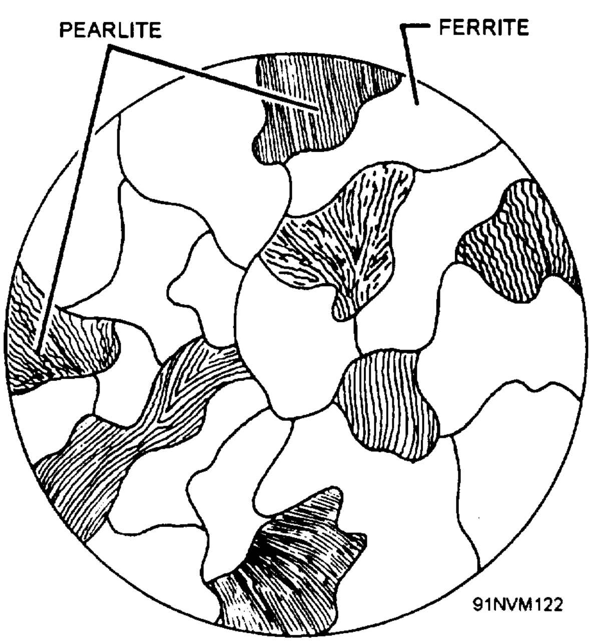


Figure 6-8.—Typical structure of steel containing less than 0.85 percent carbon.

ELASTICITY

As previously noted, a deformation or change of shape (strain) occurs when a material is subjected to external forces that cause stresses in the material. The ability of a material to return to its original size and shape after strain is the property known as elasticity.

All materials are elastic to some extent. It may surprise you to learn that a piece of steel is more elastic than a rubber band. The rubber band stretches more than the steel since it is more easily strained, but the steel returns more nearly to its original shape and size and is, therefore, more truly elastic. Glass is also more elastic than rubber.

The greatest stress that a material is capable of withstanding without taking a permanent set (that is without becoming permanently deformed) is known as the ELASTIC LIMIT. Below the elastic limit, the amount of strain is directly proportional to the amount of stress and, therefore, to the amount of externally applied force. Above the elastic limit, however, the amount of deformation that results from an increase in load is way out of proportion to the increase in load.

Strain may be axial, angular, or both, depending upon the nature of the applied load and the stresses that are developed within the material to withstand the applied load. When the elastic limit is exceeded through the application of an axial load, the material will be permanently deformed either by ELONGATION or by COMPRESSION. When the applied load is not axial (as in shear and torsion), the resulting strain is angular and, if permanent deformation results, the deformation is also angular.

As noted before, the amount of strain is proportional to the amount of stress up to (or almost up to) the elastic limit. The ratio of stress to strain is, therefore, a constant for each material. This constant, which is called the MODULUS OF ELASTICITY, is obtained by dividing the stress by the strain, which is the elongation caused by that stress. For example, suppose that a certain material is so loaded that the internal stress developed in tension is 30,000 psi and that with this stress the material elongates or is strained 0.0015 inch per inch. The modulus of elasticity (E) of this material is

$$E = \frac{\text{Stress (psi)}}{\text{Elongation (inch per inch)}}$$

$$= \frac{30{,}000 \text{ psi}}{0.0015 \text{ inch per inch}}$$

$$= 20{,}000{,}000 \text{ psi}$$

The modulus of elasticity is frequently used to determine the amount of elongation that will occur when a given stress is developed in the material. For this purpose, you divide the stress by the modulus of elasticity to obtain the elongation (inch per inch) that will occur.

Closely related to the elastic limit of a material is the YIELD POINT. The yield point is the stress at which deformation of the material first increases markedly without any increase in the applied load. The yield point is always somewhat above the elastic limit. When the stresses developed in a material are greater than the yield point (or, as it is sometimes called, the yield strength), the material is permanently deformed.

STRENGTH

Strength is the property that enables a material to resist deformation. ULTIMATE STRENGTH is the maximum stress that a material is capable of withstanding in tension, compression, or shear. The COMPRESSIVE STRENGTH of a metal is a measure of how much squeezing force it can withstand before it fails. The metal to be tested is mounted in a tensile tester, but instead of pulling on the metal, a squeezing (compression) force is applied. TENSILE STRENGTH, or the ultimate strength of a material in tension, is the term most frequently used to describe the strength of a material. Tensile strength is the ability of a metal to resist being pulled apart. This property may be measured on a tensile testing machine, which puts a stretching load on the metal. Figure 6-9 illustrates the types of loads imposed on structures.

Table 6-2 shows how the tensile strength, elongation (explained below), and yield point are affected by the carbon content of steel. As the carbon content increases, the tensile strength and yield point first increase then decrease.

Some materials are equally strong in compression, tension, and shear. However, many materials show marked differences. For example, cured portland cement has an ultimate strength of 2,000 psi in compression, but only 600 psi in tension. Carbon steel has an ultimate strength of 56,000 psi in tension and in compression, but an ultimate strength in shear of only 62,000 psi. In dealing with ultimate strength, therefore, the kind of loading (tension, compression, or shear) should always be stated.

If a material is stressed repeatedly, in a cyclical manner it will probably fail at a loading that is considerably below its ultimate strength in tension, compression, or shear. For example, you can break a thin rod with your hands after it has been bent back and forth several times in the same place, although you could not possibly cause an identical rod to fail in tension, compression, or shear merely from force applied by hand. This tendency of a material to fail after repeated stressing at the same point is known as FATIGUE.

METAL FATIGUE

Metal fatigue is the tendency for a metal to break under the action of repeated cyclic stresses. Fatigue may occur for values of cyclic stress considerably less than the ultimate tensile strength of the material. This phenomenon applies to certain fractures in metals that are caused by repeated stresses of a low enough value that a single application of the stress apparently does nothing detrimental to the structure. When enough of these seemingly harmless stresses are applied in a cyclic manner, however, they bring about a small

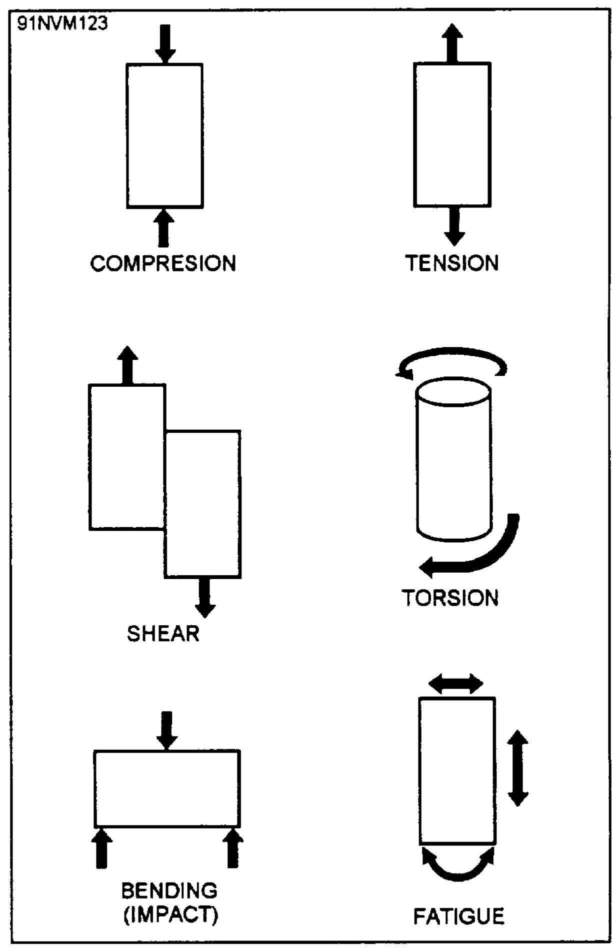


Figure 6-9.—Types of stresses or loads imposed on structures: compression, tension, shear, torsion, bending, and fatigue.

Table 6-2.—Approximate Physical Property Changes of Carbon Steel as the Carbon Content Changes

SAE AISI No.	Carbon Content in Percentages	Tensile Strength Lbs/sq. in	Yield Point Lbs/sq. in.	Elongation in Percentages
1006	.06	43,000	24,000	30
1010	-10	47,000	26,000	28
1020	.20	55,000	30,000	25
1030	.30	68,000	37,500	20
1040	.40	76,000	42,000	18
1050	.50	90,000	49,500	15
1060	.60	98,000	54,000	12
1070	.70	102,000	56,000	12
1080	.80	112,000	56,000	12
1090	.90	122,000	67,000	10
1095	.95	120,000	66,000	10

crack that grows with continued loadings until complete fracture takes place.

Since the small cracks may not be noticed, the metal may fracture with a suddenness that can be dangerous, as in fast-moving vehicles or high-speed machinery. Special inspection techniques have been developed to spot small cracks before the material fails. Fatigue failures are due to the repeated application of tensile stresses or shear stresses, which tend to pull the material apart. However, a cycle that consists of alternating equal stresses in tension and compression, called a fully reversed cycle, is usually used to obtain the endurance limits of a particular material.

HARDNESS

The property of hardness has been defined as the ability of a material to resist penetration. Because there are several methods of measuring hardness, the hardness of a material is always specified in terms of the particular test that has been used to measure this property.

To get a simple idea of the property of hardness, consider lead and steel. You can scratch lead with a pointed wooden stick, but you cannot scratch steel with such a stick. Steel is harder than lead.

TOUGHNESS

Toughness is the property that enables a material to withstand shock, to endure tensile stresses, and to be deformed without breaking. Another way of expressing this is to say that a tough material is one that can absorb a lot of energy before breaking. Toughness does not exist in metals that do not have high tensile strength; however, metals that are both strong and hard tend to have less toughness than metals that are softer and have less tensile strength.

Toughness is definitely related to the property of plasticity; materials must be plastic in order to be tough.

PLASTICITY

Materials that can withstand extensive permanent deformation without breaking or rupturing are said to be highly plastic. Note the use of the word *permanent* in this statement; the term *plastic deformation* is used to indicate a PERMANENT change of shape. Modeling clay is an example of a highly plastic material since it can be deformed extensively and permanently without rupturing. Clay could scarcely be called tough, however, even though it is highly plastic.

Plasticity is in some ways the opposite of brittleness and in other ways the opposite of elasticity. A material that is brittle will break without showing deformation. Such a material is not very plastic. A material that is highly elastic will return to its original shape after strain; consequently, such a material does not show a high degree of plasticity (below the elastic limit for the substance). Most metals are elastic, rather than plastic, up to the elastic limit; above the elastic limit, they tend to have the property of plasticity.

Plasticity, like many other properties, is relative. To some degree, all substances are plastic. Even glass, which is usually considered to be a nonplastic material, is plastic if an external force is applied to it very slowly. If you want to demonstrate this to yourself, take a sheet of glass and lay it in a horizontal position in such a way that it is supported only at the ends. Then put a weight in the middle of the glass. After several days (or possibly weeks, depending upon the kind of glass you use), you will be able to observe a visible deformation of the glass.

The substance known as "Silly Putty" is an even better example of the relative nature of the property of plasticity. When you slowly press or mold "Silly Putty," it is more plastic than chewing gum; throw it against the floor and it may either bounce like a rubber ball or break into pieces; hit it sharply with a hammer, and it will shatter almost like glass.

Before these properties are studied in detail, the welder should have an understanding of the effect of carbon on the properties of steel and a knowledge of alloys in general.

DUCTILITY AND MALLEABILITY

The properties known as ductility and malleability are special cases of plasticity. Ductility is the property that makes it possible for a material to be drawn out into a thin wire or, in other words, it is the property that enables the material to withstand extensive permanent deformation from TENSION. Ductility is the ability of a metal to be stretched. A very ductile metal such as copper or aluminum may be pulled through dies to form wire. Malleability is the property that makes it possible for a material to be stamped, hammered, or rolled into thin sheets; a malleable material is one that can withstand extensive permanent deformation from COMPRESSION.

Most metals that exhibit one of these properties also exhibit the other. However, this is not always true. Lead, for example, is very malleable (it can be permanently deformed in compression without breaking), but it is not ductile (it cannot be permanently deformed in tension to any great extent).

CREEP RESISTANCE

The term *creep* describes a special kind of plastic deformation that occurs very slowly at high temperatures when the material is under a constant stress. It is interesting to note that this stress may be considerably less than the yield point of the material at room temperature. Because creep occurs very slowly at or below room temperature (so slowly, in fact, that years are required to complete a single creep test), the importance of this type of plastic deformation has not been recognized until fairly recent. Creep-resisting steel is now used in most modem naval ships for high-temperature piping.

BRITTLENESS

Brittleness is the opposite of ductility. A brittle metal will fracture if it is bent or struck a sharp blow. A brittle material is one that fractures before exhibiting any noticeable permanent deformation. Most cast iron is very brittle.

CORROSION RESISTANCE

Corrosion resistance is the property that enables a material to resist entering into chemical combination with other substances. A high degree of corrosion resistance would be very desirable in all metals used aboard ship. Most metals are easily corroded, however, as shown by the fact that pure metals occur only rarely in nature.

The presence of impurities, or the presence of alloying elements, may greatly alter the corrosion resistance of a metal. For example, the zinc that is known as "commercially pure" contains a small amount of impurities; this grade of zinc corrodes about 10,000 times as fast as zinc that is chemically pure. On the other hand, many alloys have been developed for the particular purpose of increasing the corrosion resistance of the material. For example, pure iron would be entirely unsuitable for use in boilers because it has very poor resistance to corrosion, particularly at high temperatures; yet alloys composed primarily of iron are used successfully for this service.

WELDABILITY AND MACHINABILITY

Although not strictly properties, in the sense of the other properties we have discussed, weldability and machinability are important practical considerations in the fabrication or repair of any metal part. Weldability refers to the relative ease with which a metal may be welded. Machinability describes the ease with which a metal may be turned, planed, milled, or otherwise shaped in the machine shop. Some metals are not easily machined because they are too hard. Some soft metals are not easily machined because they are too tough. Both weldability and machinability are really based upon the combination of other properties of the material, rather than being properties themselves.

TYPES OF METAL

Metals are divided into two major fields: ferrous metals and nonferrous metals. Ferrous metals are those that are composed primarily of iron. Nonferrous metals are those that are composed primarily of some element or elements other than iron. Nonferrous metals or alloys sometimes contain a small amount of iron as an alloying element or impurity.

FERROUS METALS

Ferrous metals include all forms of iron and steel. Ferrous metals are widely used in the construction of ships.

Iron

Commercially pure iron is known as INGOT IRON. This iron is 99.85 percent iron; carbon, manganese, phosphorous, sulfur, and a trace of silicon make up the remainder. The chemical composition of this iron is very similar to the chemical composition of the lowest carbon steel.

WROUGHT IRON was used extensively for construction and even for machinery before steels came into use. Wrought iron is a mixture of very pure iron and silica slag. The slag gives wrought iron some of its desirable properties—corrosion resistance, weldability, and ductility, among others. Wrought iron is still used for some piping systems on auxiliary ships.

CAST IRON is produced by resmelting a charge of pig iron and scrap iron and removing some of the impurities from the molten metal by using various fluxing agents. There are many grades of cast iron, rated as to strength and hardness. The four major kinds of cast iron are white cast iron, gray cast iron, malleable cast iron, and nodular cast iron. With the exception of similarity between nodular and malleable cast iron, there are considerable differences in the properties of the various kinds of cast iron. The form in which the carbon exists (graphite or cementite) and the mode of its distribution are chiefly responsible for the differences in properties.

White cast iron essentially consists of an alloy of iron, carbon, and silicon. It is known chiefly for its good wear resistance and as the starting point for producing malleable cast iron. White cast iron derived its name from the bright silvery appearance it has when fractured. White cast iron is hard, brittle, wear resistant, and unmachinable, largely because the carbon it contains is present as cementite.

Gray cast iron always contains iron, carbon, and silicon, and generally contains more carbon and silicon than white cast iron. Carbon is always present in the form of graphite flakes. In addition, gray cast iron often contains appreciable amounts of nickel and other alloying elements. Gray cast iron is of three varieties: common, high strength, and alloy. All three are machinable and have good damping capacity (ability to absorb and dampen vibrations). The common gray cast irons are quite soft; the others are somewhat stronger, particularly the alloy gray cast iron. All three are brittle because the carbon they contain is largely present in graphite flakes, which act as severe stress raisers. Whether a cast iron is gray or white depends upon the cooling rate and carbon, silicon, and nickel content.

Malleable cast iron is made by heating white castings to 1700°F for about 50 hours, followed by slow cooling to room temperature. The castings are packed in a neutral slag or scale during heating and cooling. During the heating period, the cementite in the structure tends to decompose into ferrite plus temper carbon. Malleable cast iron is strong, machinable, and ductile. The mechanical properties of malleable cast iron compare favorably with those of low-carbon steels. Malleable cast iron is a great deal more ductile than either white or gray cast iron.

Nodular cast iron is produced in the same way as gray cast iron, but with much closer control of composition and with the aid of inoculating agents. The molten iron is inoculated with an alloy that will produce spherical graphite rather than flake graphite. Nodular cast iron possesses the good machinability, damping capacity, and castability of gray cast iron. Its strength is comparable to alloy gray cast irons and cast carbon steel. The ductility of nodular cast iron is about half that of cast steel, far better than gray cast iron.

Steel

Steels and other metals are classified on the basis of the method of manufacture, method of shaping, method of heat treatment, properties, intended use, and chemical composition. In addition, certain steels and other metals are often referred to by trade names.

When classified according to the method of manufacture, steels are known as (I) basic, open hearth; (2) basic, electric; (3) acid, Bessemer; (4) acid, electric; (5) acid, open hearth; or (6) basic, oxygen furnace. The method of manufacture has a lot to do with the properties of the finished steel, so these distinctions are important to metallurgists and to design engineers. Since the method of manufacture is not usually important to the HT, these processes will not be discussed in this training manual.

When classified according to the method of shaping, steels are often referred to as cold rolled steel, forged steel, drawn steel, and cast steel.

Classifying steels according to the method or methods of heat treatment leads to such terms as *annealed steel*, and *casehardened steel.*

Classifying steels according to properties gives us such classes as corrosion-resisting steels (CRES); heat-resisting steels; low-expansion steels; free-machining or free-cutting steels; casehardening steels; high tensile steels (HTS); and special treatment steel (STS).

Probably the most reasonable way to classify steels is by their chemical composition. Steels that derive their properties primarily from the presence of carbon are referred to merely as "steels" or sometimes as "plain carbon steels." Steels that derive their properties primarily from the presence of some alloying element other than carbon are referred to as "alloys" or "alloy steels." Note, however, that plain carbon steels always contain some carbon. Note, also, that the use of the word *alloy* should not really be limited to mean an alloy steel, since there are many alloys that contain no iron at all and are, therefore, not steels.

Plain Carbon Steel

Plain carbon steels vary in carbon content from about 0.05 percent to as much as 1.70 percent carbon. The properties of the steel depend upon the amount of carbon present and the particular way in which the iron and the carbon combine. The plain carbon steels are known (in increasing order of the amount of carbon present) as mild steel, low-carbon steel, medium-carbon steel, high-carbon steel, and very-high-carbon steel.

Alloy Steel

An alloy metal may be defined as an intimate mixture of two or more elements. Any ferrous or nonferrous metal may be alloyed to form an alloy metal with new and desirable characteristics.

A simple alloy consists of two metals in any proportion. An example of a simple alloy is the combination of tin and lead, which is called solder. The melting temperature of the lead is 621°F (327°C). Tin has a melting temperature of 450°F (232°C). However, as the two metals are mixed, any combination of the two results in a lower melting temperature than 621°F (327°C). At a certain proportion of the metals, the lowest melting temperature is reached. This point is called the EUTECTIC POINT.

Steel is a combination of iron and controlled amounts of carbon. Alloy steels are created by adding other elements to plain carbon steel. Alloy steels are identified by the name of the alloying element or elements, usually without reference to the carbon that is present. Alloy steels are further identified as low-alloy steels or high-alloy steels, depending upon the amount of alloying material that is present. Some elements that are alloyed with carbon steel and the qualities imparted to steel by each are as follows:

CHROMIUM—Increases resistance to corrosion and improves hardness, toughness, wear resistance, strength, and the responsiveness to heat treatment.

MANGANESE—Increases strength and responsiveness to heat treatment.

MOLYBDENUM—Increases toughness and improves the strength of steel at higher temperatures.

NICKEL—Increases strength, ductility, and toughness.

TUNGSTEN—Produces dense, fine grains; helps steel to retain its hardness and strength at high temperatures.

SILICON—Improves the electrical quality of the steel.

VANADIUM—Retards grain growth and improves toughness.

NONFERROUS METALS

Although ferrous metals are used aboard ship in greater quantities than the nonferrous metals, the nonferrous metals are nevertheless of great importance. Copper, zinc, lead, and a large number of nonferrous alloys are required in the construction and maintenance of naval ships. Some of the more popular nonferrous metals a welder encounters are copper, brass, zinc, bronze, lead, and aluminum.

The various welding processes now make it possible to satisfactorily weld practically all nonferrous metals.

Copper

Copper is one of the most important nonferrous metals used in the construction of a ship. It is used in the form of sheets, tubing, wires, and in copper alloys such as brass and bronze. It is used to give a protective coating to other metals, and to fabricate many special parts.

The properties of copper make it extremely useful for many applications. It is easy to work; it is ductile, malleable, tough, strong, resistant to wear, and machinable. Copper is highly resistant to saltwater corrosion and is an excellent conductor of both heat and electricity. Copper seams are usually joined by riveting, brazing, or soldering.

ZINC

Zinc is used as a protective coating (galvanizing) on steel and iron. Zinc is also used in the form of zinc chloride for soldering fluxes and as an alloying element in some brass and bronze.

High-purity zinc, in the form of sheets, rods, or special shapes, is used to protect hulls, hull fittings, and many types of machinery from the effects of galvanic action.

Lead

Lead is probably the heaviest metal that you will ever use on board ship. Lead weighs about 700 pounds per cubic foot, but in spite of its weight, it is soft and malleable. Lead is commonly supplied in sheet form, rolled up on a rod. To use it, you merely unroll it and cut off as much as you need.

Because of its softness, lead is often used as a backing material for punching and hammering operations. Sheet lead is used to line sinks and to protect bench tops that are exposed to acids. Lead is also used as a radiation shield.

Tin

Tin is seldom used aboard ship in its pure state, but it has many important uses as an alloying element. Tin and lead are used together to make soft solders; tin and copper are used together to make bronze. Tin and tin-based alloys have, in general, a high resistance to corrosion.

Brass

True brass is an alloy of copper and zinc. Additional elements—aluminum, lead, tin, iron, manganese, or phosphorous—may be added to give the alloy specific properties. Rolled naval brass (also known as Tobin bronze) is about 60 percent copper, 39 percent zinc, and 0.75 percent tin. This type of brass is highly resistant to corrosion.

Brass sheets and strips are available in grades known as soft, 1/4 hard, 1/2 hard, full hard, and spring. Hardness is imparted to the brass by the process of cold rolling. Most grades of brass can be made softer by annealing the metal at a temperature of 800° to 1200°F.

Bronze

A bronze made of 84 percent copper and 16 percent tin was the best metal available for tools, weapons, and so on, before techniques were developed for making steel. Many complex bronze alloys, containing additional elements such as zinc, lead, iron, aluminum, silicon, and phosphorous are now available. The name bronze is now applied to any copper-base alloy that looks like bronze; in many cases, there is no longer a real distinction to be made between bronze and brass.

Aluminum and Aluminum Alloys

Aluminum and aluminum alloys are widely used because they are lightweight, easily worked, and strong in relation to their weight. There are now so many different types of aluminum alloys in use that a special numbering system has been adopted for these alloys.

IDENTIFICATION OF METALS

Material is used daily and, normally, there will be some material left over. Quite often the means of marking the material was cut off, or worn off, leaving the material to a guessing game as to what type of material it is. Granted, it is best to make out a tag with all the important information as to the type of material, the alloy composition, and possibly the stock number of that material. Even then, tags are subject to being lost. Therefore, let us look at the various ways to identify the material according to surface appearance and identification tests.

IDENTIFICATION BY SURFACE APPEARANCE

It is possible to identify several metals by their surface appearance. Although examination of the surface does not usually give you enough information to classify the metal exactly, it will often give you enough information to allow you to identify the group to which the metal belongs. Even this much identification is helpful since it will limit the number of tests required for further identification.

In trying to identify a piece of metal by its surface appearance, consider both the color and the texture of the surface. Table 6-3 gives the surface colors of some common metals.

IDENTIFICATION TESTS

If the surface appearance of a metal does not give enough information to allow adequate identification, metal identification tests are necessary. A number of such tests are used. Some of these tests are complicated and require equipment that you are not likely to have. Others, however, are relatively simple and quite reliable when performed by a skilled person. The following tests are the most common for shop use:

- Spark test (with the power grinder)
- Oxyacetylene torch test
- Fracture test

Table 6-3.—Surface Colors of Some Common Metals

Metals	Color of unfinished, unbroken surface	Color and structure of newly fractured surface	Color of freshly filed surface
White cast iron	Dull gray	Silvery white; crystalline	Silvery white
Gray cast iron	Dull gray	Dark silvery; crystalline	Light silvery gray
Malleable iron	Dull gray	Dark gray; finely crystalline	Light silvery gray
Wrought iron	Light gray	Bright gray	Light silvery gray
Low carbon and cast steel	Dark gray	Bright gray	Bright silvery gray
High carbon steel	Dark gray	Light gray	Bright silvery gray
Stainless steel	Dark gray	Medium gray	Bright silvery gray
Copper	Reddish brown to green	Bright red	Bright copper color
Brass and bronze	Reddish yellow, yellow-green, or brown	Red to yellow	Reddish yellow to yellowish white
Aluminum	Light gray	White; finely crystalline	White
Monel metal	Dark gray	Light gray	Light gray
Nickel	Dark gray	Off white	Bright silvery white
Lead	White to gray	Light gray; crystalline	White
Copper-Nickel (70-30)	Gray	Light gray	Bright silvery white

- Color test
- Density or specific gravity test
- Ring or sound of the metal upon impacting with some other metal
- Magnetic test
- Chip test

Spark Test

The spark test is made by holding a sample of the material against a power grinder. The sparks given off, or the lack of sparks, assist in identifying the metal. The length of the spark stream, its color, and the type of sparks are the features for which you should look.

There are four fundamental spark forms produced by holding a sample of metal against a power grinder. (See fig. 6-10.) View A shows shafts, buds, breaks, and arrows. The arrow or spearhead is characteristic of molybdenum, an alloying element in steel. When swelling or buds are present in the spark line, nickel is also present as an alloying element with molybdenum. View B shows shafts and sprigs, or sparklets, which indicate a high carbon content. View C shows shafts, forks, and sprigs that indicate a medium carbon content. View D shows shafts and forks that indicate a low carbon content.

The greater the amount of carbon present in the steel, the greater the intensity of bursting that will take place in the spark stream. To understand the cause of the bursts, remember that while the spark is glowing and in contact with the oxygen of the air, the carbon present in the particle is burned to carbon dioxide. As the solid carbon combines with oxygen to form carbon dioxide in the gaseous state, the increase in volume builds up a pressure that is relieved by an explosion of the particle. An examination of the small steel particles under a microscope when they are cold reveals a hollow sphere with one end completely blown away.

Steels having the same carbon content but differing alloying elements are not always easily identified because alloying elements affect the carrier lines, the bursts, or the forms of characteristic bursts in the spark picture. The effect of the alloying element may retard or accelerate the carbon spark or make the carrier line lighter or darker in color. Molybdenum, for example, appears as a detached, orange-colored, spearhead on the end of the carrier line. Nickel seems

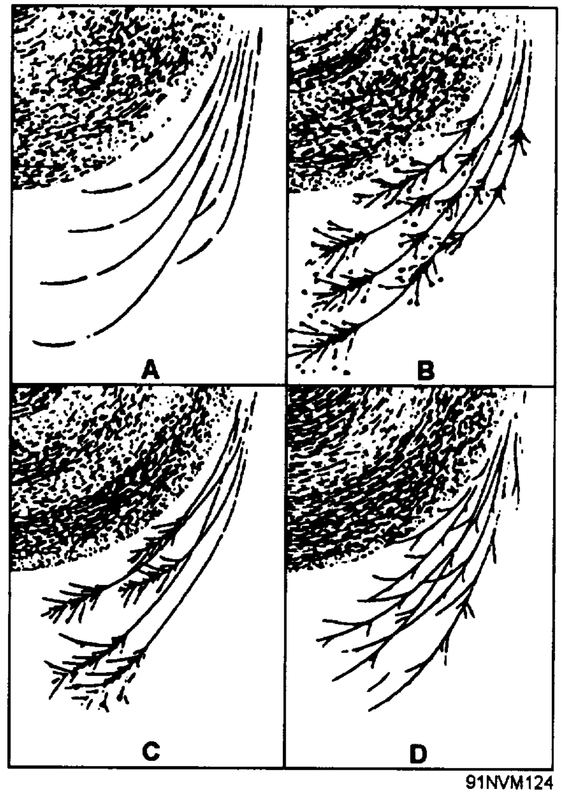


Figure 6-10.—Fundamental spark forms.

to suppress the effect of the carbon burst. However, the nickel spark can be identified by tiny blocks of brilliant white light. Silicon suppresses the carbon burst even more than nickel. When silicon is present, the carrier line usually ends abruptly in a white flash of light.

To make the spark test, hold the piece of metal against the wheel in such a manner as to throw the spark stream about 12 inches at a right angle to your line of vision. You will need to spend a little time to discover at just what pressure you must hold the sample to get a stream of this length without reducing the speed of the grinder. It is important that you do not press too hard because the pressure will increase the temperature of the spark stream and the burst. It will also give the appearance of a higher carbon content than that of the metal actually being tested. After practicing to get the feel of correct pressure on the wheel until you're sure you have it, select a couple of samples of metal with widely varying characteristics; for example, low-carbon steel and high-carbon steel. Hold first one then the other against the wheel, always being careful to strike the same portion of the wheel with each piece. With your eyes focused at a point about one-third of the distance from the tail end of the stream of sparks, watch only those sparks that cross the line of vision. You will find that after a little while, you will form a mental image of the individual spark. After you can fix the spark image in mind, you are ready to examine the whole spark picture.

Notice that the spark stream is long (about 70 inches normally) in low-carbon steel, and that the volume is moderately large; while in high-carbon steel, the stream is shorter (about 55 inches) and larger in volume. The few sparklers that may occur at any place in low-carbon steel are forked, while in high-carbon steel the sparklers are small and repeating, and some of the shafts may be forked. Both will produce a white spark stream.

White cast iron produces a spark stream approximately 20 inches in length (see fig. 6-11). The volume of sparks is small with many small and repeating sparklers. The color of the spark stream close to the wheel is red, while the outer end of the stream is straw colored.

Gray cast iron produces a stream of sparks about 25 inches in length. It is small in volume with fewer sparklers than white cast iron. The sparklers are small and repeating. Part of the stream near the grinding wheel is red, and the outer end of the stream is straw colored.

The malleable iron spark test will produce a spark stream about 30 inches in length. It is of a moderate volume with many small, repeating sparklers toward the end of the stream. The entire stream is straw colored.

The wrought iron spark test produces a spark stream about 65 inches in length. The stream is of large volume with few sparklers. The sparklers show up toward the end of the stream and are forked. The stream next to the grinding wheel is straw colored, while the outer end of the stream is a bright red.

Stainless steel produces a spark stream approximately 50 inches in length, of moderate volume, with few sparklers. The sparklers are forked. The stream next to the wheel is straw colored. The sparks form wavy streaks with no sparklers.

Monel metal forms a spark stream almost identical to that of nickel and must be identified by other means. Copper, brass, bronze, and lead form no sparks on the grinding wheel, but they are easily identified by other means, such as color, appearance, and chip tests.

You will find the spark tests easy and convenient to make. They require no special equipment and are adaptable to most any situation. Here again, experience is the best teacher.

It is good practice to compare the sparks of an unknown metal with those of a known metal. This permits an additional check on the tester's conclusion and also can distinguish between different metals that have similar spark patterns. It is the practice in many metal shops to maintain a cabinet of commonly used metals, positively identified as to grade, for comparison with unknown samples.

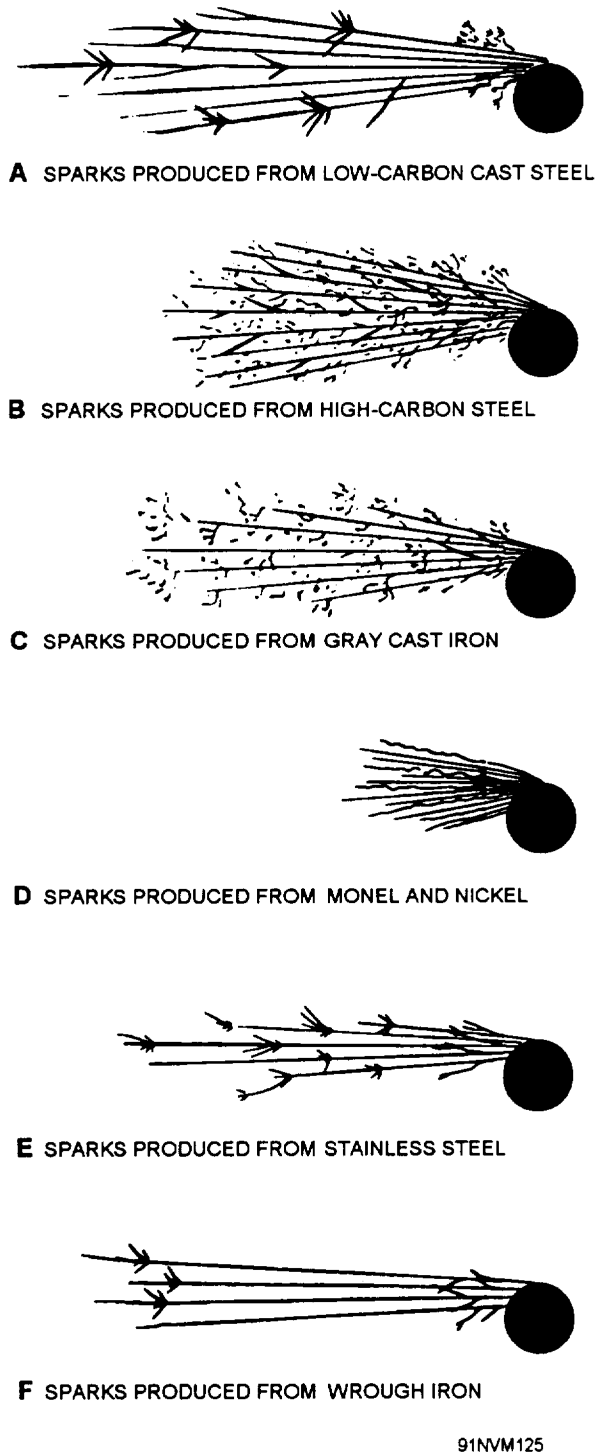


Figure 6-11.—spark pictures formed by common metals.

Proper lighting conditions are essential for good spark testing practice. Testing should not be done in strong direct lighting. A dark background for the spark pattern should be used. Heavy drafts of air against the spark pattern should be avoided as the air can change the tail sparks. Such a change will lead to incorrect identification.

Oxyacetylene Torch Test

Even if you know the physical composition and the chemical composition of a metal, you must also know whether the metal has good welding properties. For example, some cold rolled sheet steels may show very good physical and chemical properties. However, during some part of the manufacturing process, impurities may have been added to it or certain work may have been done to the metal affecting its properties. The metal may not melt and fuse readily. The final weld may be unsatisfactory. The usual cause of this condition is that there are impurities imbedded in the metal. The impurities are usually slag and roller dirt or excessive sulphur and phosphorus. For these reasons, a welder should subject steel to the torch test.

Metals may sometimes be identified by their characteristic reactions to being heated with an oxyacetylene welding torch. Identifying factors include the rate of melting, the appearance of the molten slag, and the color changes (if any) that occur during the heating. Table 6-4 indicates the reactions of various metals to the torch test.

Table 6-4.—Identification of Metals by Oxyacetylene Torch Test

Metals	Reactions When Heated By Oxyacetylene Torch
White cast iron	Metal becomes dull red before melting. Melts at moderate rate. A medium tough film of slag develops. Molten metal is watery, reddish white in color, and does not show sparks. When flame is removed, depression in surface of metal under flame disappears.
Gray cast iron	Puddle of molten metal is quiet, rather watery, but with heavy, tough film forming on surface. When torch flame is raised, depression in surface of metal disappears instantly. Molten puddle takes time to solidify, and gives off no sparks.
Malleable iron	Metal becomes bright red before melting: melts at moderate rate. A medium tough film of slag develops, but can be broken up. Molten puddle is straw colored, watery, and leaves blowholes when it boils. Center of puddle does not give off sparks, but the bright outside portion does.
Wrought iron	Metal becomes bright red before it melts. Melting occurs quietly and rapidly, without sparking. There is a characteristic slag coating, greasy or oily in appearance, with white lines. The straw-colored molten puddle is not viscous, is usually quiet but may have a tendency to spark; is easily broken up.
Low-carbon and cast steel	Melts quickly under the torch, becoming bright red before it melts. Molten puddle is liquid, straw colored, gives off sparks when melted, and solidifies almost instantly. Slag is similar to the molten metal and is quiet.
High-carbon steel	Metal becomes bright red before melting, melts rapidly. Melting surface has cellular appearance, and is brighter than molten metal of low-carbon steel; sparks more freely, and sparks are whiter. Slag is similar to the molten metal and is quiet.
Stainless steels	Reactions vary depending upon the composition.
Copper	Metal has high heat conductivity; therefore, larger flame is required to produce fusion than would be required for same size piece of steel. Copper color may become intense before metal melts; metal melts slowly, and may turn black and then red. There is little slag. Molten puddle shows mirror like surface directly under flame, and tends to bubble. Copper that contains small amounts of other metals melts more easily, solidifies more slowly, than pure copper.
Brass and Bronze	These metals melt very rapidly, becoming noticeably red before melting. True brass gives off white fumes when melting. Bronze flows very freely when melting, and may fume slightly.
Aluminum and aluminum alloys	Melting is very rapid, with no apparent change in color of metal. Molten puddle is same color as unheated metal and is fluid; stiff black scum forms on surface, tends to mix with the metal, and is difficult to remove.
Monel	Melts more slowly than steel, becoming red before melting. Slag is gray scum, quiet and hard to break up. Under the scum, molten puddle is fluid and quiet.
Nickel	Melts slowly (about like Monel), becoming red before melting. Slag is gray scum, quiet and hard to break up. Under the scum, molten puddle is fluid and quiet.
Lead	Melts at very low temperature, with no apparent change in color. Molten metal is white and fluid under a thin coating of dull gray slag. At higher temperature, puddle boils and gives off poisonous fumes.

The actual test consists of melting a puddle in the steel. If the metal is thin, the puddle penetrates through the thickness of the steel until a hole is formed. This puddling should be done with a neutral flame, held at the proper distance from the metal. The puddle should not spark excessively or boil. The puddle should be fluid and should possess good surface tension. The appearance on the edge of the puddle or hole indicates the weldability of the steel. If the metal that was melted has an even, shiny appearance upon solidification, the metal is generally considered as having good welding properties. However, if the molten metal surface is dull or has a colored surface, the steel is unsatisfactory for welding. The steel is also considered unsatisfactory for welding if the surface is rough, perhaps even broken up into small pits or porous spots.

This test is accurate enough for most welding. The test is very easily applied with the equipment on the job. The test determines the one thing that is fundamentally necessary in any welding job, that is, the weldability of the metal. Figure 6-12 shows how this test is conducted. While performing the weldability test of the metal, it is important to note the amount of sparking emitted from the molten metal. A metal that emits few sparks has good welding qualities.

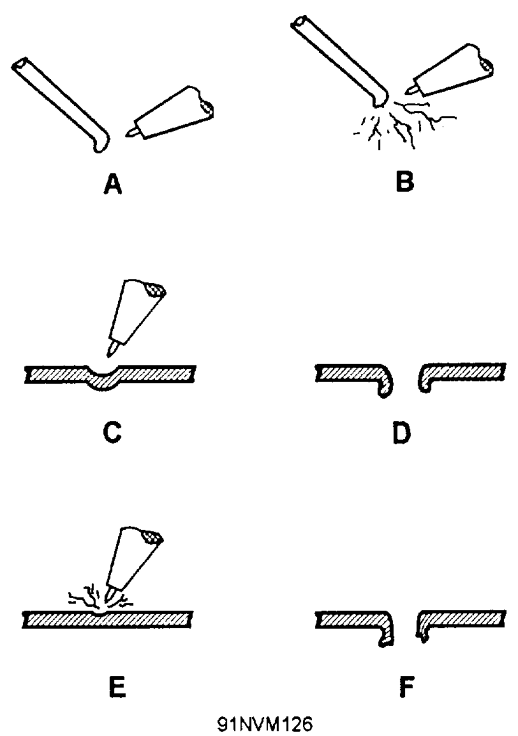


Figure 6-12.—Torch flame test: (A) Good quality filler rod. (B) Poor quality filler rod. (C) and (D) Good quality base metal. (E) and (F) Poor quality base metal.

Chip Test

Another test that must be accompanied by considerable experience is the chip test. To make a chip test, use a sharp cold chisel to remove a small amount of metal from a sample. The ease with which the chipping can be done gives some indication of the kind of metal with which you are working. The size, form, and color of the chips and the appearance of the edges (whether smooth or sawtoothed) give further clues.

In this test, the cutting action of the chisel indicates the structure and heat treatment of the metal. Cast iron, for example, when being chip-tested, breaks off in small particles, whereas a mild steel chip tends to curl and cling to the original piece. Higher-carbon, heat-treated steels cannot be tested this way because of hardness. A rough test between mild carbon steel and chrome-moly steel may be indicated by the relative hardness of the metals while being hacksawed.

You will not be able to identify metals by the chip test method until you have had considerable experience. You should practice with samples of known metals until you have learned how to identify carbon steel, carbon-molybdenum steel, chromium-molybdenum steel, chromium-nickel steel, and other metals. The information given in table 6-5 will help you to recognize some of the more common metals.

Fracture Test

The fracture test is used extensively and consists of breaking a portion of the metal in two. If it is a repair job, the fractured surface may be inspected. The appearance of the surface where the metal is cracked shows the grain structure of the metal. If the grains are large, the metal is ductile and weak. If the grains are small, the metal is usually strong and has better ductility. Small grains are usually preferred. The fracture shows the color of the metal, which is a good means of identifying one metal from another. The test also indicates the type of metal by the ease with which it may be fractured.

Color Test

The color test separates two main divisions of metals. The irons and steels are indicated by their typical gray white color. Nonferrous metals come in two general color classifications of yellow and white.

Table 6-5.—Identification of Metals by Chip Test

Metals	Chip Characteristics
White cast iron	Chips are small, brittle fragments. Chipped surfaces are not smooth.
Gray cast iron	Chips are about 1/8 inch in length. Metal is not easily chipped, so chips break off and prevent smooth cut.
Malleable iron	Chips are from 1/4 to 3/8 inch in length (larger than chips from cast iron). Metal is tough and hard to chip.
Wrought iron	Chips have smooth edges. Metal is easily cut or chipped, and chip can be made as a continuous strip.
Low-carbon and cast steel	Chips have smooth edges. Metal is easily cut or chipped, and chip can be taken off as a continuous strip.
High-carbon steel	Chips show a fine grain structure. Edges of chips are lighter in color than chips of low-carbon steel. Metal is hard, but can be chipped in a continuous strip.
Copper	Chips are smooth, with sawtooth edges where cut. Metal is easily cut. Chip can be cut as a continuous strip.
Brass and bronze	Chips are smooth, with sawtooth edges. These metals are easily cut, but chips are more brittle than chips of copper. Continuous strip is not easily cut.
Aluminum and aluminum alloys	Chips are smooth, with sawtooth edges. Chip can be cut as a continuous strip.
Monel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
Nickel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
Lead	Chips of any shape may be obtained because the metal is so soft that it can be cut with a knife.

Copper, brass, and bronze can be rather easily identified by a welder. Aluminum is a white metal. Aluminum alloys, zinc, and the like, are all of somewhat the same silver-gray color although they may vary in shade.

Density Test

Metals may also be differentiated by means of the weight or density test of the specimen. A good example of identification by density or specific gravity is identifying aluminum and lead. Roughly speaking, their colors are somewhat similar, but anyone may readily distinguish between the two metals because of their respective weights. Lead weighs about three times as much as aluminum.

Ring Test

The ring test, or the sound of the metal test, is an easy means of identifying certain metals after some experience with this method. It is used extensively for identifying heat-treated steels from annealed steels. It is also used to detect alloys from the virgin metal. An example is the difference between aluminum and duralumin, an alloy of aluminum and copper (2017-T) (the letter *T* indicates that the metal is heat treated). The pure aluminum sheet has a duller sound, or ring, than the duralumin, which is somewhat harder and has a more distinct ringing sound.

Magnetic Test

The magnetic test is another method used to aid in the general identification of metals. Frequently, the inexperienced person confused aluminum and stainless steels. Remember that ferrous metals, being iron-based alloys, are magnetic whereas nonferrous metals are nonmagnetic.

Nitric Acid Test

The nitric acid test is one of the easiest tests to distinguish between stainless steel, Monel, copper nickel, carbon steels, and various other metals. You need no special training in chemistry to perform this test. However, you must observe the following safety precautions when using or handling acids of any type:

— Never open more than one container of acid at one time.

— Use only glass containers when mixing or stowing acids.

— In mixing, always pour acid slowly into water. NEVER pour water into acid, because an explosion is likely to occur.

— If any acid is spilled, dilute it with plenty of water to weaken it so that it can safely be swabbed away.

— If an acid is spilled on the skin, wash immediately with large quantities of water. Then wash with a solution of borax and water.

— Wear safety goggles. Clear-lens goggles will make it easier to detect the reaction of a metal to an acid test, which may be evidenced by a color change, the formation of a deposit, or the development of a spot.

— Conduct tests in a well-ventilated area.

To perform the nitric acid test, place one or two drops of concentrated (full strength) nitric acid on a metal surface that has been cleaned by grinding or filing. Observe the resulting reaction (if any) for about 2 minutes. Then add three or four drops of water, one drop at a time, and continue observing the reaction. If there is no reaction at all, the test material may be one of the stainless steels.

The reaction that results in a brown-colored liquid indicates a plain carbon steel. A reaction producing a brown to black color indicates a gray cast iron or one of the alloy steels containing as its principal element either chromium, molybdenum, or vanadium. Nickel steel reacts to the nitric acid test by forming a brown to greenish-black liquid, while a steel containing tungsten reacts slowly to form a brown-colored liquid with a yellow sediment.

Instead of the brown-black colors that usually appear when ferrous metals are tested, various shades of green and blue appear as the material dissolves when nonferrous metals and alloys are subjected to the nitric acid test. Except with nickel and Monel, the reaction is vigorous. The reaction of nitric acid on nickel proceeds slowly, developing a pale green color. On Monel, the reaction takes place at about the same rate as on ferrous metals, but the characteristic color of the liquid is greenish-blue. Brass reacts vigorously, with the test material turning to a green color. Tin bronze, aluminum bronze, and copper all react vigorously in the nitric acid test, with the liquid changing to a blue-green color. Aluminum and magnesium alloys, lead, lead-silver, and lead-tin alloys are soluble in nitric acid, but the blue or green color is lacking.

From the information given thus far, it is easy to see that it will require considerable visual skills to identify the many different reactions of metals to nitric acid. As an HT, you will be mostly concerned with the identification of stainless steel, Monel, and carbon steel.

File Hardness Test

Hardness tests are commonly used to determine the ability of a material under test to resist abrasion or penetration by another material. Many methods have evolved for measuring the hardness of metal. The simplest method is the file hardness test. This test cannot be used to make positive identification of metals but can be used to get a general idea of the type of metal being tested and to compare the hardness of various metals on hand. Thus, when identification of metal by other means is not possible, you might use a file to determine the relative hardness of various metals. The results of such a test may enable you to select a metal more suitable for the job being performed.

The file hardness test is simple to perform. The metal being tested may be held by hand and rested on a bench, or held in a vise. Grasp the file, with the index finger extended along the file, and apply the file slowly but firmly to the surface being tested.

If the material is cut by the file with extreme ease and tends to clog the spaces between the file teeth, it is VERY SOFT. If the material offers some resistance to the cutting action of the file and tends to clog the file teeth, it is SOFT. If the material offers considerable resistance to the file but can be filed by repeated effort, it is HARD and may or may not have been heat treated. If the material can be removed only by extreme effort and in small quantities by the file teeth, it is VERY HARD and has probably been heat treated. If the file slides over the material and the file teeth are dulled, the material is EXTREMELY HARD and has been heat treated.

The file test is not a scientific method. It should not be used when positive identification of metal is necessary or when an accurate measurement of hardness is required.

SUMMARY

This chapter has given you a thorough overview of basic metallurgy. Remember, it is basic information only, and you will need to learn specific applications through experience and by further study in the appropriate technical manuals. Always ask a senior member of your division to explain anything in this chapter or in your work that you do not fully understand.

You have been introduced to stresses and strains, the structure, properties, and types of metals, and the ways in which metals are classified, marked, and tested. Go back now and review any of these areas that you do not understand.

CHAPTER 7

INTRODUCTION TO WELDING AND CUTTING

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Identify the principle welding processes and define terms used in basic welding.*
- *Identify the various welding symbols.*
- *Describe the types and techniques of edge preparation in welding.*
- *Describe the purpose of temperature control during and after the welding process has been performed.*
- *Describe the pipe welding process, and identify the different classes of piping.*
- *Identify the principle cutting processes.*
- *Name the important publications concerning military standards and qualification tests with which a welder should be familiar.*

INTRODUCTION

One of the primary requirements for Hull Maintenance Technicians is to make various metal objects and structures. Most of these will require welding and cutting metal. Study and practical experience are both necessary to become an expert welder. This chapter contains essential background information that will help you to learn the welding processes and to qualify for advancement. Most of the terms, phrases, and processes discussed in this chapter are standardized, and are used in the Navy as well as by civilians in the welding trades. At times, the information in this chapter may seem complex, but you need a thorough knowledge of it to perform the duties of your job. Study this chapter carefully so you can effectively assist skilled welders and eventually become a good welder yourself.

WELDING PROCESSES

A master chart of welding processes is shown in figure 7-1. The term WELDING PROCESS means that you heat metal parts to a temperature that is high enough to join the metal parts by coalescence. It is done with or without the use of pressure or by the pressure alone, and it can be done with or without the use of filler metal. Coalescence means the growing together, or growth into one body, of the base metal parts. There are two basic requirements for coalescence: heat and intimacy of contact.

HEAT

The welding processes differ depending on the source of heat, the manner in which heat is applied or generated, and the intensity of the heat. The source of heat may be the combustion of a fuel gas

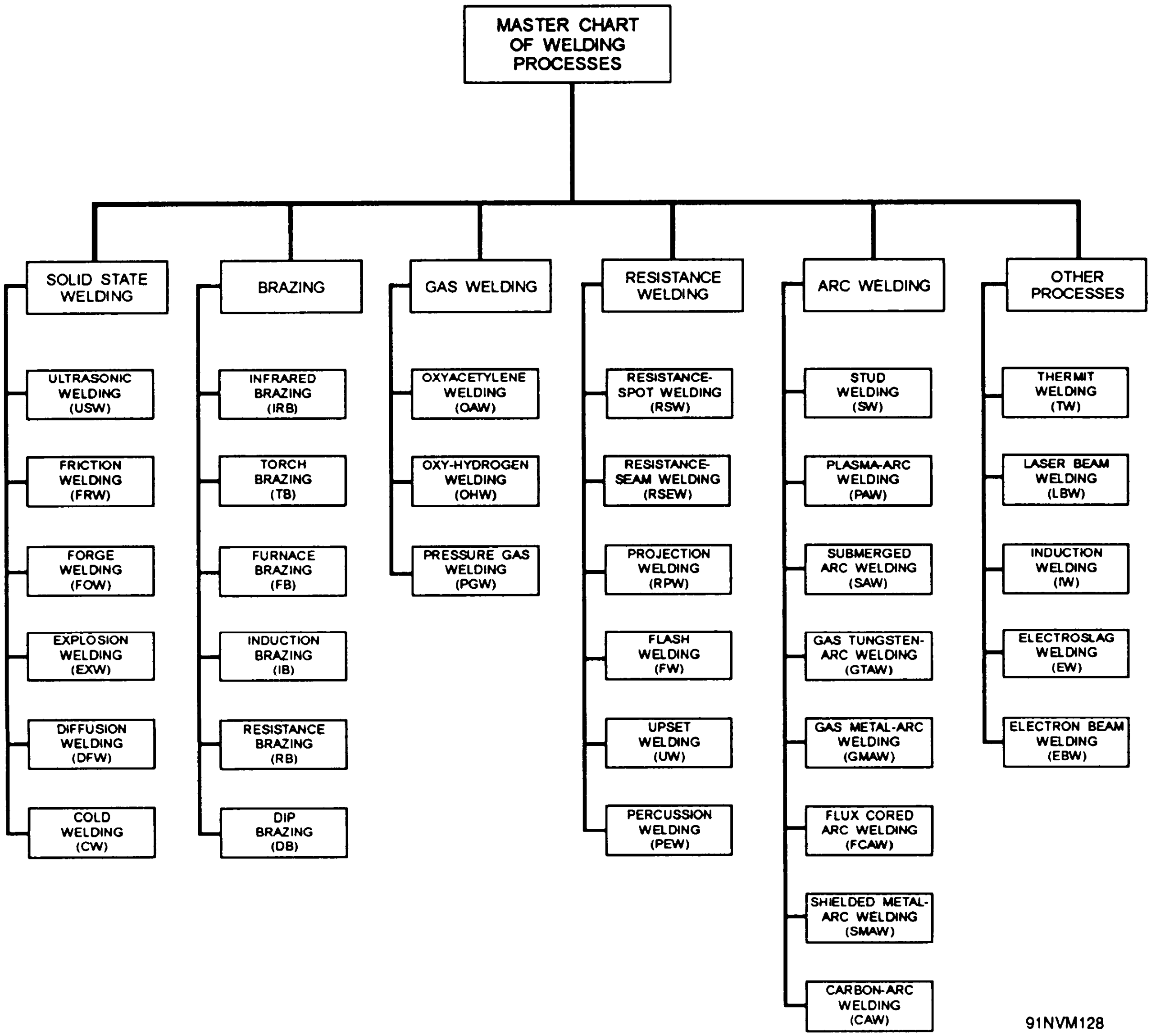


Figure 7-1.—Welding processes.

such as acetylene or hydrogen in air or in oxygen; an electric arc; an electric, gas, or oil furnace; the resistance of metal to the flow of electric current; or a chemical reaction between a metal oxide and finely divided aluminum. The welding processes most commonly used aboard ship involve the combustion of a fuel gas, as in oxyacetylene welding and torch brazing; the use of an electric arc, as in metal-arc welding; and the resistance of metal to the flow of electric current, as in spot welding.

The intensity of heat applied or generated at the joint varies according to the metals being joined and to the welding process being used. All welding processes except brazing use temperatures high enough to melt the base metals. Brazing is the ONLY welding process in which the melting of the base metal is not necessary for coalescence. Brazing is similar to soldering, except that higher temperatures are used for brazing. The term SOLDERING is used to describe a joining process using nonferrous filler alloys melting below 800°F (427°C). Soldering is NOT considered a welding process. Brazing is a welding process using nonferrous filler alloys that have a melting point above 800°F (427°C) but below that of the base metal.

INTIMACY OF CONTACT

In the second basic requirement for coalescence, intimacy of contact, the welding processes may be divided into two groups: pressure processes and nonpressure processes. In PRESSURE PROCESSES, we get intimacy of contact by applying pressure while the contact surfaces are at a high enough temperature to allow plastic flow of the metal. In NONPRESSURE PROCESSES, a space is left between the surfaces to be joined. This space is filled, either progressively or all at once, with molten metal. The molten metal may be obtained from a filler metal (welding rod or electrode), by melting the surfaces to be joined, or by combining a filler metal and melted base metal.

All nonpressure processes involve fusion, and are often referred to as FUSION PROCESSES. However, this term is somewhat misleading since some pressure processes also involve fusion.

The various welding processes differ not only in the way coalescence is achieved, but also in their ability to produce a satisfactory joint in a given kind of metal under the conditions in which the weld must be made. Many factors influence the selection of a welding process for a particular application. Some important factors to be considered are the relative cost, the amount of welding required, the location and position of welds, the service conditions the welded structure must withstand, and the qualifications of the person who does the welding. Probably the most important single factor, however, is the weldability of the metal.

WELDABILITY

The term WELDABILITY means the capacity of a metal to be fabricated by a welding process into a structure that will perform its purpose satisfactorily. Weldability also means the degree of simplicity or complexity of the procedures and techniques used to produce welds with properties that are equal to or better than the properties of the base material. For example, mild steel can be welded by most welding processes, but the welds produced may not be equally satisfactory, and one method may be more complicated or more expensive than another. While it is possible to weld mild steel through the use of a variety of welding processes, some metals such as aluminum and its alloys can be satisfactorily welded with only a few welding processes. Mild steel does not require elaborate preparations, fluxes, and special techniques because its characteristics are such that the welding operation can be easily performed. Other metals require special preparatory steps, complex welding sequences, skillful use of a specific welding technique, and extensive heat treatments after welding.

Many factors influence the weldability of a metal. Here are some of the more important ones that must be taken into account and, insofar as possible, controlled: (1) the chemical composition of the metals involved (that is, the kind and percentage of elements present) and the effect of radical temperature changes on the various elements; (2) the expansion and contraction characteristics of the base metals; (3) the filler metal (welding rod or electrode); (4) the joint design; and (5) the welding procedure.

The Navy uses a large number of different metals and alloys. Each of these materials has characteristics or properties that make its use desirable for certain applications. The characteristics and properties of a given alloy are partly determined by the kind and amount of elements present. The effect welding has on these elements and their reaction during and after the application of heat have a tremendous influence on the weldability of the metal in question.

In steel, carbon is probably the most important element that limits weldability. Carbon gives steel hardenability; that is, when certain carbon steels are heated above a critical temperature and then cooled rapidly, they be come much harder. At the same time they lose ductility. In fact, the metal may become extremely brittle. With few exceptions, the temperatures used in welding exceed the critical temperature of carbon steels. Further, more hardening may occur when the mass of relatively cold metal surrounding the weld area conducts heat away so fast that rapid cooling occurs. Thus, certain steels may become hardened by many of the welding processes.

When the percentage of carbon is less than 0.25 percent, its effect in producing hardness is slight. But when the carbon content exceeds 0.25 percent, or when such elements as manganese, vanadium, chromium, molybdenum, or titanium are present, along with a lesser carbon percentage, the weldability of the steel is decreased. Special steps should be taken to control preheat, interpass temperature, postheat, and welding sequence. Otherwise, a satisfactory weld is likely to crack and to have reduced toughness and less strength than is required. For this reason, tool steels and certain alloys like carbon-molybdenum steel are less weldable than many other steels.

Steels contain certain impurities such as sulfur, phosphorus, hydrogen, nitrogen, and oxygen. If present in large enough quantities, these impurities may decrease weldability. For example, a steel to which about 0.10 percent sulfur has been added to improve machinability is difficult to weld because the weld has a tendency to crack. An excessive amount of phosphorus decreases the ductility of the steel and thus decreases the weldability of the metal. The presence of hydrogen in a steel, filler material, or flux may lead to cracks in the welds.

Stainless steels, high-chromium steels, and other special steels are less weldable than the plain low-carbon steels. The elements that give these special steels their desirable properties for some applications also have the effect of decreasing the weldability of the metals. To make these special steels weldable, the welding procedures, the filler metal, the fluxes, the preheat and postheat temperatures, and the welding sequence must be carefully selected. This is also true for many nickel, copper, and aluminum alloys.

In some metals, the heat of the welding process may cause certain elements with low-melting points to vaporize, thus reducing the amounts of those elements present in the weld zone. Nonferrous alloys containing lead, zinc, and tin are particularly subject to such losses from vaporization. These losses may seriously affect the properties of the joint by causing porosity or oxide inclusions that weaken the weld.

The weldability of a metal is also affected by its thermal conductivity. In general, metals with high thermal conductivity are difficult to weld because they transfer the heat away from the weld so rapidly that the required temperature cannot be maintained at the joint.

Changes in temperature cause a metal to expand or contract and that also affects weldability. When metals expand and contract at different rates, the internal stresses set up by these changes can cause the joint to crack immediately or to crack later under load.

Even when the weld joins identical metals, or metals having approximately the same coefficient of expansion, the expansion and contraction may not be uniform throughout all parts of the metal. These differences lead to internal stresses, distortion, and warping. Metal parts must be free to move or a special weld sequence must be used. When heat is applied or withdrawn, expansion and contraction set up high stresses, which in turn may cause trouble in the weld itself or in the adjacent base metal. In thin materials, uneven expansion and contraction may cause the metal to warp. In heavy material, the stresses set up may exceed the ultimate strength of the metal and cause cracking to occur in the weld or in the metal next to the weld, which is called the heat affected zone.

Even if the ultimate strength of the material is not exceeded by the stresses developed during welding, the combination of welding stresses PLUS the stresses developed when the material is placed in service may be enough to cause failure of the weld. It is for this reason that many materials are STRESS RELIEVED after welding.

Another factor that influences weldability is the filler material used. The wrong electrode or incorrect welding process will make welding difficult or impossible, and it may lead to failure of the part under service conditions. It is not always essential that the welding rod or electrode be of the same chemical composition as the base metal; the important requirement is that the combination of the filler metal and the base metal will make a satisfactory welded joint.

In some processes, the flux selected for use with a welding rod has important effects on weldability. Also, the electrode covering influences the weld obtained in certain steels. Molten steels have a tendency to absorb hydrogen from the surrounding atmosphere and to expel it when they solidify. Some types of electrode coverings send a lot of hydrogen into the atmosphere surrounding the arc and the molten puddle. This hydrogen is frequently enough to cause microscopic cracks in the heat-affected zone of some steels. To eliminate this problem, low-hydrogen electrodes have been developed to weld the newer high-tensile steels.

Joint design also influences the weldability of a metal. You need to consider several factors when you select a joint design. They include the welding process, the thickness of the material to be welded, and the purpose the joint is to serve.

You can butt together thin sheets of metal without special preparation other than cleaning. But heavy plates must be beveled or grooved to make a satisfactory joint. Again, the design used is related to the purpose of the joint; that is, the way the load or stress is applied, the erosive or corrosive conditions it must resist, and the joint efficiency. The term JOINT EFFICIENCY is used to indicate the strength of a welded joint as compared with the strength of the unwelded base metal.

The terminology used to describe the various kinds of joints and the parts of a welded joint is discussed and illustrated later in this chapter. Details of joint designs for various applications and different welding processes are covered by specifications. At this point, you need to know only that joint design affects weldability.

As noted before, metals are not equally weldable with all welding processes. You should select a welding process on the basis of specifications and pertinent instructions from the Naval Sea Systems Command. For example, aluminum-base alloys are weldable by a number of processes. However, the Naval Sea Systems Command does not permit the welding of these alloys aboard ship by any welding process other than gas shielded-arc welding. These specifications and instructions must also be used to select base metals, filler metals, fluxes, and welding techniques.

Each of the welding processes has a technique or procedure peculiar to that process. Often the technique varies with the kind or size of the filler metal used or the kind of weld being made. The incorrect use of a technique, or the use of the wrong technique, may lead to defects that make the joint unsatisfactory.

TYPES OF JOINTS

Five basic types of welded joints are used in welded structures: butt, edge, tee, corner, and lap.

There are many variations, but every joint you weld will be one of these basic types. The joint area in each case is indicated by the shaded portion of the drawings in figure 7-2.

A BUTT joint is used to join the edges of two members lying in approximately the same geometric plane. The joint area is between the edges of the two members. This type of joint is frequently used in plate, sheet metal, and pipe work.

EDGE joints also may be used to join parallel members lying in the same plane, but as a rule one of the members is flanged. The edge joint in figure 7-2 shows that the members need not be in the same plane, as the members of a butt joint must be. With edge joints, the joint area is between the contacting surfaces of the members. While this type of joint has some applications in plate work, it is more often used in sheet metal work. In many cases, no filler metal is used in joining edge joints by the gas welding process. The edges are fused together, and the base metal supplies the weld filler metal. Occasionally the edge joint is used to join reinforcing plates to the flanges of I-beams and the edges of angles.

CORNER joints and TEE joints are used to join two members located at approximately right angles to each other. The joint area in each case is between the end of one member and the side or edge of another. The corner joint forms an L-shape (fig. 7-2). Corner joints are used to make tanks, boxes, box frames, and similar objects. Only

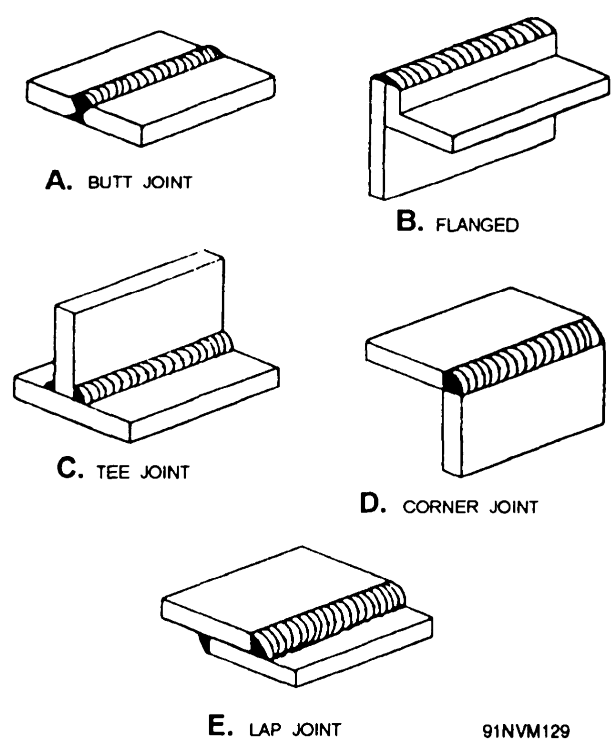


Figure 7-2.—Types of welded joints.

very-low-pressure tanks use corner joints because the root of the weld is in tension under load. The tee joint forms the shape of the letter *T.* Tee joints are used in many types of metal structures. The tee joint distributes stress more evenly throughout the structure.

The LAP joint is used to join overlapping members of a structure. The joint area of a lap joint is between the parallel surfaces of the joint members. Lap joints are often used in torch brazing processes where capillary action draws filler metal into the space between the hot surfaces. They are also used in many resistance welding processes, especially in sheet metal structures fabricated with spot welds.

TYPES OF WELDS

The types of welds most commonly used aboard ship are bead welds, fillet welds, tack welds, groove welds, plug welds, slot welds, spot welds, and seam welds. Another term that you will hear quite often is SEAL WELD. This term does not actually refer to any one type of weld; rather, it is any weld that is used primarily to obtain tightness.

Several types of bead and fillet welds are illustrated in figure 7-3. Usually a BEAD WELD (fig. 7-3, view A) is made by depositing filler metal in a single direction on an unbroken surface. However, it is also possible to make a bead without adding filler metal. In this case, the heat is applied and moved along steadily in one direction so that a molten puddle is formed in the base metal. Bead welds are used principally on butt joints and as a way of building up surfaces. The cross section of a bead weld usually has an oval shape.

A FILLET WELD is triangular in cross section. It joins two surfaces that are at approximately right angles to each other. Fillets are used to weld lap, tee, and corner joints. As shown in views B, C, and D of figure 7-3, some variations of the fillet weld are chain intermittent, staggered intermittent, and boxing.

A TACK WELD is a short weld deposit made to temporarily hold the parts to be joined in proper alignment for final welding. The sizes of tack welds are usually not specified, but they must not exceed 1 inch in length, and they must be as small as can be made, consistent with the size of the electrode being used. Tack welds must be incorporated into

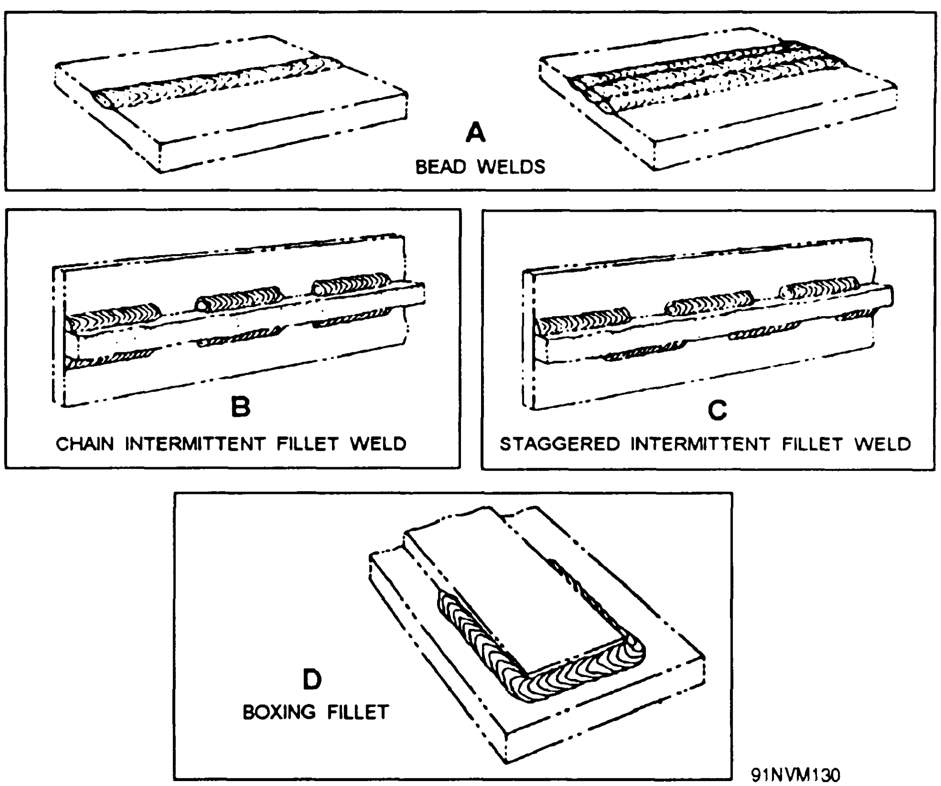


Figure 7-3.—Bead and fillet welds.

the finished weld. Cracked or broken tack welds must be chipped or ground out before the joint is finally welded.

GROOVE WELDS are made in a specially prepared groove between two members to be joined. While the edge of a vertical plate of a tee joint is sometimes beveled for welding, grooves are most frequently used for butt joints in plate and pipe work. Standard grooves for plates joined with butt joints are illustrated in figure 7-4. Groove welds are designed to provide the required strength with a minimum amount of filler metal. Plate edges may be prepared for groove welding by shearing, machining, chipping, grinding, flame cutting, or flame grooving, depending on the metal. The selection of a particular groove design is governed by the thickness of the plate to be welded, the adaptability of the design to the structure, and the accessibility of the joint for welding. For example, a joint that can be welded from only one side requires a different groove design than a joint that is accessible from both sides.

PLUG WELDS and SLOT WELDS, as illustrated in figure 7-5, are used to join overlapping plates that are not otherwise accessible for welding. A plug weld is a circular weld made through one member of a lap or tee joint to join that member to another. The plug weld may or may not be through a hole punched or cut in the first member. If a hole is used in the first member, the plug weld may fill it completely or it may fill it only partially. A slot weld is similar to a plug weld, except that an elongated hole is made in the first member of the joint. The hole may be completely or partially filled with weld metal. Slot welds are often used to join one plate to the surface of another plate, and for other purposes where a fillet weld would not be economical or would not be a good design. Incidentally, a fillet weld made at the intersection of the edge of a slot and the exposed surface of the joining member is considered a fillet weld, NOT a slot weld.

SPOT WELDS and SEAM WELDS are common types of resistance welds. These welds are shown in figure 7-6. In resistance welding, coalescence is produced by a combination of pressure and the heat obtained from the resistance of the base metal to the flow of an electric current. A spot weld is used only when the parts of the joint

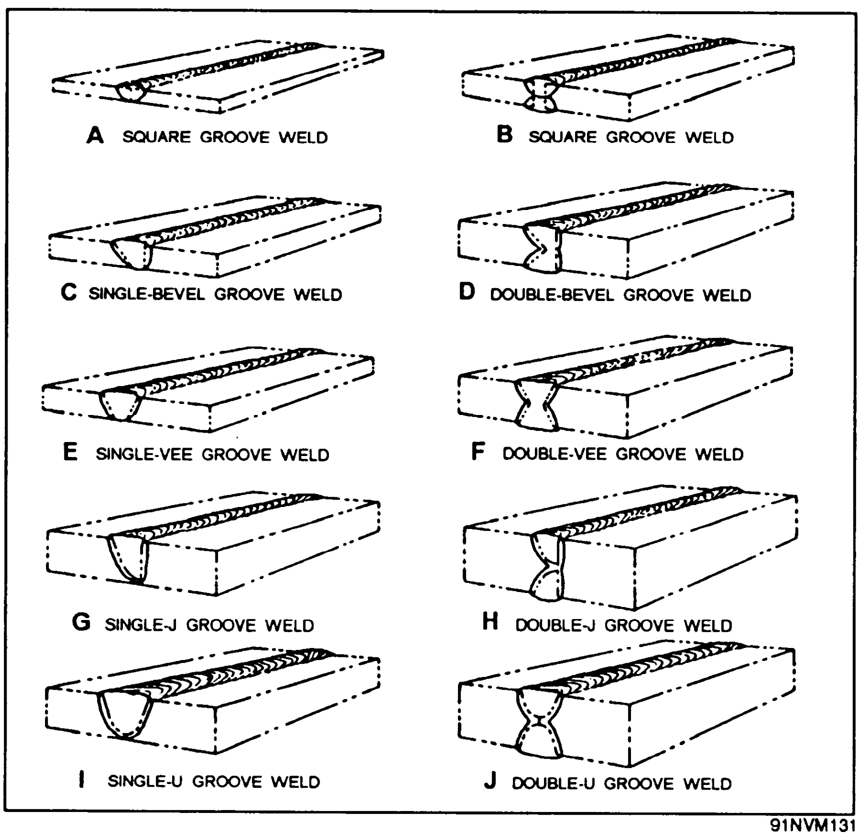


Figure 7-4.—Standard groove welds.

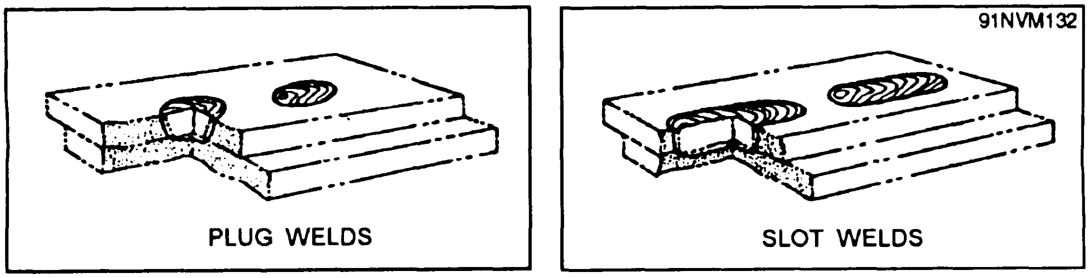


Figure 7-5.—Plug and slot welds.

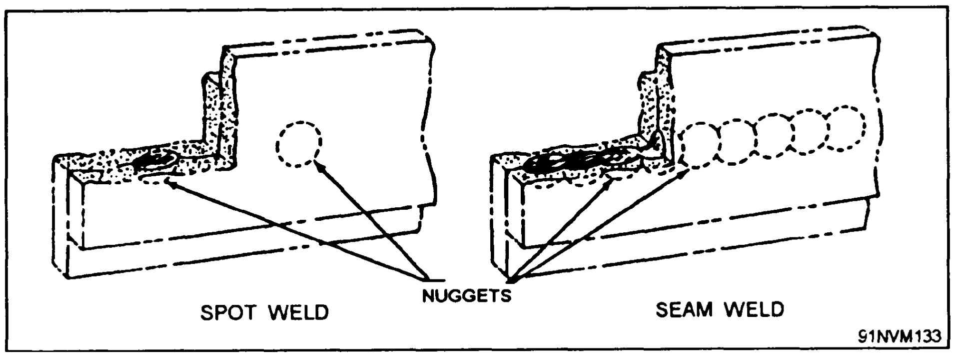


Figure 7-6.—Spot weld and seam welds.

overlap. The size and shape of the weld (often called the nugget) are determined by the size and shape of the electrode tips used in the welding machine. A seam weld is very much like a spot weld and may, in fact, be made as a series of overlapping spot welds, as shown in figure 7-6. More commonly, however, seam welds are made with a wheel-type electrode.

PARTS OF WELDS

You should be familiar with the terms used to describe the parts of welds. Figure 7-7 illustrates the face and the toe on groove and fillet welds. The FACE is the exposed surface, on the side from which the weld was made, of a weld made by a gas or arc welding process. The TOE is the junction between the face of the weld and the base metal.

The ROOT of a weld includes the points at which the bottom of the weld intersects the base metal surfaces, as seen in cross section. Figure 7-8 illustrates weld roots.

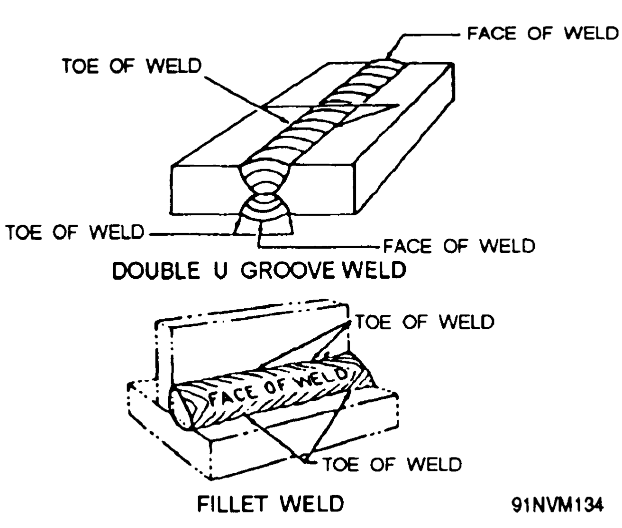


Figure 7-7.—Face and toe of groove and fillet welds.

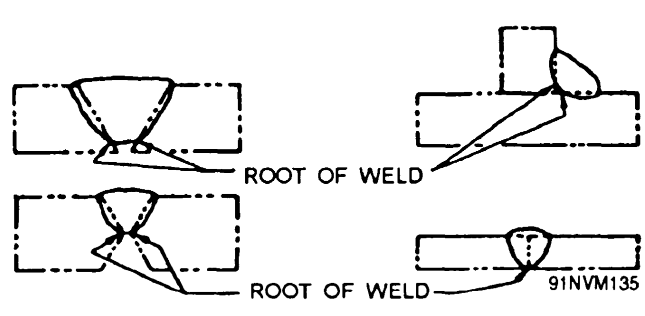


Figure 7-8.—Weld roots.

The legs and throat of a fillet weld are shown in figure 7-9. When we look at a triangular cross section of a fillet weld, the LEG is the portion of the weld from the toe to the root. The THROAT is the distance from the root to a point on the face of the weld along a line that would form a 90-degree angle with the weld face, as shown in figure 7-9.

Theoretically, the face is considered to form a straight line between the toes. If the face of the weld is convex or concave, it will not form a straight line between the toes. In that case, the actual face will be larger than the theoretical face, and the actual throat will be either larger or smaller than the theoretical throat. It should be noted that the terms LEG and THROAT apply only to fillet welds.

Several other terms are used to describe areas or zones of welds. Figure 7-10 illustrates the use of some of these terms. The BOND is the junction of the weld metal and the base metal. If weld metal is not used, the junction of the base metal parts is used. FUSION is the melting together of base and filler metal, or the melting of base metal only, that results in coalescence. The FUSION ZONE is the region of the base metal that is actually melted. The DEPTH OF FUSION is the distance that fusion extends into the base metal from the surface. Both the fusion zone and the depth of fusion are considered in terms of a cross section of the weld, as shown in figure 7-10. Another zone of interest to the welder is the HEAT-AFFECTED ZONE, also shown in figure 7-10. This zone includes that portion of the base metal that has not been melted but in which the properties and structure of the metal have been affected by the heat of welding or cutting. The extent of this zone varies with the thermal conductivity of the metal. The changes that occur within the area are related to the kind of metal being welded, the intensity and duration of heat, and the control embodied in the welding procedure.

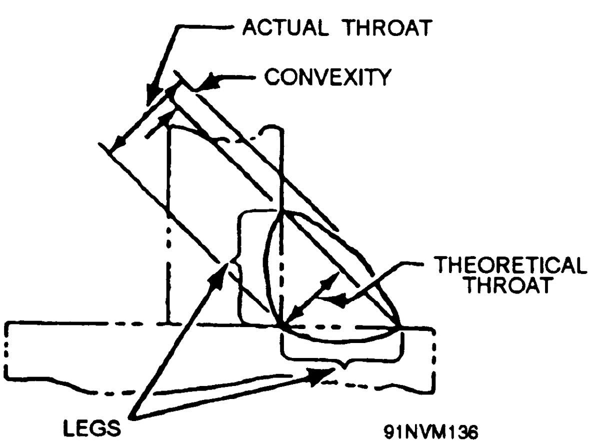


Figure 7-9.—Legs and throat of fillet weld.

PARTS OF JOINTS

To follow the specifications for any welding job, you must have a very clear knowledge of the terms used to describe parts of welds, and those used to describe parts of joints. The similarity in terms may lead to confusion. For example, the root of a weld is NOT precisely the same as the root of a joint. In other cases, it may be somewhat difficult to decide whether a term really refers to a part of a weld or to a part of a joint. In all cases, it is essential that you know EXACTLY what part, zone, or measurement is being referred to.

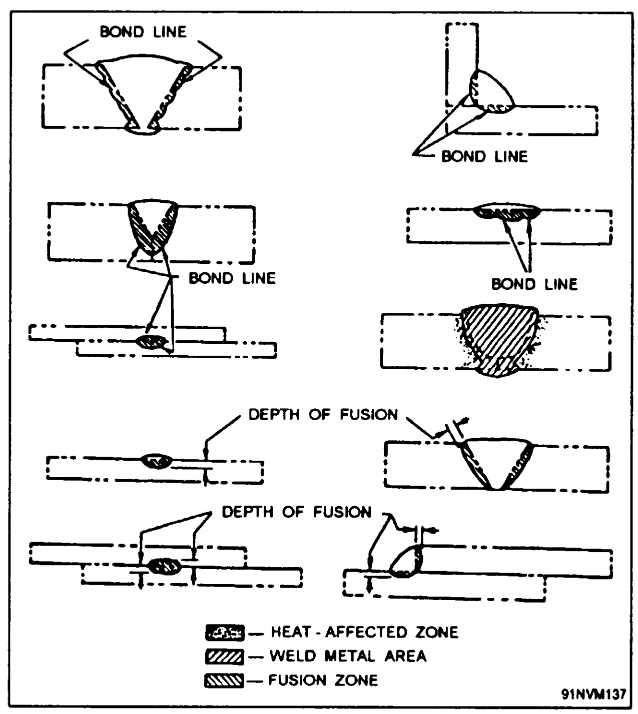


Figure 7-10.—Fusion zone, depth of fusion, heat-affected zone, and bond of weld.

Figure 7-11 shows that the GROOVE FACE is that surface of a member that is included in the groove. The ROOT of a joint is that portion of the joint where the members approach each other most closely. The root of a joint may be a point, a line, or an area when viewed in cross section. A given joint design may have a ROOT FACE or it may have a ROOT EDGE. A root face is the surface of the groove that is adjacent to the root of the joint. If the root face is of zero width, it is known as a root edge (fig. 7-11, view C).

Details of joint design involve the size of the groove and the space existing between the members of the joint. Specifications for joint design are expressed in terms of bevel angle, groove angle, groove radius, and root opening. Figure 7-12 illustrates the use of these terms.

The BEVEL ANGLE is the angle formed between the prepared edges of a member and a plane perpendicular to the surface of the member.

The GROOVE ANGLE is the included angle of the groove between the parts to be joined. For example, if the edge of each of the two plates to be joined were beveled to an angle of 30°, the groove angle would be 60°.

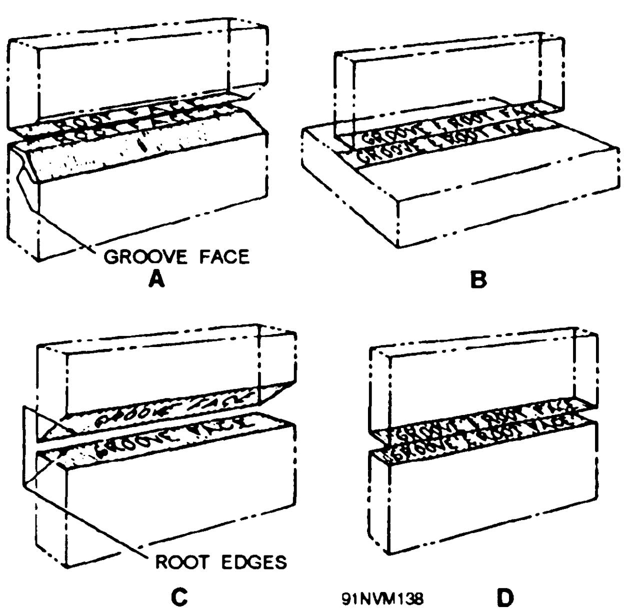


Figure 7-11.—Groove face, root face, and root edge.

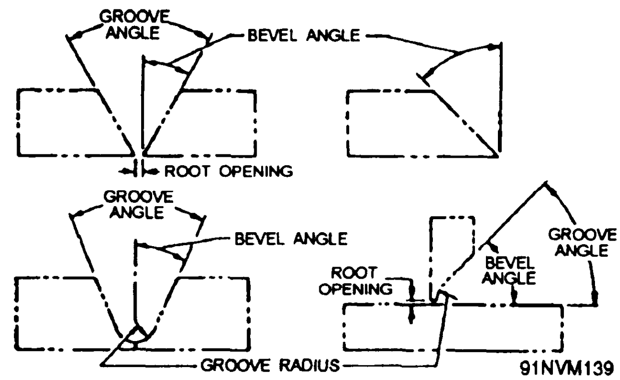


Figure 7-12.—Bevel angle, groove angle, groove radius, and root opening.

The GROOVE RADIUS is the radius of the curved portion of the opening at the bottom of the groove near the root of the joint. It exists only in special groove joint designs.

The ROOT OPENING refers to the separation between the members of the joint where the members are closest together.

The bevel angle, groove angle, and root opening of any joint will depend upon the thickness of material being welded, the kind of joint being made, and the welding process being employed. As a rule, oxyacetylene welding requires a larger groove angle than does manual metal-arc welding. Root opening is usually governed by the diameter of the filler material, which in turn depends on the thickness of the base metal and the position of welding.

Root penetration and joint penetration in groove welds are illustrated in figure 7-13. ROOT PENETRATION refers to the depth that a groove weld extends into the root of the joint. Root penetration is measured on the center line of the root cross section. JOINT PENETRATION refers to the minimum depth that a groove weld extends from its face into a joint, exclusive of any excess weld metal that is above the plate surface. Incidentally, this brings up another term you should know: REINFORCEMENT OF WELD is the term used to describe weld metal, on the face of a groove weld, that is in excess of the metal necessary for the specified weld size.

As may be seen from figure 7-13, the terms ROOT PENETRATION and JOINT PENETRATION often refer to the same dimension. This is the case in views A, C, and E of the

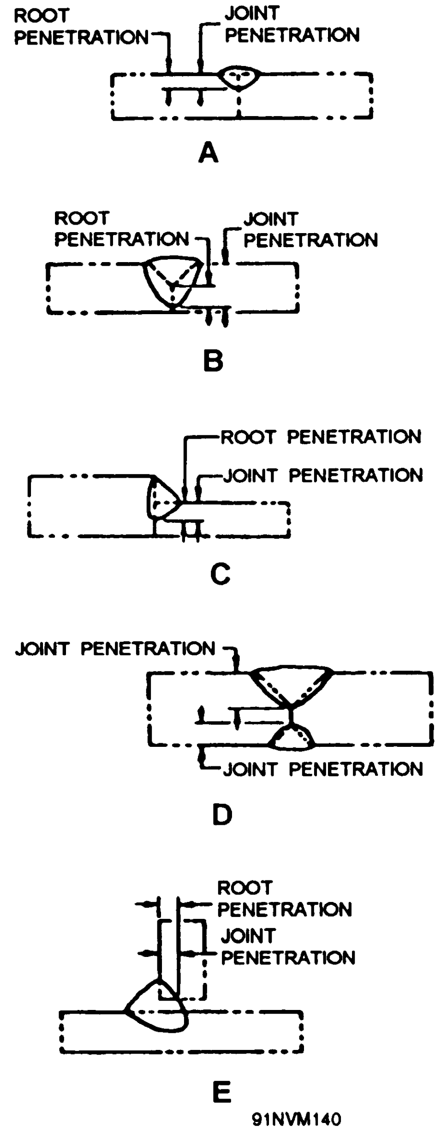


Figure 7-13.—Root penetration and joint penetration of groove welds.

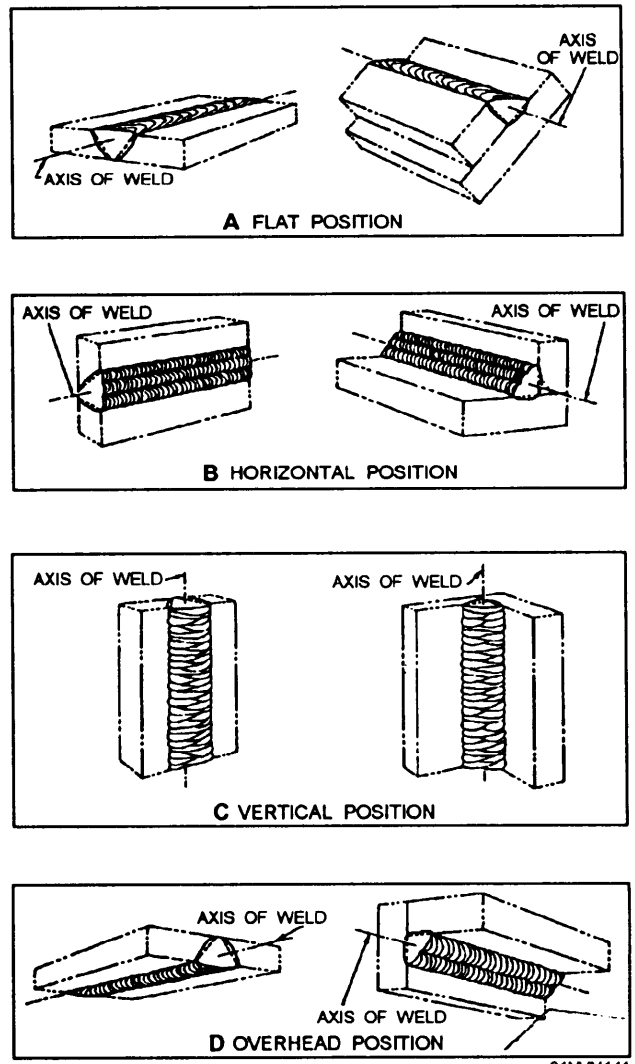


Figure 7-14.—Flat, horizontal, vertical, and overhead positions for welding.

illustration. View B, however, shows how a difference may exist between root penetration and joint penetration. View D shows joint penetration only.

WELDING POSITIONS

Welding is performed in several different positions. In plate work, as shown in figure 7-14, these positions are flat, horizontal, vertical, and overhead. When welding is performed in the FLAT position (fig. 7-14, view A), the welder works from the upper side of the joint. In this position, the upper surface of the weld deposit metal is in a horizontal plane. Note that this is the case in both flat position fillet and groove welds.

In the HORIZONTAL position of welding (fig. 7-14, view B), the structural members of the joint are in an approximately vertical position while the line of weld (axis) is approximately horizontal. A horizontal position fillet weld is slightly different from that of a horizontal groove weld. Welding a fillet in the horizontal position involves depositing filler metal on the upper size of a horizontal surface and against an approximately vertical surface. The face of a fillet weld lies in a plane approximately 45° to the surfaces of the parts joined.

When welding is performed in the VERTICAL position (fig. 7-14, view C), the axis of the weld is in a vertical plane. In the vertical position, weld metal is usually deposited in an upward direction.

In the OVERHEAD position (fig. 7-14, view D), welding is performed from the underside of the joint. The axis of the weld is in a horizontal plane, as is the axis of a flat position weld. But the overhead weld is, you might say, upside down if compared to the flat position weld. The terms FLAT, HORIZONTAL, VERTICAL, and OVERHEAD adequately describe the positions in which plate is welded. This terminology, however, does not describe the positions for welding pipe. When you weld pipe, you will weld in one of three positions: horizontal rolled position, horizontal fixed position, and vertical fixed position. Pipe welding positions are illustrated in figure 7-15. In each case, the terminology refers to the axial position and rotational freedom of movement of the pipe, not to the weld.

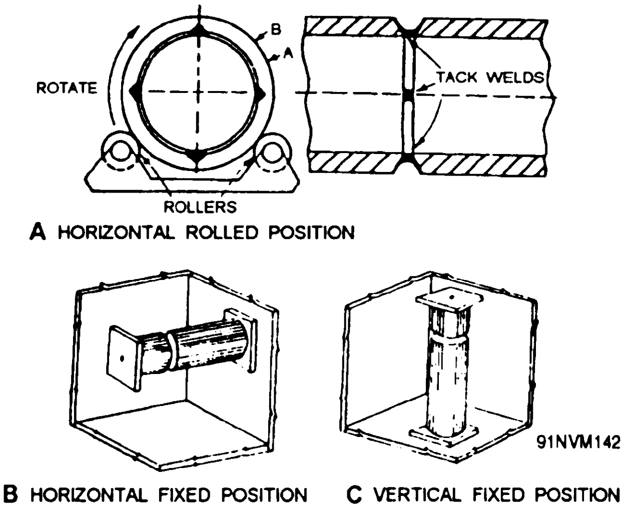


Figure 7-15.—Positions for welding pipe.

In HORIZONTAL ROLLED POSITION welds, the axis of the pipe is horizontal. The joint is made by welding in the flat position, at the same time rotating the pipe at a rate equal to the speed of filler metal deposition. Pipe welded in the horizontal rolled position is first carefully aligned and tack welded. Then it is placed in a jig, which facilitates rotation of the pipe. View A of figure 7-15 shows that all welding should be accomplished between points A and B.

The pipe axis in a HORIZONTAL FIXED POSITION weld is the same as in the horizontal rolled position weld. In this position, however, the pipe cannot be rotated. As a consequence, welding must be accomplished by progression through the overhead, vertical, and flat welding positions. When you are welding in the horizontal fixed position (fig. 7-15. view B), the weld is started at the bottom and progresses in increments upward to the top of the pipe-first on one side, then on the other.

In the VERTICAL FIXED POSITION, the pipe axis is vertical and held in a fixed position. The weld itself is made in the horizontal welding position (fig. 7-15, view C.)

PROCEDURES AND SEQUENCES

Whether large or small, simple or complex, the manufacture of any object requires careful planning. This is especially true when welding is employed to join parts into an integrated whole. One of the first decisions to be made regarding welding is the welding process to be used—that is, which of the processes is most applicable. But this is only the beginning. There are many details. Each must be worked out in such a way that the completed job serves the purpose for which it is intended.

To learn how to select a welding process, you must first understand the terms in which the job plans are expressed.

A single part of a structure consisting of several parts is called a COMPONENT. When a structure is made up of several components joined by welding, the structure is called a WELDMENT. Typical examples of weldments are gun mounts, machinery foundations, storage tanks, pressure tanks, frames, valve manifolds, and fabricated pipe fittings like crosses, tees, and elbows. The detailed plan worked out for producing the weldment is known as the WELDING PROCEDURE. The welding procedure specifies the kind of welding materials, joint design, preheat temperature, interpass temperature, postheat temperature, the chronological order and manner in which a series of joints are to be welded, and the way individual welds in the series are to be made. The chronological order of making the various welds in the weldment is called the WELDING SEQUENCE. Thus, the welding procedure spells out all the details for producing a given weldment with a predetermined welding process.

An important part of the welding procedure is the JOINT WELDING PROCEDURE. This term refers to the details pertaining to the materials, methods, and practices used to make a particular joint in the weldment. Included in the joint welding procedure is the DEPOSITION SEQUENCE. This term refers to the order in which the weld metal in a given joint is to be deposited. Do not confuse the deposition sequence with a weld sequence; weld sequences will be discussed shortly. The deposition sequence may call for an intermittent weld or a continuous weld.

There are two types of INTERMITTENT WELDS. Both are fillet welds in which weld continuity is broken by unwelded spaces. The chain intermittent weld is illustrated in view B of figure 7-3, and the staggered intermittent in view C of figure 7-3. In chain intermittent welding, the increments or parts of the weld are approximately opposite each other. In staggered intermittent welding, the weld increments are staggered with respect to each other on opposite sides of a tee joint.

A CONTINUOUS WELD is one in which the completed joint contains weld metal throughout. In other words, there are no unwelded portions in the joint as in an intermittent weld. The continuous weld is made by one of two main weld sequences, either the continuous sequence or the longitudinal sequence.

A continuous sequence has a slightly different meaning than does a continuous weld. In a CONTINUOUS SEQUENCE, welding begins at one end of the joint and proceeds continuously to the other. The continuous sequence is the least complex of all the sequences. However, a continuous weld may be produced by a welding sequence other than the continuous sequence.

In a LONGITUDINAL SEQUENCE, the end result is a continuous weld, but the weld is not made by proceeding continuously from one end of the joint to the other. Here different parts of a joint are made at different times. The longitudinal sequence specifies the order in which the various increments of the continuous weld are to be made with respect to the entire length of the joint. The longitudinal sequence is completed by one of eight standard sequences, which includes the backstep, the wandering, the buildup, the block, the cascade, the progressive block, the wandering block, and the selective block. These sequences are used in welding to minimize distortion by controlling expansion and contraction.

When the longitudinal sequence is used to produce a continuous weld, you will normally use either the backstep sequence or the wandering sequence. The backstep and the wandering sequences are illustrated in figure 7-16.

In the BACKSTEP SEQUENCE, as shown in view A of figure 7-16, the weld does not begin at the end of the joint. Furthermore, the parts or increments of the weld are deposited in a direction opposite to that in which the entire joint is made. Increment length is usually specified. If it is not, you can determine the proper weld increment length by the following procedure.

Select an electrode of the proper type and diameter. Then, using the same methods that will be used in welding the joint, run an uninterrupted bead with one electrode on a piece of scrap metal. The length of the practice bead is the proper length for the increment. Thus, if your practice bead is 6 inches long, the first increment is started 6 inches from the edge of the plate. Successive increments would start 6 inches away from the previous weld increment. The backstep sequence is sometimes called a step-back sequence.

The WANDERING SEQUENCE, as shown in view B of figure 7-16, combines some of the features of both the continuous and the backstep sequences. In this sequence, weld increments are deposited in the same direction as the weld joint proper, as in a continuous sequence. However, as the illustration indicates, the order in which the weld increments are deposited is not progressive along the joint. Instead, gaps equal in length to that of the

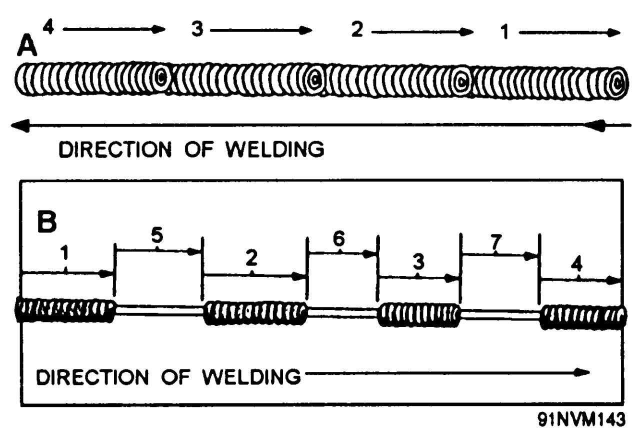


Figure 7-16.—(A) Backstep sequence; (B) Wandering sequence.

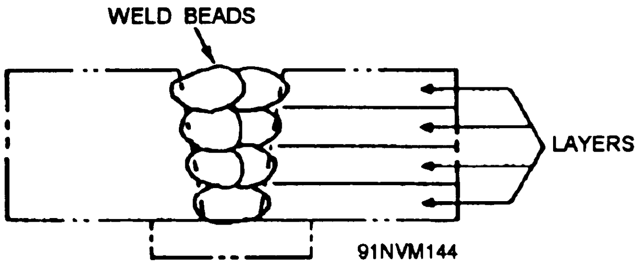


Figure 7-17.—Multiple-pass layers.

increment itself are left along the joint. Once the length of the joint has been welded in this manner, the welder fills the gaps, thus producing a continuous weld. The order in which the parts of the weld are made may differ from that indicated in view B of figure 7-16. Another order, such as 6-7-5-3-l-4-2, might be equally satisfactory. For this reason, the wandering sequence is often called the random or skip sequence. No matter which order is selected, the pattern must be predetermined. Increment length is determined in the way described for the backstep sequence. It is a good idea to lay out the joint increment lengths and number each portion according to the chronological order in which it is to be welded.

Thus far, we have considered only those sequences in which a single pass or weld bead is involved. (A PASS is a single progression of a welding operation along a joint or weld increment deposit. The result of a pass is a weld bead.) The sequences we will consider next consist of multiple-pass layer welds.

A LAYER consists of two or more weld beads. Figure 7-17 shows the use of multiple passes and layers in making a groove weld. The number of layers required to complete the weld is determined by the thickness of the metal being welded and the diameter of the welding rod being used.

Figure 7-18 illustrates block sequence, buildup sequence, and cascade sequence. Note that all of these sequences involve longitudinal sequence and multiple passes and layers. The BLOCK SEQUENCE, shown in view A of figure 7-18, is a longitudinal sequence having a specified buildup order. Individual sections or blocks of the continuous joint are partially or completely welded in an order somewhat like that of a backstep or wandering sequence before intervening sections are deposited. The term BUILDUP SEQUENCE refers to the order in which the weld beads of a multiple-pass weld are deposited with respect to the cross section of the joint. Thus, a buildup sequence is a part of any joint that requires layers of filler metal deposits to make the weld. View B of figure 7-18 shows a buildup sequence. The CASCADE SEQUENCE, shown in view C of figure 7-18, is a variation of the block sequence. It has a specified buildup order, but the weld beads are deposited in overlapping layers.

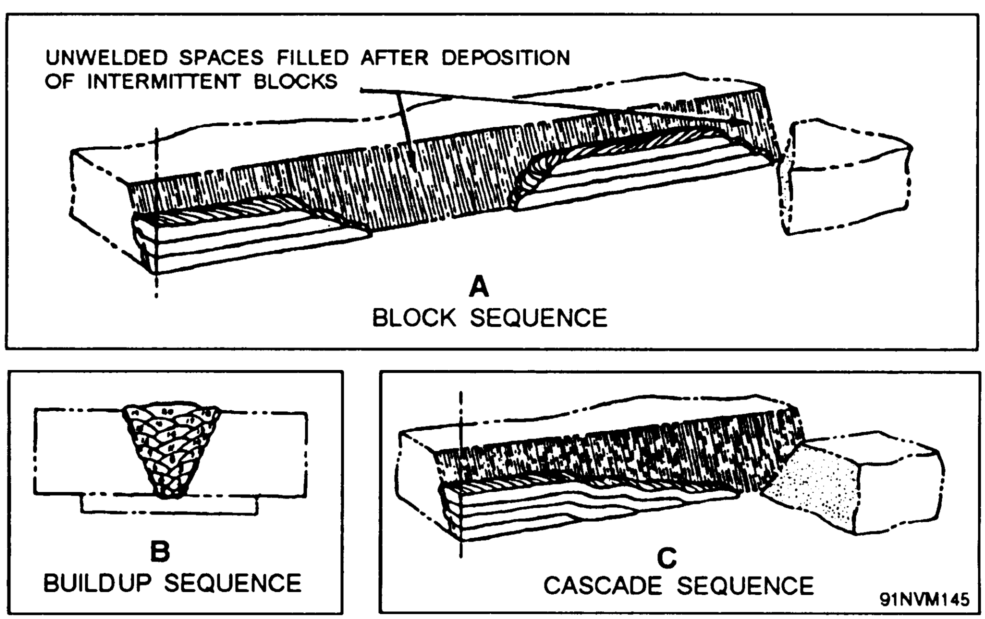


Figure 7-18.—Block, buildup, and cascade sequences.

There are several other variations of the block sequence. In the PROGRESSIVE BLOCK sequence, successive individual blocks of the continuous weld are completed progressively along the joint from one end to the other or from the center of the joint toward either end. Another variation is the WANDERING BLOCK. In this sequence, successive blocks are completed at random after several starting blocks have been completed. Still another variation is the SELECTIVE BLOCK SEQUENCE. Here the successive blocks are completed in a certain order so that a predetermined stress pattern is created within the joint.

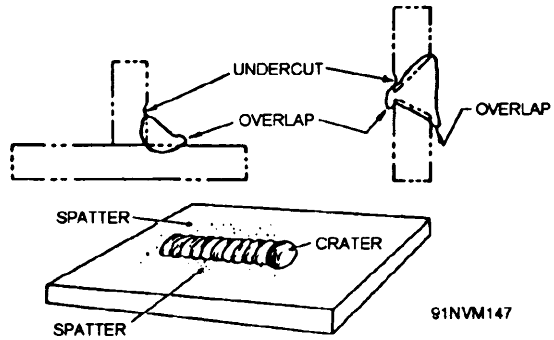


Figure 7-20.—Visible weld defects: spatter, overlap, and undercut.

WELD DEFECTS

Weld defects, like the welds themselves, must be described in standard terms. Common weld defects that you should be familiar with include incomplete fusion, inadequate joint and root penetration, spatter, overlap, undercut, root cracks, toe cracks, crater cracks, underbead cracks, voids, and inclusions.

Every welding design assumes that the specified extent of fusion and penetration will be obtained throughout the length of the joint. Welds such as those shown in figure 7-19 would be classified as defective because of incomplete fusion and lack of penetration.

Inadequate joint and root penetration is cause for rejection of a weld even if it is sound in all other respects. The strength required in a weldment is achieved only when the specified joint and root penetration is achieved.

Some visible weld defects are illustrated in figure 7-20. SPATTER is the term used to describe metal particles or globules that are expelled during welding and that do not form part of the weld. When spatter occurs, small balls of metal are stuck to the surface of the base metal along the line of weld. OVERLAP is a protrusion of the weld metal beyond the bond at the toe of the weld. An UNDERCUT is a groove melted into the base metal adjacent to the toe and not filled by weld metal. Both overlap and undercut are more serious than spatter, since either may seriously impair the strength of the weld. Overlap and undercut indicate that something is wrong with the welding techniques being employed or that something is wrong with the adjustment of the equipment.

Several kinds of cracks are classified as weld defects. Uneven expansion and contraction is usually the basic cause of cracks whether they are in the weld metal itself or in the adjacent heat-affected zone. One fairly common kind of crack is the CRATER CRACK. This occurs in the crater or depression at the termination of a weld bead in gas or arc welding.

Two other types of cracks are shown in figure 7-21. TOE CRACKS occur in the base metal, at

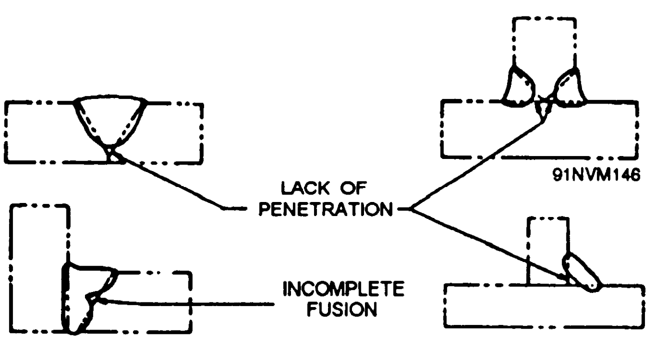


Figure 7-19.—Examples of incomplete fusion and lack of penetration.

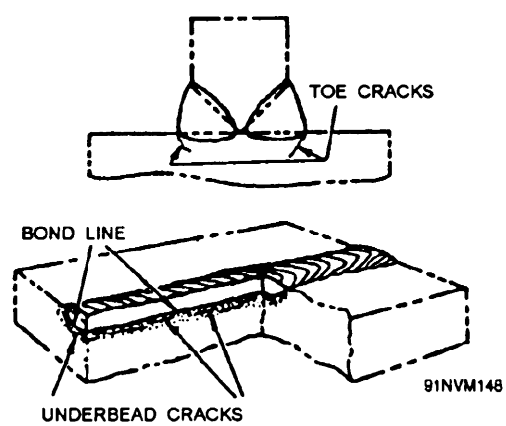


Figure 7-21.—Toe cracks and underbead cracks.

the toe of the weld. UNDERBEAD CRACKS occur in the heat-affected zone underneath a bead, and do not extend to the surface of the metal. Underbead cracks can be detected either by X ray or ultrasonic examination.

ROOT CRACKS are similar to toe cracks except that they occur at the root of the weld. Root cracks may be in the weld metal or in the base metal.

VOIDS, also known as GAS POCKETS or BLOWHOLES, are another type of weld defect. The term POROSITY is used when there are a number of voids. Voids occur as the result of gas being absorbed during the welding and then trapped as the metal solidifies. The absorbed gas is usually hydrogen. Improper welding techniques, incorrect adjustment of equipment, or moisture in electrode coating may lead to the absorption of gas and the consequent formation of voids.

SLAG INCLUSION is the term used to describe the weld defect in which nonmetallic solid material is trapped in the weld metal or at the bond between the weld metal and the base metal. The presence of slag inclusions breaks up the homogeneity of the metal, thereby providing a point for the concentration of stresses. In some cases, the concentration of stresses thus developed leads to failure of the joint.

FILLER MATERIALS

The metals that are added during the welding process are known as filler materials or filler metals. In welding processes in which a space is left between the parts to be joined, filler metals provide the intimacy of contact necessary for coalescence. Filler materials used in welding processes include welding rods and electrodes.

The term WELDING ROD refers to a filler metal in wire or rod form. It is used in gas welding processes and in certain electric welding processes, such as gas tungsten-arc welding, in which the filler metal does NOT form a part of the electrical circuit. The only purpose of a welding rod is to supply filler metal to the joint.

The term ELECTRODE refers to the metal that, in electric welding, forms a part of the electrical circuit. In gas tungsten-arc welding, electrodes melt off and are a source of the filler metal supply.

FLUXES

The welding or brazing of certain materials require the use of a flux to produce a sound joint. Fluxes are available as liquids, pastes, and powders. They have a melting point below that of the base and filler metals, and they are not incorporated into the weld. Their primary purpose is to prevent the formation of oxides on the weld joint before and during welding operations. Fluxes should never be used as a substitute for proper cleaning.

The application of fluxes will vary depending upon the type of welding being done. In silver brazing, the flux is applied directly to the joint with a brush. In other brazing operations, the filler metal is heated slightly and dipped into the flux.

The composition of fluxes is covered by a number of specifications. No one flux is satisfactory for all purposes. When the type of flux to be used is not otherwise specified, consult the *NSTM* or the latest NAVSEA instruction for the type of flux to use for a particular job.

Fluxes are not ordinarily required for oxyacetylene welding of mild steel and low-alloy ferrous metals. The oxides of these metals melt at a low temperature and flow away from the weld area. However, all brazing and soldering jobs on both ferrous and nonferrous metals require a flux. All oxyacetylene welding jobs on cast iron, cast steel, aluminum, copper, copper-base alloys, nickel, nickel-base alloys, high-chromium alloys, and silicon-bronze alloys also require a flux.

Several precautions must be observed when you are working with fluxes. Unless the base metal is properly cleaned and the correct flux applied to the joint, fluxing will hinder rather than aid in making the joint. Further, the flux must not be overheated or it will fail to serve its purpose. In addition, fluxes will also deteriorate if they are kept at brazing temperatures for too long a time. Nearly all fluxes give off fumes that may be toxic. For that reason, fluxes should always be used in a well-ventilated space. Any welding operation requires adequate ventilation, whether a flux is used or not.

EDGE PREPARATION

Joint edge preparation and proper spacing between the edges of the parts are important in any welding operation. The thickness of the plates and the joint design determine the amount of edge preparation required. Sheet metal is easily melted and does not require special edge preparation. The faces of the square edges can be butted together and welded. This type of joint can be used on sheets up to 1/16 inch thick. For metal thicknesses from 1/16 to 1/4 inch thick, a slight root opening between the parts is necessary to obtain complete penetration if welded from both sides. Plate over 3/16 inch thick and welded from one side requires beveled edges and a root opening as required by MIL-STD-22. For oxyacetylene welding on plate over 1/4 inch thick, the edges are beveled at an angle of 35° to 45°, making the groove angle from 70° to 90°. These edges can be prepared by flame cutting, shearing, flame grooving, machining, chipping, or grinding. In any case, the edge surfaces should be free of oxides, scale, dirt, grease, or other foreign matter.

Plate from 3/8 to 1/2 inch can be satisfactorily welded from one side only, but heavier sections should be welded by preparing the edges from both sides. Generally, butt joints prepared from both sides permit easier welding, produce less distortion, and ensure better qualities in the weld metal in heavy sections than do joints made from one side only.

EXPANSION AND CONTRACTION

Heat causes metals to expand, and cooling causes them to contract. Uneven heating will, therefore, cause uneven expansion, or uneven cooling will cause uneven contraction. Under such conditions, stresses are set up within the metal. These forces must be relieved, and unless precautions are taken, warping or buckling of the metal takes place. When cooling, if nothing is done to take up the stress set up by the contraction forces, further warping may result. If the surrounding cool sections of the metal are too heavy to permit this change in shape, the stresses remain within the metal itself. Such stresses may cause cracking while cooling or may remain within the metal until further force is applied, as when the piece is put into use.

Sheet metal (1/8 inch and less in thickness) has such a large surface area per unit of weight that heat stresses tend to produce warping or buckling of the sheet. This and the contraction effect encountered on long seams are the main points to be considered in sheet metal welding.

The effect of welding a long seam (over 10 or 12 inches) is to draw the seam together as the weld progresses. If the edges of the seam are placed in contact with each other throughout their length before welding starts, the far ends of the seam will actually overlap before the weld is completed.

One way of overcoming this effect is illustrated in figure 7-22. The two pieces to be welded are placed with an increased allowance at the far end, and as the welding progresses, the two pieces are drawn together. This allowance is generally one metal thickness per foot of seam.

Another method of controlling expansion and contraction is by the use of chill bars. Heavy pieces of metal are placed on either side of the weld. They absorb the heat and keep it from spreading across the whole surface area. Copper is commonly used for chill bars because of its ability to absorb heat rapidly. Welding jigs sometimes use this same principle to remove heat from the base metal. (See fig. 7-23.)

TEMPERATURE CONTROL

The control of temperature before, during, and after welding is often a matter of vital importance. Preheating and postheating are specified for many welds on many types of metals. Control of interpass temperature is important in all multipass welds.

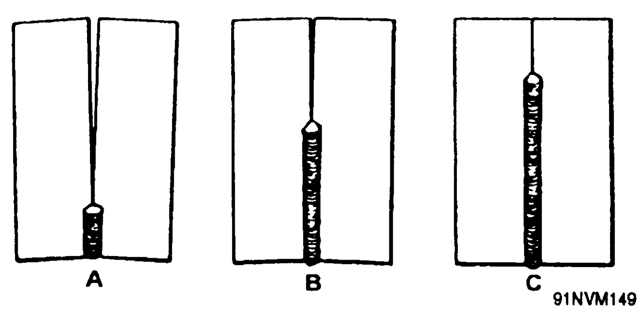


Figure 7-22.—Allowance for a straight butt weld.

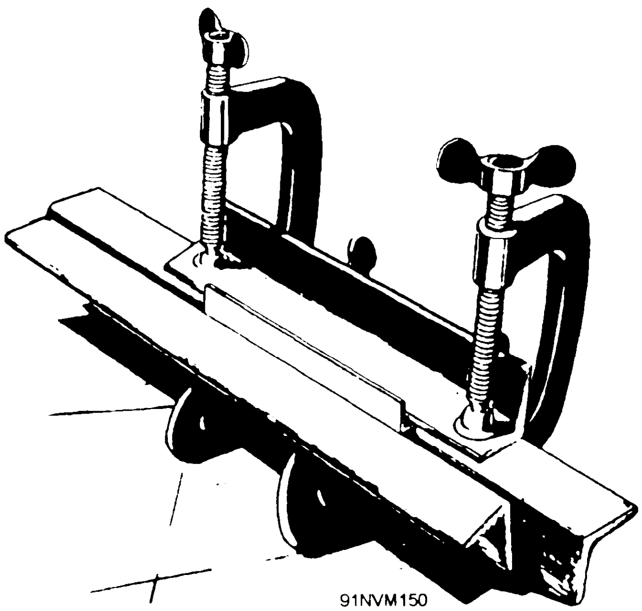


Figure 7-23.—Example of the use of jigs and chill bars.

Oxyacetylene or propane torches and electric induction or resistance coils may be used for preheating and postheating. Portable electric heaters are furnished to repair ships, tenders, and other ships and stations that normally fabricate items made of carbon molybdenum steel and chromium-molybdenum steel. The complete unit consists of control devices mounted on a portable panel, electrical supply connections, heater cable leads, and heater coils.

PREHEATING is the application of heat to the base metal before a welding or cutting operation is performed. Preheating is not required for all welds. When required, the preheat temperature and the length of time the temperature must be held (hold time) is specified in the welding process instruction being used. The preheat temperature and the hold time depend upon the chemical composition of the metal, the thickness of the metal, and to some degree upon the welding method and the type of welding rod or electrode used. Some alloys are more successfully welded without any preheat. Because of the wide variations in preheat requirements, you must follow the welding specifications for each job precisely.

INTERPASS TEMPERATURE is the temperature of the deposited weld metal before the next pass can be made. The interpass temperature (minimum or maximum as specified in the welding process instruction) will vary according to the composition and thickness of the metal being welded.

POSTHEATING is done primarily for the purpose of relieving stresses in the metal after it has been welded. The temperature, the hold time, and the cooling rate are specified for each job where postheating is required. In general, slow cooling is essential for stress-relieving. If the metal is cooled rapidly, new stresses will develop and thus defeat the purpose of the postheating.

Requirements for stress-relieving depend upon the composition of the metal, the thickness of the metals to be joined, and the complexity of the weldment. In some cases, stress-relieving may be specified for a partly welded joint. Stress relief is usually required for welded joints that will be subjected to high pressure. Tables to be used as guides for temperature control are contained in MIL-STD-278.

WELDING PIPING

The requirements for fabricating piping by welding vary according to the class of piping involved. MIL-STD-278 establishes four classes of piping: P-1, P-2, P-3, and P-LT.

CLASS P-1 includes all piping used for services where the pressure exceeds 300 psi or the temperature exceeds 650°F. It also includes ALL piping systems used for conveying deadly gases or liquids and hydrogen peroxide (regardless of the pressures and temperatures in these systems), except where such systems are covered by classes P-2 or P-3. Examples of class P-1 piping include steam lines, hydraulic systems, steam escape piping below decks, boiler generating tubes, boiler superheater and economizer elements, and other pressure-retaining tubes and piping. Class P-1 piping does NOT include nozzle and root connections to pressure vessels where such connections are covered by pressure vessel classifications.

CLASS P-2 includes piping used for services where the pressure does not exceed 300 psi and the temperature does not exceed 650°F. It also includes escape piping above decks. Class P-2 piping does NOT include piping covered by class P-3.

CLASS P-3 includes all brazed piping of unlimited pressure and a maximum temperature of 425°F. Fabrication and inspection of brazed piping should be according to the requirements of NAVSHIPS 0900-001-7000.

CLASS P-LT includes all piping of design pressure greater than 50 psi and service temperature for minus 20°F and below.

The following general considerations apply to all pipe welding:

—Whenever possible, weld pipe in the horizontal rolled position. It is much easier to weld near the top of the pipe than it is to work through the overhead and vertical positions. By using the horizontal rolled position, you get the advantages of increased speed and the likelihood of a sound weld.

—Be sure the pipe is carefully aligned.

—Tack welding is used in practically all pipe welding. The number of tack welds needed is determined by the diameter of the pipe. The size of the tack welds is determined by the wall thickness of the pipe. For 1/2-inch pipe, two diametrically opposite tack welds are used. On 12-inch pipe, you will need six tack welds. Four welds are usually sufficient for the common pipe sizes. Tack welds are generally incorporated into the finished weld; therefore, the material used for tack welding MUST be the same as the filler metal. Any tack weld that contains cracks or other defects must be removed by chipping, grinding, or gouging before the final weld is made.

—On circumferential butt welds, provide a weld buildup of 1/16 to 3/32 inch, depending upon wall thickness and pipe size.

—In multipass welding, remove all slag from each bead before depositing the next bead.

—For some welds, peening is permitted as a means of correcting distortion and minimizing residual stresses. However, peening MUST NOT be done on single bead or single layer welds nor on the last layers of multiple layer welds.

Specific information pertaining to welding on the various classes of piping is given in the following sections.

P-1 CLASS PIPING

The shielded metal-arc and gas tungsten-arc welding processes must be used for the shipboard welding of P-1 class piping that is 0.109 inch or more in wall thickness and for the shop welding of P-1 piping that is more than 0.083 inch in wall thickness. At least two layers of weld metal must be applied around all joints in this piping.

Stress relief heat treatment is generally done after welding on P-1 class piping. Factors that determine whether or not stress relief is necessary include the carbon content of the alloy, the chromium content, the thickness of the joint, and the size of the pipe (iron pipe size [ips]). Also, stress relief is required for some materials in P-l class piping if preheat and interpass temperatures of 200° to 300°F were not maintained.

All welds in P-l piping must be tested hydrostatically. Most of these welds must also be inspected by radiographic, magnetic particle, or liquid penetrant inspection. Requirements for welding and testing welds in P-l piping are normally covered by the applicable welding procedure or military standard. Use *NSTM*, chapter 074, volume 1, as a starting document. It will refer you to other applicable documents, such as MIL-STD-278 for fabrication and inspection, MIL-STD-271 for nondestructive test requirements, MIL-SD-22 for joint design, and numerous military specifications for material requirements. All of these documents are a necessary part of welding on P-l piping.

For more in-depth information on a particular job, refer to the applicable military standards, or procedures designated for use by NAVSEA.

P-2 CLASS PIPING

The manual shielded metal-arc process is used for the shipboard welding of P-2 class piping that is 0.109 inch or more in wall thickness and for the shop welding of P-2 piping that is 0.083 inch in wall thickness. Gas tungsten-arc welding may be used on P-2 piping that is less than 0.109 inch thick.

Thermal stress relief is required for P-2 class piping welds in carbon steel and carbon molybdenum alloy steels that have over 35 percent carbon.

All welds in P-2 piping must be inspected during the hydrostatic test of the piping and must be radiographed if it is required by the plans or specifications.

P-LT CLASS PIPING

In general, the manual shielded metal-arc process is used for the shipboard welding of P-LT class piping that is 0.109 inch or more in wall thickness and for the shop welding of P-LT class piping that is 0.083 inch in wall thickness.

The tests and inspections for P-LT class piping are generally the same as those for P-l class piping. Use the applicable documents that cover joint designs, welding procedures, stress-relieving, and nondestructive tests and inspections for each job as required.

P-3 CLASS PIPING

The requirements for P-3 class piping are equally as important as those for P-l, P-2, and P-LT piping. P-3 piping systems are assembled by silver brazing. Filler materials and fluxes must be selected on the basis of the metals to be joined.

The fabrication and inspection of all P-3 piping must be according to NAVSEA 0900-LP-001-7000, *Fabrication and Inspection of Brazed Piping Systems.* After the joint is cooled, all accessible sections of the joint are to be cleaned to remove any scale or flux that may be present.

In addition to being hydrostatically tested, all silver-brazed joints in P-3 class piping 2 inches ips and over must be ultrasonically tested. On

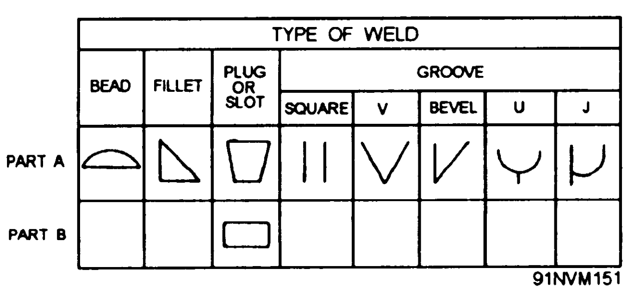


Figure 7-24.—Basic arc and gas weld symbols.

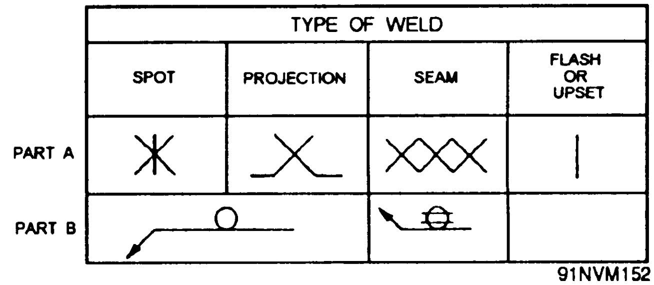


Figure 7-25.—Basic resistance weld symbols.

submarines, all silver-brazed joints 1/2 inch ips and above must be ultrasonically tested.

WELD SYMBOLS AND WELDING SYMBOLS

Special symbols are used on drawings to show the kinds of welds to be used. These symbols have been standardized by the American Welding Society and the Department of Defense. The basic reference in this field for Navy welders is the American Welding Society Standard, AWS A2.4-79. AWS A2.4-79 supersedes AWS A2.0-68, which formerly was the basic reference for the Navy welders. Although there is no need for you to memorize all the welding symbols given in AWS A2.4-79, you should be familiar with the basic weld symbols and with the standard location of all eight elements of a welding symbol.

The distinction between a weld symbol and a welding symbol should be noted. A WELD SYMBOL is a basic weld symbol used to indicate the type of weld. Thus, the basic weld symbols shown in figures 7-24 and 7-25 are weld symbols. The supplementary weld symbols shown in figure 7-26 are used when necessary in connection with the basic weld symbols. In figures 7-24, 7-25, and 7-26, view A, shows the symbols that were listed in AWS

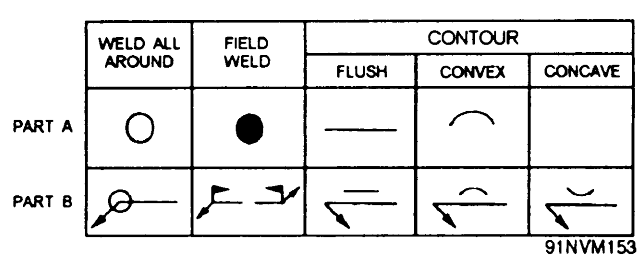


Figure 7-26.—Supplementary weld symbols.

A2.0-68. Some of the symbols, but not all, have been changed by AWS A2.4-79. View B shows the new symbols for those changed. No figure is shown in view B for those symbols that were not changed. You should be aware that some drawings available may still show the symbols that were changed.

An assembled WELDING SYMBOL consists of the following eight elements (or as many of these elements as are required): (1) reference line, (2) arrow, (3) basic weld symbols, (4) dimensions and other data, (5) supplementary symbols, (6) finish symbols, (7) tail, and (8) specification, process, or other reference. The finish symbols indicate the method of finish, not the degree of finish. The letter C is used to indicate finish by chipping, *M* indicates machining, and G indicates grinding.

The elements of a welding symbol have standard locations with respect to each other, as shown in figure 7-27.

SAFETY PRECAUTIONS

Safety precautions for welding may be considered as falling into three general categories: (1) precautions with respect to the location of the welding; (2) precautions concerning the operation of equipment; and (3) precautions related to the safety of personnel.

The safety precautions given here are general in nature and should be supplemented by study of the precautions given in chapter 1 of this manual and NSTM, chapter 074, volume 1.

LOCATION OF WELDING

A first consideration for safety in welding is the location and peculiarities of the space in which the welding operation is to be performed. Welding and cutting may be performed ONLY in locations specifically designated for this purpose, unless approval of the job and the precautions taken to eliminate fire and explosion hazards have been obtained from the proper authority.

Fire and explosion hazards are eliminated by removing or protecting combustible or explosive materials or vapors, and by taking the precautions necessary to prevent a reaccumulation of such materials. The methods for making a space safe for welding and the tests used to ensure that a space is free of fire and explosion hazards are the responsibility of the gas-free engineer, whose duties

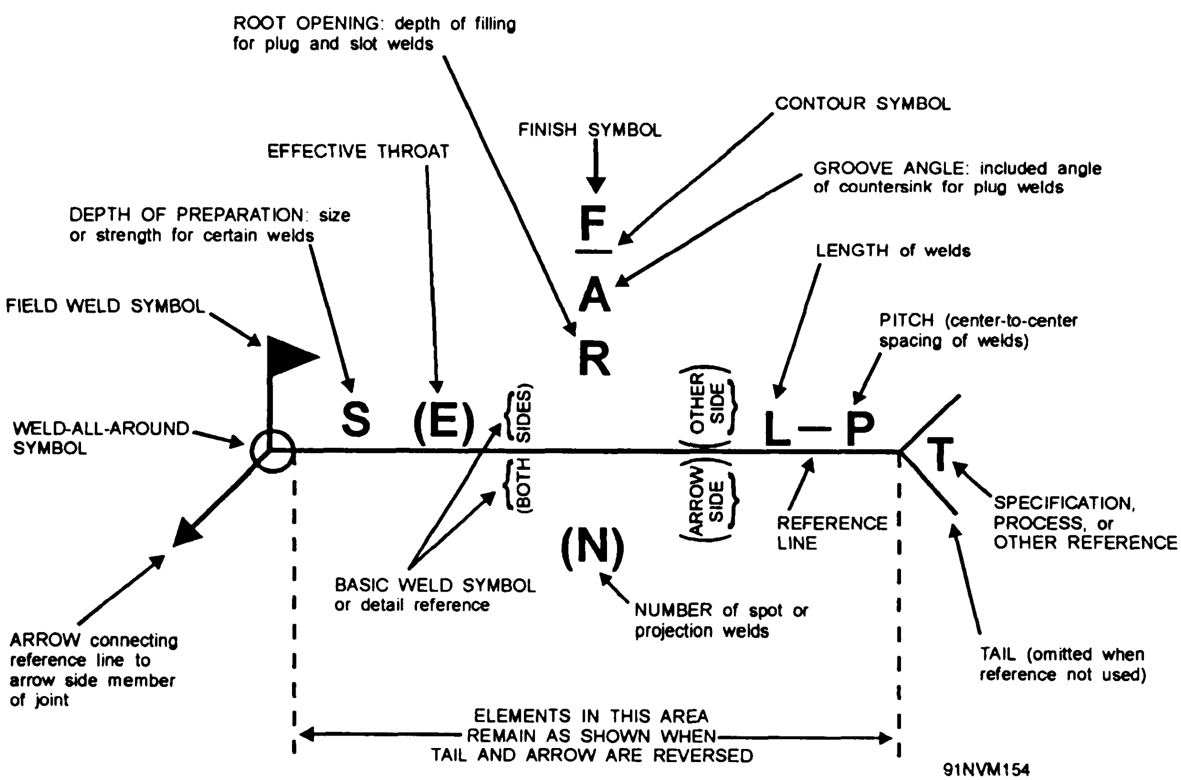


Figure 7-27.—Standard location of elements on a welding symbol.

are described in *NSTM*, chapter 074, volume 3. Keep in mind that welding MUST NOT be performed in any location outside the shop unless the necessary precautions have been taken and approval has been obtained. Any compartment, room, tank, or space adjacent there to which contains or which has contained flammable or explosive materials, liquids, or vapors must be made safe, tested, and proclaimed safe before you can weld in such a space. These restrictions also apply to closed drums, tanks, and similar containers.

When welding is being done, a fire watch must be posted in the vicinity, particularly when flammable or explosive materials are exposed. If a fire hazard exists on both sides of a bulkhead or deck, fire watches must be stationed on both sides with appropriate types of fire extinguishers. For example, if the only combustible material within range of the sparks or heat from welding or cutting operations is bitumastic waterproofing, a CO_2 extinguisher may be adequate. In a small space with a very small access opening, however, the operator might not be able to get out quickly in the event of fire. The use of CO_2 would be dangerous in this case; the use of water from a 1 1/2-inch waterline or water pump tank would be preferable. If the insulation on some electrical equipment is the only combustible material present, the use of water would be more dangerous than the fire itself. In this situation, CO_2 would be used. In each case, it is necessary to consider what kind of fire might occur and to provide the appropriate equipment to combat it. The fire watch must remain on station at least 30 minutes after a job has been completed to make sure that there is no smoldering fire.

Adequate ventilation must be provided in all spaces in which welding is being done and to eliminate health hazards such as gases, fumes, and dust caused by the welding operation. Any welding operation requires that the operator, helper, or fire watch wear approved respirators regardless of the amount of ventilation provided. When welding or cutting operations are performed on lead-bearing steels, lead-coated or cadmium-coated metals, or metal covered with paint containing lead or cadmium, an air-line mask should be worn even if the work is done in the open air or in a well-ventilated space.

When welding is performed on uncoated ferrous metals, a minimum space allowance of 10,000 cubic feet per operator or three complete air changes per hour must be provided. When welding is performed on galvanized metals, brass, bronze, and some other metals, the ventilation requirements increase by at least 10 percent. For welding performed in a confined space, positive steps are necessary to ensure the elimination of health hazards. In addition, some conditions, like welding inside a tank, make it necessary for the welder to wear an air-line mask.

As a welder, you must consider as unsafe every closed compartment or poorly ventilated space, all tanks, cofferdams, voids, and similar spaces, until the gas-free engineer has inspected the space and has indicated that adequate precautions have been taken. When the condition of the space has been determined, the gas-free engineer posts a tag describing the condition of the space. The tag posted includes complete information as to whether or not the space is safe for persons and whether or not it is safe for hot work. The information on the tag is expressed in one of the following ways, depending on the condition of the space:

- NOT safe for persons—NOT safe for hot work
- Safe for persons—NOT safe for hot work
- Safe for persons—Safe for hot work
- INERTED—NOT safe for persons INSIDE—Safe for persons and hot work OUTSIDE
- PRESSED UP (with water or oil)—Safe for persons and hot work OUTSIDE

The term *inerted* means that a nonflammable gas (usually CO_2) has been introduced into the space and that the concentration of the gas is sufficient to reduce the oxygen content of the space to a level that will not support combustion. The term *pressed up* means that the space has been entirely filled with water or oil.

When it is necessary for welding or cutting to be performed in any confined space that has a small exit, all heavy equipment, such as gas cylinders and welding generators, must be left on the outside. An attendant who can observe the welder at all times must also be stationed on the outside of the space so that in an emergency the attendant can shut off the gas or the electric current and provide such other help as the situation demands. If the welder must enter the space through a manhole or other small space, a lifeline and safety belt must be attached to the welder's body so that the welder can be quickly removed in an emergency. This equipment must be attached in such a way that the welder's body cannot be jammed in the small opening.

The discussion thus far has been primarily concerned with compartments and tanks that are part of the ship's structure. Certain special precautions should be noted for welding or cutting on any hollow metal article, whether the work is performed in or out of a welding shop.

Before allowing any welding or cutting to be done, be sure that if the hollow metal article has ever held a flammable substance, it is cleaned and made safe. Even a trace of flammable material in a drum, tank, or other hollow article would constitute a tremendous hazard. A container that has held a flammable substance may be cleaned with steam if the substance is easily vaporized. For removing heavy oils, a strong solution of caustic soda or a similar chemical is usually used. Thorough rinsing of the article is necessary. After a container has been cleaned, it should (if possible) be filled with water, carbon dioxide, or nitrogen. This precaution should be taken since it may be impossible to remove all traces of oil or grease from the seams or corners of the container.

Hollow metal articles must be vented before being welded or cut, whether or not they have ever contained a flammable substance. If they are not vented, the increase in air pressure that occurs when heat is applied may be sufficient to cause an explosion.

OPERATION OF EQUIPMENT

Safety precautions for the operation of welding equipment vary considerably because of the different types of equipment involved. Consequently, only general precautions pertaining to gas welding and to metal-arc welding are given here. Further precautions may be found in chapter 1 of this manual, in the references already mentioned, and in the technical manuals furnished by the manufacturers of the equipment.

Precautions for the operation of gas welding equipment include the following:

—Use only approved apparatus that has been examined and tested for safety.

—Stow all cylinders carefully according to prescribed stowage procedures. Cylinders should be stowed in dry, well-ventilated, well-protected places, away from heat and combustible materials. Do NOT stow oxygen cylinders in the same compartment as acetylene or other fuel gas cylinders. All cylinders should be stowed in an upright position rather than horizontally. If acetylene cylinders are not stowed in an upright position (valves at top), they must not be used until they have been allowed to stand in an upright position for at least 2 hours.

—Do not allow anyone to tamper with cylinder safety devices.

—When cylinders are in use, keep them far enough away from the actual welding or cutting so they will not be reached by sparks, hot slag, or flame.

—Never place a cylinder in such a position that it could form part of an electrical circuit.

—Never interchange hoses, regulators, or other apparatus intended for oxygen with those intended for acetylene.

—Never attempt to transfer acetylene from one cylinder to another, to refill an acetylene cylinder, or to mix any other gas with acetylene.

—Keep the valves closed on empty cylinders.

—Do not stand in front of cylinder valves while opening them.

—When a special wrench is required to open a cylinder valve, leave the wrench in position on the valve stem while the cylinder is being used so that the valve can be closed rapidly in an emergency.

—Keep oxygen cylinders and fittings away from oil and grease! Even a small amount of oil or grease may ignite violently, with explosive force, in the presence of oxygen. NEVER lubricate any part of an oxygen cylinder, valve, or fitting.

—Do not drop cylinders. Do not handle them roughly. Rough handling may cause a cylinder valve to break off, and the sudden release of gas from a full cylinder may cause it to take off like a rocket.

—Always open cylinder valves slowly. (Do not open the acetylene cylinder valve more than 1 1/2 turns.)

—Close cylinder valves before moving cylinders.

—Never attempt to force unmatching or crossed threads on valve outlets, hose couplings, or torch valve inlets. The threads on oxygen regulator outlets, hose couplings, and torch valve inlets are right-handed; for acetylene, these threads are left-handed. The threads on acetylene cylinder valve outlets are right-handed, but have a pitch that is different from the pitch of the threads on the oxygen cylinder valve outlets. If the threads do not match, the connections are mixed.

—Always use the correct tip or nozzle and the correct pressure for the particular work involved. This information should be taken from tables or worksheets supplied with the equipment.

—Do not allow acetylene or acetylene and oxygen to accumulate in confined spaces. Such mixtures are highly explosive.

—Keep a clear space between the cylinders and the work so that the cylinder valves may be reached quickly and easily if necessary.

—When lighting the torch, open the acetylene valve first and ignite the gas while the oxygen valve is still closed. Do not allow unburned acetylene to escape and accumulate in small or closed compartments.

—When extinguishing the torch, close the acetylene valve first and then close the oxygen valve.

—When welding or cutting is stopped for a period of 15 minutes or more, or when the operator leaves the area, the equipment must be secured.

Precautions for the operation of metal-arc welding equipment include the following:

—Use only approved welding equipment, and be sure that it is in good condition.

—Before starting to work, make sure that the welding machine frame is grounded, that neither terminal of the welding generator is bonded to the frame, and that all electrical connections are securely made. The ground connection must be attached firmly to the work, not merely laid loosely upon it.

—When using portable machines, take care to see that the primary supply cable is laid separately so that it does not become entangled with the welding supply cable.

—When stopping work for any appreciable length of time, be SURE to de-energize the equipment. When not in use, the equipment should be completely disconnected from the source of power.

—Keep welding cables dry and free of oil or grease. Keep the cables in good condition, and at all times take appropriate steps to protect them from damage. If it is necessary to carry cables some distance from the machines, run the cables overhead, if possible, using adequate supporting devices.

SAFETY OF PERSONNEL

If it is necessary for a welding operator to work on platforms, scaffolds, or runways at an elevation of more than 5 feet, provisions should be made to prevent falling. This can be accomplished by the use of a railing or some other equally effective safeguard.

Helmets or hand shields should be used during all arc welding or arc cutting operations. Goggles should also be worn by personnel in the vicinity of arc welding or cutting operations to protect eyes from injurious rays from adjacent work and from flying objects. The goggles may have either clear glass or colored glass, depending on the amount of exposure to adjacent welding operations. Helpers or attendants should be provided with proper eye protection.

Goggles or other suitable protection should be used during all gas welding or oxygen cutting operations.

The specifications for protectors are as follows:

1. Helmets and hand shields should be made of a material that is an insulator for heat and electricity. Helmets, shields, and goggles must be fire retardant and must be capable of withstanding sterilization.

2. Helmets and hand shields of federal specification GGG-H-21 1 should be arranged to accommodate and securely hold window lenses having the specified dimensions, with cover glass, and designed to permit easy removal of lenses. Absorptive lenses must be mounted in helmets so they are not less than 2 inches from the eyes.

3. Goggles designated as style 1 have a rigid nonadjustable bridge (or adjustable metallic bridge) without side shields.

4. Goggles designated as style 2 have a rigid nonadjustable bridge (or adjustable metallic bridge) with side shields.

5. Goggles designated as style 3 have flexibly connected lens containers shaped to conform to the configuration of the face.

6. Lens containers must be suitable to firmly hold lenses of the correct dimensions.

7. Goggles of style 2 should be provided with side shields of metal, leather, or other durable asbestos-free material. The material should also be pliable to permit adjusting the shield to the contour of the face. If side shields are of metal, they should be of wire mesh or of perforated sheet having openings not larger than 0.394 inch.

8. Goggles of style 3 should consist of eyecups and should be shaped to fit the configuration of the face. They must have adequate ventilation to prevent fogging.

9. Lenses for helmet and hand shield windows should have a height of 2 inches (50.8 mm) and a width of 4.25 inches (108 mm) where one window is provided.

10. Lenses for goggles should have dimensions not less than 1.5 inches (38 mm) in the vertical direction and 1.75 inches (44.5 mm) in the horizontal direction. It is recommended that circular lenses not involving optical correction be a uniform diameter of 1.97 inches (50 mm). Cover glasses should be provided to protect each helmet, hand shield, or goggle lens.

11. Table 7-1 is a guide for the selection of the proper shade number. These recommendations may be varied to suit the individual's needs. The shade numbers in the following list will help you select the proper lens to use.

a. Shade No. 4, in any type goggle, may be used for stray light from nearby cutting and welding operations and for light electric spot welding.

b. Shade No. 5 filter lenses are usually sufficient for light gas cutting and welding.

c. Shade No. 6 filter lenses are usually sufficient for gas cutting, medium gas welding, and arc welding up to 30 amperes.

d. Shade No. 8 filter lenses are usually sufficient for heavy gas welding and for arc welding and cutting exceeding 30 but not exceeding 75 amperes.

e. Shade No. 10 filter lenses should be used for arc cutting and welding exceeding 75 but not exceeding 200 amperes.

f. Shade No. 12 filter lenses should be used for arc cutting and welding exceeding 200 but not exceeding 400 amperes.

g. Shade No. 14 filter lenses should be used for arc cutting and welding exceeding 400 amperes.

A variety of special clothing is available to protect the body during cutting and welding operations. The protective clothing to be worn will vary with the size, location, and nature of the work to be performed. During ANY welding or cutting operation, you should wear flameproof gauntlets at all times. For gas welding and cutting, a five-finger glove is generally used. For electric-arc welding, a gauntlet-type mitt is recommended. Gauntlets protect the hands from both heat and metal spatter. The one-finger mitt designed for electric-arcwelding has an advantage over the glove because it reduces the danger of weld spatter and sparks lodging between the fingers. It also reduces the chafing of fingers, which sometimes occurs when five-finger gloves are used for electric-arc welding.

Table 7-1.—Eye Protection Shade Guidelines

Welding Operations	Shade Numbers
Shielded Metal-Arc Welding—l/16, 3/32, 1/8, 5/32-inch	10
Inert-Gas Metal-Arc Welding—(Nonferrous) 1/16, 3/32, 1/8, 5/32-inch electrodes	11
Inert-Gas Metal-Arc Welding—(Ferrous) 1/16, 3/32, 1/8, 5/32-inch electrodes	12
Shielded Metal-Arc Welding—3/16, 7/32, 1/4-inch electrodes	12
Shielded Metal-Arc Welding—5/16, 3/8-inch electrodes	14
Arc-Air Cutting and Gouging	12-14
Soldering	2
Torch Brazing	3-4
Light Cutting, up to 1 inch	3-4
Medium Cutting, 1 inch to 6 inches	4-5
Heavy Cutting, 6 inches and over	5-6
Gas Welding (Light), up to 1/8-inch	4-5
Gas Welding (Medium), 1/8-inch to 1/2-inch	5-6
Gas Welding (Heavy), 1/2-inch and over	6-8

Some light gas welding and cutting jobs require no special protective clothing other than gauntlets and goggles if the regular work clothing is worn correctly. Sleeves must be rolled down, collar and cuffs buttoned, and pockets that are not protected by button-down flaps must be eliminated from the front of work clothing. Trouser cuffs must not be turned up on the outside. All other clothing must be free of oil and grease. High-top or safety shoes should be worn, and low-cut shoes with unprotected tops should NOT be worn. Wearing clothing in the manner described decreases the probability that sparks will lodge in folds of cloth such as rolled-up sleeves and cuffs, pockets, or the shirt collar.

During medium and heavy welding, specially designed flameproof clothing made of leather, or other suitable material, may be required. A wide choice of protective clothing is available so that you can select the type required for any particular welding or cutting job.

This clothing consists of aprons, sleeves, a combination of sleeves and bib, jackets, and overalls. Sleeves provide satisfactory protection for light welding operations at floor or bench level. Capes and sleeves are particularly suitable for overhead welding because the cape protects the back of the neck, top of the shoulders, and upper part of the back and chest. Use of the bib in combination with the cape and sleeves gives added protection to the chest and abdomen in jobs where protection for the lower part of the back is not required. The jacket should be worn only when complete all-around protection for the upper part of the body is needed, such as when several welders are working near each other. Aprons and overalls provide protection to the legs and therefore are suitable for welding operations on the deck or floor.

During overhead welding operations, leather caps should be worn under helmets to prevent head burns. Where the welder may be exposed to sharp or heavy falling objects, hard hats or head protectors should be attached in such a way as to form a part of the welding helmet. For very heavy work, fire-resistant leggings or high boots should be worn. Shoes or boots having exposed nail heads or rivets should not be worn. Oilskins or plastic clothing must not be worn while welding or cutting.

If leather protective clothing is not available, woolen garments rather than cotton garments should be worn. Wood does not ignite as readily as cotton, and it affords greater protection from changes in temperature. Cotton clothing, if it must be used, should be chemically treated to reduce its flammability. Synthetic fabrics should not be worn.

Report all injuries to the medical department as soon as possible. Even a slight burn or scratch should be treated promptly to prevent infection. Eye burns should be treated IMMEDIATELY. All eye burns should be seen as soon as possible by medical personnel.

SOURCES OF INFORMATION

To keep abreast of changes in the field of welding, it is essential that you be familiar with a number of sources of information. There are numerous Navy and commercial publications pertaining to welding. Some of these publications have already been mentioned earlier in this chapter. In the field of welding, as in so many other fields, official publications are constantly under revision; therefore, it is important to make an effort to keep up with the latest changes as they are issued.

The basic naval reference on welding and allied processes is *NSTM,* chapter 074, volume 1.

HYDROSTATIC TESTS

All welded piping must be subjected to hydrostatic tests to prove the tightness and the strength of the joints. Test pressures are usually included in the instructions or specifications for the welding. If test pressures are not specified, the hydrostatic test is normally performed at 135 percent of the maximum working pressure.

NONDESTRUCTIVE TESTS AND INSPECTIONS

A number of nondestructive techniques are used to determine the quality of welds and welded structures. Nondestructive tests and inspections include visual examination, magnetic particle inspection, liquid penetrant inspection, radiographic inspection, and ultrasonic tests. Some of these techniques are widely used throughout the Navy, and others are used only at large production or repair activities. These tests will be described in chapter 11 of this training manual.

VISUAL EXAMINATION

Prior to being tested by any other nondestructive test, all welds must pass a visual examination. Visual inspection of welds is useful for detecting undercutting, large cracks, inaccurate dimensions, and other obvious defects. However, there are many serious defects that cannot be detected by visual inspection, even by an experienced inspector. Visual examination of welds is NOT adequate for determining the internal soundness of welds or for detecting very small surface defects.

SUMMARY

This chapter has covered several areas of basic welding. You now have the basic knowledge of the welding processes, basic sequences, and the positions of welding. You were given the basic information on joints, welds, weld symbols, welding symbols, weld defects, and filler metals. With the knowledge gained from this chapter, you are on your way to learning to become a good, safe, and conscientious welder. Safety can never be stressed enough.

CHAPTER 8

OXYACETYLENE CUTTING AND WELDING

LEARNING OBJECTIVES

Upon completion of this chapter; you will be able to perform the following:

- *Describe the equipment used in oxyacetylene welding and the proper procedures for setup and safe operation of the equipment.*
- *State the principles of oxyacetylene cutting.*
- *Identify the parts of a cutting torch and the function of each part, and describe some of the special cutting techniques.*
- *Identify the safety precautions you should follow when performing cutting operations.*
- *Describe the different techniques of oxyacetylene welding and the safety precautions you should follow.*

INTRODUCTION

This chapter deals with oxyacetylene cutting and welding processes, and identifies the equipment and the operation of the equipment used in oxyacetylene operations.

Oxyacetylene cutting is a method of cutting metal by using heat and a jet of pure oxygen to produce a chemical reaction known as oxidation. The results obtained by using the oxyacetylene cutting method will range from a ragged, inaccurate edge to a smooth edge. The material being cut, the cutting method used, and the skill of the operator are among the factors that determine the final results.

Oxyacetylene welding is a nonpressure process in which coalescence is produced by heat from an oxyacetylene flame formed by the combustion of oxygen and acetylene. The two gases are mixed to correct proportions in a torch. The torch can be adjusted to give various types of flame.

OXYACETYLENE EQUIPMENT

Oxyacetylene equipment consists of a cylinder of acetylene, a cylinder of oxygen, two regulators, two lengths of hose with fittings, a welding torch with tips, and either a cutting attachment or a separate cutting torch. Accessories include a friction igniter to light the torch, an apparatus wrench to fit the various connections on the regulators, the cylinders, and the torches; goggles with filter lenses for eye protection; and gloves for protection of the hands. Flame-resistant clothing is worn when necessary.

The major components of a typical portable oxyacetylene outfit are shown in figure 8-1. Figure 8-2 illustrates a stationary acetylene cylinder bank of a type used at some activities.

ACETYLENE

Acetylene (chemical formula C_2H_2) is a fuel gas made up of carbon and hydrogen. When burned with oxygen, acetylene produces a very hot flame, having a temperature between 5700°F and 6300°F. Acetylene gas is colorless, but has a distinct, easily recognized odor. The acetylene used on board ship is taken from compressed gas cylinders. The cylinder is filled with balsa wood, charcoal, finely shredded asbestos, corn pith, portland cement, or infusorial earth (an absorbent material composed of decayed organic matter). These porous filler materials are used to decrease the size of

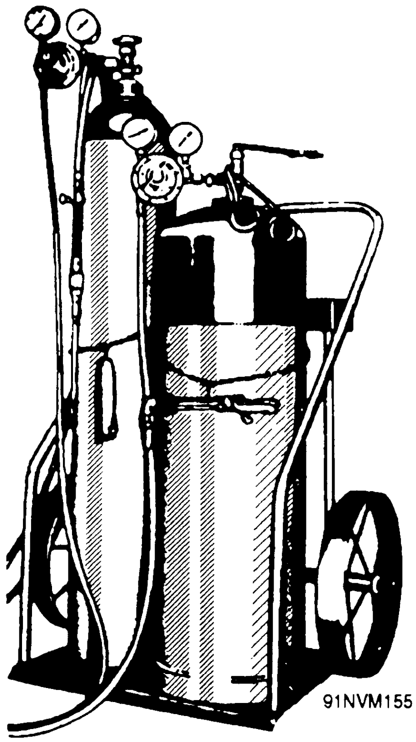


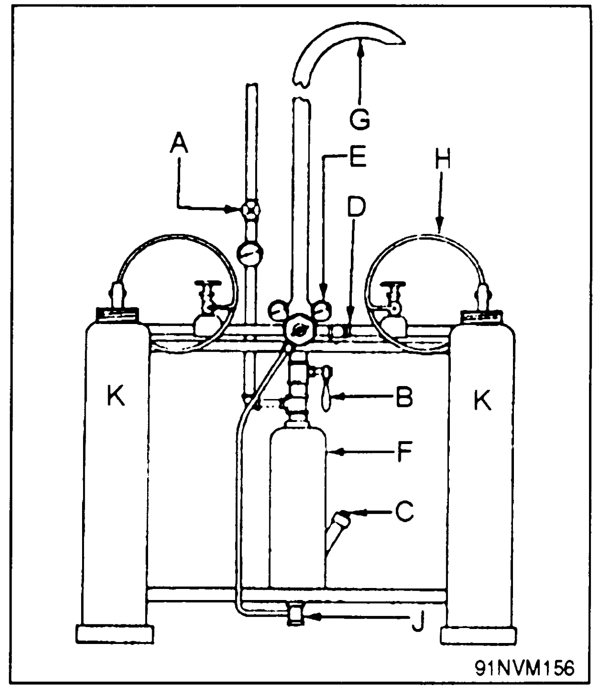
Figure 8-1.—A portable oxyacetylene outfit.

the open spaces in the cylinder and thus reduce the danger of explosion. At approximately 29 psi (pounds per square inch), pure acetylene can be exploded by nothing more than a slight shock; dissolved in acetone, however, and stored in cylinders that are filled with porous material, acetylene can be compressed safely into cylinders at pressures up to 250 psi. An acetylene cylinder is shown in figure 8-3. The acetylene cylinder must be in the vertical position a minimum of 2 hours before use to allow the porous filler material to settle and to prevent it from being drawn into the hose, gauges, and torch.

MAPP GAS

MAPP (methylacetylene-propadiene) gas is an all-purpose industrial fuel that has the high flame temperature of acetylene and the handling characteristics of propane. Being a liquid, MAPP gas is obtained by the pound rather than by the cubic foot, as with acetylene. One 70-pound (31.5-kg) cylinder of MAPP gas will do the work of more than 6 1/2, 225-cubic foot acetylene cylinders. This is a ratio of 70 pounds of MAPP gas to 1,500 cubic feet of acetylene.

The total weight for the 70-pound (31.5-kg) MAPP cylinder, which is the same physical size as a



A. Line valve
B. Release valve
C. Filler plug
D. Header pipe
E. Regulator
F. Flash arrester chamber
G. Escape pipe
H. Cylinder connection pipe
J. Check valve and drain plug
K. Acetylene cylinders

Figure 8-2.—Stationary acetylene cylinder bank.

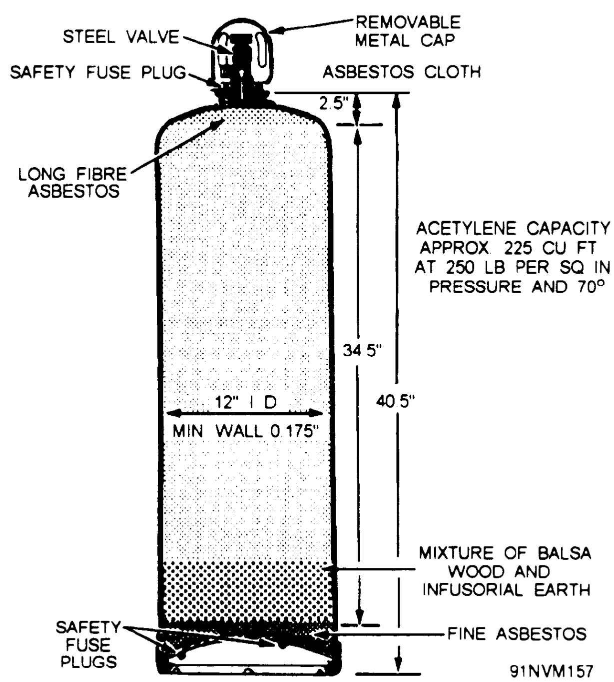


Figure 8-3.—Acetylene cylinder.

225-cubic foot acetylene cylinder, is 120 pounds (54.0 kg) when full.

MAPP cylinders contain only liquid fuel. There is no cylinder packing of acetone to impair fuel withdrawal. For heavy-use situations, a MAPP cylinder will deliver more than twice as much gas as an acetylene cylinder and for longer periods of time. The entire contents of a MAPP cylinder can be used, as there is no acetone that could be drawn into the regulators or torch. As the gas bums with oxygen, it produces a flame temperature of 5300°F (2950°C) and will equal or exceed the performance of acetylene for cutting, heating, and brazing due to its superior heat transfer characteristics.

MAPP is nonsensitive to shock and nonflammable in the absence of oxygen. There is no chance of an explosion if a cylinder is bumped, jarred, or dropped. The cylinders may be stored or transported in any position with no danger of an explosive air pocket being formed.

The characteristic odor, while harmless, gives warnings of fuel leaks in the equipment long before a dangerous condition can occur.

MAPP gas is not restricted to a maximum working pressure of 15 psig, as is acetylene. In jobs requiring higher pressures and gas flows, MAPP at the full cylinder pressure of 95 psig at 70°F (21 °C) can be used safely.

MAPP Gas Safety

Liquified MAPP gas is insensitive to shock. A MAPP gas cylinder will not detonate when dented, dropped, hammered, or even incinerated. It may also be safely used up to full cylinder pressures. The gas vapors, up to 419°F and 285 psig, will not decompose when subjected to an energy source in the absence of oxygen. The vapor also is stable up to 600°F and 1,100 psig when exposed to an 825°F probe. The explosive limits of MAPP gas are 3.4 percent to 10.8 percent in air, or 2.5 percent to 80 percent in oxygen. As you can see, these limits are very narrow in comparison with that of acetylene.

MAPP gas has a highly detectable odor. The smell is detectable at 100 ppm, or at a concentration 1/340th of its lower explosive limit.

Small fuel-gas systems may leak 1 or 1 1/2 pounds of fuel or more in an 8-hour shift. Fuel-gas leaks are often difficult to find, and many times go unnoticed. However, a MAPP gas leak is easy to detect and can be repaired before it becomes dangerous.

MAPP toxicity is rated "very slight," but high concentrations (5,000 ppm) may have an anesthetic effect. Local eye or skin contact with MAPP gas vapor causes no adverse effect. However, the liquid fuel will cause dangerous frostlike burns due to the temperature at which MAPP gas must be stored.

OXYGEN

Oxygen is a colorless, tasteless, odorless gas that is slightly heavier than air. Oxygen will not bum by itself, but it will support combustion when combined with other gases. Extreme care must be taken to ensure that compressed oxygen does not become contaminated with hydrogen or hydrocarbon gases or liquids, unless the oxygen is controlled by such means as the mixing chamber of a torch. A highly explosive mixture will be formed if uncontrolled compressed oxygen becomes contaminated. Oxygen should NEVER come in contact with oil or grease.

Oxygen cylinders are supplied in several sizes. The size most commonly used aboard ship is 9 1/8 inches in diameter, weighs about 145 pounds, and has a capacity of 200 cubic feet. At 70°F, the gas is under a pressure of 1800 psi.

REGULATORS

The gas pressure in a cylinder must be reduced to a suitable working pressure before it can be used. This is done by a regulator or reducing valve. Regulators are either the single-stage or the double-stage type. Single-stage regulators reduce the pressure of the gas in one step; two-stage regulators do the same job in two steps or stages. Less adjustment is generally necessary when two-stage regulators are used.

Figure 8-4 shows a typical single-stage regulator. The regulator mechanism consists of a nozzle through

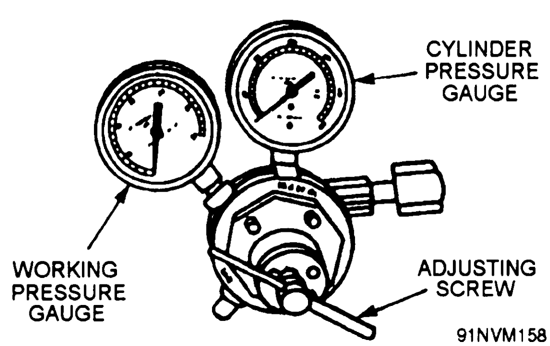


Figure 8-4.—Single-stage regulator.

which the high-pressure gases pass, a valve seat to close off the nozzle, a diaphragm, and balancing springs. These are all enclosed in a suitable housing. Pressure gauges are provided to indicate the pressure in the cylinder or pipeline (inlet), as well as the working pressure (outlet). The inlet pressure gauge, used to record cylinder pressures, is a high-pressure gauge; the outlet pressure gauge, used to record working pressures, is a low-pressure gauge. Acetylene regulators and oxygen regulators are of the same general type, although those designed for acetylene are not made to withstand such high pressures as are those designed for use with oxygen cylinders.

In the regulator, the gas enters the regulator through the high-pressure inlet connection and passes through a glass wool filter that removes dust and dirt. Turning the adjusting screw in, to the right, allows the gas to pass from the high-pressure chamber to the low-pressure chamber of the regulator, through the regulator outlet, and through the hose to the torch. Turning the adjusting screw to the right INCREASES the working pressure; turning it to the left DECREASES the working pressure. The high-pressure gauge is graduated in pounds per square inch from 0 to 3,000 for oxygen and 0 to 400 for acetylene. This permits reading of the gauge to determine cylinder pressure. The gauges are graduated to read correctly at 70°F. The working pressure gauge is graduated in pounds per square inch from 0 to 30 for acetylene and from 0 to 50, 0 to 100, 0 to 200, or 0 to 400 for oxygen, depending upon the purpose for which the regulator is designed. For example, on regulators designed for heavy cutting, the working pressure gauge is graduated in pounds per square inch from 0 to 400.

The two-stage regulator is similar in principle to the one-stage regulator, the chief difference being that the total pressure drop takes place in two steps instead of one. In the high-pressure stage, the cylinder pressure is reduced to an intermediate pressure. In the low-pressure stage, the pressure is reduced from the intermediate pressure to a working pressure. A two-stage regulator is shown in figure 8-5.

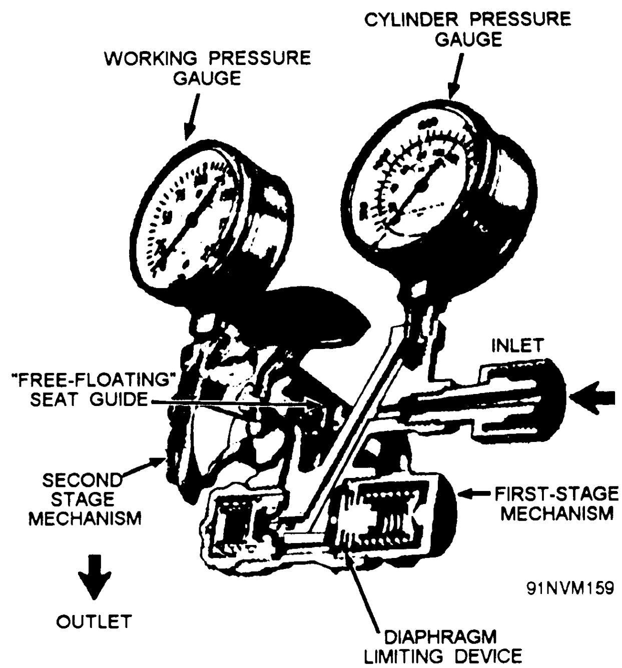


Figure 8-5.—Two-stage regulator.

WELDING TORCHES

The oxyacetylene welding torch is used to mix oxygen and acetylene gas in the proper proportions and to control the volume of these gases burned at the welding tip. Torches have two needle valves, one for adjusting the flow of oxygen and the other for adjusting the flow of acetylene. In addition, they have a handle (body), two tubes (one for oxygen and one for acetylene), a mixing head, and a tip. Welding tips are made from a special copper alloy, which dissipates heat (less than 60 percent copper), and are available in different sizes to handle a wide range of plate thicknesses.

There are two types of welding torches, the low-pressure type and the medium-pressure type. In the low-pressure type, the acetylene pressure is 1 psi or less. A jet of high-pressure oxygen is necessary to produce a suction effect, which draws in the required amount of acetylene. This is accomplished by the design of the mixer in the torch, which operates on the injector principle. The welding tips may or may not have separate injectors designed into the tip. A typical mixing head for the low-pressure or injector type of torch is shown in figure 8-6.

In the medium-pressure torches, the acetylene is burned at pressures from 1 to 15 psi. These torches are made to operate at equal pressures for acetylene and oxygen. They are sometimes called equal-pressure or balanced-pressure torches. The medium-pressure torch is easier to adjust than the low-pressure torch and, because equal pressures are used, you are less likely to get a flashback. This means that the flame is less likely to catch in or back of the mixing chamber. A typical equal-pressure torch is shown in figure 8-7.

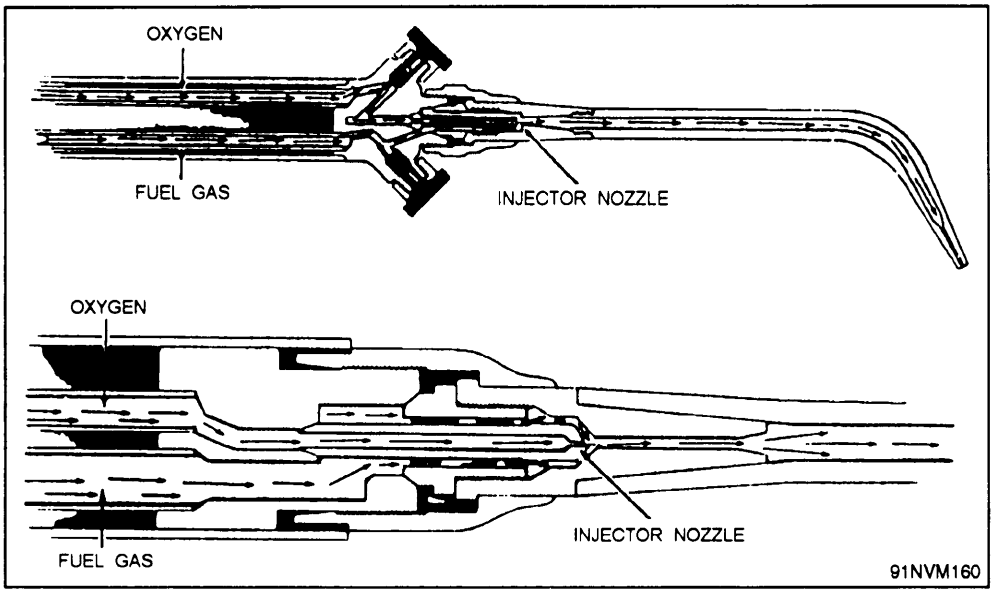


Figure 8-6.—Mixing head for a low-pressure torch..

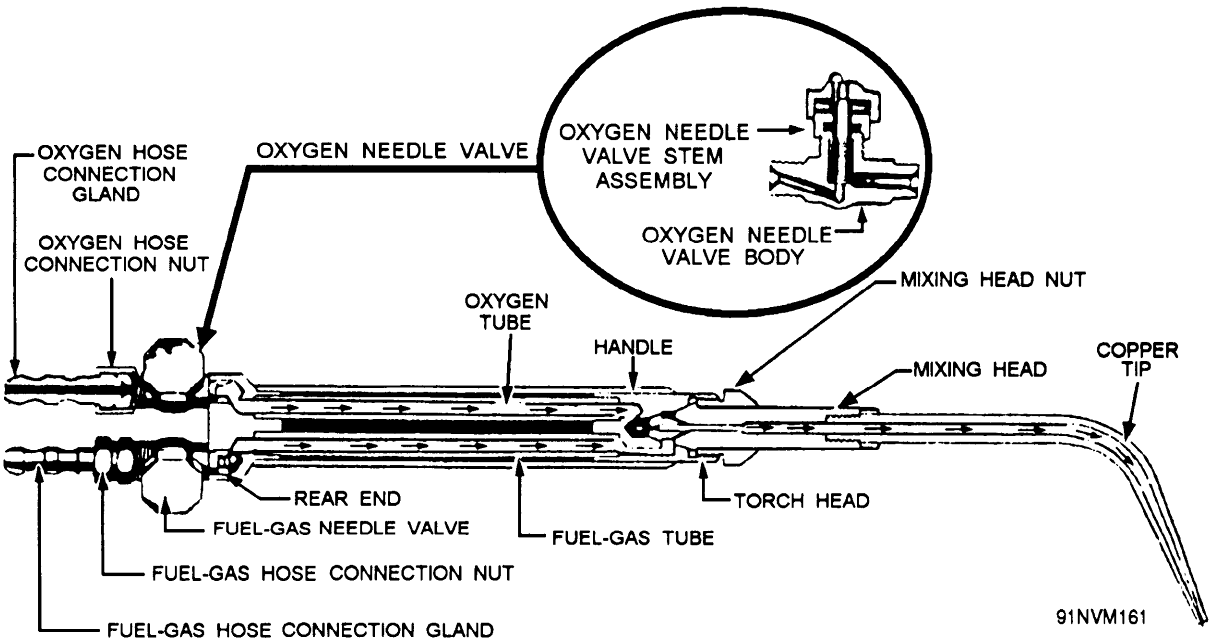


Figure 8-7.—Equal-pressure welding torch.

Welding tips and mixers made by different manufacturers differ in design. Some makes of torches are provided with an individual mixing head or mixer for each size of tip. Other makes have only one mixer for several tip sizes. Tips come in various types. Some are one-piece, hard copper tips. Others are two-piece tips that include an extension tube to make connection between the tip and the mixing head. When used with an extension tube, removable tips are made of hard copper, brass, or bronze. Tip sizes are designated by numbers, and each manufacturer has its own arrangement for classifying them. Tips have different hole diameters.

No matter what type or size tip you select, the tip must be kept clean. Quite often the orifice becomes clogged with slag. When this happens, the flame will not bum properly. Inspect the tip before you use it. If the passage is obstructed, you can clear it with wire tip cleaners of the proper diameter or with soft copper wire. Tips should not be cleaned with machinists' drills or other sharp instruments. These devices may enlarge or scratch the tip opening and greatly reduce the efficiency of the torch tip.

HOSE

The hose used to make the connection between the torch and the regulators is strong, nonporous, and flexible and light enough to make torch movements easy. It is made to withstand high internal pressures, and the rubber used in its manufacture is specially treated to remove sulfur to avoid the danger of spontaneous combustion. Welding hose is available in various sizes, depending upon the size of work for which it is intended. Hose used for light work is 3/16 or 1/4 inch in diameter and has one or two plies of fabric. For heavy-duty welding and cutting operations, the hose will have an inside diameter of 1/4 or 5/16 inch and three to five plies of fabric. Single hose may be ordered in various lengths up to 600 feet on a spool. Some manufacturers make a double hose that conforms to the same general specifications. The hoses used for acetylene and oxygen are the same in grade, but they differ in color and have different types of threads on the hose fittings. The oxygen hose is GREEN and the acetylene hose is RED. For added protection against mixing of the hoses during connection, the oxygen hose has right-hand threads and the acetylene hose has left-hand threads. The acetylene fittings also have a notch that goes around the circumference of the fittings for an additional identification factor.

WELDING RODS

The term *welding rod* refers to a filler metal, in wire or rod form, used in gas welding and brazing processes and in certain electric welding processes (tungsten inert-gas) in which the filler metal is not a part of the electric circuit. A welding rod serves only one purpose—it supplies filler metal to the joint.

As a rule, rods are uncoated except for a thin film resulting from the manufacturing process. Welding rods for steel are often copper-coated to protect them from corrosion during storage. Most rods are furnished in 36-inch lengths and a wide variety of diameters, ranging from 1/32 to 3/8 inch. Rods for welding cast iron vary from 12 to 24 inches in length and are frequently square rather than round in cross section. The rod diameter selected for a given job is governed by the thickness of the metals being joined.

Except for rod diameter, the welding rod selected is determined by specification on the basis of the metals being joined. These specifications may be either federal or military. This means that they apply to all federal agencies and the military establishment. Filler metals are presently covered by one or both of these specifications.

Many different types of rods are manufactured for welding ferrous and nonferrous metals. In general, shipboard welding shops stock only a few basic types that are suitable for use in all welding positions. These basic types are known as general-purpose rods. One such general-purpose rod that will be found in any Navy welding shop is a rod suitable for oxyacetylene welding of low-carbon steel. Such a rod is class 1, type A, as specified in AWS-A5.2-88. The same specification covers welding rods (class II) for use on cast iron.

Rods for gas welding on other common materials are covered by other specifications. At the time this manual was written, the following specifications applied: copper-base alloys, MIL-R-19631B; corrosion-resisting and heat-resisting steel, MIL-R-5031B, class 5; nickel-base alloys, including Monel, QQ-R-571C; and nickel-chromium-iron alloys, MIL-T-23227.

SETTING UP THE EQUIPMENT

The procedure for setting up oxyacetylene equipment is as follows:

1. Secure the cylinders so that they cannot be upset. Ensure that the acetylene cylinders have been in the vertical position a minimum of 2 hours before removing the protective caps.

2. Crack the cylinder valves slightly to blow out any dirt that may be in the valves. Close the valves. Check for grease and oil on or near the valves and fittings of the cylinders. Wipe the connections with a clean cloth.

CAUTION

Never crack gas cylinder valves toward an individual and always wear safety glasses.

3. Connect the acetylene pressure regulator to the acetylene cylinder and the oxygen pressure regulator to the oxygen cylinder. Using the appropriate wrench provided with the equipment, tighten the connecting

nuts enough to prevent leakage. Never use vice grips, pliers, adjustable wrenches, and so on to open or close gas cylinder valves or to tighten equipment fittings. You will only ruin the valve stem and damage equipment, making it impossible to open or close the equipment in an emergency.

4. Connect the red hose to the acetylene regulator and the green hose to the oxygen regulator. Tighten the connecting nuts enough to prevent leakage.

5. Back off on the regulator screws, and then open the cylinder valves slowly. Open the acetylene valve one-fourth to one-half turn. This will allow an adequate flow of acetylene, and the valve can be turned off quickly in an emergency. (NEVER open the acetylene cylinder valve more than 1 1/2 turns.) The oxygen cylinder valve should be opened all the way to eliminate leakage around the stem. (Oxygen valves are double-seated or have diaphragms to prevent leakage when they are open.) Read the high-pressure gauge to check the pressure of each cylinder.

6. Blow out the oxygen hose by turning the regulator screw in and then back out again. If it is necessary to blow out the acetylene hose, do it ONLY in a well-ventilated place that is free from sparks, flames, or other possible sources of ignition.

7. Connect the hose to the torch. The torch hose connections should be marked with a small “ac” or “acet” for acetylene or “ox” for oxygen stamped on the connection or the needle valve. Also, to prevent you from cross-connecting hoses or equipment, all acetylene connections have left-hand threads and all oxygen connections have right-hand threads.

8. Test all oxyaceteylene connections for leaks. There are several ways to test oxyacetylene connections for leaks after the system has been pressurized. The preferred method is to coat all connections with a soapy water solution and check for the formation of small bubbles. The formation of small bubbles at the connection indicates leaking gas and you should retighten the connection as needed. Another way to check fittings for leakage is to secure the system at the cylinder by closing the cylinder valve and check for a pressure drop on the regulator gauges. Any drop in pressure, on the gauges, indicates a loose connection and you should retighten all connections.

9. Adjust the tip. Screw the tip into the mixing head and assemble in the torch body. Tighten by hand and adjust to the proper angle. Secure this adjustment by tightening with the wrench provided with the torch.

10. Adjust the working pressures. A standard, working pressure of 20 to 25 psi oxygen and 5 to 7 psi acetylene is recommended. The acetylene pressure is adjusted by turning the regulator screw to the right until the desired pressure is attained. (Due to the instability of acetylene at high pressures, you should never exceed 15 psig on the regulator gauge.)

11. Light and adjust the welding flame. Open the oxygen needle valve a very slight amount and then the acetylene needle valve considerably more than the oxygen needle valve. Light the flame with a friction igniter. Make sure that the flame path is pointed in a safe direction and that your hands are not in front of the torch tip. Adjust the oxygen and acetylene needle valves as necessary to get a proper flame.

ADJUSTING THE FLAME

A pure acetylene flame is long and bushy and has a yellowish color, as shown in figure 8-8. It is burned by the oxygen in the air, which is not sufficient to bum the acetylene completely; therefore, the flame is smoky, producing a soot of fine, unburned carbon. The pure acetylene flame is unsuitable for welding. When the oxygen valve is opened, the mixed gases burn in contact with the tip face. The flame changes to a bluish-white color and forms a bright inner cone surrounded by an outer flame envelope. The inner cone develops the high temperature required for welding.

There are three types of flame commonly used for welding. These are neutral, reducing or carburizing, and oxidizing flames. (See fig. 8-8.) The NEUTRAL flame is produced by burning one part of oxygen to one part of acetylene. Together with the oxygen in the air, it produces complete combustion of the acetylene. The luminous white cone is well defined and there is no greenish tinge of acetylene at its tip, nor is there an excess of oxygen. The welding flame should always be adjusted to neutral before either the oxidizing or carburizing flame mixture is set. A neutral flame is obtained by gradually opening the oxygen valve to shorten the acetylene flame until a clearly defined inner luminous cone is visible. The neutral flame is used for most welding and for the preheating flames during cutting operations. The temperature at the tip of the inner cone is about 5900°F, while at the extreme-end of the outer cone it is only about 2300°F. This gives you a chance to exercise some temperature control by moving the torch closer or farther from the work. When steel is welded with this flame, the puddle

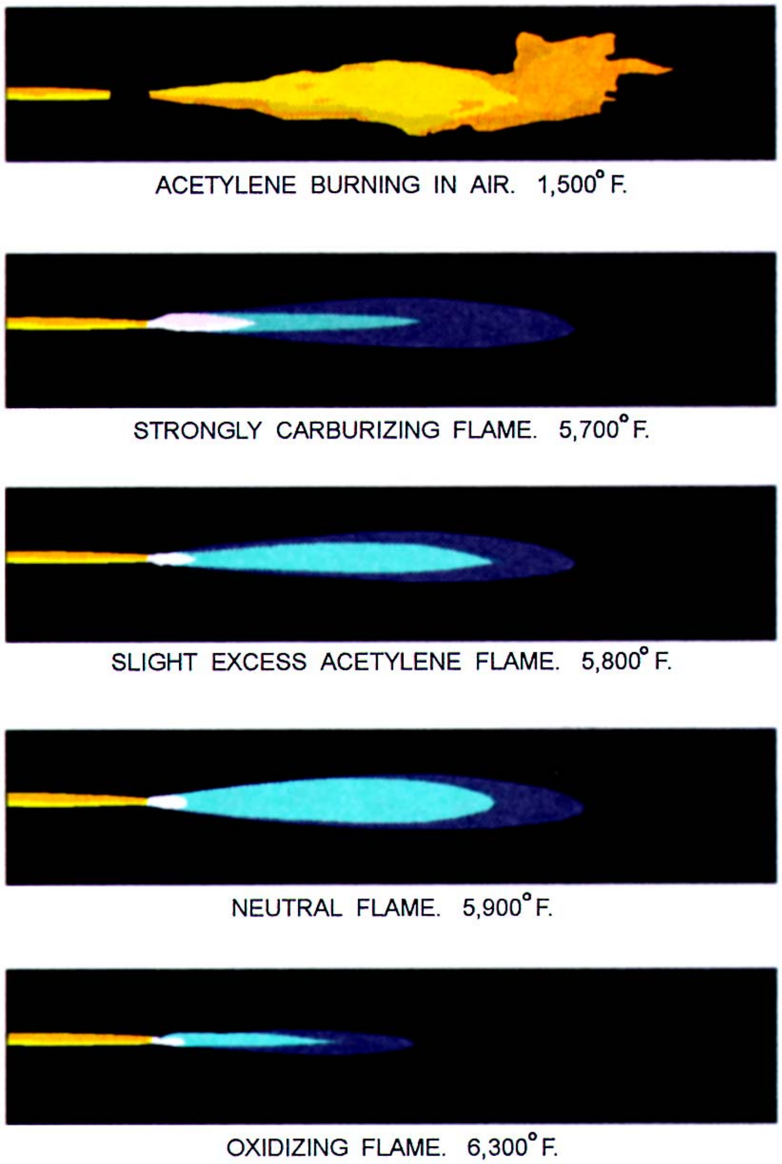


Figure 8-8.—Characteristics of the oxyacetylene flame.

of molten metal is quiet and clear, and the metal flows without boiling, foaming, or sparking.

The REDUCING (or CARBURIZING) flame is produced by burning an excess of acetylene. You will be able to recognize it by the feather at the tip of the inner cone. At the end of the inner cone, this feathery tip has a greenish color. The degree of carburization can be judged from the length of the feather. For most welding operations, the length of the feather should be about twice the length of the inner cone. You can always recognize the carburizing flame by its three distinct colors. These are the bluish-white inner cone, a white intermediate cone, and the light-blue outer flame. The carburizing flame bums with a temperature of about 5700°F at the tip of the inner cone. When it is used for welding steel, the metal boils and is not clear. A carburizing flame is best for welding high-carbon steels, for hard-surfacing, and for welding nonferrous alloys such as Monel.

The OXIDIZING flame is produced by burning an excess of oxygen. The oxidizing flame bums with a temperature of about 6300°F at the tip of the inner cone. You can identify this flame by the short outer flame and the small, white, inner cone. It takes about two parts of oxygen to one part of acetylene to produce this flame, and you will find that the adjustment for the oxidizing flame is a bit more difficult to make than the adjustment for other flames. To adjust for the oxidizing flame, first adjust to a neutral flame and then open the oxygen valve until the inner cone is about one-tenth of its original length. An oxidizing flame makes a hissing sound, and the inner cone is somewhat pointed and purplish in color at the tip. The oxidizing flame has a limited use and is harmful to many metals. When it is applied to steel, the oxidizing flame causes the molten metal to foam and give off sparks. This means that the extra amount of oxygen is combining with the steel, causing the metal to burn. However, the oxidizing flame does have its uses. A slightly oxidizing flame is used to braze weld steel and cast iron, and a stronger oxidizing flame is used for fusion welding of brass and bronze. You will have to determine the amount of excess oxygen to use in this type of flame adjustment by watching the molten metal.

EXTINGUISHING THE FLAME

To extinguish the oxyacetylene flame and to secure equipment after completing a job, or when work is to be interrupted temporarily, the following steps should be taken:

1. Close the acetylene needle valve first; this extinguishes the flame and prevents a flashback. (Flashback is discussed later in this chapter.) Then close the oxygen needle valve.

2. Close both oxygen and acetylene cylinder valves. Leave the oxygen and acetylene regulators open temporarily.

3. Open the acetylene needle valve on the torch and allow gas in the hose to escape for 5 to 15 seconds. Do not allow gas to escape into a small or closed compartment. Close the acetylene needle valve.

4. Open the oxygen needle valve on the torch. Allow gas in the hose to escape for 5 to 15 seconds. Close the valve.

5. Close both oxygen and acetylene cylinder regulators by backing out the adjusting screws until they are loose.

The foregoing procedure should be followed whenever work is interrupted for an indefinite period. If work is to stop for only a few minutes, securing cylinder valves and draining the hose is not necessary. However, for any indefinite work stoppage, the entire extinguishing and securing procedure should be followed. For overnight work stoppage in areas other than the shop, you should always remove the pressure regulators and the torch from the system, double check the cylinder valves to make sure they are closed securely, and reinstall the cylinder valve protection cap.

OXYACETYLENE CUTTING

Oxyacetylene cutting is the most commonly used method of cutting ferrous metals by the application of heat. The principle of oxyacetylene cutting is simple. The metal is heated to its ignition temperature by oxyacetylene flames. Then a jet of pure oxygen is directed at the hot metal, and a chemical reaction known as OXIDATION takes place. Oxidation is a familiar chemical reaction. When it occurs rapidly, it is called COMBUSTION or BURNING; when it occurs slowly, it is called RUSTING. When metal is being cut by the oxyacetylene torch method, the oxidation of the metal is extremely rapid-in short, the metal actually burns. The heat liberated by the burning of the iron or steel melts the iron oxide formed by the chemical reaction, and it also heats the pure iron or steel. The molten material runs off as slag, exposing more iron or steel to the oxygen jet.

In oxyacetylene cutting, only that portion of the metal that is in the direct path of the oxygen jet is oxidized. Thus, a narrow slit (called a kerf) is formed in the metal as the cutting progresses. Most of the material removed from the kerf is in the form of oxides (products of the oxidation reaction). The remainder of the material removed from the kerf is pure metal, which is blown or washed out of the kerf by the force of the oxygen jet.

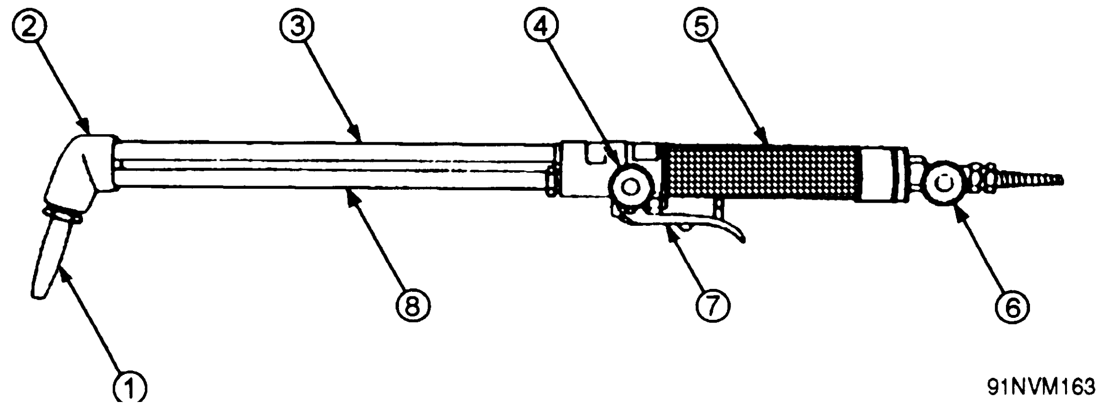
Since oxidation of the metal is a vital part of the oxyacetylene cutting process, this process is not suitable for metals that do not oxidize readily, such as copper, brass, stainless steel, and so on. Low-carbon steels are easily cut by the oxyacetylene cutting process, but special techniques (described later in this chapter) are required for the oxyacetylene cutting of many other metals.

The walls of the kerf formed by oxyacetylene cutting should be fairly smooth and parallel. When you develop skill in handling the torch, you will be able to hold the cut to within reasonably close tolerances. Also, you will be able to guide the cut along straight, curved, or irregular lines, and to cut bevels or other shapes that require holding the torch at an angle.

CUTTING TORCHES

The standard cutting torch looks very much like the oxyacetylene welding torch. The main difference in the two torches is that the cutting torch has an extra tube for high-pressure (cutting) oxygen. The flow of high-pressure oxygen is controlled by a lever valve assembly on the handle of the cutting torch. A standard cutting torch is shown in figure 8-9. This torch is of rugged, trouble-free construction; and it is designed for operator comfort, and ease and economy of maintenance and repair if it is damaged. This torch is available with either a 75-degree or 90-degree cutting head. The spiral mixer chamber provides excellent mixing of the oxygen and acetylene to the preheating flame.

Some welding torches are furnished with a cutting attachment that may be fitted to the torch in place of the welding head (tip). With this type of attachment (shown in fig. 8-10), the welding torch may be used as a cutting torch. This type of torch is generally called a combination torch. High-pressure oxygen is controlled by a lever on the torch handle.



1. Tip **2. 90° Head** **3. Cutting Oxygen Tube** **4. Oxygen Valve Assembly** **5. Handle** **6. Acetylene Valve Assembly** **7. Cutting Oxygen Lever** **8. Acetylene Tube**

Figure 8-9.—Standard oxyacetylene cutting torch.

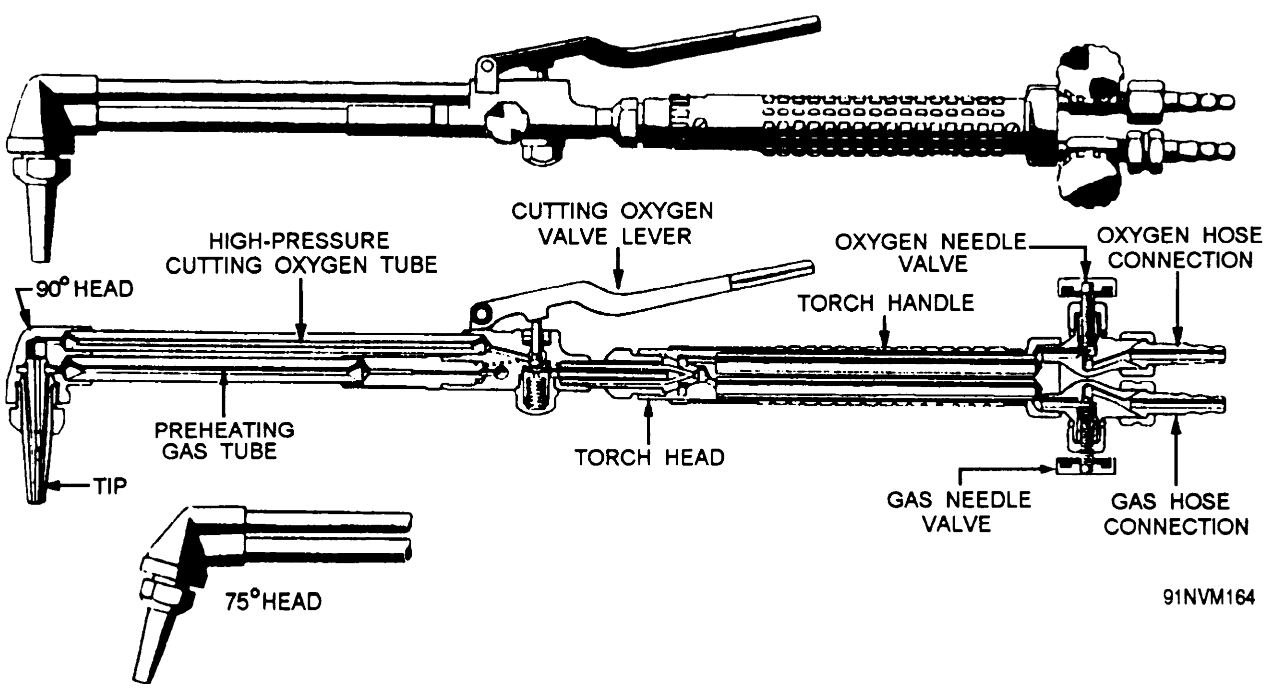
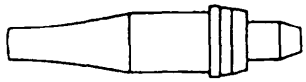
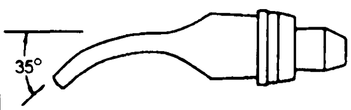
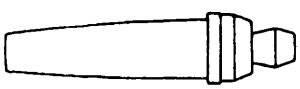
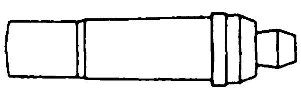
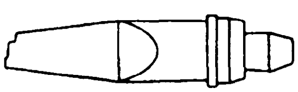
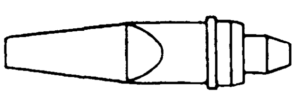
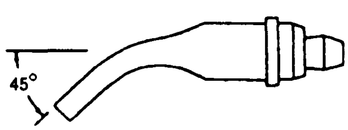
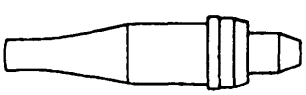
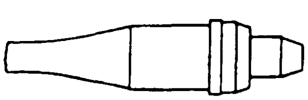


Figure 8-10.—Cutting attachment for an oxyacetylene cutting torch.

CUTTING TIPS

Just as in welding, you must use the proper size cutting tip if quality work is to be done. The preheat flames must furnish just the right amount of heat, and the oxygen jet orifice must deliver the correct amount of oxygen at just the right pressure and velocity to produce a clean cut (kerf). All of this must be done with a minimum consumption of oxygen and fuel gases. All too often, careless workers or ones not acquainted with the correct procedures waste both oxygen and fuel gas.

Cutting tips are made of copper or of tellurium-copper alloy. Each manufacturer has cutting tips of different designs. The orifice arrangements and tip material are much the same among various manufacturers; however, the part of the tip that fits into the torch head often differs in design. Figure 8-11 shows several different orifice arrangements and their uses.

STYLE	PRE-HEAT	DESCRIPTION	SIZE	TYPE
	Medium	**MAPP* GAS—One-Piece** Preheat: Medium Typical use: Hand and machine cutting.	00-6	1-303M
	Medium	**MAPP* GAS—One-Piece** Preheat: Medium. Typical use: Cutting close to bulkheads, hand cutting of rivet heads, machine cutting 35° with torch perpendicular.	1, 2, 3	1-312M
	Medium	**MAPP* GAS—Two-Piece** Preheat: Medium. Typical use: General-purpose cutting hand and machine thru 4".	000-4	2-210M
	Heavy	**MAPP* GAS—Two-Piece** Preheat: Heavy. Typical use: General-purpose cutting hand and machine 4" and over.	5-8, 10	2-210M
	Light	**ACETYLENE** Preheat: Very light. Typical use: Clean metal. Plate cutting and trimming.	00-2	1-110
	Medium	**ACETYLENE** Preheat: Medium. Typical use: Clean plate, straight line or circle machine cutting and trimming. Special lengths available on request.	00-4	1-111
	Medium	**ACETYLENE** Preheat: Medium. Typical use: Cutting close to bulkheads, hand cutting of rivet heads. Machine cutting 45° with torch perpendicular.	00-4	1-112
	Light	**ACETYLENE** Preheat: Light. Typical use: Hand & machine cutting. Clean plate.	0, 1, 2	1-100
	Medium	**ACETYLENE** Preheat: Medium. Typical use: General hand & machine cutting.	000-8	1-101

91NVM165

Figure 8-11.—Common cutting torch tips and their uses.

Table 8-1.—Ranges of Oxyacetylene Cutting Tips

TIP IDENTIFICATION	CUTTING OXYGEN ORIFICE (DRILL SIZE)	PREHEAT ORIFICES		APPROXIMATE CUTTING RANGE, STRAIGHT EDGE CUTTING OF MEDIUM STEEL (INCHES)
		DRILL SIZE	HOW MANY	
1–62–64	62	64	4	1/8 to 1/2
2–56–62	56	62	4	1/4 to 1 1/4
3–52–59	52	59	4	1 to 2 1/2
4–43–57	43	57	6	2 to 6
5–30–56	30	56	6	6 to 12

The central opening or orifice in the tip is for the jet or stream of high-pressure oxygen that does the cutting. The smaller orifices are for oxyacetylene flames used for preheating the metal to its ignition temperature. There are usually four or six of these preheat orifices in each oxyacetylene cutting tip; however, some heavy-duty tips have many more preheat orifices.

Cutting tips are furnished in various sizes. In general, the smaller sizes are used for cutting thin metal and the larger sizes are used for cutting heavy metal. Tip sizes are identified by numbers. When numbers such as 000, 00, 0, 1, 2, 3, 4, and 5 are used to identify tip sizes, the lower numbers indicate the smaller tips; for example, a 000 tip is smaller than a number 1 tip, and a number 1 tip is smaller than a number 5 tip. Some manufacturers identify cutting tips by giving the drill size number of the orifices. Large drill size numbers indicate small orifices; for example, drill size 64 is smaller than drill size 56. In military

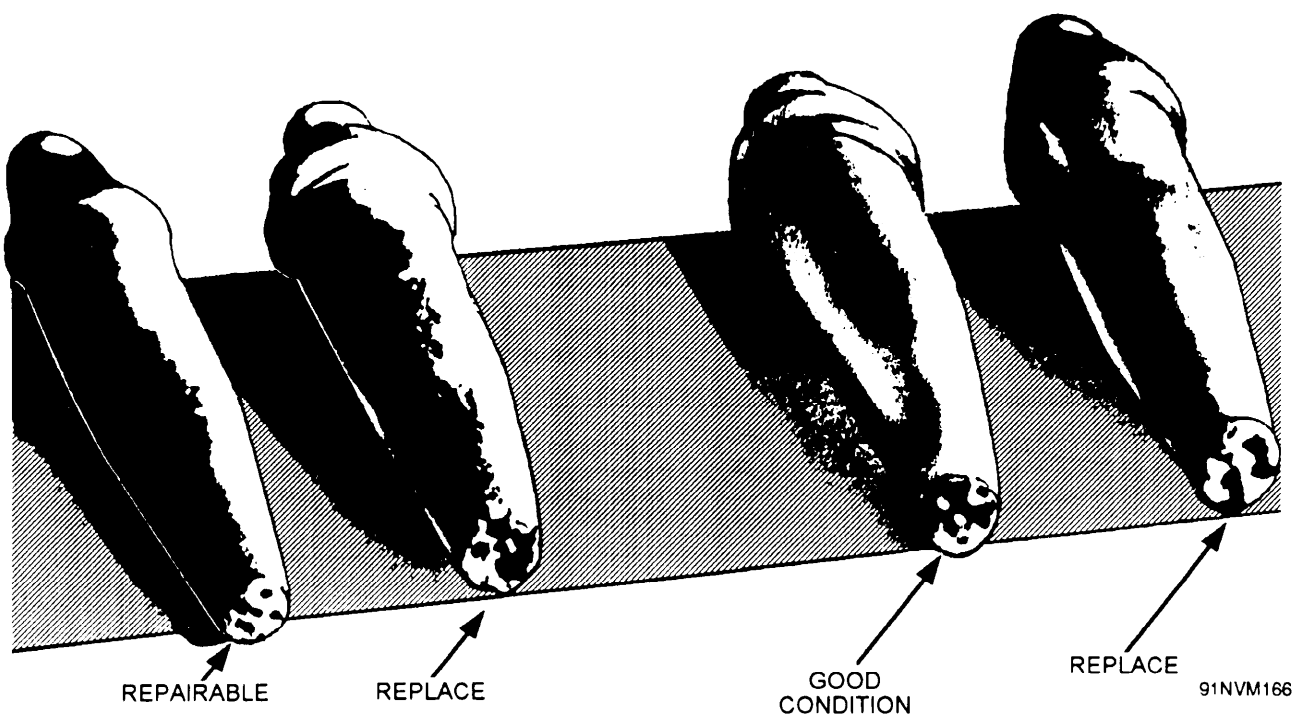


Figure 8-12.—Cutting tips in various conditions.

specifications and standards, oxyacetylene cutting tips are identified by three-part numbers. The first part is the tip size (0, 1, 2, 3, and so on). The second part is the drill size number of the orifice for the cutting oxygen. The third part is the drill size number of the preheat orifices. For example, the number l-62-64 identifies a number 1 tip with a cutting oxygen orifice of drill size 62 and preheat orifices of drill size 64.

Table 8-1 gives tip numbers, orifice sizes, and approximate cutting ranges of various sizes of oxyacetylene cutting tips. Cutting tips from different manufacturers are not interchangeable; when changing tips, you must match the right tip with the right torch.

The tips and seats are designed and constructed to produce a good flow of gases, to keep the tips as cool as possible, and to produce leakproof joints. If the joints leak, the preheat gases may mix with the cutting oxygen or they may escape to the atmosphere.

It is very important that the orifices and passages be kept clean and free of burrs to permit a free gas flow and a well-shaped flame. Figure 8-12 shows four tips: one that is repairable, two that need replacing, and one in good condition. Since it is extremely important that the sealing surfaces be kept clean and free of scratches or burrs, the tips should be stored in a container that cannot scratch the seats, preferably an aluminum or wood rack.

MAPP Gas Cutting Tips

There are four basic types of MAPP gas cutting tips; two are designed for use with standard pressures and normal cutting speeds, and two for use with high pressures and high cutting speeds. Only the standard pressure tips, types SP (standard pressure) and FS (fine standard), will be covered here since they are the ones that HTs will most likely use.

SP TIP.—The SP tip (fig. 8-13, view A) is a one-piece standard-pressure tip. It is used for cutting by hand, especially by welders who are accustomed to one-piece tips. SP tips are also likely to be used in situations where MAPP gas is replacing acetylene as the fuel gas.

FS TIP.—The FS tip (fig. 8-13, view B) is a two-piece, fine-spline, standard-pressure tip. It is used for cutting by hand as well as by machine. Welders accustomed to two-piece cutting tips will use them in hand cutting, especially in cases where MAPP gas is replacing natural gas or propane as the fuel gas. The FS tips will produce heavier preheating flames and

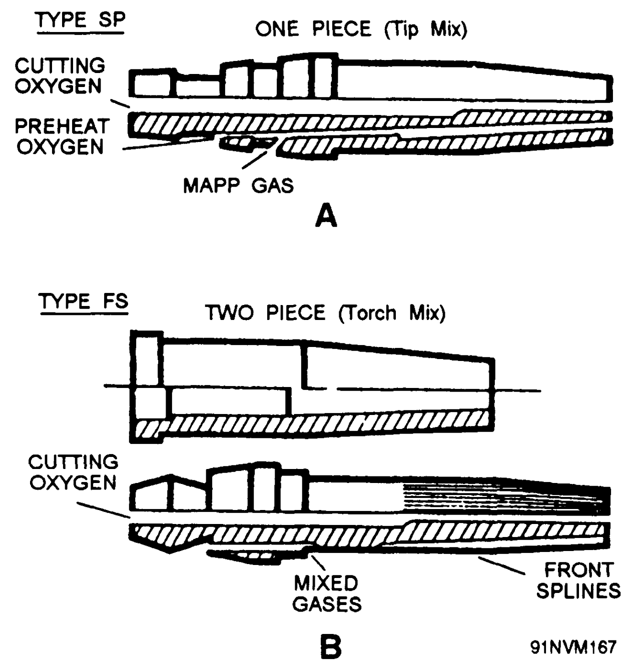


Figure 8-13.—MAPP gas cutting tips.

faster starts than the SP tips. However, two-piece tips will not take as much thermal abuse or physical abuse as will one-piece tips. But in the hands of skilled welders, they should last just as long as one-piece tips.

Care of Tips

In cutting operations, the stream of cutting oxygen sometimes will blow slag and molten metal into the orifices and cause them to become partly clogged. When this happens, you should clean the orifices thoroughly before you use the tip again; even a very small amount of slag or metal in an orifice will seriously interfere with the cutting operation. The recommendations of the torch manufacturer should be followed as to the size of drill or tip cleaner to use for cleaning the orifices. If you do not have a tip cleaner or a drill, then you may use a piece of soft copper wire. Do not use twist drills, nails, or welding rods for cleaning tips, as these items are likely to enlarge and distort the orifices.

The orifices of the cutting torch tip are cleaned in the same manner as the single orifice of the welding torch tip. Remember that the proper technique for cleaning the tips is to push the cleaner straight in and out of the orifice; be careful not to turn or twist it.

Occasionally the cleaning of the tips will cause enlargement and distortion of the orifices even if the proper tip cleaners are used. If the orifices become enlarged, you will get shorter and thicker preheating flames; in addition, the jet of cutting oxygen will spread rather than leave the torch in the form of a long thin stream. If the orifices become belled for a very short distance at the end, it is sometimes possible to correct this condition by rubbing the tip back and forth against emery cloth on a flat surface. This wears down the end of the tip where the orifices have been beveled, thus bringing the orifices back to their original size. Obviously, this procedure would not work if the enlargement is very great or if the belling extends more than a slight distance into the orifice.

After reconditioning a tip, you may test it by lighting the torch and observing the preheating flames. If the flames are too short, the orifices are still partially blocked. If the flames snap out when the valves are closed, the orifices are still distorted.

If the tip seat is dirty or scaled so that it does not fit properly into the torch head, you should heat the tip to a dull red and quench it in water. This will loosen the sale and dirt enough so that they can be rubbed off with a cloth.

OXYACETYLENE CUTTING OPERATIONS

Before beginning any oxyacetylene cutting operation, be sure you have selected the right size tip for the job. Follow the manufacturer's recommendations concerning tip sizes to use for different kinds of work. The oxygen and acetylene pressures to be used with various sizes of tips are also given by the manufacturer. Before fitting a cutting tip into the torch head, inspect the tip carefully to be sure that it is clean and not distorted, and that the orifices are not clogged with slag.

Cutting Low-Carbon Steel

To cut low-carbon steel with the oxyacetylene cutting torch, adjust the preheating flames to neutral. Hold the torch perpendicular to the work, with the inner cones of the preheating flames about one-sixteenth inch above the end of the line to be cut, as shown in figure 8-14. Hold the torch in this position until the spot you are heating is a bright red. Introduce the cutting oxygen by depressing the oxygen lever slowly but steadily.

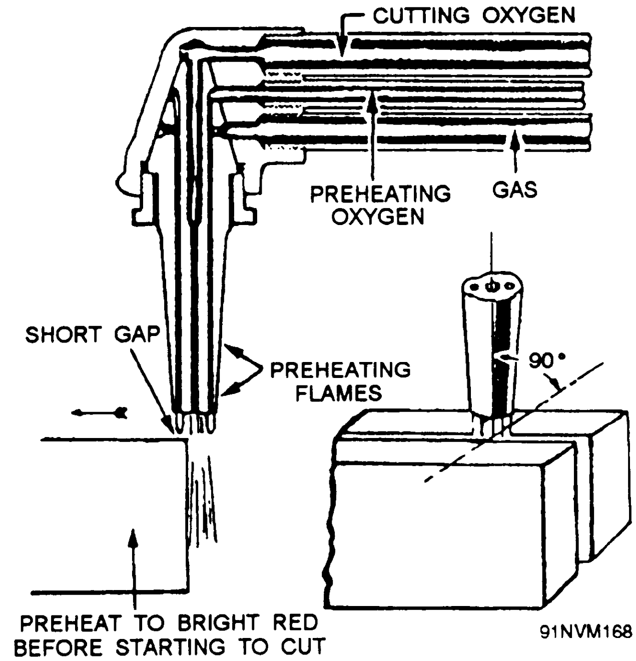


Figure 8-14.—Position of torch tip for starting a cut.

If the cut is being started correctly, a shower of sparks will fall from the opposite side of the work, indicating that the cut is going all the way through. Move the cutting torch forward along the line just fast enough for the cut to continue to penetrate the work completely. If you have made the cut properly, you will get a clean, narrow cut that looks somewhat like one made by sawing. When cutting round bars or heavy sections, you can save time and gas if you raise a small burr with a chisel where the cut is to start. This small raised portion will heat quickly, and cutting can be started sooner. If you have a cut to start from the center on some portion of metal other than the edge, use the following method for starting the cut. Preheat to a bright red the spot on the surface where the cut is to start. Tilt the torch at an angle of about 45° from the perpendicular, in line with the direction of the cut. Press the cutting oxygen lever very slowly. As the torch begins to cut, start righting it to a perpendicular position to the surface of the plate. Continue to right the position of the torch gradually as it cuts until it is at 90° to the surface of the plate and is cutting all the way through. Move it forward along the line of cut as fast as complete penetration can be accomplished. If you do not follow this procedure, you are likely to blow the slag back on the cutting tip, clogging the orifices or otherwise damaging the equipment. When you have started a cut, move the torch slowly along the cutting mark or guide. As you move the torch along, watch the

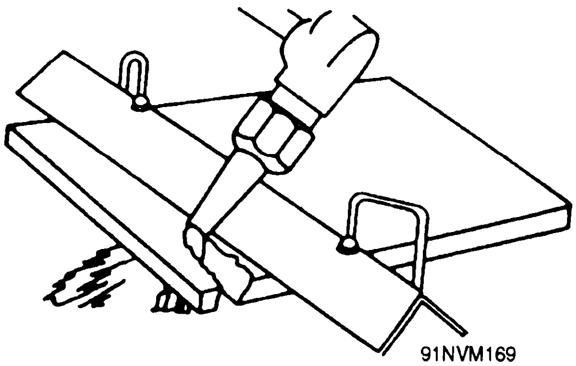


Figure 8-15.—Bevel cutting with an oxyacetylene torch.

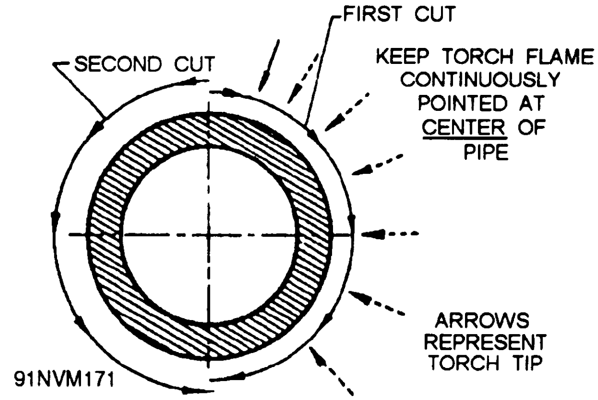


Figure 8-17.—Cutting pipe with a cutting torch.

cut so you can tell how it is progressing. Make torch adjustments if necessary. You must move the torch along at the right speed. If you go too slowly, the preheating flame will melt the edges along the cut and may even weld them back together at the top surface. If you go too fast, the oxygen will not penetrate completely through the metal, and the cut will be incomplete. If you must restart or recut your work, do so on the waste side of your metal. This serves three purposes. First, it is easier to restart your cut on the edge of the kerf than in the center. Second, you don't leave an unsightly gouge or nick in your finished work where you restarted your cut. And finally, you don't cut your metal too short by recutting the edge.

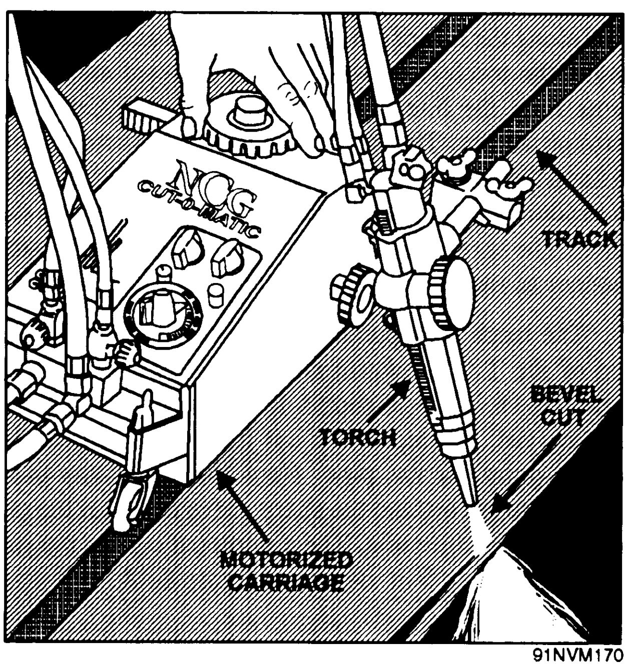


Figure 8-16.—Bevel cutting on a circular path with a radiograph automatic cutting machine.

Beveling Plate

You will frequently have to cut bevels to form joints for welding. To make a bevel cut of 45° in 1-inch steel, the flame must actually cut through 1.4 inches of metal. Consider this when selecting the tip size and gas working pressures. You will have to use more pressure and less speed for a bevel cut than for a straight cut. When you are bevel cutting, adjust the tip so that the preheating orifices are lined up for efficient preheating. A piece of 1 -inch angle iron, clamped with the angle up, makes an excellent guide for beveling straight edges. Pull the torch along the guide as shown in figure 8-15.

If you are aboard a repair ship or a tender, you may have a radiograph automatic cutting machine similar to the one in figure 8-16. This is a motor-driven cutting machine designed to support the cutting torch and guide it along the line of cut. It can be set to make uniformly clean cuts or bevels on steel plate. Straight-line cutting or beveling is done by guiding the machine along a straight line on steel tracks. Arcs and circles are cut by guiding the machine with a radius rod pivoted about a center point.

Cutting and Beveling Pipe

When you are cutting off a piece of pipe, keep the torch pointed toward the center line of the pipe. Start the cut at the top and cut down one side. Then begin at the top again and cut down the other side, finishing at the bottom of the pipe. The procedure is shown in figure 8-17.

Sometimes it is necessary to take T and Y fittings from pipe. Here the cutting torch is a most valuable tool. The usual procedure for fabricating pipe fittings is to develop a pattern like that shown in figure 8-18, view A, step 1. After the pattern is developed, it is wrapped around the pipe as shown in figure 8-18, view A, step 2. Be sure to leave enough stock so that the ends will overlap. Trace around the pattern with soapstone or a scriber. It is a good idea to mark the outline with a prick punch at about one-fourth-inch intervals. When the metal is heated during the cutting procedure, the punch marks will stand out, making it easier to follow the line of cut. Place the punch marks so that they will be removed during cutting. If punch marks are not removed, they provide notches from which cracking may start.

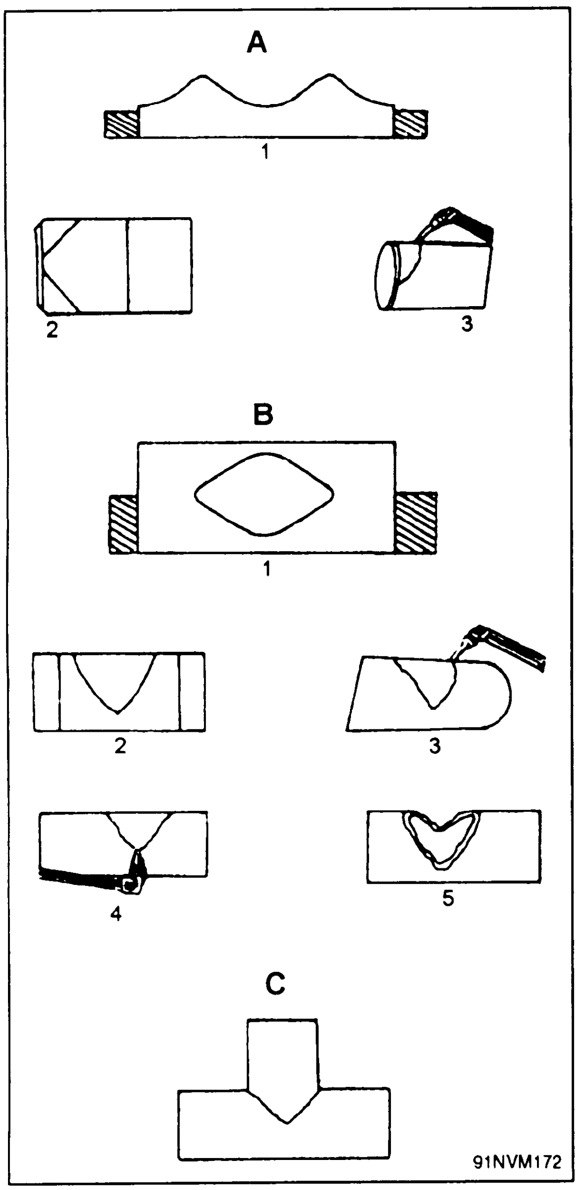


Figure 8-18.—Fabricating a T fitting.

An experienced burner can cut and bevel pipe at a 45-degree angle in one operation; however, a person with little experience may have to do the job in two steps. The first step is to cut the desired part at a 90-degree angle. The second step is to bevel the edge of the cut to a 45-degree angle. When employing the two-step procedure, another line must be marked on the pipe. This second line follows the contour of the line traced around the pattern, but it is drawn away from the original pattern line at a distance equal to the pipe wall thickness. The first (or 90°) cut in the two-step procedure is made along the second line. The second (or 45°) cut is made along the original pattern line. The two-step procedure is time consuming and uneconomical in terms of oxygen and acetylene consumption.

When you are experienced enough to use the one-step cutting and beveling procedure, you will find that it is not complicated. However, both a steady hand and a great deal of practice are necessary to turn out a first-class job. The one-step procedure for cutting and fabricating a T is shown in figure 8-18. View A of figure 8-18 outlines the step-by-step procedure for producing the branch; view B shows the steps for preparing the other section of the T; and view C shows the assembled T, tack welded and ready for welding. Figure 8-18, view A, step 3, shows the procedure for cutting the miter on the branch. The cut is started at the end of the pipe and worked around until one-half of one side is cut. The torch is manipulated so that at all times the tip is at an angle of 45° to the surface of the pipe along the line of cut. While the tip is at a 45-degree angle, the torch is moved steadily forward and at the same time the butt of the torch is swinging upward through an arc. This torch manipulation is necessary to keep the cut progressing in the proper direction and to produce a bevel that will be 45° at all points on the miter. The second portion of the miter is cut in the same manner as the first.

The torch manipulation necessary for cutting the run of the T is shown in steps 3 and 4 in view B of figure 8-18. Step 3 shows the torch angle for the starting cut. At step 4, the cut has progressed to the lowest point on the pipe. Here the angle has been changed to get around the sharp curve and start the cut in an upward direction. The completed cut for the run is shown in step 5 in view B of figure 8-18.

Before the parts of any fabricated fitting are assembled and tack welded, be sure to clean the fit of the joint. The bevels must be smooth to allow complete fusion when the joint is welded.

Piercing Holes

The cutting torch is also a valuable tool for piercing holes in steel plate. The steps are illustrated in figure 8-19. Lay the plate out on two firebricks so that the flame will not hit something else when it bums through the plate. Hold the torch over the hole location with the tips of the inner cone of the preheating flames about one-fourth inch above the surface of the plate. Continue to hold the torch in this position until a small round spot has been heated to a bright red. Introduce the cutting oxygen by gradually depressing the oxygen lever, and at the same time slightly raise the tip away from the work to keep from blowing slag back onto the cutting tip. As you start raising the torch and introducing the cutting oxygen, start rotating the torch with a spiral motion. This will cause the molten slag to be blown out of the hole. The hot slag may fly around, so BE SURE your goggles are well fitted to your eyes and face, and avoid having your head directly above the cut.

If you need a larger hole, outline the edge of the hole with a piece of chalk, and follow the procedure given in the previous paragraph. Start the cut from the hole that you have pierced by moving the preheating flames to the normal distance and by working to and following the line that has been drawn on the plate. Round holes can be made by using a cutting torch with a radius bar attachment.

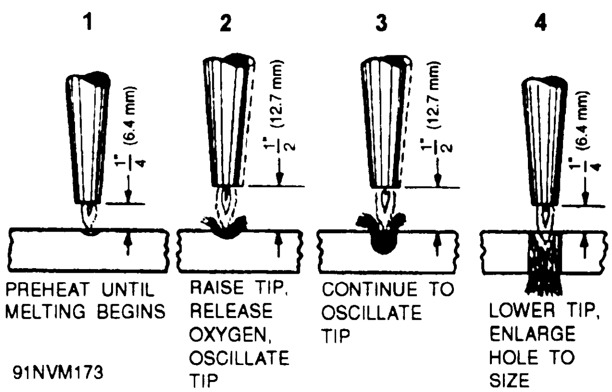


Figure 8-19.—Piercing a hole with an oxyacetylene cutting torch.

Cutting Rivets

When you are required to remove rivets from plates that are to be disassembled, you will find the cutting torch a good tool. The cutting procedure is shown in figure 8-20. Use the preheating flames of the

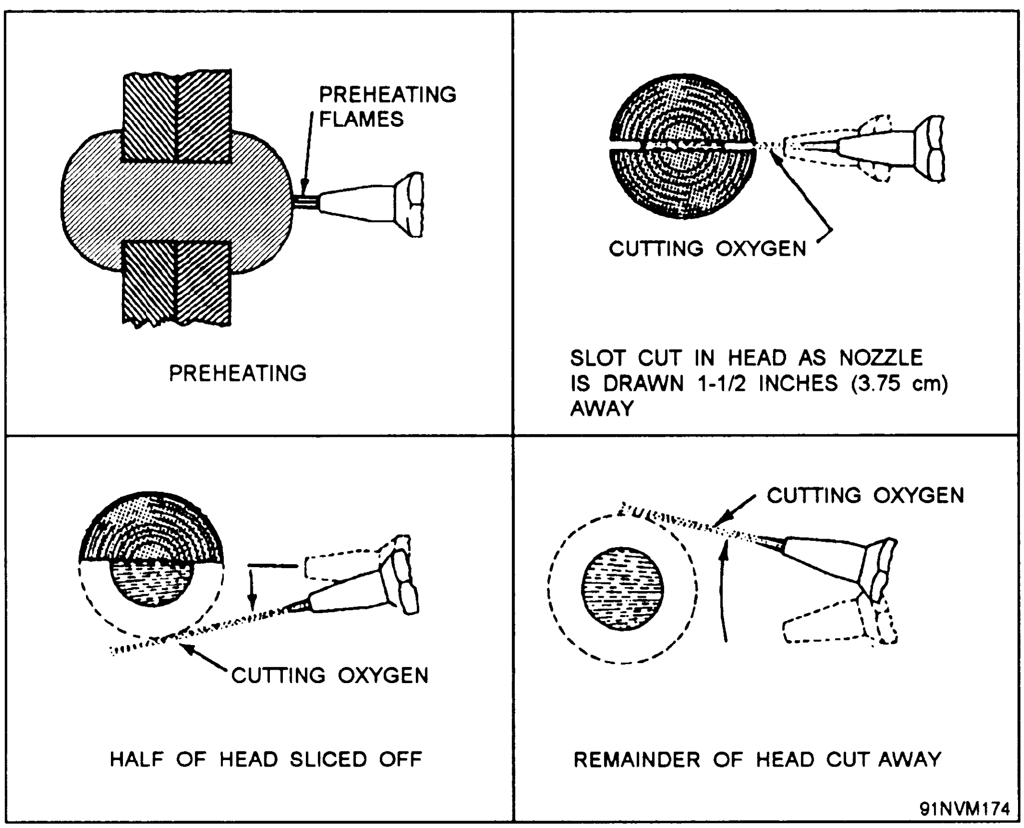


Figure 8-20.—Using a cutting torch to remove the head of a rivet.

cutting torch to bring the head of the rivet up to the proper temperature; then introduce the cutting oxygen by gradually depressing the oxygen lever, and wash off the rivet head. The remaining portion of the rivet can then be punched out with a light hammer blow. The step-by-step procedure follows:

1. Use the size of tip and the oxygen pressure required for the size and type of rivet you are going to cut.

2. Heat a spot on the head until it is bright red.

3. Move the tip to a position parallel with the surface of the plate and slowly turn on the cutting oxygen.

4. Cut a slot in the rivet head like the screwdriver slot in a roundhead screw. When the cut nears the plate, draw the nozzle back at least 1 1/2 inches from the rivet so that you will not cut through the plate.

5. When you have cut the slot through to the plate, swing the tip through a small arc. This slices off half of the rivet head.

6. Then swing the tip in an arc in the other direction to slice off the other half of the rivet head.

By the time the slot has been cut, the rest of the rivet head has usually been heated to cutting temperature. Just before you get through the slot, draw the torch tip back 1 1/2 inches to allow the cutting oxygen to scatter slightly. This keeps the torch from breaking through the layer of scale that is always present between the rivet head and the plate. It allows the head of the rivet to be cut off without damaging the surface of the plate. If you do not draw the tip away, you may cut through the film of scale and into the plate.

A low-velocity cutting tip is best for cutting buttonhead rivets and for removing countersunk rivets. A low-velocity cutting tip has a cutting oxygen orifice with a large diameter. Above this orifice are three heating orifices. Always place a low-velocity cutting tip in the torch so that the heating orifices are above the cutting orifice when the torch is held in the rivet cutting position. To remove countersunk rivets from a vertical sheet or plate, use the method shown in figure 8-21 and follow these instructions:

1. Hold the torch horizontally and turn it so that the tip also points horizontally.

2. Tilt the tip upward about 15° and hold the preheating flames on a point slightly below the center of the rivet head.

3. When you get the area heated to a dull red, move the torch upward, still keeping the upward tilt, and press the cutting oxygen lever.

4. Hold the torch steady with the cutting stream directed at the center of the rivet. As the rivet is cut away, the angle of the torch should be decreased until the tip is perpendicular to the sheet or plate and the cutting stream is directed at the center of the rivet.

5. When you have cut through the head to the shank of the rivet, wash away the remainder of the head with one circular wiping motion. Always move the torch so that the cutting stream will follow the preheat.

6. The shank may then be removed by a light tap with a hammer and punch.

Buttonhead rivets may be removed in the same manner as countersunk rivets with the low-velocity cutting tip. The process is illustrated step by step in figure 8-22. Remember that it is important to start below the center of the rivet head so that molten metal and slag will not be deposited on the plate.

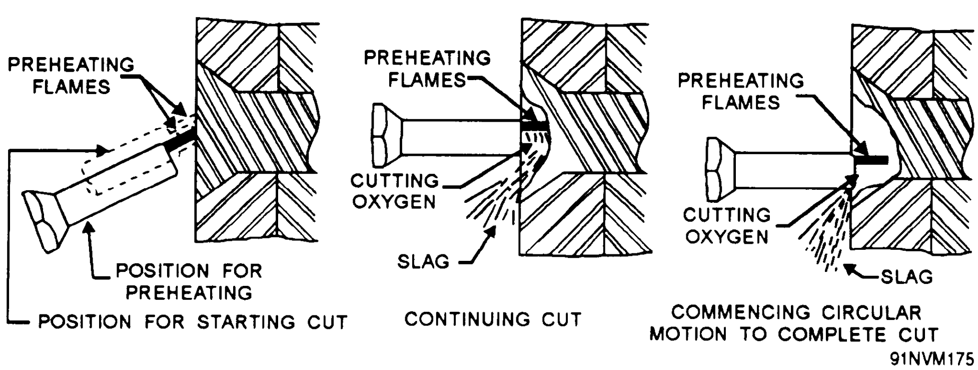


Figure 8-21.—Cutting a countersunk rivet with a low-velocity cutting tip.

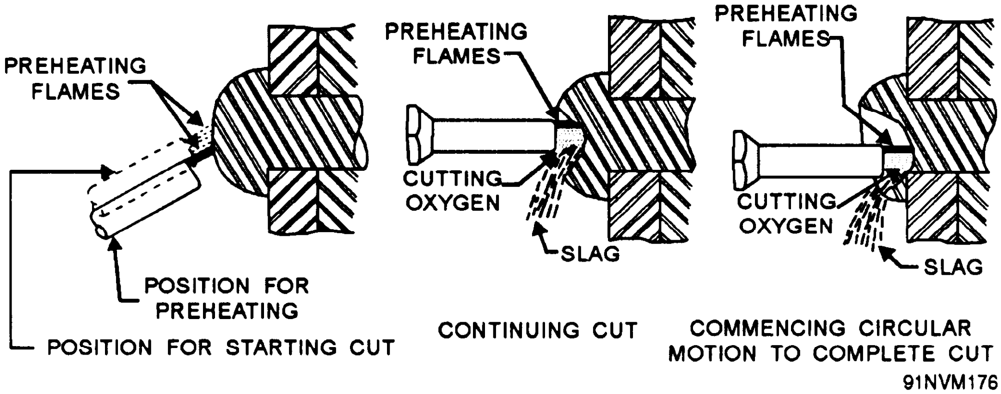


Figure 8-22.—Cutting buttonhead rivets with a low-velocity cutting tip.

Special Cutting Techniques

Carbon steels containing up to 1.0 percent carbon are easily cut with the oxyacetylene cutting torch. Nonferrous metals, however, and ferrous metals such as cast iron, carbon steels containing more than 1.0 percent carbon, and many alloy steels can be successfully flame cut only if special techniques are used. These special techniques include using more intense and more widely distributed preheat; using different flame adjustments; introducing iron or low-carbon steel into the cutting area; varying the torch movements; and using fluxes.

PREHEAT.—Preheating the metal before cutting reduces the amount of oxygen and fuel gas required to make the cut. It also tends to prevent or minimize distortion and to prevent surface hardness of the piece after the cut has been made. While preheating is helpful in any cutting operation, it is essential for some of the metals and alloys that are not easily cut. The preheating temperatures generally used for oxyacetylene cutting range from 200° to about 600°F, although considerably higher temperatures are occasionally used.

Preheating is usually accomplished by using the preheating orifices in the cutting tip. Special tips having larger and more numerous preheating orifices are available for cutting cast iron and other materials that require intense and widely distributed preheat. Preheating furnaces are sometimes used to bring heavy sections to a uniform preheat temperature.

FLAME ADJUSTMENT.—A neutral preheating flame is used for most oxyacetylene cutting. For some metals, however, other flame adjustments give better results. For example, a highly carburizing flame is used for preheating cast iron. The excess acetylene in the carburizing flame ignites when it combines with the cutting oxygen deep in the kerf, thus increasing both the intensity and the distribution of the preheat. For cutting cast iron, the length of the feather on the preheating flame should be approximately equal to the thickness of the cast iron. A slightly less carburizing flame is used for cutting stainless steel.

INTRODUCTION OF IRON OR LOW-CARBON STEEL.—Introducing iron or low-carbon steel into the cutting area greatly simplifies the cutting of some metals. When the oxides of a metal have a higher melting point than the metal itself, the oxides protect the base metal from the cutting action of the oxygen. In such a metal, introducing iron or low-carbon steel into the cutting area solves the problem because the rapid oxidation of the iron or steel liberates enough heat to melt the oxides that would otherwise interfere with the cutting. When alloying elements are responsible for the difficulty of cutting the metal, the introduction of iron or low-carbon steel reduces the percentage of these alloying elements and so makes the metal easier to cut.

Several techniques are used to introduce iron or low-carbon steel into the cutting area. An easily cut steel waster plate may be clamped firmly to the surface of the metal to be cut; a steel welding rod may be fed into the kerf as the cutting proceeds; a bead of low-carbon steel may be deposited along the line of cut before the cut is made; or finely divided iron powder may be blown into the stream of cutting oxygen through special orifices in the cutting tip.

Cast iron, chromium irons, stainless steels, and various alloys having small ferrous content can be successfully cut with the oxyacetylene torch when iron or low-carbon steel is introduced into the cutting area.

TORCH MOVEMENTS.—For most oxyacetylene cutting, the torch is moved steadily forward along the line of cut, as shown in view A of figure 8-23. Metals that are difficult to cut often require special torch movements. For example, the oscillating movement, shown in view B of figure 8-23, is suitable for cutting thin sections of cast iron; view C shows the oscillating movement that is best for cutting heavier sections of cast iron. View D shows the reciprocating (or back and forth) torch movement that is most effective for cutting stainless steels.

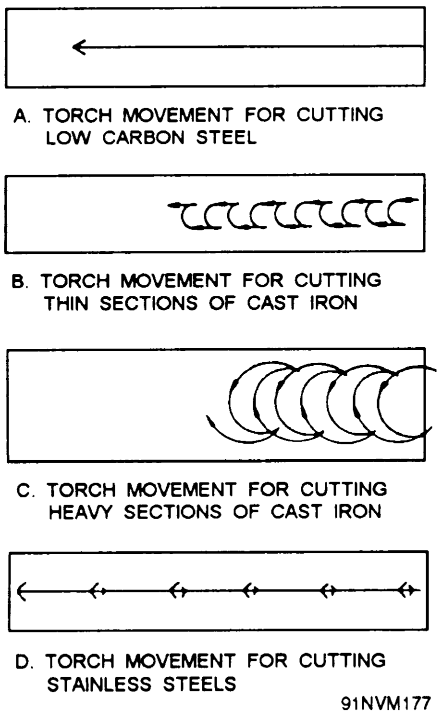


Figure 8-23.—Manipulation of the oxyacetylene cutting torch.

FLUXES.—Although fluxes are not used for most oxyacetylene cutting, they are used for cutting stainless steels, chromium irons, and other metals that are hard to cut. Fluxes used for cutting are nonmetallic compounds in powder form. As the powdered flux is injected into the kerf, it reacts chemically with the oxides, which have a higher melting point than the base metal. The result of this chemical reaction is a slag that melts at a lower temperature. The stream of cutting oxygen washes the molten slag out of the cut and exposes the base metal to the cutting action of the oxygen.

Fluxes are introduced into the cut by means of an attachment to the standard cutting torch. The attachment, shown in figure 8-24, consists of a canister for holding the flux, a length of air hose, and a copper tube that is secured to the cutting torch with clamps. Air pressure forces the powdered flux into the kerf; the stream of cutting oxygen carries the flux deeper into the kerf.

Judging the Quality of Oxyacetylene Cuts

To know how good a job of cutting you are doing, you must know what constitutes a good oxyacetylene torch cut. In general, the quality of an oxyacetylene cut is judged by (1) the shape and length of the drag lines, (2) the smoothness of the sides, (3) the sharpness of

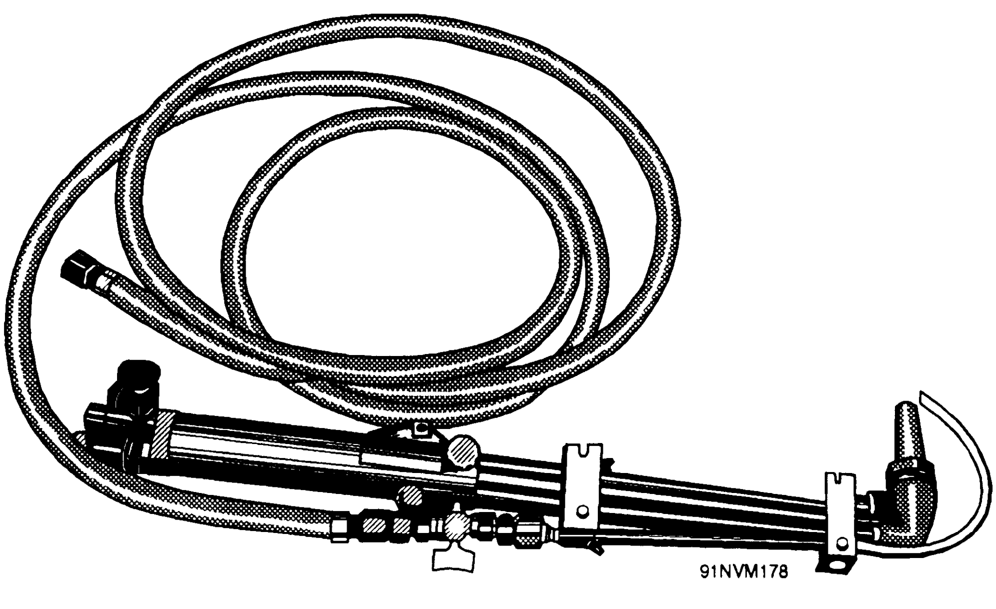


Figure 8-24.—Flux cutting attachment.

the top edges, and (4) the amount of slag adhering to the metal.

DRAG LINES.—Drag lines are the line markings that show on the cut surfaces. Good drag lines are almost straight up and down, as shown in view A of figure 8-25. Poor drag lines are long and irregular or excessively curved, as shown in view B of figure 8-25; drag lines of this type indicate poor cutting procedure which may also result in loss of the cut (views B and C of fig. 8-25).

Drag lines are probably the best single indication of the quality of an oxyacetylene cut. If the drag lines are short and almost vertical, the smoothness of the sides, the sharpness of the top edges, and the slag conditions are almost sure to be satisfactory.

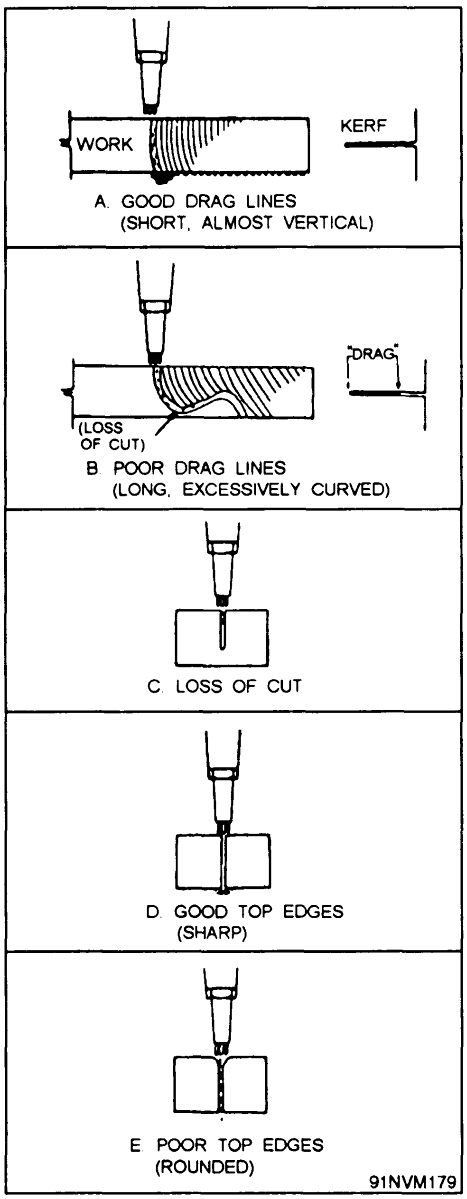


Figure 8-25.—Effects of correct and incorrect cutting procedures.

SMOOTHNESS OF SIDES.—A satisfactory oxyacetylene cut shows smooth sides. A grooved, fluted, or ragged cut surface indicates a cut of poor quality.

SHARPNESS OF TOP EDGES.—The top edges resulting from an oxyacetylene cut should be sharp and square (view D, fig. 8-25). Rounded top edges, such as those shown in view E of figure 8-25, are not considered satisfactory. Melting down of the top edges may result from incorrect preheating procedures or from moving the torch too slowly.

SLAG CONDITIONS.—An oxyacetylene cut is not considered satisfactory if slag adheres so tightly to the metal that it is difficult to remove.

SAFETY PRECAUTIONS

In all cutting operations, be careful to see that hot slag does not come in contact with any combustible material. Globules of hot slag can roll along a deck for quite a distance. Do not cut within 30 or 40 feet of unprotected combustible materials. If combustible materials cannot be removed, cover them with sheet metal or noncombustible materials. Keep the acetylene and oxygen cylinders far enough away from the work so that hot slag will not fall on the cylinders.

Many of the safety precautions discussed in chapter 1 of this training manual apply to cutting as well as to welding. Be sure that you are entirely familiar with all appropriate safety precautions before attempting any oxyacetylene cutting operation.

OXYACETYLENE WELDING TECHNIQUES

Oxyacetylene welding may be accomplished by either the forehand or the backhand method. Each of these techniques has special advantages; you should be skillful with both. Whether a technique is considered to be forehand or backhand depends on the relative position of the torch tip and filler rod in relationship to the direction of welding. The best technique to use depends upon the type of joint, its position, and the necessity for controlling the heat on the parts to be welded.

FOREHAND WELDING (also called puddle welding or ripple welding) is the oldest method of welding.

The filler rod is kept ahead of the torch tip in the direction in which the weld is being made. Point the flame in the direction of the welding and hold the torch tip at an angle of about 45° to 60° to the plates. (See fig. 8-26.) This position of the flame preheats the edges you are welding just ahead of the molten puddle. By moving the torch tip and filler rod back and forth in opposite, semicircular paths, you balance the heat to melt the end of the filler rod and the side walls of the joint into a uniformly distributed molten puddle. As the flame passes the filler rod, it melts off a short length of the filler rod and adds it to the puddle. The motion of the torch tip distributes the molten metal evenly to both edges of the joint and to the molten puddle. This method is used in all positions for welding sheets and light plates up to one-eighth inch thick because it permits better control of a small puddle and results in a smoother weld. The forehand technique is not the best method for welding heavy plate.

BACKHAND WELDING is a newer method of welding. In this method, the torch tip precedes the filler rod in the direction of welding, and the flame is pointed back at the molten puddle and the completed weld. The end of the filler rod is placed between the torch tip and the molten puddle, and the welding torch tip should make an angle of about 45° to 60° with the plates or joint being welded. (See fig. 8-27.)

Less motion is required in the backhand method than in the forehand method. If you use a straight filler rod, it should be rotated so that the end will roll from side to side and melt off evenly. You may also bend the filler rod and, when welding, move the filler rod and torch tip back and forth at a rather rapid rate. If you are making a large weld, you should move the filler rod so as to make complete circles in the molten puddle. The

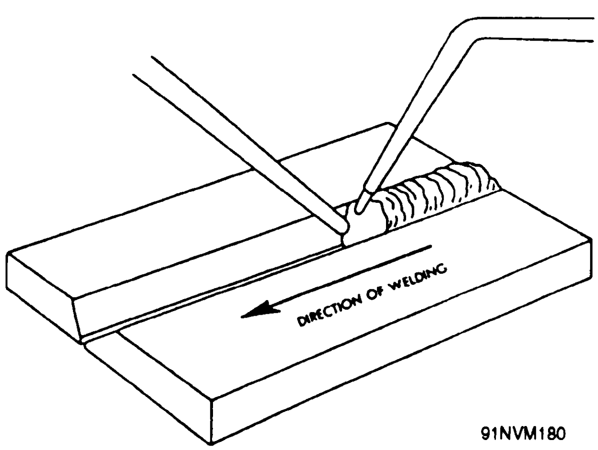


Figure 8-26.—Forehand welding.

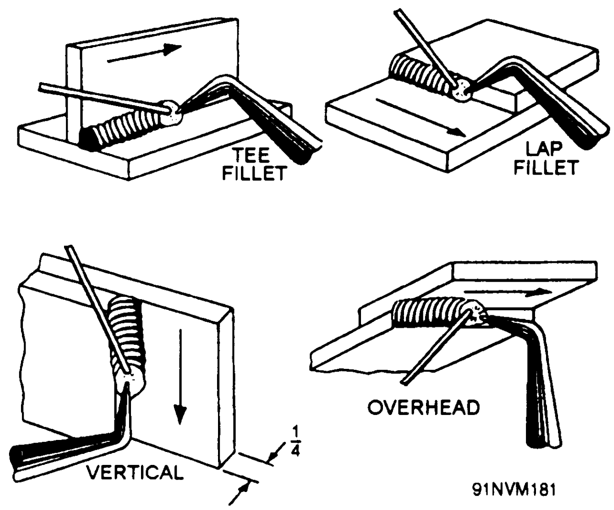


Figure 8-27.—Backhand welding.

torch tip is moved back and forth across the weld while it is advanced slowly and uniformly in the direction of the welding. You'll find the backhand method best for welding material more than one-eighth inch thick. You can use a narrower V at the joint than is possible in forehand welding. An included angle of 60° is a sufficient angle of bevel to get a good joint. It doesn't take as much filler rod or puddling for the backhand method as it does for the forehand method.

By using the backhand technique on heavier material, you can obtain increased welding speeds, better control of the larger puddle, and more complete fusion at the root of the weld. Further, by using a reducing flame with the backhand technique, a smaller amount of base metal is melted while welding the joint. When welding steel with a backhand technique and a reducing flame, the absorption of carbon by a thin surface layer of metal reduces the melting point of the steel. This speeds up the welding operation.

MULTILAYER WELDING is used in welding thick plate and pipe to avoid carrying too large a puddle of molten metal, which is difficult to control. Concentrate on getting a good weld at the bottom of the V in the first pass. Then in the next layers, concentrate on getting good fusion with the sides of the V and the previous layer. The final layer is easily controlled to get a smooth surface. This method of welding has an added advantage in that it refines one layer as the succeeding layer is made. In effect, it heat treats the weld metal by allowing one layer to cool to a black heat before it is reheated. This improves the ductility of the weld metal. If this added quality is desired in the last layer, an additional or succeeding layer is deposited and then machined off.

PRACTICE PROJECTS

A great deal of practice is required to master the techniques of welding. A good way to acquire skill in oxyacetylene welding is to practice on scrap pieces of mild steel (sheet of plate). Try your hand at the various problems described in the following section. Oxyacetylene welding may be done in any position. In the examples given here, we will start with the flat position, since this is usually the easiest, and go on to the more difficult positions. Before trying any of these projects, be sure that the equipment is set up properly and that all safety precautions are being observed. Until you have gained considerable skill in welding, your practice should be done under the supervision of an experienced welder.

Running a Bead Without Filler (Flat Position)

For this project, you are not welding two pieces together but are merely running a bead. Select a piece of plate about 2 inches by 4 inches by 1/8 inch thick. Place the two firebricks as shown in figure 8-28.

If you are right handed, start at the right and work to the left. If you are left handed, start at the left and work to the right. Hold the torch so that the tip forms a 45-degree angle with the plate along the line of weld. Direct the inner cone of the flame at a point near the right edge of the metal and hold it there until a molten puddle forms. Keep the tip of the cone from one-sixteenth to one-eighth inch away from the surface of the molten metal. As soon as the puddle is formed, move the torch tip slowly forward with a slight weaving or oscillating motion, as indicated in figure 8-28. Both the forward motion and the weaving motion must be uniform to produce a smooth, regular bead.

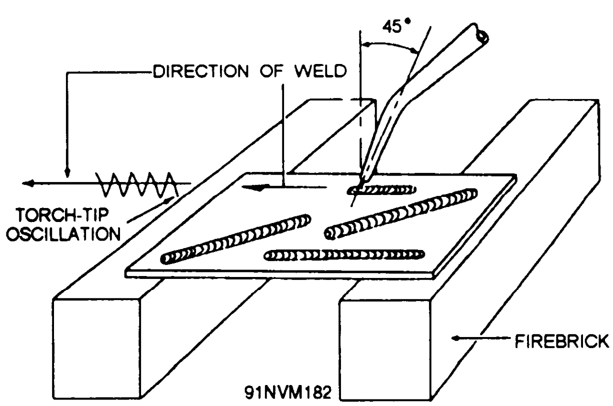


Figure 8-28.—Running a bead without using filler rod (flat position).

A good weld bead must be of uniform width at the weld face and must have a weld surface that is slightly below the surface of the base metal. The surface of the weld should be covered with a thin film of oxides. The speed with which the flame is carried along the plate should be regulated to obtain good fusion without burning through the metal.

When you have developed skill in running a bead without filler on a piece of one-eighth inch mild steel, try the same thing on a piece of thinner stock. A bead without filler can be used to join two pieces along an edge, in the manner shown in figure 8-29. To do this, tack weld the ends by fusing them together; then start a puddle and run a bead along the edges.

Running a Bead With Filler (Flat Position)

The next step in learning to perform oxyacetylene welding is to run a bead in the flat position, using filler metal. This job is very similar to the first one, but requires manipulation of a filler rod as well as of the torch tip. The bead is built up by the filler metal, as shown in figure 8-30; it should be built up about 25

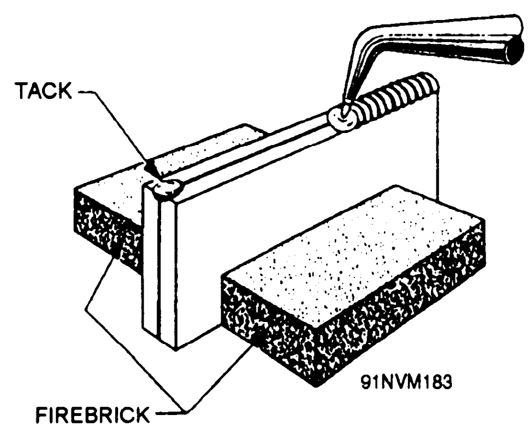


Figure 8-29.—Bead weld without filler, used to join two pieces along an edge.

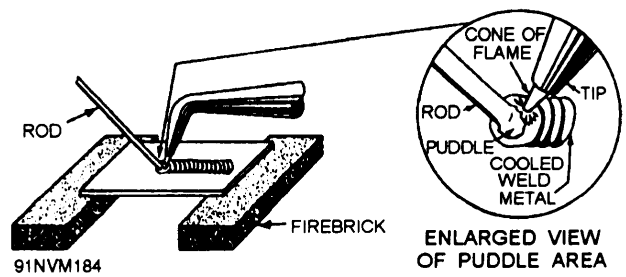


Figure 8-30.—Bead weld with filler (flat position).

percent, or an amount equal to one-fourth the thickness of the stock.

Start the puddle in the usual way. As soon as the puddle is formed, dip the filler rod into the middle of the puddle. Oscillate both the filler rod and the torch tip. The filler rod should be moved in a direction OPPOSITE to the direction of movement of the flame. When the flame is on one side of the puddle, the rod should be on the other side. Stir the end of the rod in the puddle, not above it. Do not direct the flame at the end of the filler rod; the filler rod should be melted by the puddle, not by the flame. Direct the flame so that it preheats the weld area uniformly. The direction of the flame is very important from the point of view of obtaining good fusion and avoiding undercutting or overlapping.

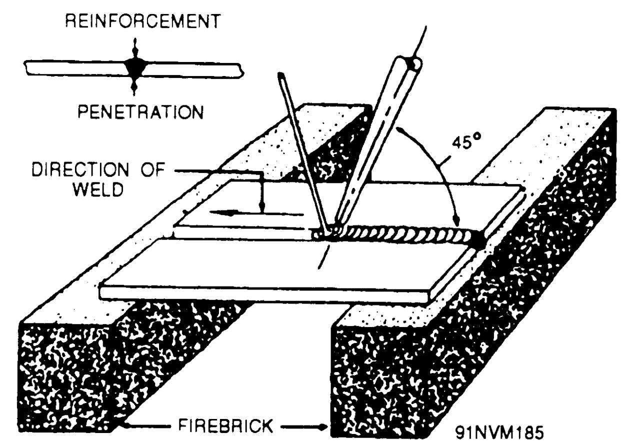


Figure 8-31.—Welding a butt joint in the flat position.

Making a Butt Joint (Flat Position)

Butt welding in the flat position is often used to join sheet metal. First tack the two pieces of sheet together, leaving a slight gap for a root opening. Be sure the flame is correctly adjusted to a neutral or slightly carburizing flame. Let the tacks cool, and then start a puddle at one end.

The position of the torch tip and the filler rod must be just right to achieve the fusion and penetration required for a good weld of this type. Hold the torch tip at an angle of 45° to the base metal, as shown in figure 8-31. Apply the flame at the root of the joint, first to one part of the joint and then to the other until the side walls melt or break down to form a pool of molten metal that bridges the gap between the plates at the root. Add filler metal to the molten pool until the pool is sufficiently large. Carry the puddle forward by manipulating the torch with an oscillating motion. If you weave the torch tip and the filler rod correctly, you can carry along a molten puddle that will give complete penetration and also provide enough filler metal to reinforce the weld. Avoid overheating the puddle; overheating can actually bum the metal and thus greatly impair the strength of the finished weld.

Making a Butt Joint (Vertical Position)

When welding in the vertical position, you have the problem of keeping the molten metal from running down and accumulating at the bottom of the joint. To control the flow of molten metal, hold the flame below the filler rod. The flame should point upward at an angle of 45° to the base metal. The gas pressure from the torch tip will support the molten metal and distribute it evenly along the joint. Bending the filler rod to an angle of 90°, a short distance from the end, makes it easier to get the end of the filler rod into the puddle. Figure 8-32 shows the positions of the torch tip and the filler rod with respect to the base metal.

Making a Butt Joint (Overhead Position)

When welding in the overhead position, you will have to overcome the tendency of the molten metal to drop down or to sag on the plate. Keeping the puddle small helps to control the molten metal. If the molten puddle gets too large, remove the flame for an instant to allow the metal to freeze; then resume the welding.

Figure 8-33 illustrates the welding of a butt joint in the overhead position. Direct the flame so that it will melt both edges. Add enough filler to keep the puddle the right size and to provide some metal for

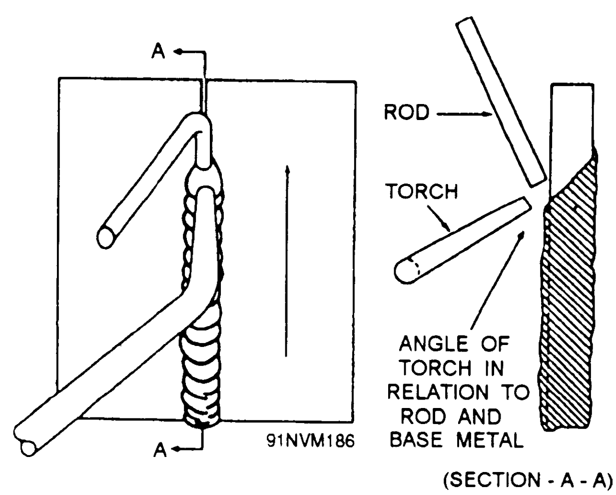


Figure 8-32.—Welding a butt joint in the vertical position.

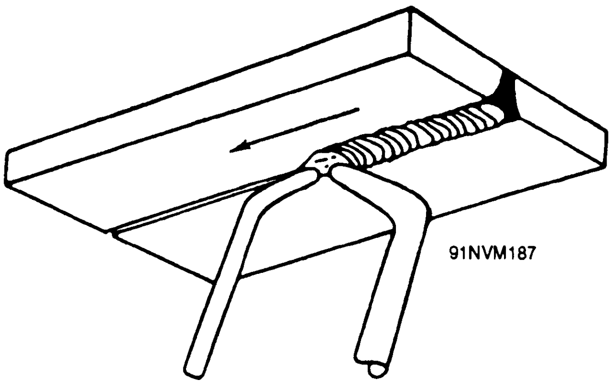


Figure 8-33.—Welding a butt joint in the overhead position.

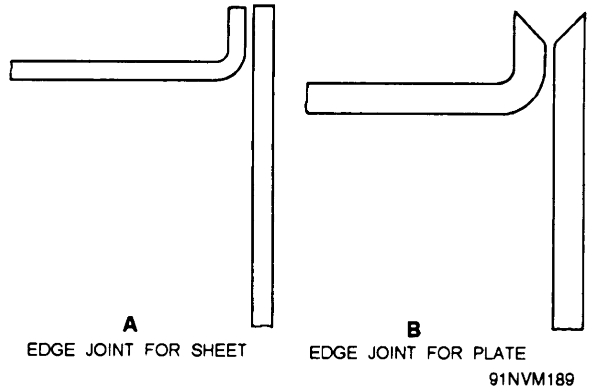


Figure 8-35.—Edge joints for sheet and plate.

reinforcement of the weld. Keep the flame in such a position that it will support the molten metal and distribute it along the joint. Use a small filler rod; this will help you to keep the puddle small. In many overhead welding jobs, it is possible to weld from one side only. In such cases, particular care is required to make sure the heat is evenly distributed, so that one plate will not be burned through.

Making a Corner Joint

The comer joint is used to join the edges of two plates when the surfaces of the plates make a 90-degree angle with each other. Figure 8-34 shows three designs that are commonly used for corner joints. The CLOSED comer joint (view A) is used on lighter sheets and plates where strength requirements for the joint are not a factor. In making this joint, melt the overlapping edge with the torch and add only a small amount of filler metal. When using this joint design for heavier sections, V-bevel or U-groove the lapped plate to permit penetration to the root of the joint.

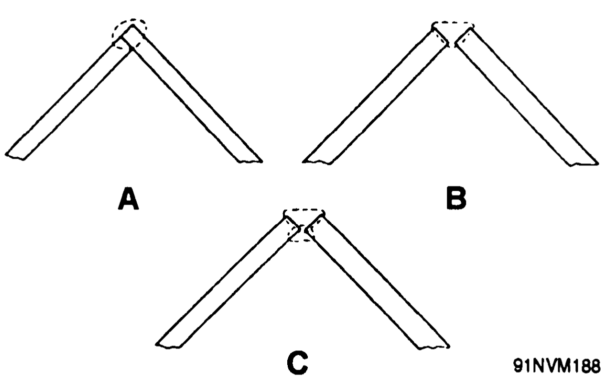


Figure 8-34.—Corner joints. A. Closed joint. B. Open joint, welded from one side. C. Open joint, welded from both sides.

View B of figure 8-34 shows an OPEN corner joint that is often used on heavy sheets and plates. To make this joint, melt down the edges of the plate and add enough filler metal to build up the comer from one side.

View C shows an open corner joint that is welded from both sides. First weld the joint from the outside, then reinforce the joint and seal it (as for use in drip pans) from the inside with a seal bead weld.

Making an Edge Joint

Edge joints are used mainly to join the edges of sheet metal and to weld reinforcing plates on flanges of I-beams or edges of angles. Figure 8-35 shows two common types of edge joints. The joint shown in view A is used for welding thin sheets; this joint requires no edge preparation other than cleaning the edges and tacking them together. The joint shown in view B is used for heavier plate. To make this joint, bevel the edges to allow good penetration and fusion of the side walls. In making both of these joints, use enough filler metal to fuse both edges and to reinforce the joint.

Making a Lap Joint

The lap joint is the simplest of all weld joints and is formed by overlapping two plates of metal. Lap joints may be welded from one side or from two sides. They are stronger when welded from both sides, but even a lap joint that is welded from only one side is stronger than a butt joint in some applications.

Making a Joint

The T joint is another simple joint that is formed by butting the edge of a piece of plate up to the face of another plate to form the letter T. A plain T joint in thin material requires little preparation. For thicker plate, the edges should be prepared as shown in figure 8-36.

GUIDE FOR OXYACETYLENE WELDING OF FERROUS METALS

Low-carbon steel, low-alloy steel, cast steel, and wrought iron are easily welded by the oxyacetylene process. A flux is not necessary with these materials, since the oxides melt at a lower temperature than the base metal. You must keep the molten puddle of metal enclosed by an envelope of flame at all times during the welding process. If the metal is permitted to come in contact with the air while it is in a molten condition, it will oxidize rapidly. Care should be taken to prevent overheating the metal. Use a neutral or slightly reducing (carburizing) flame. Do NOT use an oxidizing flame. Manipulate the torch and the filler rod so that the top of the oxyacetylene cone is about one-sixteenth to one-eighth inch from the surface of the metal. Melt the end of the filler rod in the puddle, not with the flame. The welding of low-carbon steels and cast steels presents no special problems other than the selection of the proper welding rod. Low-alloy steels usually require preheating and postheating.

As the carbon content increases, steels become more difficult to weld. Steels with a carbon content of 0.30 to 0.50 percent should be welded with a slightly reducing (carburizing) flame, and should be postheated to develop the best physical properties and to reduce internal stress.

High-carbon steels and tool steels require somewhat special techniques if they are to be successfully welded. Slow preheating to about 1000°F is required; the metal should be protected from drafts during the preheating. No flux is required. The welding should be completed as rapidly as possible with a carburizing flame. The filler rod and the torch tip should not be manipulated for the welding of high-carbon steels and tool steels. Filler metal should be added in small amounts, just as it is needed. A smaller flame and a lower gas pressure should be used for these materials than for low-carbon steel since there is even more danger of overheating the high-carbon steels and the tool steels. High-carbon steels and tool steels must be heat treated after welding.

The procedure for oxyacetylene welding of wrought iron is the same as for low-carbon steel. However, certain special considerations should be

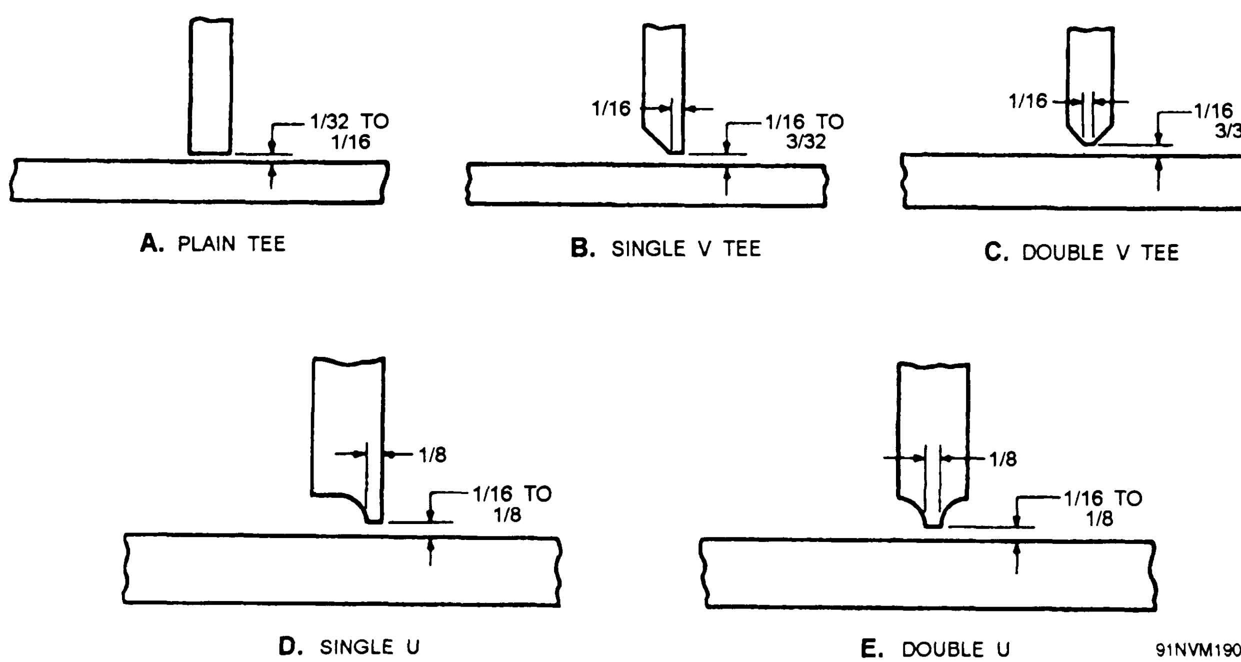


Figure 8-36.—Edge preparation required for various types of T joints.

kept in mind. Wrought iron contains a slag that is incorporated in it during the manufacturing process. This slag gives the surface of the molten puddle of weld metal a greasy appearance. Do not confuse this greasy appearance with the appearance of actual fusion. Continue heating the metal until the side walls of the joint break down into the puddle. Best results with wrought iron are obtained when the filler metal (usually mild steel) and the base metal are mixed in the molten puddle with as little agitation as possible.

Oxyacetylene welding of cast iron requires different procedures than those used for welding steels. Special edge preparation is usually required. The entire weldment should be preheated to between 750° and 900°F before the welding is begun. The welding should be done with a neutral flame, by a backhand technique. Use a cast iron filler metal. Flux is required but should be used sparingly, as needed, to overcome temporary difficulties. The filler metal is added by directing the inner cone of the flame against the rod into the puddle. The filler metal should be deposited in layers that are no more than one-eighth inch thick. The weldment must be stress relieved after welding; heat it to a temperature of between 1100° and 1150°F and then cool it slowly.

Oxyacetylene welding is successful with some chromium-nickel steels (stainless steels). As a rule, oxyacetylene welding is used only for light gauge sheet metal. Heavier pieces of these steels are usually joined by one of the electric arc welding processes, which will be discussed in chapter 10. On material 0.040 inch or less in thickness, a flange equal to the thickness of the metal is turned up and the weld is made without filler metal. Before being welded, the joint surfaces of the metal should be cleaned with sandpaper or other abrasive and then coated with stainless steel flux. The torch tip used for welding stainless steel should be one or two sizes smaller than the tip used to weld mild steel of the same thickness. The torch should be adjusted to produce a carburizing flame that has an excess acetylene feather extending about one-sixteenth inch beyond the tip of the inner cone, as seen through the goggles. The torch should be held so that the flame makes an angle of 80° with the surface of the sheet. The tip of the cone should almost, but not quite, touch the molten metal. Make the weld in one pass, using a forehand technique. Do not puddle or retrace the weld. Uniform speed is essential in welding stainless steels. If it is necessary to stop the welding before it is completed, or to reweld a section, wait until the entire weld has cooled before beginning to weld again.

GUIDE FOR OXYACETYLENE WELDING OF NONFERROUS METALS

Although brazing is used extensively to make joints in nonferrous metals, there are many situations in which oxyacetylene welding is suitable for this purpose. In general, joint designs are the same for nonferrous metals as for ferrous metals. Oxyacetylene welding of nonferrous metals may require mechanical cleaning of the surfaces before welding and the use of a flux during welding. Filler metal must be suitable for the base metal being welded.

Copper

Where high joint strength is required, the only kind of copper that can be successfully welded by oxyacetylene welding is DEOXIDIZED copper (copper that contains no oxygen). Either a neutral or a slightly oxidizing flame adjustment may be used. With a neutral flame, a flux is necessary; with an oxidizing flame, no flux is needed because the oxide formed on the surface protects the molten metal. Because of the high thermal conductivity of copper, it is necessary to preheat the joint area to between 500° and 800°F and to use a large size torch tip for welding. The larger size tip supplies more heat to the joint and thus makes it possible to maintain the required temperature at the joint. After welding has been completed, the part should be cooled slowly.

Copper-Zinc Alloys

Copper-zinc alloys (brasses) may be welded in the same way as deoxidized copper. However, a silicon-copper rod is used for welding brasses. Preheat temperature is from 200° to 300°F. Copper-silicon alloy (silicon bronze) requires a different oxyacetylene welding technique. This material should be welded with a slightly oxidizing flame. A flux with a high boric acid content should be used. Add filler metal of the same composition as the base metal; as the weld progresses, dip the tip of the rod under the viscous film that covers the puddle. Keep the puddle small so that the weld will solidify rapidly.

Copper-Nickel Alloys

Oxyacetylene welding of copper-nickel alloys requires surface preparation and preheating. The flux used for this welding is in the form of a thin paste; it is applied by brush to all parts of the joint and to the welding rod. The torch should be adjusted to give a slightly carburizing flame; the tip of the inner cone should just touch the base metal. Do not melt the base metal any more than is required to give good fusion. Keep the end of the welding rod within the protective envelope of the flame, adding the filler metal without agitating the molten puddle. Run the weld from one end of the joint to the other without stopping. After welding is completed, cool the part slowly and then remove the remaining traces of flux with warm water.

Nickel and High-Nickel Alloys

Oxyacetylene welding of nickel and high-nickel alloys is similar to that for copper-nickel alloys. Good mechanical cleaning of the joint surfaces is essential. Plain nickel is welded without a flux, but high-nickel alloys require a special boron-free and borax-free flux in the form of a thin paste. The flux is applied by brush to both sides of the seam, to the top and bottom, and to the welding rod. The torch should be adjusted to give a slightly carburizing flame; the tip selected should be the same size as (or one size larger than) for steel of the same thickness. Keep the tip of the cone in contact with the molten puddle, and keep the welding rod well within the protective envelope of the flame at all times. After the weld is completed, postheat the part and cool it slowly. Then remove the flux with warm water.

Lead

Oxyacetylene welding of lead requires special tools and special techniques. A flux is not required. The metal in the joint area must be thoroughly cleaned before welding. This cleaning is accomplished by shaving the joint surfaces with a scraper and then wire-brushing the metal with a clean stainless steel wire brush to remove oxides and foreign matter. The lap joint is used for practically all oxyacetylene welding of lead, except that a square butt joint may be used when the welding is done in the flat position. When the lap joint is used, the edges should overlap each other from 1/2 inch to 2 inches, depending upon the thickness of the lead.

A special lightweight torch is used for the oxyacetylene welding of lead. The gas pressures range from 1 1/2 to 5 psi. A completely neutral flame must be used; the length of the flame should be somewhere between 1 1/2 to 4 inches, depending upon the gas pressures that are used. A soft, bushy flame is best for welding lead in the horizontal position and in the flat position. A more pointed flame gives better results in the vertical position and in the overhead position.

For oxyacetylene welding of lead, the filler metal should be of the same composition as the base metal. The molten puddle is controlled and distributed by manipulating the torch so that the flame moves in a semicircular or V-shaped pattern. Each tiny segment of the weld is made separately, and the torch is flicked away at the completion of each semicircular or V-shaped movement. Joints are made in thin layers. Filler metal is not added on the first pass, but is added on subsequent passes. When welding lead or lead alloys, wear a respirator of a type approved for protection against lead fumes. LEAD FUMES ARE POISONOUS.

SAFETY PRECAUTIONS

Whether you are welding, torch brazing, flame cutting, or heating with oxyacetylene equipment, certain precautions must be observed to protect personnel and the structure from injury by fire or explosion. The precautions that follow apply specifically to oxyacetylene work. Other safety precautions are listed in chapter 1 of this manual and in OPNAVINST 5 100.19.

1. CLOTHING: You should use goggles, a faceplate, respirators, flameproof gloves, jackets, leggings, and boots, as appropriate. Do not keep any type of lighter on your person and do not wear synthetic clothing.

2. CYLINDER SAFETY: You should follow these safety precautions when working with compressed gas cylinders during cutting or welding operations:

— Place cylinders a safe distance away from the actual welding or cutting operations so that sparks, hot slag, or flame will not touch them.

— Do not tamper with, or attempt to repair, cylinder valves.

— Always place fuel-gas cylinders with the valve end up. Acetylene cylinders should be stored in the vertical position for a minimum of 2 hours before use to stabilize the gas.

— Handle cylinders carefully; avoid rough handling that could damage cylinders.

— Close cylinder valve and release gas from the regulator before attempting to remove the regulator from the cylinder valve.

— Do not place anything on top of an acetylene cylinder that may interfere with the quick closing of the cylinder valve.

— Always use regulators to reduce compressed gases to a suitable working pressure.

— Copper tubing should not be used with acetylene gas because of the potential of an explosive chemical reaction.

3. OPERATIONS: The improper operation of oxyacetylene equipment is the major cause of accidents. Follow these basic safety precautions when operating oxyacetylene equipment:

— Check all gas connections for leakage.

— Do not use defective or damaged equipment.

— Never use petroleum-based products (oil or grease) to lubricate oxyacetylene equipment. Oil or grease in the presence of oxygen under pressure will ignite violently.

NOTE: Glycerin is a suitable lubricant for oxyacetylene equipment.

— Do not use vice grips, adjustable wrenches, pliers, or other similar tools to tighten connections or to open gas cylinder valves. You will only damage the connections rendering them unusable in an emergency.

— Always leave the apparatus wrench on the acetylene cylinder valve so the cylinder can be secured quickly in an emergency.

— Never open an acetylene cylinder valve more than 1/4 to 1/2 of a turn.

— Fully back out the adjusting screw on a regulator and stand to one side when pressurizing a compressed gas system. Regulators have been known to explode if pressurized improperly.

— Never run oxyacetylene hoses on the deck. The hoses should always be run in the overhead. When running hoses through hatches, doors, or scuttles, locate the connection near the access and block open the door to prevent the hose from being cut.

— Never use matches, lighters, or any open flame to light your torch; use a friction lighter only. Butane lighters have been known to explode if exposed to excessive heat or if the casing melts.

— When lighting the torch, open the acetylene valve first and ignite the gas before introducing oxygen to the flame.

— Never allow unburned acetylene to escape into small or closed spaces.

— Report any safety discrepancy or unsafe act to your immediate supervisor.

4. BACKFIRE AND FLASHBACK: Unless the system is thoroughly purged of air and all connections in the system are tight before the torch is ignited, the flame is likely to bum inside the torch instead of outside the tip. The difference between the two terms *backfire* and *flashback* is this: in a backfire, there is a momentary burning back of the flame into the torch tip; in a flashback, the flame bums in or beyond the torch mixing chamber. A backfire is characterized by a loud snap or pop as the flame goes out. A flashback is usually accompanied by a hissing or squealing sound. At the same time, the flame at the tip becomes smoky and sharp pointed. When a flashback occurs, immediately shut off the torch oxygen valve, then close the acetylene valve. By closing the oxygen valve, the flashback is stopped at once. The occurrence of a flashback indicates that something is radically wrong either with the torch or with the manner of handling it. A backfire is less serious. Usually the flame can be relighted without difficulty. If backfiring continues whenever the torch is relighted, check for these causes: overheated tip, gas working pressures greater than that recommended for the tip size being used, loose tip, or dirt on the torch tip seat. These same difficulties may be the cause of a flashback, except that the difficulty is present to a greater degree. For example, the torch head may be distorted or cracked.

In most instances, backfires and flashbacks result from carelessness. These difficulties can be avoided by making certain that (1) all connections in the system are clean and tight; (2) torch valves are closed (not open or merely loosely closed) when the equipment is stowed; (3) the oxygen and acetylene working pressures used are those recommended for the torch employed; and (4) the system is purged of air before the apparatus is used. Purging the system of air is especially necessary when the hose and torch have been newly connected or a new cylinder is incorporated into the system. Purging a system is accomplished as follows: Close torch valves tightly, then slowly open the cylinder valves. Next, open the regulator slightly. Open the torch acetylene valve and allow acetylene to escape for 5 to 15 seconds, depending on the length of the hose. Close the acetylene valve. Repeat the procedure on the oxygen side of the system. After purging air from the system, light the torch as described previously.

SUMMARY

As you look back at this chapterr, you will find that you now have a knowledge of the components of oxyacetylene equipment and the use of the equipment. You also have the information required to perform certain welding techniques and oxyacetylene cutting operations. Review of the safety precautions is highly recommended. Failure to obey some of the precautions could cause a fire, personnel injury, or equipment damage. However, failure to follow other precautions may just cost you your life.

CHAPTER 9

BRAZING AND BRAZE WELDING

LEARNING OBJECTIVES

Upon completion of this chapter; you should be able to do the following:

- *Identify the tools and equipment used in silver brazing.*
- *Describe the techniques used in braze welding and silver brazing, and define the different types of filler metals available.*
- *Explain the necessity of using fluxes, the different types of flux available, and the correct procedures to use in applying fluxes.*
- *Describe the procedures for hydrostatically testing silver-brazed joints.*
- *Describe hard surfacing and identify the materials and techniques used in hard surfacing.*
- *Describe the uses of powdered metals and the correct procedures in the application of powdered metals.*
- *Describe the technique used in soldering.*

INTRODUCTION

This chapter will cover silver brazing, braze welding, surfacing, powdered metal flame spraying, and soldering processes. The various associated equipment will also be discussed along with its safe operation. You will find that silver brazing and braze welding are two welding processes that you will use quite often. There are a number of ways to silver braze, but it is done most often with an oxyacetylene torch.

Braze welding and silver brazing are similar in many ways, but they are two different welding processes. In silver brazing, a silver-base alloy is used as a filler metal and the base metal is NEVER melted. The filler metal is distributed throughout the joint by capillary attraction. In braze welding, a copper-base alloy is used as a filler metal and it is deposited in groove and fillet welds exactly at the points where it is to be used. Limited base metal fusion may also occur in braze welding; capillary attraction is not a factor.

You will often see the word tinning used in connection with silver brazing and braze welding. The surface of the base metal is said to be tinned when a very thin continuous film of tiller metal precedes the main part of the filler metal. Tinning can only occur on metal that has been cleaned, fluxed, and heated to the correct temperature. If tinning does not occur, the main part of the filler metal will not adhere to the base metal. Tinning will be discussed later in this chapter.

SILVER BRAZING

Silver brazing is a process where coalescence is produced by heating with a gas flame. It uses a silver alloy filler metal with a melting point above 800°F, but below the melting point of the base metal. The filler metal is distributed in the joint by capillary attraction.

Let's consider some everyday examples of the process used in silver brazing. When you use a blotter, the ink is drawn up into the blotter by capillary attraction. The wick on an oil lamp can be lit because the oil rises in the wick by capillary attraction. In each of these examples, we have a liquid that moves into an opening in a solid by the process called capillary attraction. A basic rule of the process is that the distance the liquid will be drawn into the opening in the solid depends on the size of the opening in the solid. The smaller the opening, the farther the liquid will be drawn in.

This same capillary attraction causes the melted filler metal used in silver brazing to be drawn into the narrow clearance between the joining members. Capillary attraction will not work unless the tiller metal is in a fluid state and the size of the opening is quite small (usually 0 to 0.012 depending on pipe or tube size). Therefore, the application of heat and the use of a very small clearance between joining members are essential to silver brazing. The heat is necessary to melt the filler metal and to keep it molten. The small clearance is necessary to allow capillary attraction to draw the molten metal into the space between the joint members.

You will often hear silver brazing called SILVER SOLDERING or HARD SOLDERING. Silver brazing is similar in many respects to soldering. The basic distinction between a welding process and a soldering process is that the metals or alloys used for a welding process have melting points above 800°F, while those used for a true (or SOFT) soldering process have melting points below 800°F.

TORCHES

Silver brazing depends largely upon the operator’s manipulation of the torch to control the application of heat. A lightweight torch with or without a flexible extension tube (fig. 9-1) simplifies the silver brazing procedure and helps reduce operator fatigue. The flexible extension tube is made of soft copper. It can be bent as needed to heat the surfaces to be joined.

Since one tip size cannot be used for making joints on all thicknesses of metal, torches are provided with various sizes of tips. Tips are designed to heat a large area and still allow little or no “bounce” (reflected heat). Figure 9-2 shows the shapes of the flame at the ends of different kinds of tips.

The tip shown in view A of figure 9-2 has the lowest velocity and heats the largest area. This tip should be used in joining with silver alloys.

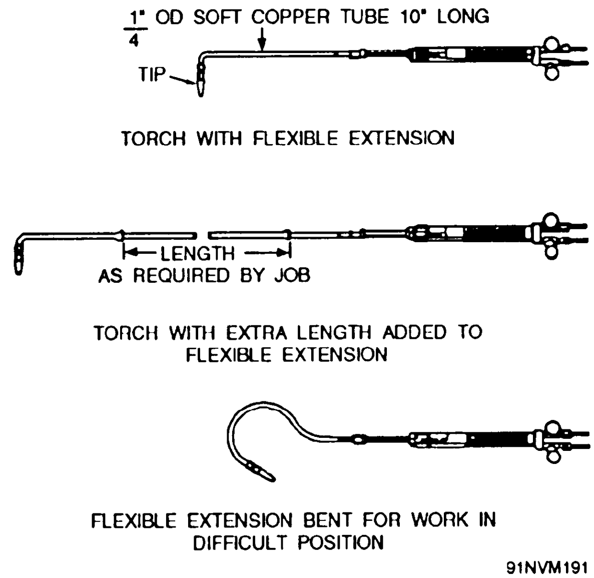


Figure 9-1.—Lightweight oxyacetylene torches with flexible extension tubes.

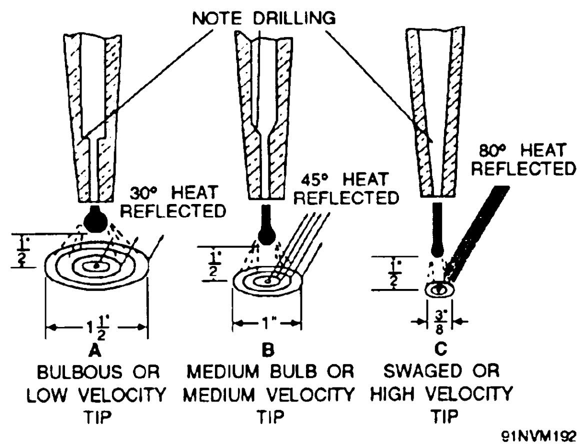


Figure 9-2.—Tip designs.

The size of tip selected for the torch should be determined by the size and type of work to be done. For silver brazing sheet stock, for instance, you would ordinarily use size 4, 5, or 6. Table 9-1 may be used as a general guide.

SILVER BRAZING FILLER METALS

Silver brazing filler metals are nonferrous metals or alloys that have a melting temperature above 800°F, but below the melting point of the base metal being joined. You may have heard these silver brazing filler metals referred to as silver solder, hard solder, or brazing alloys, but the correct term is *silver brazing filler metals.*

Table 9-1.—Tip Sizes and Gas Pressures for Silver Brazing Various Thicknesses of Metal

Tip No. (Bulbous-type tips)	Drill size	Metal thickness (inches)	Oxygen pressure (psi)	Acetylene pressure (psi)
1	68	1/16	1.0	1.0
2	62	3/32	2.0	2.0
3	56	1/8	3.0	3.0
4	54	3/16	4.0	4.0
5	51	1/4	5.0	5.0
6	48	5/16	6.0	6.0
7	44	3/8	7.0	7.0
8	40	1/2	7.0	7.0
9	35	5/8	7.5	7.5
10	30	3/4 & over	9.0	9.0

Silver brazing filler metals covered in Navy specifications have the following major characteristics:

- Low melting point
- High tensile strength
- High resistance to corrosion
- Flows readily at the lower brazing temperatures
- Brazes readily to copper and to copper alloys

The metals commonly used for silver brazing filler metals include silver, copper, zinc, phosphorus, cadmium, and nickel. The percentage of the various metals determines the color, strength, melting point, and flow point of the filler metal. All grades of silver brazing alloy can be obtained in strips, wires, pigs, shot, or chips, as required.

Table 9-2 lists the silver brazing filler metals commonly used in the Navy. There are six different filler metals: grades 0, I, II, III, IV, and V.

Grades 0, I, and II are suitable for joining ferrous metals. They cost less and are often used for large quantities of work.

Grade III is used for brazing copper and copper-base alloys. It is not intended for use with ferrous metals.

Grade IV is used for joining ferrous and nonferrous metals, except those having melting points lower than the filler metal.

Grade V is used when the characteristics of grade IV are required, but where close tolerances cannot be maintained or when the addition of a filler is desired. Grade V should be used for brazing hard materials.

FLUXES

All silver brazing operations require the use of a flux. The flux prevents the oxidation of the metal surfaces and removes oxides already present. Flux also increases the flow of the brazing filler metal and increases its ability to adhere to the base metal. It brings the brazing filler metal into immediate contact with the metals being joined and permits the tiller to penetrate the pores of the metal. Silver brazing flux (as specified in table 9-3) must be applied evenly to each brazing surface.

For best results, a flux must become active at a temperature slightly below the melting point of the filler metal, and must remain fluid at the brazing temperature. Regardless of the type of flux you select, you need to apply it in such a manner that all oxide film is removed.

You can get flux in three forms: liquid, paste, and powder. When used either in paste form or in liquid form, the flux is applied with a brush to both parts of the joint and to the filler metal. Use a circular motion to brush it on, and let the flux extend outside the joint or fitting. For best results, flux should be applied after cleaning and before heating. Brush the flux on with a circular motion to give a uniform coating and lessen the

Table 9-2.—Silver Brazing Metals Commonly Used in the Navy

Brazing Filler Metal	Grade No.	Composition (%)	Melting and Flow Point[1]	Shape	Color	Suggested Use
Copper-silver	0	Silver . . . . . . 20 Copper . . . . . 45 Zinc 35	1430°F 1500°F	Strip	Yellow	Seal joints operating up to 1230°F. Suitable for joining ferrous metals.
Copper-silver	I	Silver . . . . . . 45 Copper . . . . . 30 Zinc 25	1250°F 1370°F	Strip or wire.	Nearly white.	Seal joints operating up to 1050°F. Suitable for joining ferrous metals.
Copper-silver	II	Silver . . . . . . 65 Copper . . . . . 20 Zinc 15	1280°F 1325°F	strip	White	High silver content primarily for color match. Suitable for joining ferrous metals.
Copper-silver	III	Silver . . . . . . 15 Copper . . . . . 80 Phosphorous . . 5	1200°F 1300°F	Strip or wire.	Gray-white.	For brazing copper and copper-base alloys.
Copper-silver	IV	Silver . . . . . . 50 Copper . . . . . 15 Zinc . . . . 17 Cadmium 18	1160°F 1175°F	Strip or wire.	Yellow-white.	For brazing all ferrous and nonferrous metals except those having lower melting points. Use only where proper tolerances can be maintained.
Copper-silver	V	Silver . . . . . . 50 Copper . . . . . 15 Zinc . . . . 15 Cadmium . . . . 17 Nickel 3	1195°F 1270°F	Strip or wire.	Yellow-white.	For same applications as grade IV but where close tolerances cannot be maintained. For brazing hard metals.

[1]In all instances, the lesser temperature indicates melting point and the higher temperature indicates flow point of the brazing filler metal.

possibility of bare spots that will oxidize during heating. Flux the filler metal by heating the filler rod and dipping it into the flux. Enough flux to do the job will stick to the hot rod.

Borax or a mixture of borax and other chemicals is most often used as a flux. Up to a certain point, heat causes borax to swell and bubble. Common crystalline borax contains approximately 47 percent water of crystallization (water that is chemically combined in a crystallized substance). When the borax is heated, this water is driven off, and the borax appears to boil. Borax may be mixed with water to form a paste. However, borax can hold water, and it will quickly take up the water and become crystalline borax again. If

Table 9-3.—Types of Silver Brazing Fluxes

Metals	Fluxes
Brass, copper, tin . . .	Rosin
Lead	Tallow, rosin
Iron, steel	Borax sal ammoniac
Galvanized iron	Zinc chloride
Zinc	Zinc chloride
Aluminum	Stearine, special flux

Table 9-4.—Maximum Permissible Diametrical Clearances

MAXIMUM PERMISSIBLE DIAMETRICAL CLEARANCES[1]		
Pipe or Tube Size (Inches)	Maximum Clearances (Inches) at Ambient Temperature	
	Class P-3a	Class P-3b
1/4 to 1/2 Inclusive	0.005	0.010
Over 1/2 to 1 Inclusive	0.006	0.010
Over 1	0.008	0.012

[1]In fitting up joints for brazing, it is the responsibility of the fabricator to use a clearance within the limits established by this table, which assures conformity to inspection or test requirements set forth in this document or in other specifications or standards governing brazed piping systems.

commercial powdered borax is used, see that it is kept in sealed glass jars.

If a prepared flux is not available, a mixture of 12 parts of borax and 1 part boric acid may be used as a flux for brazing.

When you apply flux or assemble the parts, avoid handling the polished parts of the joint or you will defeat the purpose of cleaning. If the parts are not assembled immediately, the fluxed surfaces should be protected so that the flux will not be contaminated by dirt or washed or brushed off. If the coating of flux dries before the parts are assembled, remove the old flux and apply a fresh coat of flux. It should always be applied as soon as a joint area is cleaned, even though it will not be brazed immediately. Joints that have been assembled but not brazed within 24 hours must be disassembled, recleaned, and refluxed before brazing. After you finish the brazing, allow the work to cool below 200°F before cleaning the joint with warm water to remove the residue left by the flux.

TYPES OF JOINTS

The filler metal used in silver brazing must be distributed by capillary action. Therefore, the joints must be of a type that requires closeness of fit. In silver brazing there are three basic joint designs: lap, butt, and scarf. The joint members in which these designs are used may be flat, round, tubular, or irregular in cross section.

The lap joint design is used most frequently in silver brazing, especially in pipe work. Good practice requires a length of lap at least three times the thickness of the metal being joined. The maximum permissible diametrical clearances used in silver brazing range from 0.001 to 0.012 depending on the pipe or tube size and the classification of the brazed piping system. (See table 9-4.)

High-strength butt joints can be made if a joint clearance between 0.001 and 0.003 inch can be maintained in the finished braze. The edges of the joint must be perfectly square so that you have a uniform clearance between all portions of the joint surfaces. Butt joints are usually used where you do not want the double thickness of a lap joint. In these situations, the scarfjoint is probably better.

A scarf joint provides an increased area of bond without increasing the thickness of the joint. The area of bond, however, depends on the angle at which the edges of the joint are scarfed. Usually, you will want an area of bond two to three times that of a butt joint in the same thickness of material. A 30-degree scarf angle gives a bond area twice that of a 90-degree butt joint, and a 19 1/2-degree scarf angle gives a bond area three times that of a butt joint.

You will use modifications of these basic joint designs. In some instances, you will add the silver brazing filler metal when the proper temperature has been attained. In other instances, you will preplace the filler metal in the joint before heat is applied. This technique is common in pipe work where special fittings containing preinserted rings of silver brazing. filler metal are used. The technique is also used in sheet metal work involving locked scams. Here, you will place the silver brazing filler metal in the seam before it is locked. The preplaced insert method produces a strong leaktight joint in both sheet metal and pipe work.

SILVER BRAZING TECHNIQUES

You will need some knowledge of the principles of heat flow through metals to understand silver brazing techniques.

The following points are particularly important:

1. Heat always flows from a hotter area to a colder area.

2. The process by which heat flows from molecule to molecule through a metal (fig. 9-3) is called conduction. Conduction takes place quite rapidly in most metals, but air is a very poor conductor of heat. Therefore, if two pieces of metal that are to be joined by silver brazing are not in contact with each other, each piece must be heated separately. If the two pieces are in contact with each other, you can heat both by applying heat to one of them. The second piece will be heated by conduction from the first piece. These principles are shown in figure 9-4.

3. In the molten state, filler metal flows from the colder toward the hotter areas on a heated surface. Therefore, you might say that the filler metal flows in a direction OPPOSITE to the direction of flow of the heat. This principle is shown in figure 9-5.

4. The filler metal and the flux used in silver brazing cannot occupy the same space at the same time. Therefore, a clearance must be provided in the setup of the joint so that the filler metal can flow in and the flux can flow out. Heat should be applied in the manner shown in figure 9-6 so that the flux will flow out when the filler metal reaches the bonding temperature.

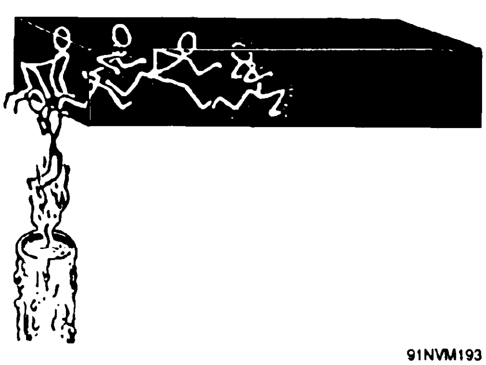


Figure 9-3.—Conduction of heat.

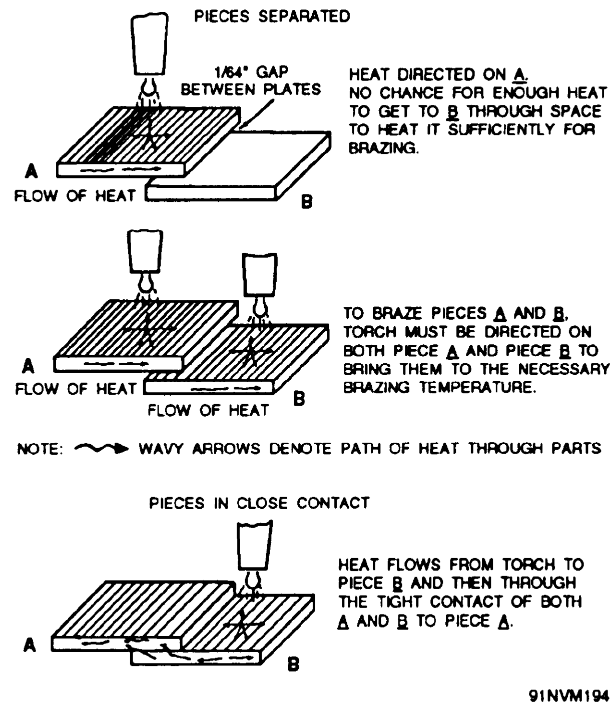


Figure 9-4.—Flow of heat.

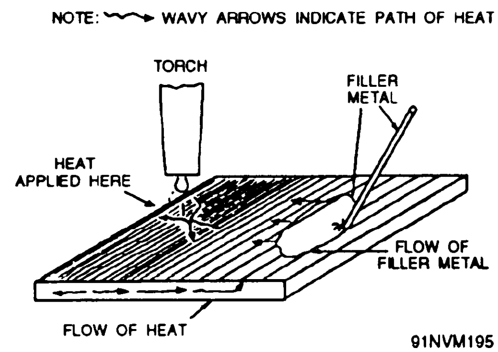


Figure 9-5.—Flow of molten filler metal.

5. Heat travels faster through some metals than through others (fig. 9-7). All metals and alloys have high conductivity as compared with most other substances, but there is a good deal of variation in the speed with which various metals and alloys will conduct heat. Copper, for example, is a very rapid conductor of heat. When two pieces of different metals are to be joined by silver brazing, the difference in heat conductivity of the two metals causes some problems in heating. For example, if you are trying to join a steel part and a copper part by silver brazing, you will find that the steel part reaches the joining temperature more rapidly and has a tendency to overheat because the heat

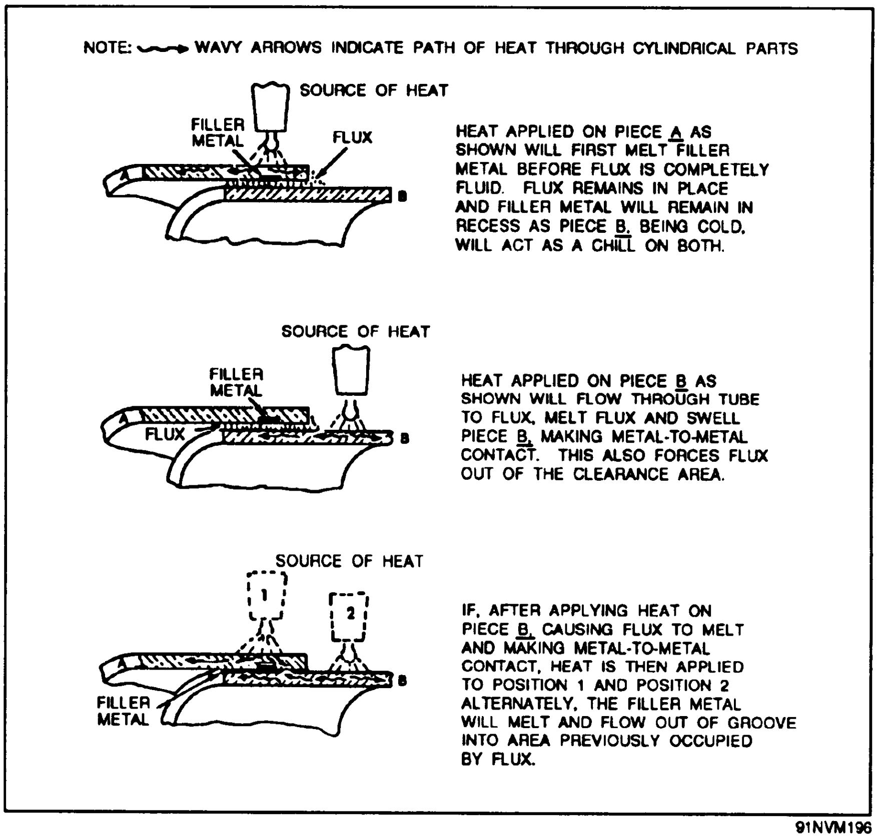


Figure 9-6.—Flow of flux and filler metal.

is carried away from it more slowly. The copper part, on the other hand, conducts heat away from the brazing area more rapidly than does the steel part. Therefore, more heat is required to bring the copper part to the brazing temperature.

Control of heat is one of the most difficult parts of silver brazing. To do it properly, you must manipulate the torch correctly, and you must remember the points just discussed concerning the flow of heat through metals. Basically, the problem of heat control in silver brazing is one of bringing BOTH parts to the correct temperature at the same time. If one piece is hot enough but the other is not, the filler metal will flow onto the hot piece, but it will not bond to the cooler piece.

If you have heavy and thin metal sections that must be silver brazed, be careful to avoid overheating the thin part. A good example is the silver brazing of thin copper tubing to a heavy cast fitting. If the same amount of heat were applied to the tubing as to the casting, the tubing would be overheated and probably burned. Therefore, most of the heat must be directed toward the heavier part. Frequently, heavy parts and large areas must be

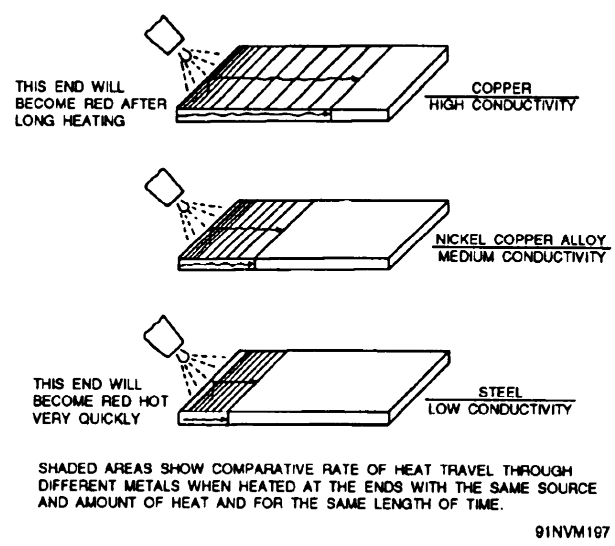


Figure 9-7.—Relative rate of heat flow through copper, nickel-copper alloy, and steel.

preheated for best brazing results. Preheating may be done with a forge, a furnace, or a welding torch.

Joints must be clean and properly fitted for satisfactory silver brazing. All parts to be brazed must be thoroughly cleaned to remove surface scale, oxide,

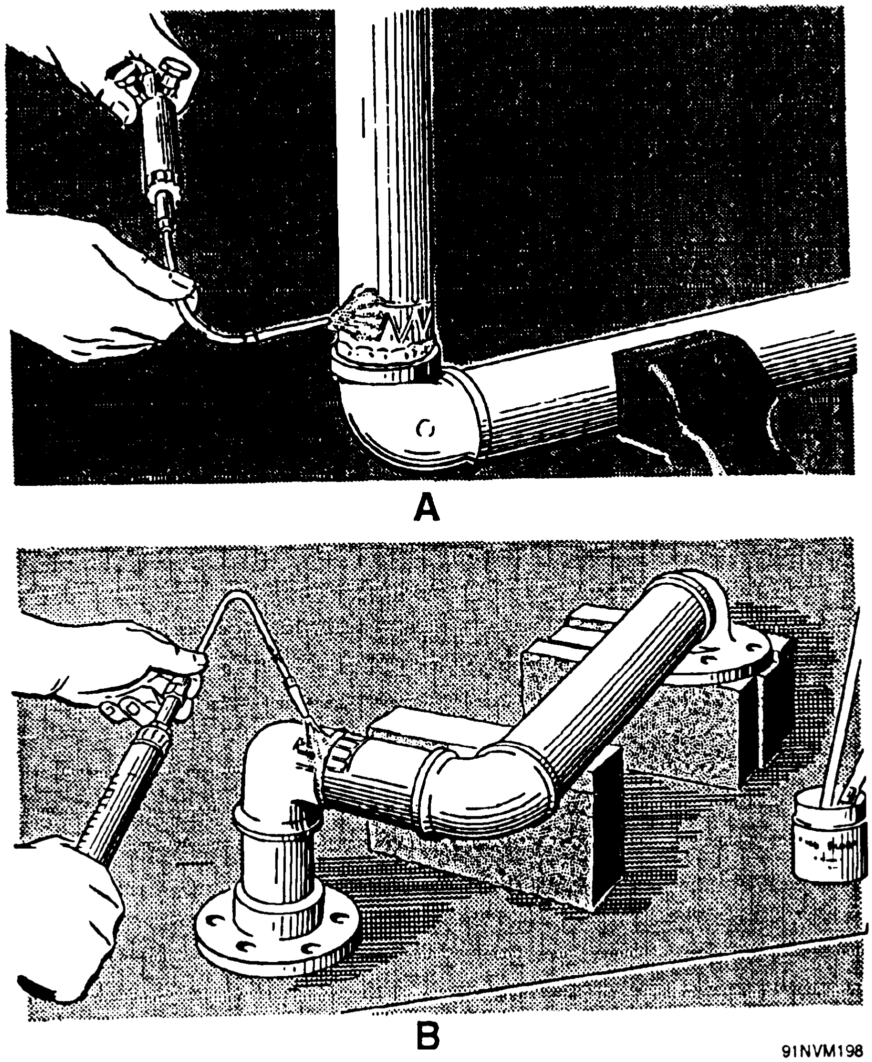


Figure 9-8.—Applying heat for silver brazing a tube and fitting.

oil, and grease. Any one or a combination of the following methods must be used for the cleaning of scale and oxides or other foreign substances:

- Abrasive cloth, followed by wiping with an acetone-, alcohol-, or water-damp clean cloth.
- Stainless steel wire brush, hand or rotary, followed by wiping with an acetone-, alcohol-, or waterdamp clean cloth.
- Metallic stainless steel wool followed by wiping with an acetone-, alcohol-, or water-damp clean cloth.
- Commercial cleaning solutions or degreasing baths may be used when included in an approved brazing procedure or specification.

Rust and corrosion should be removed by sanding, grinding, sandblasting, wire brushing, or filing. Oil and grease should be removed with solutions of trichloroethylene or trisodium phosphate, not by heat. The cleaned surfaces should not be handled unnecessarily. When parts have been cleaned and the elapsed time before fluxing is more than 8 hours, the parts should be recleaned. Brazing alloy should be free of all visible oxides, grease, oil, or other foreign substances when assembled or fed into the joint. Never try to braze dirty metal.

Use a slightly carburizing flame to apply heat with the oxyacetylene torch for brazing with a silver-base filler metal. Select a torch tip to suit the type of work you are doing. Ordinarily a size 4, 5, or 6 tip is suitable for silver brazing. Keep the inner cone of the flame from one-fourth to one-half inch away from the metal. Play the flame over the surface with a circular, sweeping motion so that you obtain uniform heating of the parts to be joined. The flame should be soft so that it will not blow or boil the molten filler metal.

Bring up the temperature of the parts until the flux on them is melted. Continue heating the parts to be joined until they are hot enough to melt the tiller rod. The filler should be melted by the heat of the joint, not by the flame. It should flow like water wherever the flux has been applied. Avoid overheating. Use just enough heat to get the parts of the joint hot enough to melt the filler metal so that it can flow.

Two methods are used to make joints with silver-base brazing filler metal: the insert method and the feed-in method (more commonly referred to as face feeding). With either method, the parts must be adequately supported during heating to maintain alignment and tolerances or fit. The work must be held firmly in positionuntil the silver brazing tiller metal has completely solidified.

When you use the insert method, insert a strip of the silver-base filler metal in the joint before assembly. Before brazing the parts, clean them with emery cloth, sandpaper, or some other abrasive, and apply flux with a brush. Next, fit the two parts together and align them. Then, light-off the torch and direct the heat on the tube or thinner portion, as shown in figure 9-8. The lines drawn on the tube indicate the path of the torch while the tube is being heated.

Heat applied to the tubing causes it to swell. This brings the surface of the tube into contact with the inside surface of the fitting. The clearance area is closed, forcing the flux from either end of the joint. Be sure to heat the entire circumference of the tube until the flux begins to flow. Flux flow tells you that the tube has expanded sufficiently, and signals you to proceed to the second phase of heating. The flux flows freely shortly after fluidity becomes apparent. At that time, direct the flame to that portion of the fitting hub farthest from the junction of the tube and the fitting. Sweep the flame over the joint segment in a circular motion until the brazing filler metal appears at the junction of the pipe and fitting. At that moment, flick the torch away so that the flame wipes toward the pipe. This completes one segment of the joint. Repeat the procedure until all segments are completed. A satisfactory joint shows a continuous ring of filler metal at the end of the fitting. The ring must be smooth and concave.

In the insert method, the filler metal will not leave the recess unless both parts are at the proper bonding temperature. One of the parts may be up to temperature while the other is not. At that point, the filler metal will not flow because it will be cooled or quenched by the surface not yet up to temperature. Play the torch over a 2- or 3-inch section of the fitting. That will cause the fitting to stretch or open up and let whatever remaining flux is present run out. Hold the torch off the work and the fitting will return to normal size and force the filler metal to the edge of the fitting. You may be sure that a good joint is formed when you can see the filler metal at one or both edges of the joined area. Figure 9-9 shows the step-by-step process of brazing by the insert method.

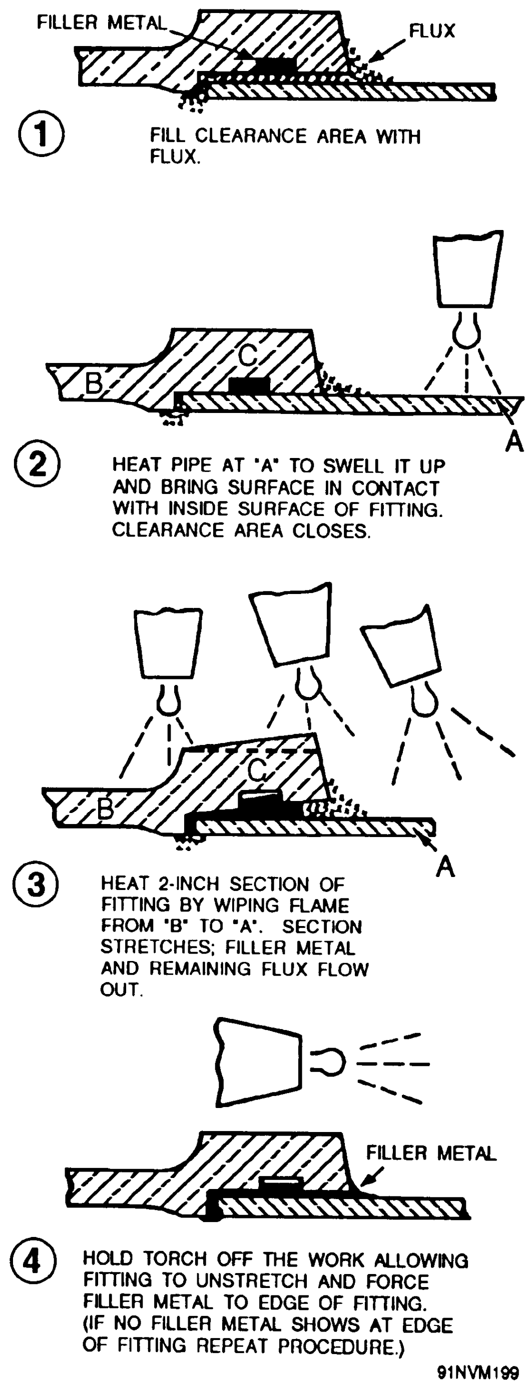


Figure 9-9.—Insert method of silver brazing.

The feed-in method, sometimes called the face-feed method, is accomplished by feeding the filler metal by hand into the area to be joined. Remember that the filler metal always flows along a heated surface from the cooler to the hotter section. In other words, the filler metal flows toward the source of heat or to the point where the heat is being applied. Feed the tiller metal to the outer edge of the joint while you direct heat to the inner edge of the joint. Figure 9-10 illustrates the stepby-step technique for brazing a joint by the feed-in method.

The parts to be joined are cleaned and fluxed in the same manner as in the insert method. When the parts are fitted together, the clearance area is tilled with flux. After aligning the parts, apply heat as previously described. Then apply heat to the fitting or the inner edge of the joint at the same time that the filler metal is fed at the outer edge of the joint. The filler metal will flow toward the hottest section. This means it will flow through the joint toward the point at which heat is being applied. It is left entirely to your judgment to decide when both parts are properly heated and when to feed the filler metal. It is also left to your judgment to decide when enough filler metal has been fed into the joint to completely fill the space between the two parts being joined. Skillful torch manipulation is necessary to apply heat to the proper point to cause the filler metal to flow from the cooler to the hotter section. Filler metal visible at the edge of the joint does not necessarily indicate that the entire joint is filled.

The difference, then, between making a joint by the insert method and by the feed-in method is in procedure. When using the insert method, you heat a section and remove the torch with a wiping motion, which causes the filler metal to flow from the insert. In the feed-in method, after you heat a section, you must direct the flame to the inside edge of the joint while the filler metal is being fed in at the outside edge of the fitting.

After the joint has cooled, clean the joint area with a wire brush and warm water to remove flux, scale, and discoloration. If flux is allowed to remain on the joint area, it will cause corrosion and future failure of the joint. After cooling and prior to performance of pressure or leak testing, completed piping systems should be cleaned and flushed to the extent necessary to ensure satisfactory operation of the system and components in service. Special cleaning, when required, will be according to the specified requirements in the shipbuilding, overhaul, or component specification. Unless otherwise specified, all P-3a special category systems (often referred to as P-3a critical systems) in

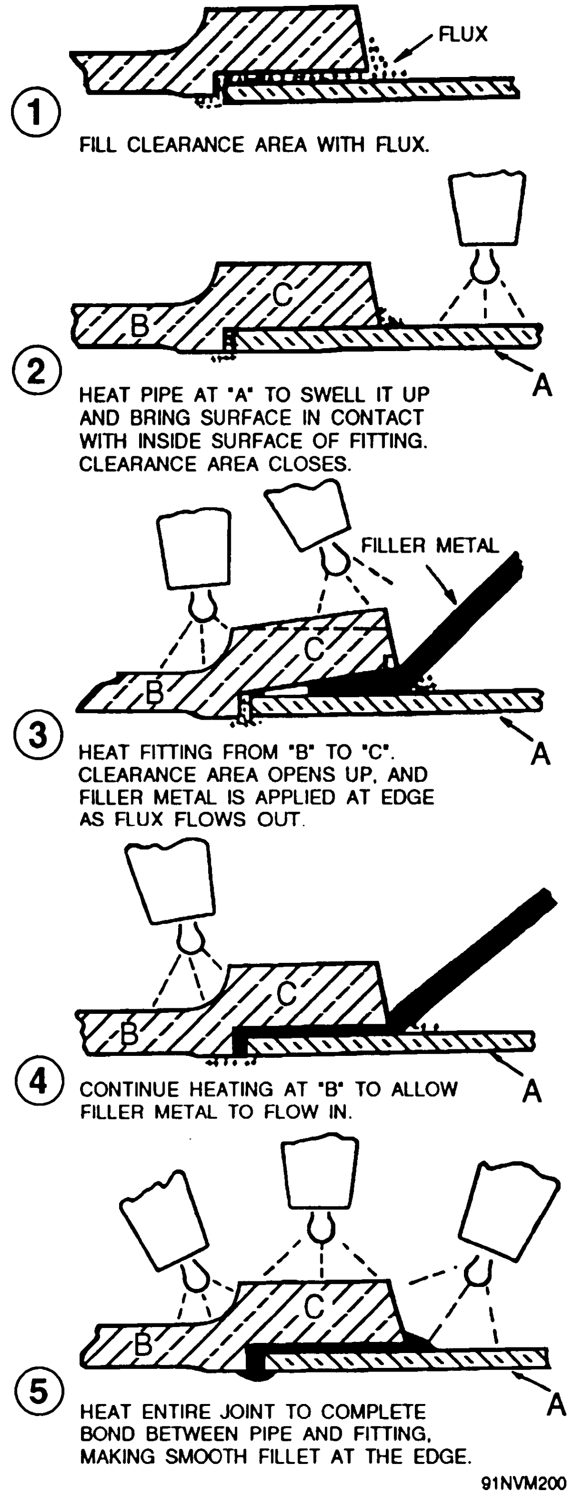


Figure 9-10.—Feed-in method of silver brazing.

submarines, as shown in table 9-5, will be flushed according to one of the following procedures:

—Hot flush with fresh water for 1 hour while ensuring that the temperature at any part of the system does not go below 110°F.

Table 9-5.—Class P-3a Special Brazed Joint Categories

Category	SYSTEMS SERVICE	SUBMARINES	SURFACE SHIPS
A	Steam and Steam Drain Sys	2.375” O.D. and Larger & above 300 psi	2.375” O.D. and Larger & above 300 psi
B	Sea Water Sys Subject to Submergence Pressure	(1)	NA
C	Missile Booster Suppression Sys	NA	1.315” O.D. and Larger
D	Hydraulic Sys	1.660” O.D. and Larger & above 600 psi (2)	2.375 O.D. and Larger & above 600 psi
E	Lube Oil Sys	2.375” O.D. and above	2.375” O.D. and above
F	Flammable or Lethal Fluid Sys (e.g., Gasoline, Cleaning Fluids, JP-5, Fuel Oil, Oil Sys other than Hydraulic, Lube Oil and Freon	0.840” O.D. and Larger (3)	2.375” O.D. and Larger (3)
G	Oxygen Sys	0.840” O.D. and Larger & above 10 psi	2.375” O.D. and Larger & above 10 psi
H	Air Sys (including compressed gases-Nitrogen, Helium, and Fixed CO_2	0.840” O.D. and Larger & above 600 psi (4)	2.375” O.D. and Larger & above 600 psi
I	Other systems where specified by NAVSHIPS	0.840” O.D. and Larger	0.840” O.D. and Larger

Inspection Requirements: (See 7.3.1.)

Ultrasonic inspection is required on all brazed joints of sizes and pressures shown for the various categories in this table except ultrasonic inspection is not required on freon (halocarbon) refrigerant systems.

NA = Not applicable

NOTES TO TABLE 3-1

(1) Joints in systems, 0.840” O.D. and larger, subject internally to sea water at submergence pressure where failure of the joint would result in direct internal flooding within the full and which normally operate at depths in excess of 200 feet.

(2) Joints in the following hydraulic piping having a system design pressure above 600 psi also require ultrasonic inspection.

a. Tubing and piping 0.830” O.D. and larger in supply mains which supply components in more than one compartment, and in the branch supply lines from these mains up to the first isolation valve in the branch.

b. Tubing and piping 0.840” O.D. and larger, failure of which could result in simultaneous loss of normal and emergency modes of control for any steering or diving control service.

c. Piping, 0.840” O.D. and larger, in the emergency sea water valve control system necessary to ensure the integrity of the independent system (this includes all joints from the hydraulic actuator for the sea valve to the isolation valve(s) in the branch line(s) serving the flood control and normal operating station).

(3) Joints excluded from this category include those in segments of piping within their respective tanks, piping passing through tanks which contain identical fluid, and all sounding tubes, air escapes, vents and overflow piping.

(4) This includes low pressure MBT blow piping external to the pressure hull which is designed for external pressure greater than 600 psi.

—Conduct a hot recirculating procedure with fresh water for a period of 1 hour for systems where such an arrangement is feasible. Again the system temperature must be monitored so that no part of the system falls below 110°F. Following the recirculation, flush the system with fresh water for 15 minutes at a minimum temperature of 60°F.

—Cold soak the system for 12 hours using fresh water at a minimum of 60°F. At the completion of the 12-hour soak, flush the systems with fresh water at a minimum of 60°F for 4 hours.

The description of the brazing techniques in the preceding paragraphs apply specifically to joints between tubes and fittings in piping systems. Except for minor differences, the procedure is the same when brazing sheet, strap, or bar stock. Here you probably will use the feed-in method rather than the insert method. Lap joints are used with material less than one-eighth inch thick, while scarfjoints are usually used when the section thickness is greater than oneeighth inch. The following description points out the difference between pipe brazing and seam brazing.

Seam brazing requires some means for holding the parts in position. Short pieces can be clamped or riveted at the ends. Longer pieces are wired to size by using wire clamps. After the parts are wired or clamped in position, place additional flux along the outside of the seam. Then, tack weld both ends of the seam. Make additional tack welds along the seam approximately 8 inches apart. To make a tack weld, direct the flame to both parts of the seam on a spot approximately 6 inches in diameter. As soon as the flux becomes liquid in this spot, direct the flame to the sheet forming the underneath part of the seam. Place a layer of silver brazing filler metal approximately 1 inch long on the edge of the seam. Now direct the flame to the sheet forming the upper part of the seam. This will draw the silver brazing filler metal through the joint, completing the tack weld. When all tacks are completed the seam is ready for brazing.

The seam is brazed in sections 4 or 5 inches in length. Start the braze about 3 inches away from the tack at the edge of the seam. Hold the torch so that the flame is pointed in the direction that brazing is to be done. Direct the flame first along one sheet and then along the other until the flux becomes liquid. When this happens, direct the flame to the sheet forming the underneath part of the seam. At the same time, deposit a layer of filler metal along the edge of the seam. Brazing filler metal is drawn into and through the joint by a wiping motion of the torch, forming the brazed joint in that section. Repeat this procedure continuously along the joint until the entire seam has been completed.

Remember that silver brazing filler metal flows along a sheet in the direction of the hottest point. This point is usually where the torch flame is being applied. Apply heat long enough to draw the filler metal through the seam. Take care to avoid forming beads or globules along the inside edge of the seam.

Repairs to or alterations of a piping system often involve the disassembly of silver-brazed joints. For operations of this kind, use a tip one or two sizes larger than that used for brazing a similar joint. The fitting or tube must be held securely in a fixed position before heat is applied. With the exception of the initial tube-heating phase, the same rotary torch manipulation you used to make the joint is used to break the joint. Cover the joint with flux and use it to gauge the temperature. Add a little new filler metal while heating. When the filler metal flows, pull the parts apart.

Fittings and valves are easily damaged by shock when they are hot. Therefore, handle them carefully.

Piping and fittings removed from a system can be cleaned, resized, and reused if they meet the following inspection criteria (cracked piping and fittings must not be reused):

- Old flux and brazing alloy can be removed to the extent necessary to facilitate a new joint assembly. Do not use hand grinding to prepare the inside diameter of a fitting for reuse. All traces of tightly adherent brazing alloy need not be removed.
- After brazing alloy removal, the fitting must be liquid penetrant inspected or visually inspected at 5X magnification on both the inside and outside diameter surfaces in areas that have been heated to brazing temperatures for cracks.
- The wall thickness of fittings must not be reduced below the allowable minimum.
- Brazing alloy rings may be slightly rounded on the outer comers to fit insert grooves of reused fittings to aid in the assembly of joints.
- With the exception of copper-nickel alloy pipe, pipe may be reused without inspection, unless otherwise specified.
- After sizing copper-nickel alloy pipe intended for reuse, perform a liquid penetrant inspection or visually inspect at 5X magnification the entire

pipe periphery for a length of 2D (nominal) or 2 inches (whichever is less) plus the socket depth.

Reassemble piping and fittings by using the same method you used for new installations. All silver-brazed piping sections that have been removed for repairs, and newly fabricated sections, must be hydrostatically tested before they are installed. Procedures for conducting hydrostatic tests will be discussed in chapter 11.

BRAZE WELDING

Braze welding is used to make a groove, fillet, plug, or slot weld using a copper-base alloy filer metal with a melting point above 800°F but below that of the base metal. The filler metal is not distributed in the joint by capillary attraction. In the past, this process has been called brazing. Earlier in this chapter, we said that all brazing is done by capillary attraction. Braze welds are made without melting the base metal, although some fusion may occur between the filler metal and the base metal. This method is very useful for repairing cast iron and steel.

The fact that braze welds are made without melting the base metal simplifies the welding procedure. Since braze welding requires less heat, the speed of welding is increased.

The lower temperatures required for braze welding mean that preheating is also easier. As a rule, braze welding operations can be done with only local preheating; that is, preheating only that portion of the part to be braze welded. This makes it possible to repair broken castings and other parts in place, thus saving the time and expense of disassembling and reassembling.

Braze welding is widely used to repair gray iron castings. It is used not only to repair broken castings, but also to rebuild worn parts, such as gear teeth or valve disks and seats. You can also repair and rebuild pistons, rotary valves, guides, and other sliding surfaces on pumps, engines, and machinery.

Braze welding should not be used to repair or rebuild castings where the difference in color between the filler metal and cast iron would be objectionable. Nor should it be used to join parts that will be subjected to temperatures above 650°F, or to repair working parts or containers used in chemical processes.

The best filler metal for braze welding is a naval brass that has a copper-zinc ratio of about 60 percent copper and 40 percent zinc. This ratio produces the best combination of high tensile strength and ductility. This filler metal has considerable strength when hot, and it has the narrowest freezing range (solidifies quickest) of the entire usable copper-zinc combinations. This is an additional advantage, since a quick-freezing filler metal has much better weldability than one that remains mushy over a wide temperature range.

Most of the commercial braze welding filler metals are modifications of this 60/40 copper-zinc-zinc alloy, with small additions of tin, iron, nickel, manganese, silicon, and other elements.

Strong braze-welded joints depend on proper preparation, the use of the correct technique, the strength of the filler metal, and coalescence of the filler metal and the base metal. The strength of a braze-welded joint does not depend upon a thin film of filler metal between close fitting surfaces as is true in a silver-brazed joint. Heavy deposits of silver-base filler metals have low strength values. However, heavy deposits of copper-base braze welding filler metals frequently attain strength comparable to welded joints.

Adequate preparation, which includes thorough cleaning, is essential in braze welding. Remove all foreign matter such as oil, grease, and oxides. The metal on the underside and on the top of the joint must be bright and clean. If the parts to be joined or repaired are less than one-fourth inch thick, it is not necessary to vee the edges. Cross sections of base metal one-fourth inch or larger must be beveled to about a 90-degree vee.

Coarse-grained soft castings are harder to tin than close-grained castings. A cast-iron part that has been in contact with fire will sometimes be difficult to tin. The same is true of castings that have been exposed too long to steam and oil at high temperatures. Also, it may be difficult to tin castings that have been in salt water or chemicals for some time. One way to make such pieces easier to tin is to alternately heat and cool the casting. When tinning is difficult, it may be necessary to remove the affected surfaces of the metal so that it will take the filler metal.

When you have cleaned the parts, the next step is to align them. Obviously, the parts must be kept in proper alignment and kept that way during the brazing process. You can do this best by using clamps and by tack welding.

In braze welding, a casting must be heated along the line of the weld. This sets up strains caused by expansion and contraction, unless the casting is properly preheated. In a small casting, up to about a hundred pounds, the heat from the torch is enough to preheat the entire casting. Larger castings should be more thoroughly preheated. This relieves stresses, speeds up the braze welding operation, and requires less oxygen and acetylene.

Preheating can be done with a torch, or with an improvised firebrick furnace covered with insulating-type fire-retardant cloth. At times, castings attached to a machine may be welded in place. These castings often can be preheated if you play the flame along the line of the weld and protect the surrounding surfaces with insulating cloth. Large castings should be postheated to relieve stresses. Flux is essential in braze welding with an oxyacetylene flame for two reasons: (1) it removes oxide that forms ahead of the welding zone due to the oxygen in the air, and (2) it dissolves the oxides formed in the braze welding operation. Use plenty of flux in the tinning operation, but use flux sparingly to fill the vee. When you see that more flux is required, add it carefully. The puddle should not be made mirror clear, but it should be left slightly clouded with oxide. Where the braze welding is rapid, coat the rods entirely with flux. If the operation is slow, as with heavy castings, dip the hot end of the welding rod into the flux and add to the puddle as required.

Use a slightly oxidizing flame for braze welding. Make periodic checks to be sure that this adjustment is maintained. A slightly oxidizing flame makes a better bond between the filler metal and the base metal. It also keeps a slight film of oxide over the puddle. This film protects the weld metal from the oxygen in the air.

After the parts have been properly prepared—cleaned, fluxed, aligned, and preheated if necessary—they should be tack welded together. Heat the metal with a torch at the point where the braze weld is to start. Play the torch flame over the part to be heated, using a circular motion. As the base metal gets hot, test its temperature with a drop of metal from the welding rod. When the base metal is at the right temperature, molten filler metal spreads evenly over the surface. This produces a tinning coat on the base metal.

You can tin the base metal in braze welding only when the conditions are just right for it. If the base metal is too cold, the filler metal will not run out and spread over the heated surface as it should. If the base metal is too hot, the filler metal will form little balls like drops of water on a hot stove. If the temperature of the base metal is right and the tinning is done properly, the molten filler metal will spread over the surface like water spreading over a clean, moist surface. Tinning is the most important step in the braze welding process. This free-flowing film of deposited filler metal forms the intimacy of contact necessary for coalescence between the base metal and the filler metal. When the immediate area under the torch flame is tinned, additional metal is added as necessary to fill the vee. Tinning must, at all times, continuously precede filling the joint.

As the tinning action is in progress, continue to feed the brazing filler metal into the molten puddle to build the weld up to the desired size. The puddle should be small in size, but increased as it is moved forward, until it completely fills the vee and a full-sized braze weld is made. Be sure that the tinning action takes place continuously, just ahead of the puddle. Good braze welding makes one continuous operation of the tinning action and the building up of the braze weld to the desired size.

The inner flame cone is kept from oneeighth to one-fourth inch away from the surface of the metal. Usually the flame is pointed ahead of the completed part of the weld at an angle of about 45°, with the puddle under and slightly behind the flame. You vary the angle, however, when welding in flat, overhead, and vertical positions. Also, the angle will vary with the size of the puddle being carried, the nature of the surface, and the speed of welding. Braze welding can be done in any position, but the flat position should be used if possible.

Bright spots on the metal in the puddle mean that oxides and impurities are present. They should be worked out with the torch flame or with flux. Don’t use too much flux; it is wasteful and prevents making the best joint. Use just enough to get a good tinning action between the filler metal and the base metal. The proper rate of braze welding is controlled by the rate of tinning; never allow the puddle to get ahead of the tinning action.

If it is necessary to deposit filler metal in layers, as when braze welding heavy materials, the tinning of the base metal is particularly important. If the tinning is good and fusion between the layers is complete, a strong braze weld is assured.

After you have finished the braze welding operation, the internal stresses will need to be relieved. To do this, play the torch over the weld and on either side of the weld for several inches. The size of the weld and the size of the casting determine the size of the area that should be heated. Continue to heat until all sections of the part have been brought to even heat. If the repaired part is small, bury it in dry slaked lime. If it is large, cover it with an insulating-type fire-resistant cloth. Always cool the repaired part slowly. The part should be protected from drafts and cold air, which cause uneven cooling. Never subject a braze-welded joint to stress until it has completely cooled.

SURFACING

Surfacing is a process in which a layer of some special ferrous or nonferrous alloy is welded to the surface of new or old parts. The purpose is to increase their resistance to abrasion, impact, corrosion, and erosion, or to obtain other properties. Surfacing is also used to build up undersized or worn parts. In this latter instance, the procedure restores the efficiency of pistons, guides, shafts, and other parts. The filler alloy used for such jobs is the copper-base alloy used for braze welding. In fact, the technique is essentially the same. A word of caution: COPPER-ZINC FILLER METAL SHOULD NOT BE USED IF THE WORKING TEMPERATURE OF THE BUILT-UP SURFACE EXCEEDS 500°F. Steel parts subjected to high stress should be built up or resurfaced only once. Cast iron and copper-base alloys may be resurfaced as often as necessary.

Figure 9-11 shows the principal steps used to build up a worn steel piston with copper-base alloy. For this kind of job, Machinery Repairmen will cut the grooves and machine the finished job to size. Your job is to apply the surfacing alloy.

Weld the rough-turned grooves first. Then, build up the surface with one, two, or three layers of bronze as required by the finished dimensions. When built-up repairs are made on cylindrical objects, the work should be set up to allow the surfacing operation to progress up a slight incline of about 30°. When building up a thick surface, it's a good idea to do the job in several passes. On the first pass, concentrate on tinning. On the following passes, concentrate on good fusion between the layers of surfacing alloy. Use flux sparingly after the tinning pass or you'll wind up with a porous weld. The two most important safety precautions in repair welding operations are as follows:

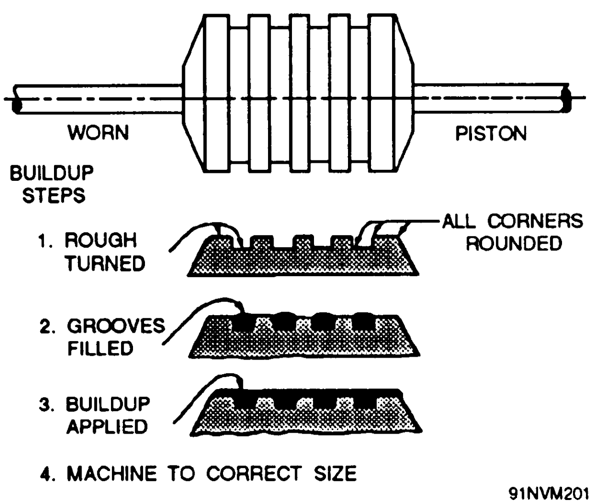


Figure 9-11.—Surfacing a steel piston.

1. CORED OR OTHERWISE ENCLOSED SPACES MUST BE VENTED. If not vented, they will vent themselves in a drastic manner—by exploding. Play safe by removing vent plugs or by drilling small holes through which expanding gases may escape when the part is heated.

2. DON'T BREATHE ZINC FUMES. Provide plenty of ventilation and wear a respirator when you're working with brasses and bronzes, because they contain up to 45 percent zinc.

A surfacing operation using a copper-base alloy filler metal produces a relatively soft surface. Use other types of alloys to produce a surface that is corrosion- and wear-resistant at relatively high temperatures. Two examples are facings for valve seats and disks used in high-pressure steam lines.

While many rods and electrodes are manufactured, only a few meet Navy specifications. Be sure your filler alloys are approved by the Naval Sea Systems Command for the work you are doing.

Three types of hard-surfacing materials are generally used in the Navy. They are chromium-cobalt, tungsten carbide, and iron-base alloys containing manganese, chromium, carbon, nickel, and other hardening elements. Of these, the chromium-cobalt (MIL-R-17131) alloy is probably the most important. It is used to repair disks and seats of high-pressure steam system valves. At present, no electrodes meet the Naval Sea Systems Command specification for this purpose. Noncritical surfacing operations, that is, disks and seats of valves manufactured from material other than carbon-molybdenum or chromium-molybdenum steels, need different materials. A MIL-E-19141 electrode or a 46R3C oxyacetylene welding rod may be used if a hard surface is required. For critical carbon or chrome-moly steel surfacing jobs, use a chromium-cobalt rod applied with the oxyacetylene flame.

Chromium-cobalt surfacing filler metal is an alloy of about 60 percent cobalt, 30 percent chromium, 5 percent tungsten, and 5 percent other alloys, including molybdenum and traces of iron. At room temperature this alloy is about as hard as ferrous tool steels. However, chromium-cobalt has the property to retain its hardness at high temperatures. With the exception of high-speed tool steels, common ferrous alloys do not have this characteristic.

Surfacing alloys are usually applied so that the material forms a thin layer over the base metal to which it is applied. The thickness of the deposit is usually from one-sixteenth to one-eighth inch, is seldom over one-fourth inch, and is generally deposited in a single pass. Cleanliness is just as important for surfacing as it is for braze welding. Scale, rust, and foreign matter must be removed before surfacing to prevent the formation of blow holes. If the surface of the base metal is clean and properly prepared, then these three points are important for a good hard-surfacing job using chromiumcobalt ahoy: (1) flame adjustment, (2) base metal surface appearance at the time the ahoy is applied, and (3) surfacing ahoy application to the base metal.

When you are surfacing with chromium-cobalt, use an oxyacetylene flame with an excess acetylene feather about three times as long as the inner cone. Your success depends upon the flame adjustment and the condition of the base metal surface when the surfacing ahoy is applied. Unless the excess acetylene flame is used, you cannot develop the proper base metal surface condition, and the surfacing ahoy will not spread over the surface of the part.

The torch manipulation used and the surfacing procedure itself are similar to those used in braze welding. However, you need higher temperatures (about 2,200°F) and tips one size larger than normal. The heating phase of the surfacing operation is as follows: With a sweeping motion of the torch, heat a small area of the base metal until the surface takes on a sweating appearance. Then, bring the end of the surfacing ahoy into the flame and allow it to melt. Do not stir or puddle the ahoy; let it flow. If the surface area has been properly sweated, the ahoy will flow freely over the surface of the base metal.

Good surfacing requires that you are able to recognize a sweated surface. This sweating occurs when the temperature of steel is raised to a white heat with a carburizing flame. An extremely thin layer of the base metal is carburized. The carburized layer has a lower melting point than the rest of the base metal. As a result, it becomes a liquid while the underlying metal remains a solid. This liquid film provides the medium for flowing the filler metal over the surface of the base metal. The liquid film is similar to, and serves the same purpose as, a tinned surface in soldering and braze welding. The carburized layer is approximately 0.001 inch thick.

The surfacing ahoy is added to the carburized layer at this time. It flows over the sweated surface and absorbs the film of carburized metal. It is easy to see this surface condition, but you should make several practice passes before you try to surface a valve disk or seat for the first time. Perfect the technique on scrap metal before you try it on critical metal. A typical stepby-step application of chromium-cobalt surfacing is illustrated in figure 9-12.

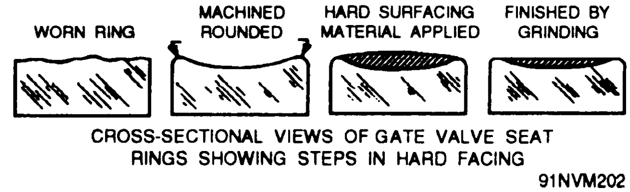


Figure 9-12.—Surfacing a valve seat ring.

Tungsten-carbide is another surfacing material that is applied with the oxyacetylene flame. This material is used to build up wear-resistant surfaces on steel parts that must withstand severe abrasion. It is used for such noncritical applications as aircraft tailskids and earth- and rock-moving equipment. The melting point of this material is so high that it cannot be applied by gaseous flame melting procedures. It is applied either in the form of inserts, which are welded or brazed to the base metal, or through the use of composite cast rod in which tungsten-carbide particles are evenly distributed. When this latter material is used, the surfacing technique is the same as that used for oxyacetylene welding with a slightly carburizing flame adjustment.

Iron-base surfacing alloys are used for a number of applications requiring various degrees of hardness. They can be applied by using either oxyacetylene or electric arc welding. Hard-surface deposits are so hard they cannot be filed or machined. They must be ground to size and shape. Because of their extreme hardness, they should be built up only slightly larger than the exact size, to eliminate unnecessary grinding.

Figure 9-13 shows the method used to make lathe and shaper tools by applying a surfacing ahoy. Other uses for surfacing material aboard ship are lathe centers, shear blades, and similar tools. When you prepare any

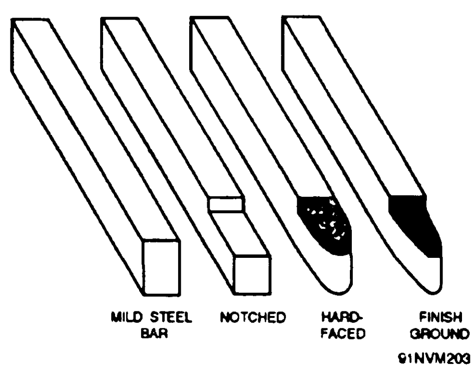


Figure 9-13.—Surfacing a lathe cutting tool.

of these jobs for surfacing, be sure that the edges of grooves, comers, or recesses are well rounded to prevent overheating of the base metal.

Hard surfacing may be applied to all low-carbon ahoy and stainless steels as well as to Monel and cast iron. It is not intended for aluminum, copper, brass, or bronze. Tool steels can also be surfaced, but they offer difficulties caused by shrinkage and strain cracks. If tool steels are surfaced, they should be in an annealed, not a hardened, condition. If necessary, heat treating and hardening can be done after the surfacing operation.

Surfacing with special alloys is not done as often as brazing or braze welding. But when the technique is used, it must be done perfectly, especially when chromium-cobalt ahoy is applied to carbon or chrome-moly valve parts for high-pressure, high-temperature piping systems. On the whole, the silver brazing, braze welding, and surfacing processes are important among the welding procedures you will use in the welding shop.

POWDERED METAL FLAME PROCESS

Another welding process being used throughout the Navy is the eutalloy process, which is most commonly called the powdered metal flame spray process. This process was developed by the Eutectic Corporation, formerly the Eutectic Welding Alloys Corporation.

The powdered metal flame spray process can, and should, be used alone for certain applications, but it is not necessarily a separate, isolated technique. It combines with, and works to supplement, conventional oxyacetylene and electric arc welding, if overlays and joining metals cannot be done by either of the two other processes. It is very useful where the control of the shape and thickness of the deposit helps reduce machining time. This process is used for the repair of both small and large parts. It is also used for surfacing parts that are subject to abrasion, friction, and corrosion.

The powdered metal flame spray process uses the low heat input principle. Control of the surface temperature enables the powder to surface bond in the shortest time. This eliminates unnecessary saturation of the base metal with needless heat. Such overheating does nothing to promote bonding, and usually results in distortion and stresses in the base metal.

The main elements of the powdered metal flame spray process are a unique gas torch with special features for feeding powders and a group of powdered metal alloys developed especially for this process. These powders are packaged in moistureproof bellows modules to prevent contamination.

ADVANTAGES OF THE POWDERED METAL FLAME SPRAY PROCESS

This process offers many advantages over the conventional oxyacetylene and metal arc welding processes. Absolute control of the thickness, width, and deposition of the deposit can be attained by regulating the amount of ahoy released, the rate of travel, and the path of the torch. Deposits can be placed with pinpoint precision because only the torch tip is used rather than a tip and filler rod, or electrode holder and electrode. This is especially true when it is used in confined and hard-to-get-at spaces.

Powdered metal deposits are surface alloyed to the base metal. They do not dig into the base metal and set up fracture zones. There is also little or no problem with underbead cracking. Deposit dilution, caused by base metal pickup, is held to a minimum because of surface alloying.

The powdered metal flame spray process also has advantages over the metal spray process. Although fusion sometimes occurs when the metal spray process is used, the deposits have, essentially, a mechanical bond. On the other hand, powdered metal deposits actually surface ahoy to the base metal and, as a result, give a higher strength bond. Since the fuel gases propel the alloy to the base metal surface, there is no compressed air equipment that might offer additional complications. Deposits made by the powdered metal flame spray process also have greater density than those made by the metal spray process. When you prepare the base metal, you need to ensure only that the surface is free of all dirt and grease. No time-consuming knurling and roughing of the surface is necessary, as is required with the metal spray.

TORCHES

The torches used in the powdered metal flame spray process are precision instruments, manufactured to very close tolerances. They have very few moving parts and require only routine cleaning and maintenance. These torches are designed specifically for this process. They should not be used for other gas welding applications.

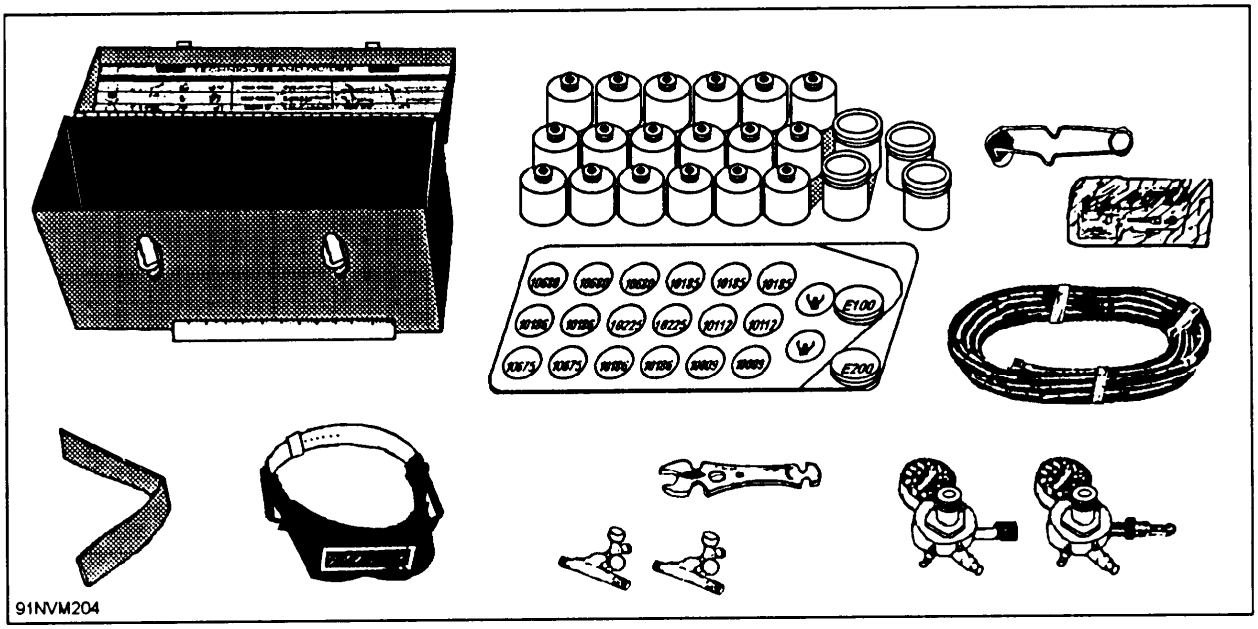


Figure 9-14.—Powdered metal torch and accessories.

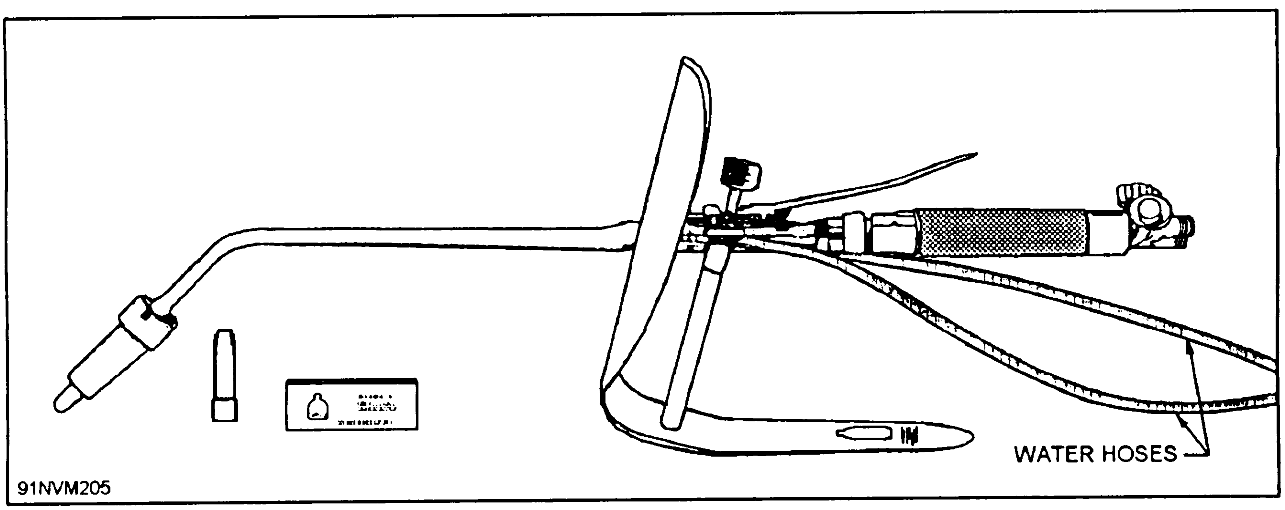


Figure 9-15.—Powdered metal torch with a water-cooled tip.

The torch shown in figure 9-14 is used to overlay and join metals where there is no danger of the torch tip overheating from reflected heat. The nucleus of the torch is a precision forged chamber that contains the vacuum mixer and the control valve. Internal design prevents hazardous detonation and assures positive control over the powder flow. This torch is supplied with three welding tips to help you weld a variety of thicknesses of metals.

The torch shown in figure 9-15 is similar to the torch in figure 9-14, but it has the added feature of a water-cooled tip. This torch was designed especially for overlaying surfaces in areas where there would be danger of overheating the tip. Overheating of the torch

Table 9-6.—Powdered Metal Alloys and Some of Their Uses

Powdered Metal Ahoy		General Uses
BOROTEC 10009	Hardness: RC 55-62	Abrasion-resistant nickel-base ahoy for steel, stainless, nickel-base alloys and cast irons. Corrosion resistant. Good hardness at high temperature. Low coefficient of friction. Nonmachinable.
GRITALLOY 10011	Tungsten carbide	Ahoy for a thin, rough surface that will abrade, grip, or resist. Uniformly distributed tungsten carbide grit firmly anchored in a hard, corrosion-, and heat-resistant nickel-base matric. Nonmachinable.
COBALTEC 10091	Hardness: RC 46-52	Cobalt-base ahoy overlay for steel, stainless, cast iron, and nickel alloys. Corrosion and abrasion resistant. Holds hardness at high heat. Low coefficient of friction.
TUNGTEC 10112	Hardness: RC 57-64	Severe abrasion-resistant ahoy overlay for steel, stainless steel, cast iron, and nickel alloys. Tungsten carbide particles held in a nickel-base matrix. Nonmachinable.
BRONZOTEC 10146	Tensile Strength: 65,000 psi	High-strength, machinable ahoy for joining steels, copper, and high-melting copper alloys. Copper-base ahoy deposits offer good corrosion resistance and electrical conductivity. For fillet forming and poor fit-up.
CUPROTEC 10180	Tensile Strength: 42,000 psi	High-strength, joining ahoy for copper and copper alloys. Copper-base ahoy with good corrosion resistance and excellent electrical conductivity in joints of proper clearance.
BRONZOCHROM 10185	Hardness: RC 36-42	Abrasion-, corrosion-, and heat-resistant nickel-base ahoy overlay for steel, nickel alloys, cast iron, and stainless. Crack-resistant deposits, for both overlaying and joining, are machinable.
STAINTEC 10670	Tensile Strength: 70,000 psi Hardness: RC 80-90	High-strength, corrosion-resistant nickel-base ahoy for joining or cladding steels, stainless, cast irons, and nickel alloys. Excellent machinability.

tip will cause the torch to backfire; the weld deposit will be blown away, and the torch tip may be damaged. Cooling water is circulated around the tip of the torch, preventing reflected heat from affecting it. This torch is often used to surface valve seats where the seat cannot be removed from the valve body.

POWDERED METALS

Powdered metals are available to cover a wide variety of applications. Table 9-6 contains some of the different powders developed by the Eutectic Welding Alloys Corporation. The ahoy chemistry and particle size of each powder assures complete metal-melt during passage across the torch flame. It also makes certain of the optimum bonding and wetting of the deposit with the surface of the workpiece.

These powders are contained in a bellows module that locks directly into the torch. The unique bellows action helps the flow of the powder through the torch. The modules are capped when not in use to prevent contamination from moisture or foreign matter.

SETTING UP THE POWDERED METAL TORCH

When you assemble the powdered metal torch, hand tighten the large threaded nut on the mixing chamber onto the torch body. (Synthetic O-rings are used to ensure sealing of the seats; a wrench is not required for tightening.) The double O-ring seats must be properly seated for the torch to perform satisfactorily. The O-rings or seats should be replaced if they are damaged through wear or misuse. Next, thread on the tip assembly and tighten it wrenchtight. The tip should point downward for normal flat work. Remove the closure from the bellows module, invert the torch, and insert the module into the connective junction at the top of the valve assembly. To do this, you will need to align the lugs on the module with the openings in the junction. Next, seat the module by turning it 90° clockwise; take care that the connective junction on the torch is clean and free of all foreign matter.

CAUTION: Do not turn the module beyond 90°, as improper seating may occur. Connect the torch body to oxyacetylene hoses which have standard 1/4-inch fittings.

The gas pressures used with the powdered metal torch will vary according to the size of tip being used. When using the larger tips, set the oxygen regulator pressure from 25 to 30 psi and the acetylene regulator pressure from 4 to 5 psi. When using the small tip, set the oxygen regulator pressure from 15 to 18 psi and the acetylene regulator pressure from 2 to 3 psi. When all connections have been properly made and the appropriate gas pressures set, the powdered metal torch is ready for operation.

OPERATING PROCEDURES

The powdered metal torch is lit in the same manner as an oxyacetylene torch. Open the acetylene valve and ignite the gas. Then, open the oxygen valve and adjust the flame to suit the work. A neutral flame is generally best. In the event that you experience difficulty in maintaining the flame, adjust both the needle valves and the regulators until the right combination is reached. The smaller tip should be used for small flames. (Cutting back the gases will choke the flame and cause the tip to overheat.)

After adjusting the flame for the alloy being used, preheat the base metal, keeping the torch in constant motion. The method and amount of preheat are determined by the type of work. When color begins to show in the base metal, concentrate the flame at the starting area until a dull red color (for steels) is reached. At this point, slowly depress the lever and observe the passage of powder through the flame.

The torch is best operated with the lever fully depressed, but you should experiment with the lever to achieve proper powder supply. Powder supply depends upon base metal temperature. The powder may be applied and fused simultaneously or it may be sprayed to the work surface and then fused (wetted-out). Whether you spray and fuse simultaneously or fuse after spraying, do not travel forward with the torch, leaving unfused powder behind.

Once sufficient base metal temperature is reached, you should usually make the balance of the deposit with the torch lever in the fully depressed position. However, you may experiment with the position of the lever to ensure continuous operation. If necessary, you can adjust either the needle valves or the regulators to get better operating conditions. When making powdered metal deposits, a slight weaving motion is generally your best technique. The exact area and shape of the surface where the deposit is being made will determine the extent of the weaving motion. To ensure proper fusion at the end of the beads, shut off the powder supply by releasing the lever, and fill the final crater by using previously deposited powder.

The actual distance between the torch tip and the work surface will vary depending upon the type of work and the operator of the torch. Usually, this distance will vary from one-fourth to three-fourths inch. In some joining applications, it may be best to hold the gap more than three-fourths inch, depending upon joint design and base metal thickness.

When you apply powdered metal to flat surfaces, hold the tip vertical to the work, and keep the bellows module as near perpendicular as possible. You can rotate the tip assembly a full 360° to help you apply powder in the vertical, horizontal, and overhead positions, and the module will still be maintained in a near perpendicular position. The thickness of the deposits will depend on any or all of these five factors:

- Size of tip
- Quantity of powder fed into the flame
- Speed of torch over work (slower speeds are used for greater buildups)
- Temperature of base metal
- Rate of (continuous or intermittent) power fed into the flame

POWDERED METAL APPLICATION

When you apply powdered metals, preparation of the base metal is very important. The surface to be overlayed should be free of all rust, oxides, or grease and oil. The surface may be machined, filed, or cleaned with emery cloth to ensure that it is clean.

Figures 9-16 through 9-21 show repairs being made to an output shaft using the powdered metal torch. The assembled output shaft unit is chucked up in a lathe as true as possible. The thinnest possible machine-cut is then made to remove the plating in the scored seal area only (fig. 9-16). All grease, contaminants, and other foreign matter have been removed with a good solvent. A finished preparation lathe-cut of the scored area is then made (fig. 9-17). The unit is then removed from the lathe and the spline section is separated. The part is now ready for the powdered metal overlay deposit.

The hollow shaft is slipped over a suitable mandrel or other similar device for hand turning (fig. 9-18). The best position of the shaft is horizontal, but the deposit can also be made with the shaft in the vertical position.

The oxygen and acetylene pressures used should be those recommended by the manufacturer for the tip you are using. Use a neutral flame with a slight feather so that when the powder feed lever is depressed a true neutral flame is formed. Keep a minimum distance of one-fourth inch between the flame cone and the work.

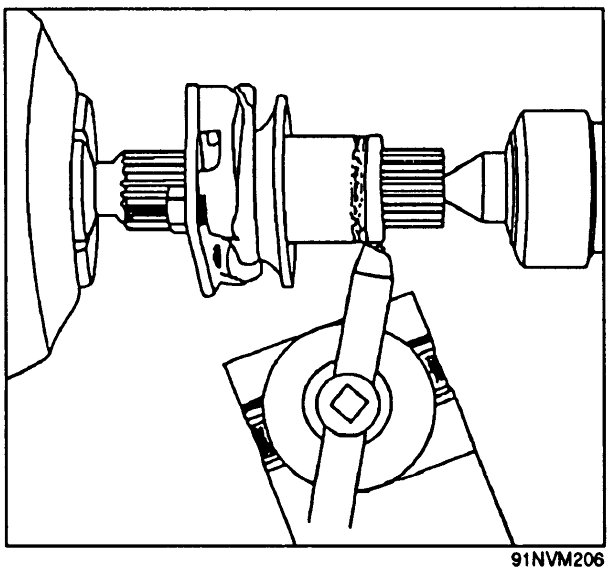


Figure 9-16.—Removing plating from the scored area of an output shaft.

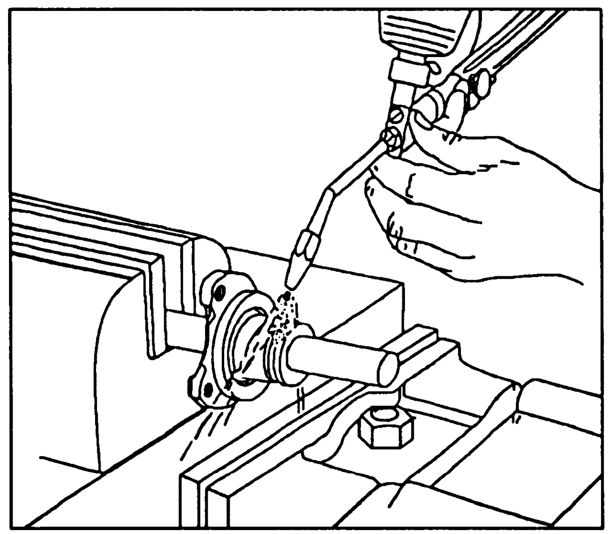


Figure 9-18.—Making a powdered metal overlay deposit.

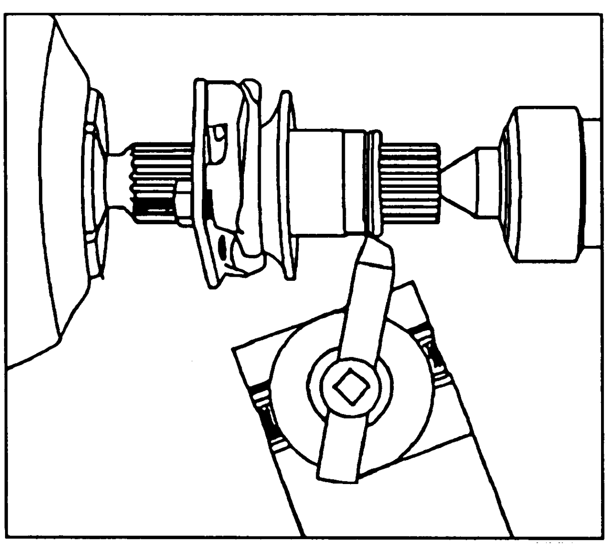


Figure 9-17.—Final lathe-cut being made prior to making an overlay deposit.

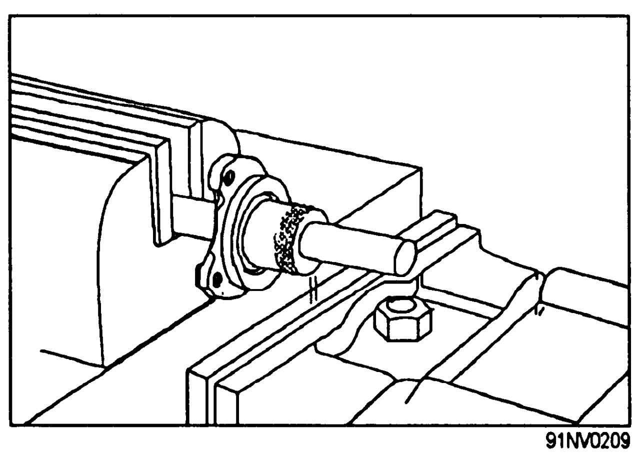


Figure 9-19.—Completed overlay deposit cooling prior to machining.

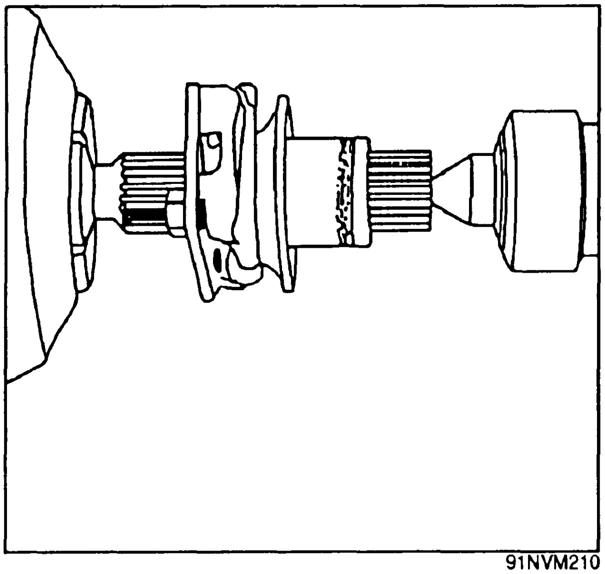


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Figure 9-20.—Machining the overlayed section of an output shaft to its original dimensions.

That way you will not obstruct the flow of the alloy powder or overheat the oxidation of the base metal. When you reach the proper preheat, depress the powder feed lever to apply and fuse the powdered metal simultaneously. Use gloves or pliers when you turn or move the hot part.

Figure 9-19 shows the completed overlay being cooled before it is machined. This deposit was made with Bronzochrom 10185 and has a Rockwell “C” scale hardness of 36. The finished deposit will work harden in service. You can get a harder grind finish and specific corrosion- and wear-resistant characteristics by using Cobaltec 10091 or Borotec 10009. Follow the same procedure regardless of the alloy powder used. After the overlayed part has cooled, reassemble it to the spline and chuck it up in the lathe for machine cutting or grinding (fig. 9-20). Clean all overspray areas by wirebrushing with a stainless steel brush.

Figure 9-21 shows the completed repairs and the output shaft assembled and ready for reuse. Consider factors such as corrosive media, wear patterns, base metal, and desired hardness before you select the powdered metal alloy. The repairs made to this output shaft and similar repairs makes it unnecessary to have to premachine for an undersize shaft, silver braze a collar sleeve on the shaft, and remachine to the required dimensions. The parts will last longer than the original or new replacement parts, saving time, material, and money.

PRECAUTIONS

To improve safety and to ensure proper operation and care of the powdered metal torch, you should take the following precautions:

- Be sure all connections are tight. The connection between the torch body and the mixing chamber has neoprene scats. These should be tightened only by hand.
- Keep the tip orifice clean and unclogged at all times.
- Use tip cleaners as often as necessary for proper flame adjustment and powder passage.

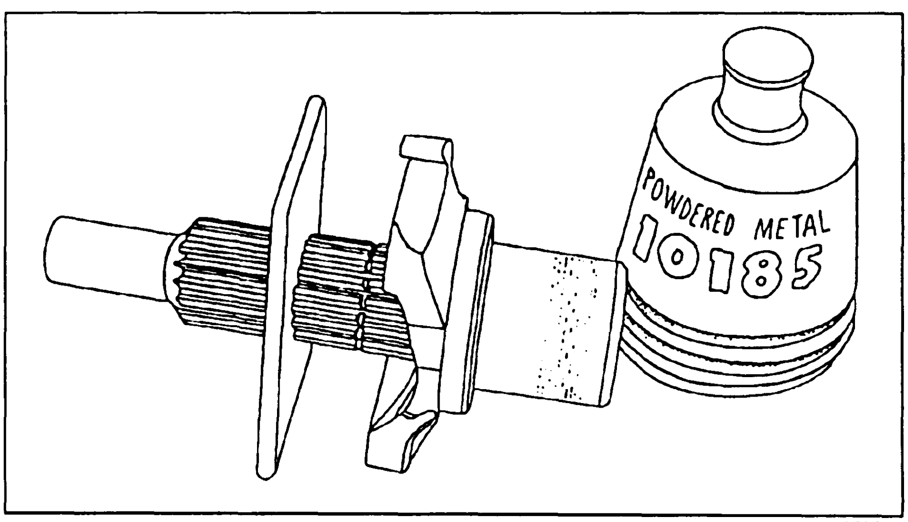

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Figure 9-21.—Repaired output shaft unit reassembled.

- Never rub the tips against a fire brick to remove clogged powder.
- Do not drill the tip orifice to a different size.
- When changing from one type of powder to another, be sure the torch is free of all previously used powders.
- Be sure the powdered metal module is properly seated (90-degree turn only) and the connective junction is free of all foreign matter.
- Observe all standard safety precautions for handling and using oxyacetylene equipment.
- Handle all maintenance and repairs according to the manufacturer's instructions.

SOLDERING

Soldering is used to join iron, nickel, lead, tin, copper, zinc, aluminum, and many alloys. Soldering is a simple, fast, and effective joining process. It is particularly useful for securing electrical connections, joining sheet metal, and sealing seams against leakage. Soldered joints are not as strong as welded joints, and should not be used where any great mechanical strength is required. Soft solders always have melting points below 800°F and below the melting points of the metals to be joined.

SOLDERING EQUIPMENT

Soldering requires only a small amount of equipment. For most soldering jobs, you will need only a source of heat, irons, solder, and a flux. The sources of heat vary according to the method used and the equipment that is available. Welding torches, furnaces, and other heating devices may be used. In most cases, the heating devices are used to heat soldering irons, which are then used to heat the surfaces and thus to melt the solder. However, the heating devices are sometimes used for the direct heating of the surfaces to be joined. In this case also, the solder is melted by the heated surfaces.

If you use a welding torch as a source of heat for soldering, use it carefully. A welding torch gives out much more heat than is actually required for soldering. If you overheat the soldering coppers, you will have to retin them and perhaps reforge them. Excessive heat also may damage or warp the metal that is being joined and may cause deterioration of the solder.

Soldering Gun

The soldering gun (fig. 9-22) operates from any standard 115-volt outlet and is rated in size by the number of watts it consumes. The guns used in the Navy are rated between 100 and 250 watts. All good quality soldering guns operate in a temperature range of 500° to 600°F. The important difference in gun sizes is not the temperature. Instead, it is the capacity of the gun to generate and maintain a satisfactory soldering temperature while giving up heat to the joint soldered. The tip heats only when the trigger is depressed, and then very rapidly. These guns afford easy access to cramped quarters, because of their small tip. Most soldering guns have a small light that is focused on the tip working area.

The tip of a soldering gun should be removed occasionally to clean away the oxide scale that forms between the tip and the metal housing. This increases the heating efficiency of the gun. If the tip does get damaged, replace it.

A Hull Maintenance Technician seldom works on electronic equipment. Still, you should remember never to use a soldering gun on solid-state equipment. The strong electromagnetic field surrounding the tip can cause serious damage to solid-state components.

Soldering Irons

There are two general types of soldering irons in use by the Navy. One is electrically heated and the other is nonelectrically (externally) heated.

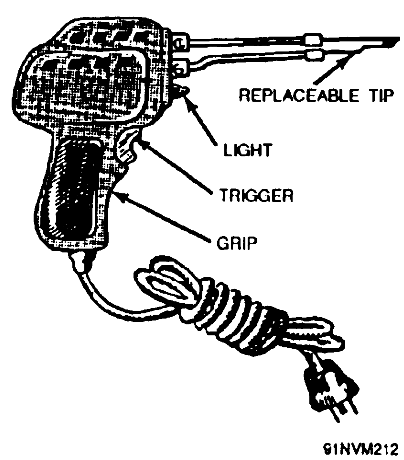


Figure 9-22.—Electric soldering gun.

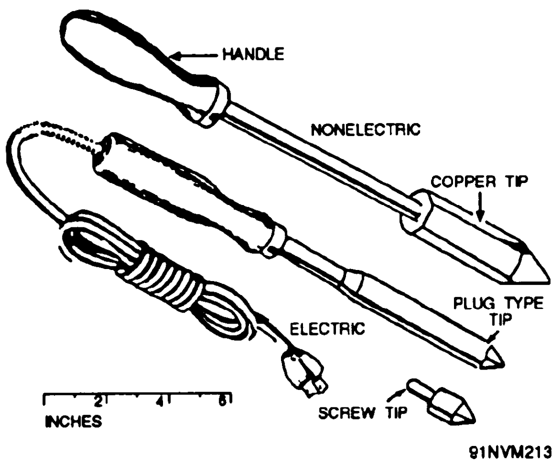


Figure 9-23.—Soldering irons

A nonelectric soldering iron (fig. 9-23) is sized according to its weight. The commonly used sizes are the 1/4-, 1/2-, 3/4-, 1-, 1 1/2-, 2-, and 2 1/2-pound irons. The 3-, 4, and 5-pound sizes are not used in ordinary work Nonelectric irons must be heated over a gas flame.

The electric soldering iron (fig. 9-23) transmits heat to the copper bit after the heat is produced by an electric current that flows through a self-contained coil of resistance wire; this coil is called the heating element. Electric soldering irons are rated according to the number of watts they consume when operated at the voltage stamped on the iron, and the diameter of the copper bit in inches (table 9-7).

There are two types of bits on electric irons. They are plug bits that slip into the heater head and that are held in place by a setscrew, and screw bits that are threaded and that screw into or onto the heater head. Some bits are offset and have a 90-degree angle for soldering joints that are difficult to reach.

Electric iron bits must be securely fastened in the heater unit. The bits must be clean and free of copper oxide. Sometimes the shaft oxidizes and causes the bit to stick in place. Remove the bit occasionally and scrape off the scale. If the shaft is clean, the bit will receive more heat from the heater element, and it will be easier to remove when you need to replace the bit.

Table 9-7.—Selection of Soldering Iron for Work to be Done by Copper Bit Size

Work to be done	Electrically Heated Irons		Externally Heated Irons
	Choice of Bit Dia.	Heat Rating Watts	Size of Bit, lb.
Very light soldering.	1/4 to 7/16	44-52	1/2
Medium soldering of electrical appliances and light manufacturing.	3/8 to 1/2	60-70	1
Fast soldering on radios, electrical appliances, and light medium manufacturing.	3/8 to 9/16	85-100	1-1/2
Medium light soldering on tin ware, plumbing, and wiring.	5/8 to 7/8	130-150	2
High-speed soldering of light tin ware and small metal patterns.	5/8 to 1	170-200	2-1/2
Medium manufacturing such as ventilation ducts and other shipboard repairs.	7/8 to 1-318	225-250	3
Heavy tin ware, metal patterns, galvanized iron and copper.	1-1/8 to 1-3/8	300-350	4
Heavy ventilation ducts, tanks, plumbing, and ship building.	1-3/8 to 1-7/8	350-650	5

Filing and Tinning Copper Bits

New copper bits must be tinned (coated with solder) before they are used. Also, bits must be filed and retinned whenever they have been overheated or have lost their coating of solder. The procedure for filing and tinning a bit is as follows:

1. Heat the bit to a cherry red.

2. Clamp the bit in a vise, as shown in figure 9-24.

3. File the bit with a single-cut bastard file. Rear down on the forward stroke, and release pressure on the return stroke. Do not rock the file. Continue filing the tapered sides of the bit until they are bright and smooth.

CAUTION: Remember that the bit is hot! Do not touch it with your bare hands.

4. Smooth off the point of the bit and smooth off any sharp edges.

5. Reheat the bit so that it will be hot enough to melt the solder.

6. Rub each filed side of the bit back and forth across a cake of sal ammoniac, as shown in figure 9-25.

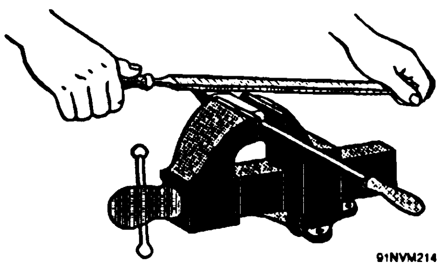


Figure 9-24.—Filing a soldering copper.

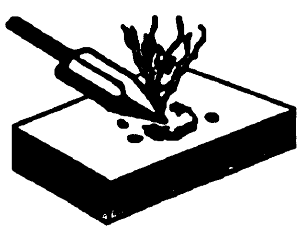


Figure 9-25.—Tinning a copper (solder placed on a cake of sal ammoniac).

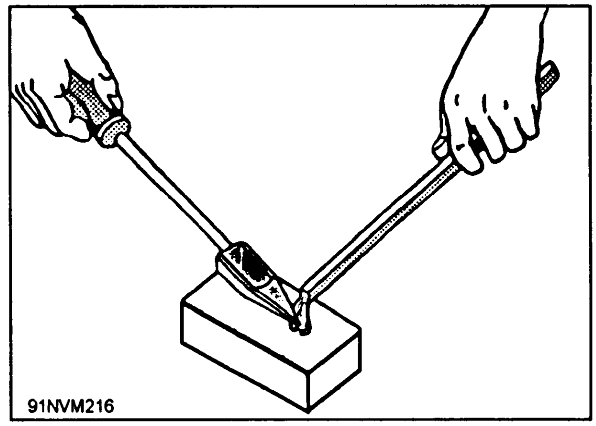


Figure 9-26.—Tinning a copper (solder placed directly on copper).

7. Apply solder to the bit until it is tinned. The solder may be rubbed directly on the bit or it may be placed on the cake of sal ammoniac.

If sal ammoniac is not available, use rosin. Dip the filed bit into a container of rosin, then apply the solder as shown in figure 9-26.

Commercially prepared soldering salts may also be used to tin soldering bits. These salts are available in powder form. Dissolve the powder in water to make a solution, following the directions that accompany the material. Dip the soldering bit into the solution, and then apply the solder.

Cleaning Soldering Bits

Soldering bits should be cleaned just before they are used. Sal ammoniac is usually used for this purpose. Rub the copper on a cake of sal ammoniac or dip it into a container of powdered sal ammoniac. Wipe it clean with a cloth to remove all grams of sal ammoniac. Another way to clean soldering bits is to dip the bit in a solution made by dissolving a small amount of sal ammoniac in water.

SOLDERS

Most soft solders are alloys of tin and lead. Occasionally, antimony, silver, arsenic, or bismuth are added to give special properties to the solders. Solders used for joining aluminum are usually alloys of tin and zinc or of tin and cadmium. As mentioned before, soft solders have melting points below 800°F and below the

Table 9-8.—Tin-lead Melting Points

TIN-LEAD MELTING POINTS	
Composition (percent)	Melting Point (° F)
10/90	573
20/80	533
30/70	496
40/60	460
50/50	418
60/40	374
70/30	376
80/20	396
90/10	421

Table 9-9.—Fluxes Used for Soldering Some Common Metals

FLUX	METAL SOLDERED
Muriatic Acid (raw acid)	Galvanized Iron Dull Brass Dull Copper
Zinc Chloride (cut acid)	Black Iron Copper Brass Iron Zinc Monel Tarnished Tin Plate
Rosin	Tin Plate Lead Bright Copper Terne Plate
Phosphoric Acid	Stainless Steel

melting points of the metals being joined. Table 9-8 shows the melting points of most tin-lead solders.

Tin-lead solders are usually identified by numbers, which indicate the percentage of tin and the percentage of lead. The first number gives the percentage of tin, the second gives the percentage of lead. For example, a 30/70 solder is an alloy of 30 percent tin and 70 percent lead. Solders containing a high percentage of tin are more expensive than those containing a high percentage of lead. In general, the solders that contain a high percentage of tin have lower melting points than those that contain a high percentage of lead. Solders are available in bars, wires, ingots, and powders. Wire solder is available with or without a flux core.

FLUXES

To make a satisfactory joint, you must be sure that the metal to be joined and the solder are free of dirt, grease, oxides, and other foreign matter that would keep the solder from adhering to the metal. Fluxes are used to clean the joint area, to remove the oxide film that is normally present on any metal, and to prevent further oxidation. Fluxes also decrease the surface tension of the solder and thus make the solder a better wetting agent. Table 9-9 shows the fluxes that are generally used with some common metals.

Fluxes are generally classified as corrosive, mildly corrosive, and noncorrosive. Corrosive fluxes have the best cleaning action. However, any trace of corrosive flux that remains on the work will cause corrosion of the metal. Therefore, corrosive fluxes are not used for soldering electrical connections, for other work in which thorough cleaning is not possible, or where corrosion would cause a serious problem.

The most commonly used corrosive fluxes are sal ammoniac (ammonium chloride) and zinc chloride. The fluxes are frequently used in solution or in paste form. The solvent evaporates as the work is heated, leaving a layer of solid flux on the work. At the soldering temperature, this layer of flux melts and partially decomposes, releasing hydrochloric acid. The hydrochloric acid dissolves the oxides from the surface of the work and from the solder.

Zinc chloride (sometimes called cut acid or killed acid) should be made up in small amounts, as required for use. To prepare zinc chloride, pour a small amount of muriatic acid (the commercial form of hydrochloric acid) into a container. Then, add pieces of zinc to the muriatic acid until the liquid no longer boils and bubbles when the zinc is added. The zinc and the acid enter into a chemical reaction that produces zinc chloride and hydrogen gas. When the liquid no longer boils and bubbles, the reaction is complete and the liquid in the container is no longer muriatic acid. Instead, it is a solution of zinc chloride in water.

Strain the zinc chloride solution before using it as a flux. Any solution that is not used immediately should be stored in a tightly sealed glass container.

Observe the following precautions when you prepare zinc chloride:

- Do not inhale the fumes given off by muriatic acid or by the mixture of muriatic acid and zinc.

These fumes are dangerous to you and corrosive to metals.

- Do not prepare zinc chloride in a closed space. Hydrogen gas is released as the zinc reacts chemically with the muriatic acid. HYDROGEN IS VIOLENTLY EXPLOSIVE! Because of this, zinc chloride should always be prepared out in the open or very near openings to the outside. Also, take all necessary steps to prevent flames or sparks from coming in contact with the released hydrogen.

Another type of corrosive flux that you may use is known as soldering salts. Commercially prepared soldering salts are usually furnished in powder form. The powder is dissolved in water to make a solution.

When a corrosive flux has been used for soldering, the flux residue should be removed from the work as completely as possible. Most corrosive fluxes are soluble in water. Wash the work with soap and water and then rinse thoroughly with clear water to remove the residue of corrosive fluxes. Do this cleaning immediately after you finish soldering.

Mildly corrosive fluxes, such as citric acid in water, are sometimes used for soldering. These fluxes have some of the advantages of the more strongly corrosive fluxes, and some of the advantages of the noncorrosive fluxes. The mildly corrosive fluxes clean the surfaces of the work but do not leave a strongly corrosive residue. These fluxes are generally used for soldering parts that can be rinsed with water after they have been soldered or for work in which a mildly corrosive residue can be tolerated.

Noncorrosive fluxes are used for soldering electrical connections and for other work that must be completely protected from any trace of corrosive residue. Rosin is the most commonly used noncorrosive flux. In the solid state, rosin is inactive and noncorrosive. When it is heated, it becomes active enough to reduce the oxides on the hot metal and thus perform the fluxing action. Rosin is available in powder, paste, and liquid forms.

Rosin fluxes frequently leave a brown stain on the soldered metal that is difficult to remove. You can prevent it to some extent by adding a small amount of turpentine to the rosin. You can also add glycerine to the rosin to make the flux more effective.

SOLDERING WITH IRONS

When you are soldering with irons, follow this procedure:

1. Select a soldering bit of the proper size and shape for the work to be done. File and tin the bit if necessary.
2. Heat the bit.
3. Position the work on a suitable support. When a seam is to be soldered, position the work as shown in figure 9-27 so that the seam does not rest on the support. This will ensure that you do not lose heat to the support.
4. Apply the flux with one or two strokes of a brush or a swab.
5. Clean the hot soldering bit with sal ammoniac, as described earlier in this chapter.
6. Touch the solder with the hot bit so that a small amount of solder flows over the tip of the bit, as shown in figure 9-28.
7. Tack the pieces together, if necessary, so that the work will stay in position while you are

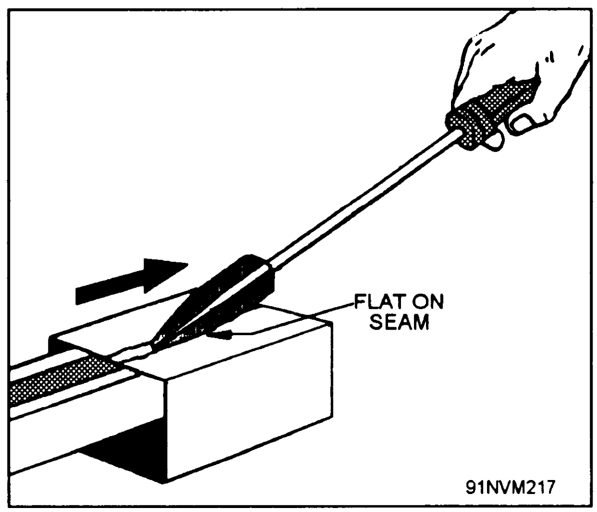


Figure 9-27.—Soldering a seam.

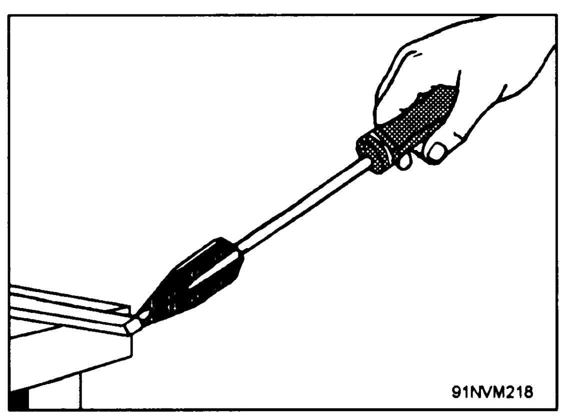


Figure 9-28.—Picking up solder.

soldering it. Heat the spot by holding the bit against the work. The metal to be soldered must absorb enough heat from the bit to melt the solder, or the solder will not adhere.

8. After the pieces have been firmly fastened together, solder the seam. Hold the bit so that one tapered side of the head is flat against the seam, as shown in figure 9-27. When the solder begins to flow freely into the seam, draw the bit along the seam with a slow, steady motion. Add as much solder as necessary, without raising the bit from the work.

9. To make the best soldered seams, solder without lifting the bit from the work and without tracing completed work.

10. Allow the joint to cool and the solder to set before moving the joint.

11. If you used a corrosive flux, clean the joint by rinsing it with water and then brushing or wiping it with a clean, damp cloth.

Riveted seams are often soldered to make them watertight. Figure 9-29 shows the procedure for soldering a riveted seam.

Sometimes solder beads or solder shots are used to solder square, rectangular, or cylindrical bottoms. To make the solder beads, hold solder against a hot bit and allow the beads to drop onto a clean surface, as shown in figure 9-30.

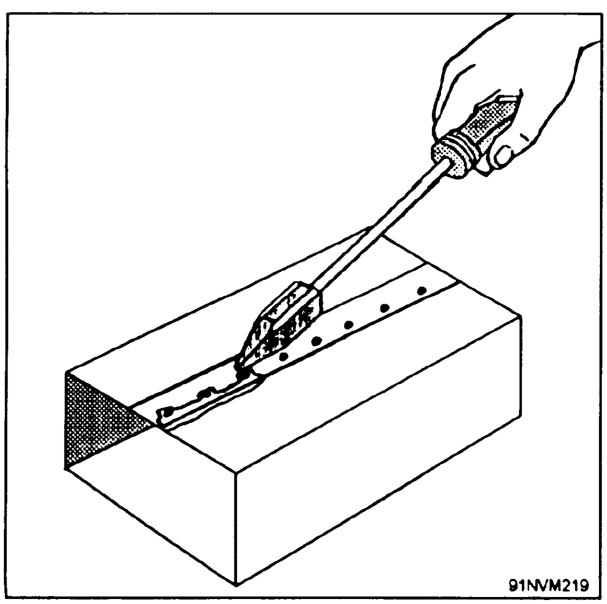


Figure 9-29.—Soldering a riveted seam.

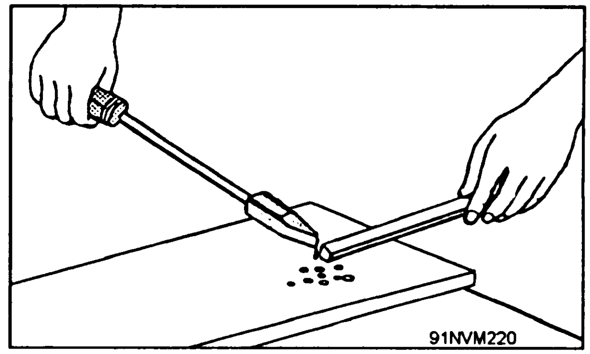


Figure 9-30.—Making solder beads.

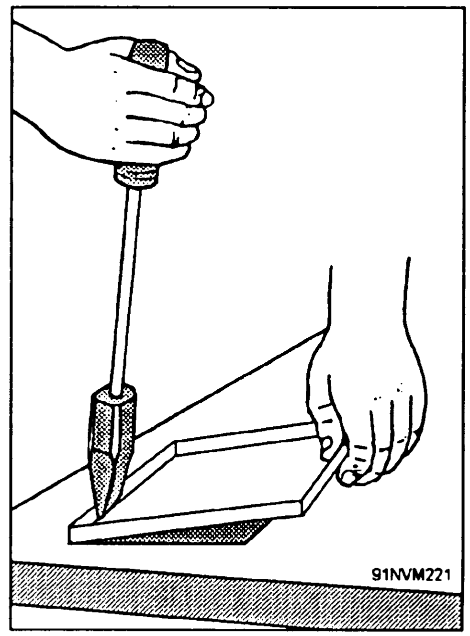


Figure 9-31.—Soldering a bottom seam.

To solder the bottom seam with solder beads, first flux the seam. Then drop one of the cold beads of solder in the bottom of the container. Heat, clean, and dip the soldering bit and place it against the seam, as shown in figure 9-31. Hold the soldering bit in one position until the solder starts to flow freely into the seam. Draw the bit slowly along the seam, turning the work as you go. Add more beads as you need them. Reheat the copper as necessary.

Be very careful not to overheat an electric soldering bit. Never go off and leave an electric soldering iron plugged in. Overheating will probably bum out the electrical element and damage the tinning.

TORCH SOLDERING

Parts to be joined may be too large to be heated by a soldering bit, or shaped in a way that would make rapid soldering difficult. In these cases, the soldering heat may be provided by an oxyacetylene torch. Play the flame of the torch on adjacent surfaces and then apply the solder cold, in bar or wire form, to an appropriate cross section of the area to be soldered. Flames should not impinge directly on the fluxed surfaces. The heated surfaces melt the solder, and the excess solder is removed by wiping the joint with a damp cloth before complete solidification of the solder.

Soldered joints in low-pressure, low-temperature piping systems are sometimes made up by the torch soldering method. If you must solder a joint near a previously soldered joint, wrap the previously soldered joint with a cool wet rag to keep the solder from melting.

SOLDERING BY SWEATING

Sweating is commonly used to make electrical connections. To make a sweated joint, clean and flux each surface to be joined; then tin each surface. Hold the pieces firmly together and heat the joint with a soldering copper or with a torch until the solder melts and begins to run out. Remove the source of heat and hold the parts firmly in position until the solder has completely hardened.

SOLDERING ALUMINUM ALLOYS

Soldering aluminum alloys is more difficult than soldering many other metals because aluminum alloys are always covered with a layer of oxide. The thickness of the layer depends on the type of alloy and the conditions to which it has been exposed.

Many aluminum alloys can be successfully soldered, if you use the proper techniques. Wrought aluminum alloys are normally easier to solder than cast aluminum alloys. Heat-treated aluminum alloys are extremely difficult to solder, just as are aluminum alloys containing more than 1 percent magnesium.

The solders used on aluminum alloys are generally tin-zinc or tin-cadmium alloys. They are usually called aluminum solders. Most of these solders have higher melting points than the tin-lead solders used for ordinary soldering. Both corrosive and noncorrosive fluxes are used for soldering aluminum.

The first step in soldering aluminum is to clean the surfaces completely and remove the layer of oxide. If a thick layer of oxide is present, remove the main part of it mechanically by filing, scraping, sanding, or wire brushing. You can use a corrosive flux to remove a thin layer of oxide. The flux, of course, must be completely removed from the joint after the soldering is finished.

After you clean and flux the surfaces, tin them with aluminum solder. Apply flux to the work surfaces and to the solder. You can tin the surfaces with a soldering iron or with a torch. If you use a torch, do not apply heat directly to the work surfaces, to the solder, or to the flux. Instead, play the torch on a nearby part of the work and let the heat be conducted through the metal to the work area. Do not use any more heat than is necessary to melt the solder and tin the surfaces. Work the aluminum solder well into the surfaces. After the surfaces have been tinned, the parts may be sweated together.

SUMMARY

The knowledge you have gained here will be helpful to you. Silver brazing is a daily job for the Hull Maintenance Technician. Braze welding, surfacing, powdered metal flame spraying, and soldering are not done as often as silver brazing, but they are done on a frequent basis. Review each of the processes and then practice them on scrap material. Knowledge is the first step in being efficient in your job. However, practice is also required.

CHAPTER 10

METAL-ARC WELDING AND CUTTING

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Identify the equipment of arc-welding systems and describe the procedures and techniques used in shielded metal-arc welding.*
- *Identify the different types and classes of bare and covered electrodes and select the proper electrode and heat settings for typical welding.*
- *Describe the safety equipment used in metal-arc welding and the correct procedures for striking, establishing, maintaining, and breaking the arc.*
- *Describe the characteristics of aluminum, their effect on its weldability, and the procedures required to prepare aluminum for welding.*
- *Recognize the basic techniques used in gas tungsten-arc (GTA) welding, and describe the function and maintenance requirements of associated welding equipment.*
- *Specify the methods used in making gas metal-arc (GMA) welds in various positions, and describe some of the equipment used.*
- *State the procedures to be followed in metal and carbon-arc cutting operations.*
- *Explain the procedures to follow in air carbon-arc cutting.*

INTRODUCTION

Electric welding processes include shielded metal-arc welding, shielded gas metal-arc welding, stud welding, and resistance welding. This chapter deals primarily with the first two processes; shielded metal-arc welding and shielded gas metal-arc welding. The other processes are summarized briefly at the end of the chapter along with the arc cutting processes.

To understand the operation of electrical welding equipment, you must have a basic understanding of electricity. In particular, you must be familiar with the terms used to describe electrical equipment and with the units of measurement used with electricity. If you do not understand the terms or units of measurement used in this chapter, study the applicable parts of NEETS, modules 1 and 2.

SHIELDED METAL-ARC WELDING

Most of your metal-arc welding will be done by the shielded metal-arc process. This is a nonpressure process, and the heat necessary for coalescence is generated by an electric arc between a heavily covered electrode and the base metal. The arc develops an intense heat that melts the base metal and forms a molten pool of metal. At the same time, the electrode tip is also melted, and metal from the tip is carried across the arc into the molten pool. The decomposition of the electrode covering shields the molten metal from oxidation. The temperature of the arc between the electrode and the base metal is approximately 6500°F.

WELDING MACHINES

The Navy has a wide variety of shielded metal-arc welding equipment. In general, this equipment is classified as either ac or dc; either stationary or portable; and either single-operator or multiple-operator equipment. In addition, it may be classified according to the source of power and the number of amperes delivered at certain arcvoltages.

The types of equipment available on any particular ship or IMA will depend upon the kind of electrical power available and the size and mission of the ship. Since most ships are equipped with ac power, we will discuss only the welding machines that use an ac power supply or are diesel-driven. Small combatant-type ships, such as destroyers, may be equipped with two motor-driven, single-operator, dc generator sets; whereas, cruisers and aircraft carriers will have a larger number of these types of welders. The motor-driven dc generator set uses an ac power supply to run the motor, and the generator provides dc welding current. Repair ships and tenders may also be equipped with diesel-driven, motor-generator sets as well as the electric motor-generator sets.

All types of arc-welding machines require a source of power that will allow you to strike and maintain a stable arc suitable for welding. The principal sources of power for shipboard welding are as follows:

- A dc generator with variable voltage characteristics may be used in a single-operator welding system. The generator is so designed that it delivers a voltage high enough to start the arc and reduce the voltage as required to maintain the arc during the welding.

- A rectifier may be used to convert ac to dc for welding.

The power from these sources is used in various types of welding equipment to provide the necessary current. The basic types of welding equipment used for shielded metal-arc welding are (1) the variable-voltage, dc generator welding unit, and (2) the rectifier-type welding machine.

Variable-Voltage, DC Generator Welding Unit

This unit consists of a dc generator driven by an ac electric motor or by a gasoline or diesel engine. The voltage produced by the generator usually ranges from 15 to 45 volts across the arc, and the current output varies from 40 to 400 amperes, depending on the type of unit. In most units, the voltage and ampere output of the generator is controlled automatically by the self-regulating or drooping voltage characteristics in the generator. (An increase in current through the generator results in a decrease in voltage.) In addition, the generator output is manually controlled by one or two manual adjustments.

Welding machines of this type may have single or dual controls. In the usual single-control generator, output is adjusted by shifting the position of generator brushes or by moving a portion of the magnetic field structure of the generator. In the usual dual-control generator, output is adjusted by varying the generator shunt field strength and varying the strength and direction of the series field. The machine shown in figure 10-l is a dual-control type fastened on an ordnance handling truck. A ground plate is attached to the work to be welded, and the electrode is clamped in the electrode holder.

When an electric power supply is available, welding generators are usually driven by an electric motor connected to the generator by a flexible coupling. Others are set up with the generator and the motor on the same shaft. When an electric power supply is not available, you must have a

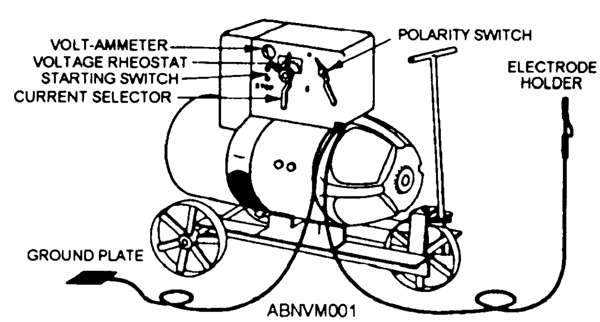


Figure 10-1.—Variable-voltage dc generator welding unit (dual-control type).

gasoline or diesel engine to rotate the generator. In this case, the engine is equipped with a governor to compensate for the varying loads imposed by the welder.

All dc generator welding units deliver either straight or reverse polarity welding current. The correct polarity is essential in metal-arc welding, so let's see what the term *polarity* really means. To understand polarity, you must first have a clear understanding of the welding circuit. The welding circuit consists of (1) a source of welding current, (2) a lead attached at one end to the power source and at the other end to the electrode holder, and (3) a ground lead or work lead attached at one end to the power source and at the other end to the work. In any electrical circuit, current flows only when the circuit is closed. When a dc welding circuit is closed, electrons flow from the negative terminal, through the circuit, to the positive terminal of the generator. The polarity can be changed by use of the polarity switch located on the machine. (See fig. 10-1.) If the machine does not have a polarity switch, simply reverse the hookup of the electrode lead and the ground lead, as shown in figure 10-2.

Polarity is important because it determines the location of the major portion of the welding heat. About two-thirds of the heat of the arc is developed at the positive pole. In straight polarity welding (electrode negative), the greatest amount of heat is concentrated on the work side of the arc. In reverse polarity (electrode positive), the greatest amount of heat is concentrated on the electrode side of the arc.

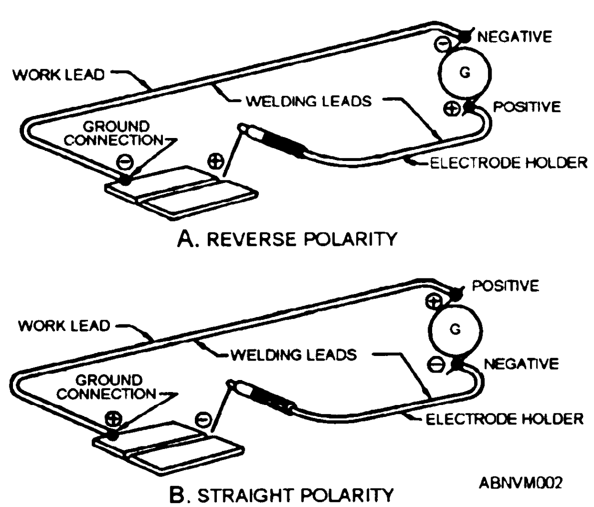


Figure 10-2.—Reverse polarity and straight polarity.

Note that the concept of polarity applies only to dc welding circuits. In ac circuits, the direction of current flow is constantly reversing; therefore, an ac circuit has no polarity affecting the operation of the electrode.

The polarity recommended for a particular type of electrode is specified by the manufacturer. If you use the wrong polarity for a given electrode, the arc will have a hissing sound and will be very difficult to control. When the proper polarity is used, the arc will have a sharp, crackling sound.

In general, reverse polarity gives a slower rate of electrode burn-off, together with deeper and more certain penetration. Reverse polarity also causes greater fluidity and slower solidification of the weld metal.

Joints in sheet metal are usually welded with straight polarity. Reverse polarity is specified for many other types of welds, particularly for welds made in the vertical or overhead position.

Before placing any unit in operation, check the nameplate data and the manufacturer's technical manual for exact instructions on setting up the unit. Check the following points in particular:

1. If the generator is driven by an electric motor, be sure that the power supply agrees with the motor requirements. Never attempt to operate a dc motor on ac power or an ac motor on dc power.

2. Check the motor supply cable and the fuses. Make sure the wiring to the motor is large enough to carry the load, and be sure the line fuses are adequate. If you have any reason to doubt the adequacy of the cable or the fuses, have the equipment checked by an Electrician's Mate.

3. On machines using an ac power supply for the motor, ensure that the rotation of the motor is in the indicated direction. You may reverse the rotation of three-phase ac motors by interchanging any two supply leads.

4. Before applying power to the motor, turn the shaft by hand to make sure it turns freely.

Check to see that the generator and motor brushes are in place and that they fit properly.

5. Before starting the motor, insulate the electrode holder from the ground and attach the work and electrode welding leads to the proper generator terminals. On machines equipped with reversing switches, connect the ground (or work) lead to the terminal marked GROUND and the electrode lead to the terminal marked ELECTRODE. Then set the reversing switch for the desired polarity. On machines not equipped with reversing switches, connect the leads to the terminals in the manner indicated on the nameplate or in the manufacturer's technical manual. To change polarity on these machines, interchange the leads.

6. Adjust the welding current according to the manufacturer's instructions. Single-control machines are designed to give adequate voltage at each current setting. Dual-control machines have separate voltage and current adjustments.

Some values required for a given welding job are beyond the capacity of a single-operator welding generator. When this happens, the required current can be obtained by interconnecting or paralleling two single-operator generators (fig. 10-3). As a rule, the sets that are paralleled should be of identical rating. However, it is usually possible to parallel sets of different ratings if you observe the proper precautions. If sets with different current ratings are paralleled, take special care to ensure that the total load is divided in proportion to machine ratings and that the current rating of neither machine is exceeded. Paralleling instructions are contained in the manufacturer's technical manuals furnished with your equipment.

All dc generator welders should be located in clean, dry, well-ventilated places, away from acid fumes or steam. Given proper care, the unit should give many years of trouble-free service. Like most mechanical devices, welding generators occasionally fail to operate properly. Common problems include the following:

- The machine fails to start.
- The machine runs but fails to generate current.

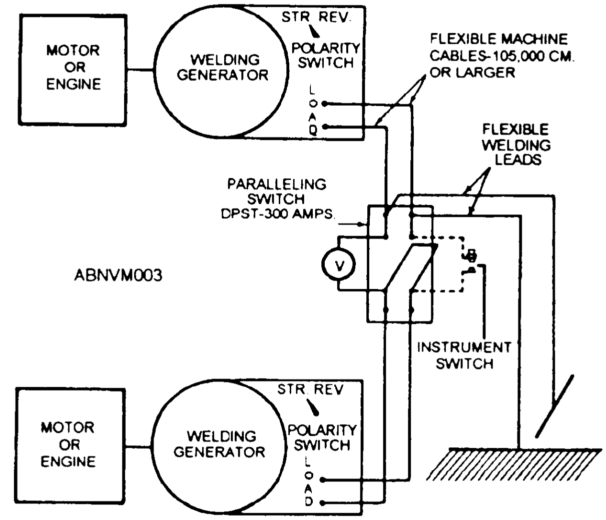


Figure 10-3.—Paralleling connection for a single-operator welding generator.

- The overload device does not hold the motor in the circuit.
- The machine fails to hold its amperage.
- The welding arc spatters excessively.

An Electrician's Mate is usually needed to determine causes and to make repairs. However, there are some things that you can and should do before you call in the Electrician's Mate.

If the machine fails to start, the trouble may be an open or disconnected switch. You can check switches yourself. If the machine runs but will not generate current for the welding circuit, the motor may be rotating in the wrong direction. You can check the direction of rotation with the direction arrow on the outside housing of the equipment. On a three-phase motor, rotation may be changed by interchanging any two of the motor power leads. Have an Electrician's Mate change the motor power leads if the rotation is wrong. If rotation is correct and the machine still will not generate, the trouble is elsewhere. You should call an Electrician's Mate if the motor repeatedly cuts out of the circuit, or if the machine does not hold its amperage after you ensure that all welding cable connections are tight and that the unit is properly adjusted.

Excessive arc spatter may result from several causes, such as arc blow, poor welding technique, incorrect current setting, incorrect electrode, or incorrect polarity. Check the current output settings and make any needed adjustment. If that does not solve the spatter problem, check the polarity. Either reverse the polarity of the generator or try an electrode of the opposite polarity. Excessive spatter should not occur if you use the proper welding technique, the right polarity, and the correct current output adjustment.

Most difficulties with generator welding units can be avoided through routine maintenance and periodic overhaul. Here again the Electrician's Mate has primary responsibility. However, you are responsible for keeping the outside of the equipment clean. Once each month, blow the outside and inside of the unit free of dust with clean, dry, compressed air. At that time, oil the wheel bearings on portable welding units. Operate each of the machines for at least a few minutes once a week. In addition to routine maintenance, inspection, and testing, each machine should be completely dismantled, thoroughly cleaned, and overhauled as necessary every 2 years. Again, this is a job performed by Electrician's Mates. Instructions governing maintenance and overhaul of electrical equipment, including welding machines, are discussed in the *NSTM*, chapter 074.

Rectifier-Type Welding Machine

The rectifier-type welding machine operates from an ac power source but delivers ac high frequency and dc welding current. There are several types of rectifier welders, but they are basically the same. The majority of the units consist of three major parts: (1) a transformer, to change the power supply voltage (220 or 440 volts) to lower voltage suitable for welding; (2) a movable core reactor, to adjust the welding current; and (3) a rectifier cell (copper oxide or selenium plates), to change the ac to dc.

WELDING CABLES

The welding cables conduct the welding current from the power source to the weldment and then back to the source. They must be flexible, durable, well insulated, and large enough to carry the required current. Only cable that is designed for welding should be used for welding. A highly flexible cable must be used between the welding machine and the electrode holder. The ground cable, which connects the work and the machine, need not be so flexible as the cable that connects the machine and the electrode holder.

Two factors determine the size of the welding cable that should be used: the amperage rating of the machine, and the distance between the work and the machine. If either amperage or distance is increased, the cable size must also be increased. A cable that is too small for the amperage used will become overheated. A cable that is too small for the distance between the machine and the work will not carry enough current to the arc without becoming overheated. On the other hand, the larger sizes of cable are more difficult to handle. The best size, therefore, is one large enough to meet the manufacturer/*NSTM* requirements.

As a rule, the cable between the machine and the work should be as short as possible, preferably one continuous length of cable. If it is necessary to use more than one length of cable, join the sections with insulated, lock-type cable connectors. Joints in the cable should be at least 10 feet away from the operator.

GROUNDING ELECTRICAL WELDING EQUIPMENT

Most shipboard welding is done by the shielded metal-arc welding process, and you will frequently be responsible for seeing that the equipment is properly set up and properly grounded. Incorrect grounding permits the electric current to return to the welding generator through the water, the ship's hull, and the piping systems. This may result in electrolytic corrosion and cause serious damage to the ship's underwater body, shafting, and propellers.

CAUTION

Grounding must comply with the criteria of *NSTM*, chapter 074, volume 1.

Location of ground cables should be a major concern when setting up welding machines. When welding on systems, such as piping, pressure vessels, or machinery, the ground-return cable connection should be located as close to the work as possible. This ensures that welding current does not flow through bearings, threaded joints, and other joints where arcing could occur. If arcing is allowed to happen across bearings in motors, lathes, and other similar components, they could be fused together. Also, you should NEVER use electrical equipment as a grounding circuit. They are not designed for such use and the induced magnetic field produced by welding could damage electrical equipment. You should install ground-return cable connections no further than 10 feet from your work.

The requirements for grounding welding equipment vary slightly, depending upon the situation. However, there are a few basic rules to follow. Set up the equipment so that electrode and ground leads are connected only to the vessel on which welding is to be done. Secure the ground lead to an integral part of the vessel, making a good metal-to-metal contact. Be sure that both the electrode and ground leads are thoroughly insulated and that they are NOT in contact with water. Figure 10-4 shows the correct methods for hooking up welding leads in three common situations. Note that in each case, the only ground in the circuit is to the ship where the welding is to be done.

When welding leads and grounds are arranged as shown in figure 10-4, all the welding current flows through the cables. When the welding equipment is NOT correctly grounded, some or all of the welding current returns to the generator by way of the water. The portion of current that will flow through the water will depend upon the particular grounding error that is made.

One very common error is to attach the ground to one ship and then to weld on another ship. This situation often occurs when a welding generator on a repair ship or tender is used to weld on a ship alongside. When this occurs, all of the welding current returns through the water.

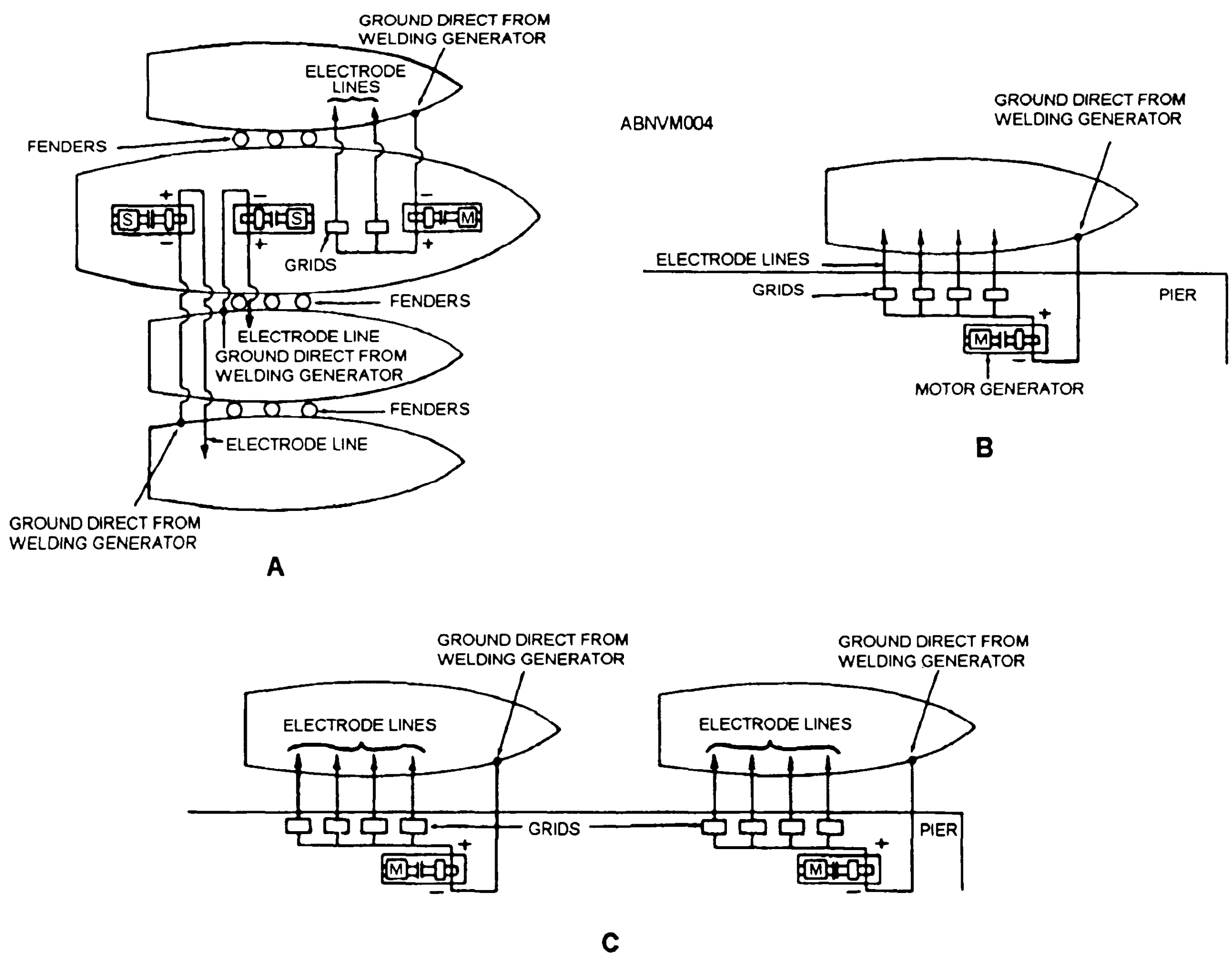


Figure 10-4.—Correct grounding procedure for metal-arc welding. (A) Arrangement for ships afloat. (B) Arrangement for a single ship at a pier. (C) Arrangement for two ships at a pier.

Another incorrect grounding procedure occurs when the ground is connected to both the ship on which the generator is located and the ship on which the welding is being done. In this situation, part of the welding current returns through the water.

When grounding welding equipment, always insulate the negative cable of the generator from the ship on which the generator is located and run both the positive and negative leads to the ship where the welding is being done.

As an additional precaution, make a ship-to-ship connection with a heavy copper cable. The cable should be welded or bolted securely to bare metal on each ship. If properly attached, the copper cable will prevent most of the welding current from returning through the water.

CAUTION

This is an additional precaution, NOT a substitute for correct use of the regular welding grounds.

ELECTRODE HOLDERS

An electrode holder is essentially a clamping device for holding the electrode securely in any position. The welding cable passes through the hollow, insulated handle of the holder. The advantage of an insulated holder is that it may be touched to any part of the work without danger of short circuiting. Electrode holders permit quick and easy change of electrodes.

Electrode holders are made in a number of different sizes and designs (fig. 10-5). Each holder is intended for use within a specified range of electrode diameters and within a maximum welding current amperage. A larger holder isrequired when welding with a machine having a 300-ampere rating than when welding with a 100-ampere unit. A holder will overheat if it is smaller than that specified for use with a particular amperage.

WELDING ELECTRODES

Electrodes are manufactured in a variety of metals and are available for use with any alloy that is classed as weldable by the electric arc-welding process. This includes various types of stainless steel, high-tensile steels, and manganese steels. Electrodes are also available for welding nonferrous metals and alloys such as aluminum, copper, nickel, and certain types of bronze and brass, some of which were originally considered unweldable.

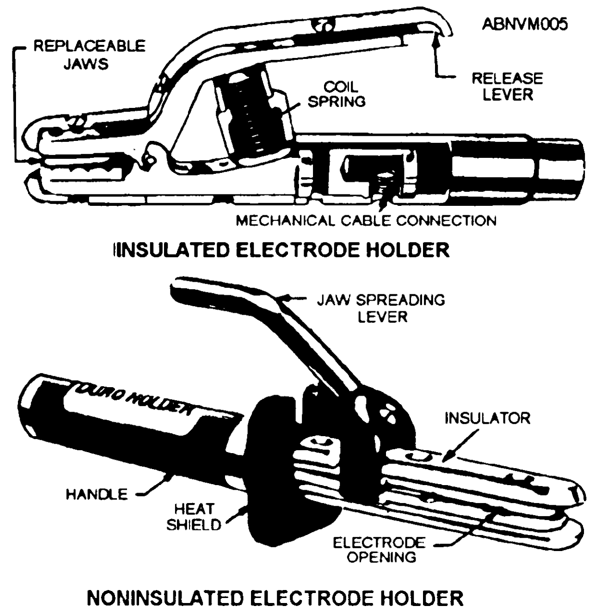


Figure 10-5.—Electrode holders.

Electrodes are manufactured for use with either straight polarity, reverse polarity, or both. They are also designed to be used in the different welding positions. For example, an E6030 electrode is designed for flat welding and is not suitable for vertical or overhead welding positions. Electrodes are available in a variety of diameters ranging from one-sixteenth to three-eighths inch and in lengths generally shorter than the rods used in gas welding. Standard lengths are 9, 12, 14, and 18 inches. They are also available in rolls for use in machine welding. Some of these coatings may produce a slag, but it is quite thin and does not act in the same manner as the shielded arc type of electrode slag.

Heavy Coated Electrodes

The surface of heavy coated electrodes is comparatively thick. These coatings have been designed to improve the physical properties of the weld. They also control arc stability and, as a result, increase the speed and ease of welding in the vertical and overhead positions. These electrodes are manufactured by the extrusion, wrapping, or heavy dipping processes, or combinations of these methods.

The coatings used on these electrodes consist of two basic materials: mineral coatings and cellulose coatings. However, a combination of the two materials may also be used. The mineral coatings consist of metallic oxides such as clay, feldspar, and titanium. The cellulose coatings consist of materials such as wood pulp, sawdust, and cotton.

These heavy coating materials on the electrodes accomplish the following:

—They produce a reducing or nonoxidizing atmosphere, which acts as a shielding medium around the weld deposit, excluding the oxygen and nitrogen of the air.

—They stabilize the arc and improve the flow of metal from the end of the electrode to the puddle on the work.

—The coating controls fluidity of the puddle and shape of the bead by providing those ingredients (oxides and silicates) that, when melted, form a slag over the molten metal. This slag, being quite slow to solidify, holds the heat and allows the metal to solidify and cool slowly. This slow solidification allows dissolved gases to escape and permits solid impurities to float to the surface. The slow cooling also has an annealing effect on the weld deposits.

—They control the physical properties of the weld deposit and the composition of the deposit by the addition of various metals and alloys to be deposited during the welding process.

Figure 10-6 shows the arc characteristics when using a heavy coated electrode.

Coated electrodes should be kept stored in their original containers or in a dry area, such as holding ovens, to prevent the coating from absorbing moisture from the air, especially when the relative humidity is very high. This is especially true of the iron powder and low hydrogen coatings. An increase in their moisture content will produce unsatisfactory welds. In some cases, it is necessary to dry out the electrode coatings by baking the electrodes in a furnace or oven before using them to weld.

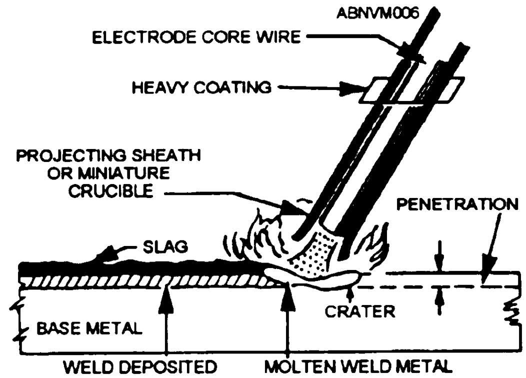


Figure 10-6.—Welding with a heavy coated electrode.

CLASSIFICATION OF ELECTRODES

Electrode classification tables are prepared and published jointly by the American Welding Society (AWS) and the American Society for Testing Materials (ASTM). These tables are available in booklet form from either of these organizations. Electrodes are also classified with MIL SPEC classification of MIL-E-22200 or other classifications according to type and use of the electrode. To illustrate these tables, the E60 series classifications are shown in table 10-1. As shown in the table, the electrode classifications contain the electrode classification number, type of coating, welding positions, and recommended current and polarity.

To understand the significance of classification numbers, consider the E6010 classification shown in table 10-1. The E represents the word electric. The first two numbers, 60, refer to the minimum tensile strength in the nonstress-relieved (as welded) condition, or 60,000 psi. The third number explains the possible welding positions, such as 1 for all welding positions (flat, vertical, overhead, and horizontal); or 2, which designates a greater restriction in choice by being usable only in the horizontal and flat positions. Whereas, a 3 as the third number indicates that these electrodes may be applied in the flat position only. The fourth number in the classification is used to indicate such things as the proper power supply, quality, type of arc, amount of penetration, type of flux, and so on.

Some electrodes are classified in five-digit numbers instead of four. In this case, the first three digits apply to the minimum tensile strength as previously explained for the four-digit classification.

Table 10-1.—Electrode Classifications

AWS-ASTM classification	Type of coating or covering	Capable of producing satisfactory welds in posit ions shown	Type of current
E60 Series.-Minimum Tensile Strength of Deposited Metal in As-Welded Condition 60,000 psi (or higher).			
E6010	High cellulose sodium	F, V, OH, H	For use with dc, reverse polarity (electrode positive) only.
E6011	High cellulose potassium	F, V, OH, H	For use with ac or dc reverse polarity (electrode positive).
E6012	High titania sodium	F, V, OH, H	For use with dc, straight polarity (electrode negative) or ac.
E6013	High titania potassium	F, V, OH, H	For use with ac or dc, straight polarity (electrode negative).
E6014	Iron powder, titania	F, V, OH, H	For use with dc, either polarity or ac.
E6015	Low hydrogen sodium	F, V, OH, H	For use with dc, reverse polarity (electrode positive) only.
E6016	Low hydrogen potassium	F, V, OH, H	For use with ac or dc reverse polarity (electrode positive).
E6018	Iron powder, low hydrogen	F, V, OH, H	For use with ac or dc, reverse polarity.
E6020	High iron oxide	H-Fillets, F	For use with dc, straight polarity (electrode negative), or ac for horizontal fillet welds; and dc, either polarity, or ac, for flat-posit ion welding.
E6024	Iron powder, titania	H-Fillets, F	For use with dc, either polarity, or ac.
E6027	Iron powder, iron oxide	H-Fillets, F	For use with dc, straight polarity (electrode negative), or ac for horizontal fillet welds; and dc, either polarity, or ac, for flat-posit ion welding.
E602a	Iron powder, low hydrogen	H-Fillets, F	For use with ac or dc, reverse polarity.
E6030	High iron oxide	F	For use with dc, either polarity, or ac.

The abbreviations F, H, V, OH, and H-Fillets indicate welding positions as follows:

F = Flat V = Vertical
H = Horizontal OH = Overheard
H-Fillets = Horizontal Fillets

} For electrodes 3/16 in. and under, except 5/32 in. and under for classifications EXX14, EXX1S, EXX16 and EXX18.

In addition to the electrode classification numbers, iron and steel electrodes may be identified by a standard color code set up by the National Electrical Manufacturers' Association (NEMA).

This method of electrode identification uses a two-color system consisting of a primary color located on the end of the electrode and a secondary color located near the top end of the electrode. Figure 10-7 shows the location of the primary and secondary on the end grip and center grip electrodes. Part of the electrode color identification table produced by NEMA is reproduced in table 10-2.

PREPARATIONS FOR WELDING

Before beginning to weld, be sure you have all the required equipment for welding and all the equipment needed for your personal protection. Be sure the welding machine is in good condition. Do

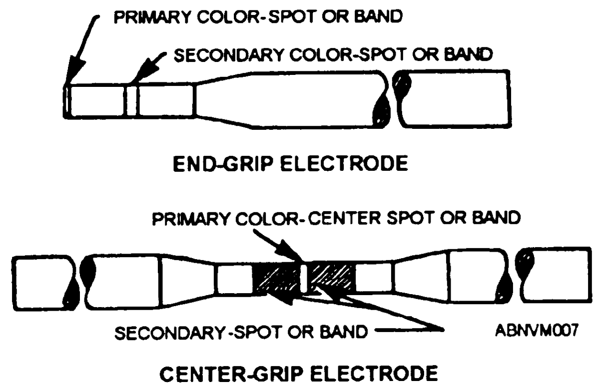


Figure 10-7.—Electrode color markings.

Table 10-2.—Color Markings For Electrode Identification

	Primary colors				
Spot or secondary color	Mild steel and low alloys (See Note I)			Special purpose	Hard surfacing (See Note II)
	All position	Horizontal fillets & flat	Flat position only		
	No color	Blue	White	Orange	Brown
No color	E6010	E6020	E6030	Mild steel for cast iron	0.40-0.70% Carbon
Blue	E6011				0.90-1.10% Carbon
White	E6012			Cast iron for cast iron	Brinell 200 min
Brown	E6013			051.0% Ni	Brinell 300 min
Green	E7010	E7020	E7030	2.0-3.0% Ni	Brinell 400 min
Red	E7011			12.0-14.0% Mn	Brinell 500 min
Yellow	E8010 E8011	E8020	E8030	Ni Mn	Brinell 600 min
Black	E9010 E9011	E9020	E9030	Ni Cr MO	Brinell 700 min
Orange	El0010 E10011	El0020	El0030	Ni Cr Cu	
Violet					
Gray					

Note I: Electrodes listed with prefix letter are AWS designated grades.

Note II: Hardness shall be determined as follows:
(a) Use a base plate of mild steel 5" square × 1" thick.
(b) Use 3/16" electrode.

Table 10-3.—Typical Current Ranges in Amperes for Electrodes

Electrode diameter, inch	E6010 and 6011	E6012	E6013	E6020 and E6030	E6027	E6014 and E7014	E6015, E6016, E7015, and E7016	E6018 and E7018	E6024, E6028, E7024, and E7028
1/16	. . .	20 to 40	20 to 40	. . .	. . .	. . .	. . .	. . .	. . .
5/64	. . .	25 to 60	25 to 60	. . .	. . .	. . .	. . .	. . .	. . .
3/32	40 to 80	35 to 85	45 to 90	. . .	. . .	80 to 125	65 to 110	70 to 100	100 to 145[a]
1/8	75 to 125	80 to 140	80 to 130	100 to 150	125 to 185	110 to 160	100 to 150	115 to 165	140 to 190
5/32	110 to 170	110 to 190	105 to 180	130 to 190	160 to 240	150 to 210	140 to 200	150 to 220	180 to 250
3/16	140 to 215	140 to 240	150 to 230	175 to 250	210 to 300	200 to 275	180 to 255	200 to 275	230 to 305
7/32	170 to 250	200 to 320	210 to 300	225 to 310	250 to 350	260 to 340	240 to 320	260 to 340	275 to 365
1/4	210 to 320	250 to 400	250 to 350	275 to 375	300 to 420	330 to 415	300 to 390	315 to 400	335 to 430
5/16	275 to 425	300 to 500	320 to 430	340 to 450	. . .	390 to 500	375 to 475	375 to 470	. . .

[a]These values do not apply to the E6028 and E7028 classifications.

not attempt to use a welding machine until you are entirely familiar with the procedures for setting it and using it. Procedures for setting welding machines vary according to the type of machine and the manufacturer. Remember, you must set a welding machine for the correct amperage, the correct voltage, and the correct polarity.

There are a number of variable factors affecting the machine setting. These include size and type of electrode, thickness of metal to be welded, type of joint, and skill and technique of the welder. With these variables to be considered, it is apparent that any set of current values could be merely generalization. Current ranges as published by different manufacturers vary considerably for the same classification and size of electrode.

Table 10-3, compiled by the AWS, is included for information, but the current values in this chart are merely suggestive. A setting on the welding machine within these ranges should be used only as a preliminary setting since the table is intended to cover all welding positions.

The proper welding current for a given set of conditions can be determined from the degree of electrode heat. If the electrode is too hot, then the current is too high. Welds of good quality cannot be made if the electrode overheats. In these instances, the current must be reduced or the size of the electrode increased. With proper current and electrode, you should get a smooth, uniform bead.

In addition to the major items of equipment that we have considered so far, you may also need a container for carrying electrodes, a chipping hammer and a wire brush for removing slag from the weld between passes, fillet weld gauges, a hammer, a center punch, a scriber, a flexible rule, and other supplementary equipment. Some welding shops may have a welding positioner, a device fitted with T-slots to help secure the work. It also has a system of hand-operated or power-operated gears used to adjust the weldment so that all welds can be made in the flat position. After all equipment has been assembled and the machine has been properly set, clamp the bare end of the electrode in the electrode holder so that the entire length of the electrode can be used without breaking the arc. Safety note: NEVER INSERT AN ELECTRODE IN A HOLDER WITH YOUR BARE HANDS.

STRIKING THE ARC

The arc may be started either by the striking or brushing method or by the tapping method. In either case, the arc is formed by short-circuiting the welding current between the electrode and the work. The length of an arc is normally equal to the diameter of the electrode's filler metal. The heat of the current at the arc melts both the end of the electrode and the part of the work that it touches.

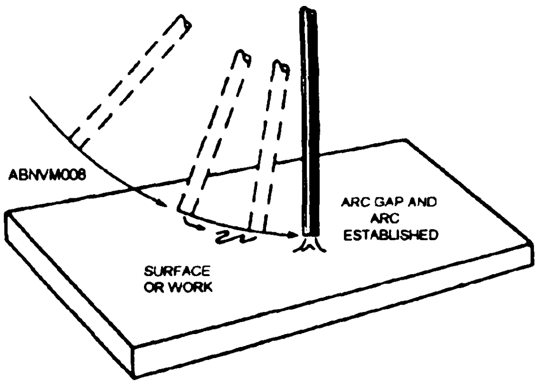


Figure 10-8.—Striking or brushing method of starting the arc.

To start the arc by the striking or brushing method, bring the end of the electrode down to the work in a continuous motion that describes the arc of a circle. In other words, strike your arc in the same manner that you would strike a wooden match. As soon as the electrode touches the base metal, check the downward motion and raise the electrode to make the arc. The distance between the electrode and the base metal should be about equal to the diameter of the electrode. You can tell when the distance is right by the sharp, cracking sound the arc will make. Figure 10-8 shows the striking or brushing method of starting the arc.

To start the arc by the tapping method, hold the electrode at right angles to the work, as shown in figure 10-9. To establish the arc, lower the electrode and tap it or bounce it on the surface of the base metal, and then slowly raise it a short distance. If you raise the electrode too quickly, you will lose the arc. If you raise it too slowly, the electrode will freeze or stick to the base metal. If this happens, you can usually free the electrode by giving it a quick, sidewise twist. If you cannot free the electrode in this way, remove the holder from the electrode or stop the machine. Then chip off the electrode with a chisel, to free it from the base metal.

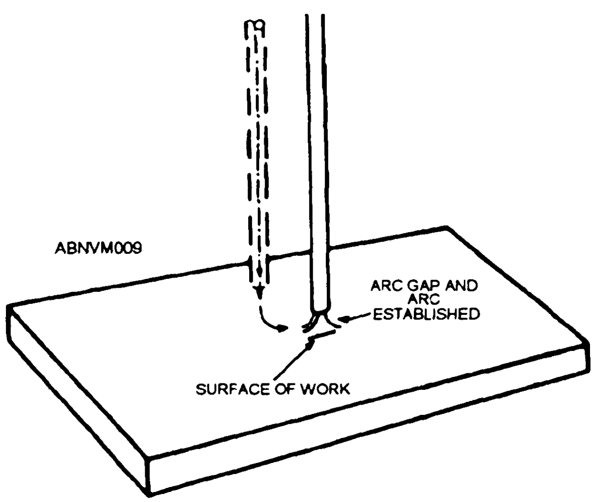


Figure 10-9.—Tapping method of starting the arc.

CAUTION

NEVER REMOVE YOUR HELMET OR THE SHIELD FROM YOUR EYES AS LONG AS THERE IS ANY POSSIBILITY THAT THE ELECTRODE WILL ARC.

After the arc is struck, particles of metal melt off the end of the electrode and are fed into the molten crater of the base metal. The length of the electrode is thus gradually shortened. Unless you keep moving the electrode closer to the base metal, the length of the arc will increase. If the electrode is fed down to the plate and along the surface at a constant rate, a bead of metal will be deposited or welded on to the surface of the base metal. Before advancing the arc, hold it for a short time at the starting point to ensure good fusion and to build up the bead slightly. Good arc welding depends upon good control of the motion of the electrode down to and along the surface of the base metal.

BREAKING THE ARC

There are two correct methods for breaking an arc. The most commonly used method is to shorten the arc, and then quickly move the electrode sidewise out of the crater. The other method is to hold the electrode stationary until the crater is filled, and then slowly withdraw the electrode.

REESTABLISHING THE ARC

When it is necessary to reestablish the arc (as when the length of weld requires the use of more than one electrode), the crater must be cleaned before striking the arc. Strike the tip of the new electrode at the forward (cold) end of the crater.

Move the arc backward over the crater, and then move forward again to continue the weld. This procedure fills the crater, and it prevents porosity and slag.

ARC-WELDING TECHNIQUES

The types of welds, the types of joints, and the welding positions used in shielded metal-arc welding are generally the same as those used in oxyacetylene welding. The techniques, of course, are somewhat different because of the different equipment involved.

In arc welding, the position of the electrode in relation to the joint being welded is a matter of great importance. Increasing the electrode angle in the direction of welding builds up a bead.

When welding a bead in the flat position (fig. 10-10), you should hold the electrode at a 90-degree angle to the base metal. To get a good view of the molten puddle, you may find it convenient to tilt the electrode forward, in the direction of welding, to the angle that is 5° to 15° off from the 90-degree angle. Do not move the electrode from side to side as you run a bead. To keep the arc constant, move it forward just fast enough to deposit the weld metal uniformly, and move it downward as rapidly as necessary.

Use a short arc, about one-eighth inch in length, and weld in a straight line at a constant speed. You cannot judge the length of an arc by looking at it. You will have to depend upon experience and the sharp, cracking sound that is made by a good, short arc. This sound should be heard all during the time the arc is being moved along the joint.

A good weld bead made by the shielded metal-arc welding process should have little or no spatter on the surface of the plate. The arc crater in the bead should be approximately the same size as the electrode diameter or larger when the arc has been broken. The bead should be built up slightly, but should not have any metal overlap at the top surface. There should be good penetration of approximately one-sixteenth inch into the base metal. Figure 10-11 shows properly made weld beads in the flat position.

A butt joint in the flat position should be set up in the same manner as for oxyacetylene welding. Plates less than one-fourth inch in thickness can be welded in one pass. They do not require any edge preparation, but the pieces should be tacked together to keep them in alignment. Use the same electrode motion that you used for forming a bead in the flat position. Plates one-fourth inch or more in thickness require edge preparation by beveling or U-grooving.

The first bead or root pass is deposited to seal the space between the two pieces of the joint at the root. This bead must be thoroughly cleaned of all slag before any other weld layers are made. The second, third, and fourth layers of weld metal are deposited using stringer beads in the order shown in

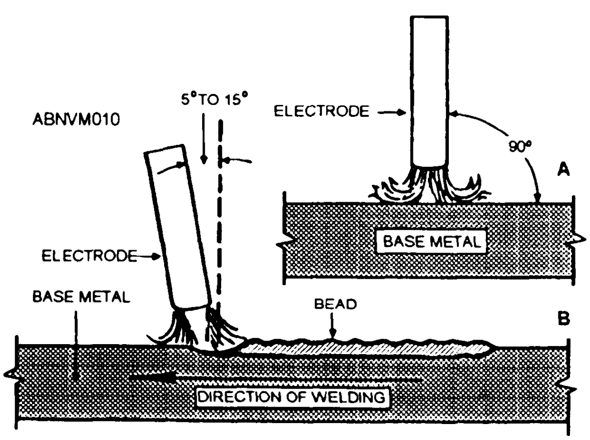


Figure 10-10.—Position of the electrode in making a bead in the flat position.

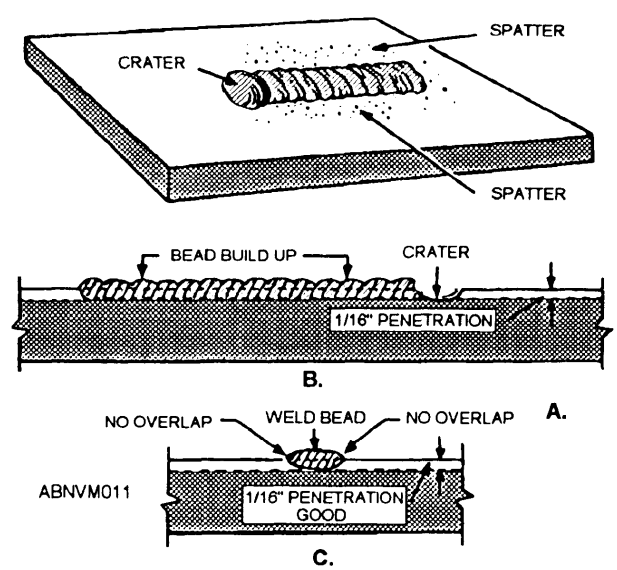


Figure 10-11.—Properly made weld beads (flat position).

view A of figure 10-12. Each bead must be cleaned prior to depositing additional beads.

To ensure adequate penetration at the root, use a backing strap when you make a butt weld in any position. The backing strap should be about 1/2 to 1 1/2 inches wide and from 1/8 to 1/4 inch thick.

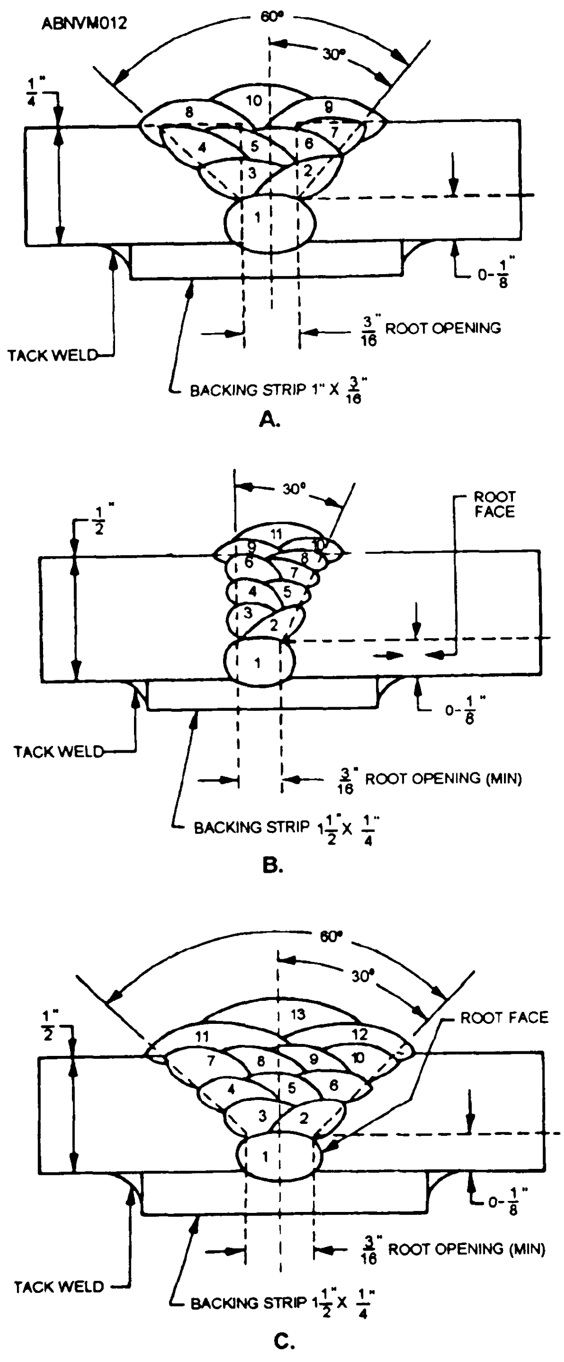


Figure 10-12.—Use of backing strips in welding butt joints.

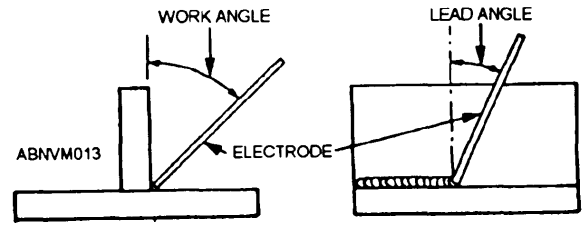


Figure 10-13.—Electrode work angle and lead angle.

The thickness and width of backing straps depend upon the thickness of the plate being welded. You should consult MIL-STD-22 for correct dimensions. Tack weld the strap to the base of the joint and use it as a cushion for the first layer of weld metal deposited in the joint. Then complete the joint by adding additional layers of weld metal in the regular way. If the backing strap must be removed, do so with a cutting torch or grinder. You must be careful when cutting a backing strap with a torch so that you do not gouge the plate or remove excess material. If excess metal is removed, weld repair will be required. The use of backing straps in welding butt joints is shown in figure 10-12.

In making fillet welds, pay particular attention to lead angles and work angles. In figure 10-13, the work angle is the angle between the electrode and the work in a plane at right angles to the long axis of the joint.

The lead angle is the angle between the electrode and the joint in the direction of the welding. Work angles and lead angles for various types of electrodes are usually specified by electrode manufacturers.

Figure 10-14 shows the fillet welding of a T-joint in the flat position. The surfaces of the pieces to be

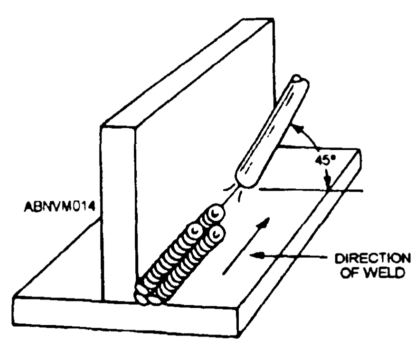


Figure 10-14.—Fillet welding a T-joint (flat position).

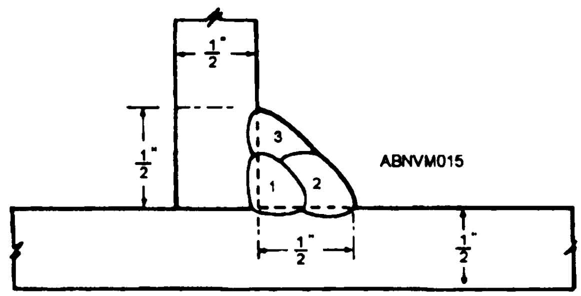


Figure 10-15.—Order of making stringer beads for a T-joint in heavy plate.

joined make a 90-degree angle with each other. First weld a tack at each end to hold the pieces in position. To make the fillet weld, use a short arc and hold the electrode at a work angle of 45° to the plate surfaces. Tilt the electrode to a lead angle of about 15°. Light plate can be welded in one pass, without any weaving motion of the electrode. Heavier plate may take two or more passes, and you must use a semicircular weave motion with the second pass to get good fusion without undercutting. To weld plate that is one-half inch or more in thickness, use stringer beads in the order shown in figure 10-15. Lap joints in the flat position are made in the same way as T-joints, except that the electrode should be held so as to form a 30-degree angle with the vertical.

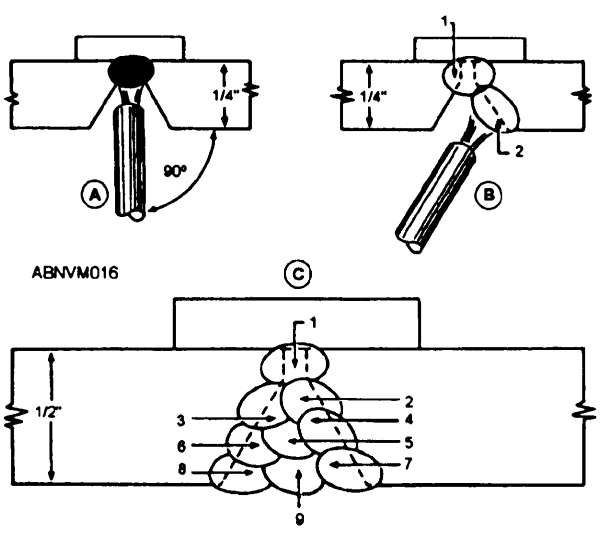


Figure 10-16.—Bead sequence and electrode angle for welding a butt joint in the overhead position.

When welding in the overhead position, keep a short arc of about one-eighth inch, hold the arc at an angle of 90° to the base metal, and avoid weaving. Butt joints in the overhead position are most easily made with backing straps. If backing straps are not permitted, the root can be welded from the top of the joint. Each bead must be cleaned and any rough places should be removed before the next pass is made. Figure 10-16 shows the correct electrode angle and the correct sequence for running beads when making a butt joint in the overhead position.

Figure 10-17 shows the fillet welding of a T-joint in the overhead position. The welding should be done with a short arc, using stringer beads. Hold the electrode about 30° from the vertical plate, and move it uniformly in the direction of welding. Control the arc motion so as to get good root penetration and good fusion with the side walls. If the pool of molten metal gets too large and begins to sag, shorten the arc and speed up the travel rate of the electrode. Then return the electrode to the crater, and continue the welding. On heavy plate, several passes may be required to make either T-joints or lap joints in the overhead position. Make the second, third, and fourth passes of a weld, like the one shown in figure 10-18, with a slight circular movement of the end of the electrode. The lead angle should be about 15°. Each bead must be cleaned of all slag and oxides before the next bead is added.

Welding in the vertical position is difficult because molten metal tends to run down. A short arc and careful control of voltage are particularly important for welding in the vertical position. Current setting (amperage) is lower for welding in the vertical position than it is for welding in the flat position. Also, less amperage is used for welding down than for welding up in the vertical position. When welding up in the vertical position, hold the electrode at an angle of 90° to the vertical.

ARC BLOW

Welding with dc involves a special problem known as arc blow (also known as magnetic arc blow). It is important that you understand what arc blow is and that you know how to recognize it and what to do about it.

Arc blow is caused by distortion in the electromagnetic field that surrounds a

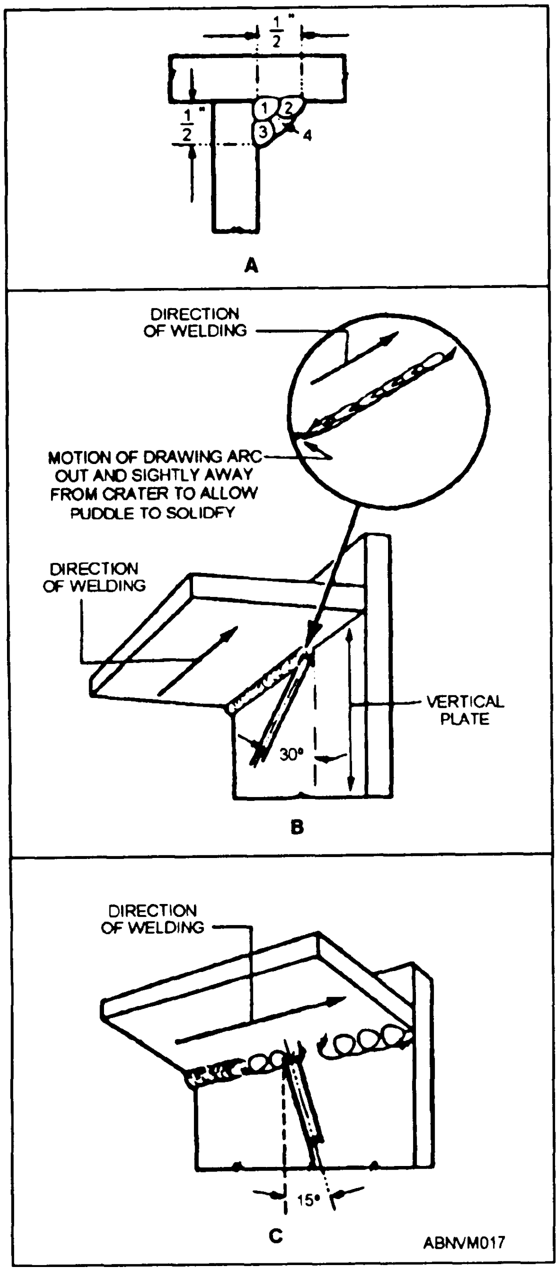


Figure 10-17.—Fillet welding of a T-joint in the overhead position.

current-carrying conductor. The distortion occurs as you approach any sudden turn in the welding; for example, when you are welding on an I-beam or a U-beam. When the field is distorted, a greater pull exists on one side than on the other. When that happens, the arc tends to blow out the side of the electrode, consuming the covering faster on that side than on the other side. The magnetic force takes control of the arc and causes it to pull this way and that in a wild and uncontrollable fashion. The situation must be corrected at the first sign of trouble or the heat will become intense and the arc will fluctuate wildly. In a very short time, the arc will be lost, usually with an explosive burst that carries away the molten metal of the weld. Arc blow causes incomplete fusion and excessive spatter.

Arc blow can often be overcome. Following is a list of some of the methods used most often by experienced welders:

- Changing the direction of the current flow (Remember some electrodes can only be welded with straight or reverse polarity)
- Changing ground connections
- Modifying the magnetic field with metal bars across the weld groove
- Working toward the ground from any bend in the line of weld, or by tilting the electrode

You will have to learn by experience which of these measures works best under various conditions.

DISTORTION

Distortion is a temporary or permanent change in the shape or dimensions of a welded part as a result of welding.

Expansion and contraction are the principal causes of distortion in welding operations. During welding, the metal is differentially heated and subjected to drastic temperature gradients. It becomes weaker and more easily deformed as it is heated, and the tendency to distort is aggravated by the degree of restraint at the weld joint.

During all welding operations, the weld metal and heated base metal undergo considerable contraction when they are cooled to room temperature. The surrounding cold metal offers resistance to the shrinking of the heated area. The weakness of the metal at elevated temperatures and the small mass of heated metal compared to the structure as a whole means that most of the adjustment must be made by the weld metal.

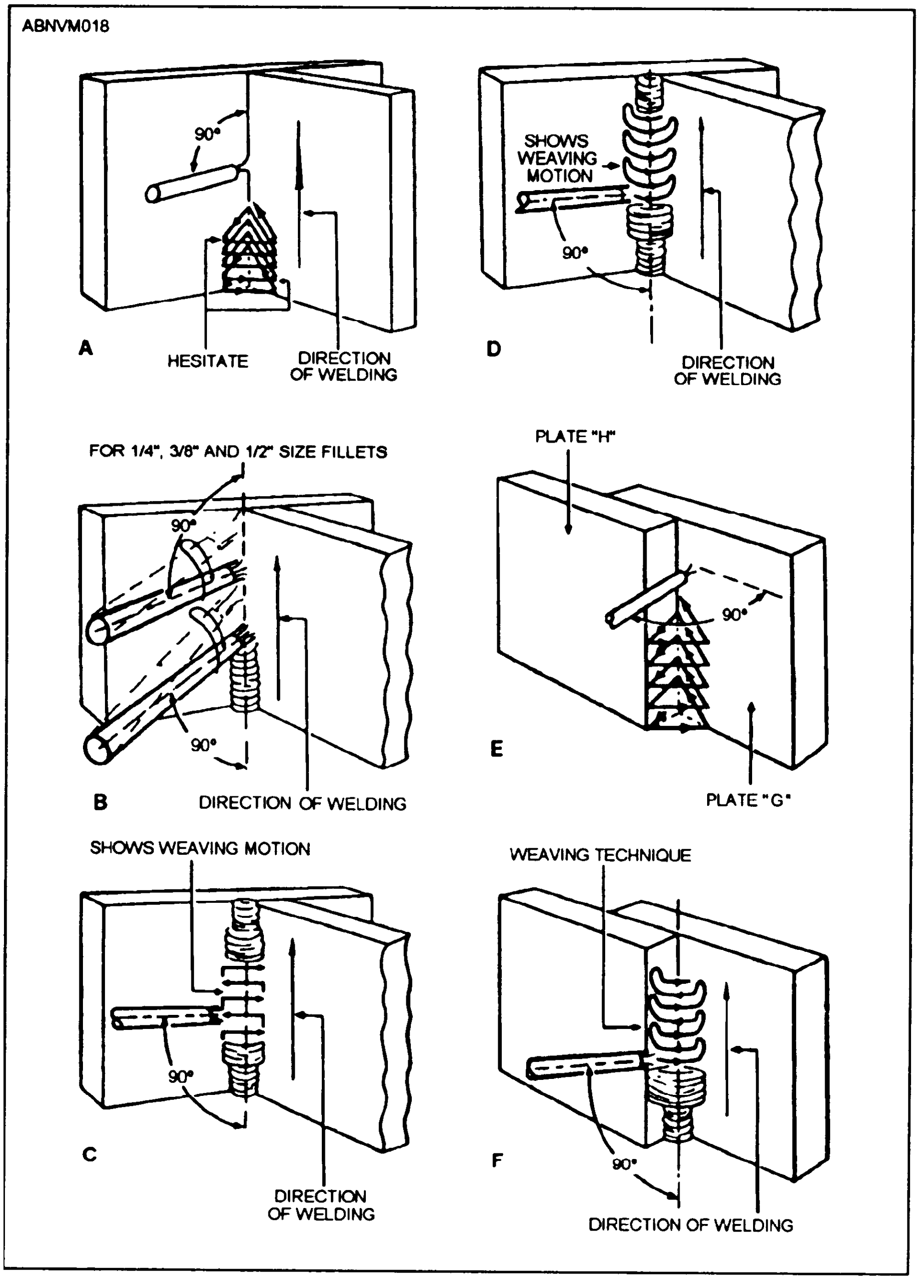


Figure 10-18.—Welding in the vertical position.

When the part being welded is free to move, distortion will be caused by contractual stresses. Distortion may be prevented by the restraint of jigs, structural rigidity, or the support of previous welding. Under such conditions, you may expect residual stresses up to the yield point of the metal. If the required plastic flow exceeds the metal's capacity to flow, cracking may result. When a bar of steel is heated thoroughly and uniformly, it will expand in all directions. If it is allowed to cool evenly, and without restraint of any kind, it will contract to its original shape and size. On the other hand, if the bar is restrained in any way during heating, it will not be able to expand in the direction of the restraint. For example, a metal bar placed in a vise so that the jaws close against the two ends, as shown in figure 10-19, cannot expand towards the two ends. Any expansion would have to be lateral. When it contracts upon cooling, however, there is no restraint and it will contract in all directions. It does not return to its original shape and size but becomes shorter and thicker, as shown in figure 10-19. Thus, a return to an original shape and size is possible only when a part is free to expand and contract freely and without restraint.

If a bar is heated over a small area, the expansion will be local and uneven. The mass of surrounding metal will not expand, and tends to prevent expansion of the heated metal in all directions except upon the surface. Consequently, when the yield point has been reached, the metal becomes permanently deformed. When the bar cools, it does not return to its original form, and distortion results.

The factors governing distortion are the resistance of the structure to the free contraction of the weld metal; the temperature gradient, which is determined by the rate at which heat is applied and the rate at which heat is conducted away from its point of application; the coefficient of expansion of the metal, which determines the total amount of plastic movement; and the yield strengths of the base and weld metal, which limit the residual forces that can exist within the structure. Generally speaking, there are six basic means of controlling distortion:

Stretching the metal, preferably while still hot, by a series of hammer blows (peening)

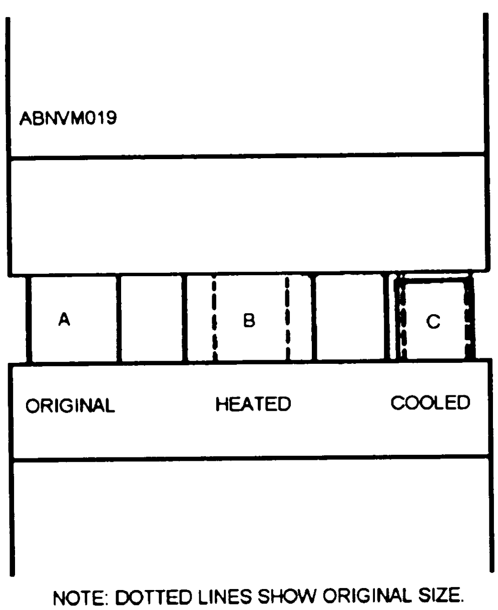


Figure 10-19.—Dimensional changes due to restrained expansion and unrestrained contraction.

- Distributing and balancing the forces and stresses produced by weld shrinkage by special welding techniques and sequences

- Forcibly restraining the parts being joined from movement during welding by suitable jigs and fixtures

- Selecting the joint and the geometry of the joint selected

- Selecting the welding process

- Selecting the weld joint bead procedure

Preheating involves raising the temperature of the base metal or a section of the base metal above the ambient temperature before welding. Preheat temperatures may vary from as low as 60°F to as high as 600°F for highly hardenable steels and 1200°F for ductile cast iron.

Preheating is a very effective means of reducing weld metal and base metal cracking. Preheating may improve weldability generally, but has two major beneficial effects: it retards the cooling rates in the weld metal and heat-affected base metal, and it reduces the magnitude of shrinkage stresses. However, when you are welding quenched or age-hardened materials, the effects of preheating can be detrimental unless they are controlled within allowable limits.

In many operations, the temperature to which the base metal is heated must be carefully controlled. The best means of control is to heat the part in a furnace held at the desired temperature, by electric induction coils, or by electric resistance heating blankets. In these methods, temperature indicators are attached to the part being preheated. Figure 10-20 shows electric induction coils set up for preheating pipe prior to welding.

When using the oxyacetylene torch for preheating, it is important to prevent localized overheating and deposits of incomplete combustion of gases on the surfaces of the joints of areas to be welded. Temperature-indicating crayons that melt at known temperatures are used for measuring the temperature of the preheated part.

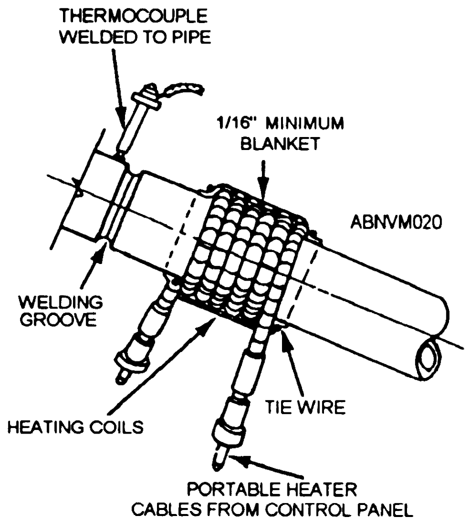


Figure 10-20.—Electric induction coils set up for preheating pipe.

Cooling rates are usually faster for a weld made without preheat. The higher the preheating temperature, the slower the cooling rates after the weld is completed. The temperature gradient is reduced and, in the case of iron, the thermal conductivity is decreased. At 1100°F, the thermal conductivity of iron is 50 percent less than at room temperature. At 1472°F, the thermal conductivity of many carbon steels is approximately 50 percent less than at room temperature. Low thermal conductivity ensures slow cooling rates because the heat is transferred from the welding zone at a lower rate.

Distortion, weld metal and base metal cracking, and porosity may be eliminated or reduced by an appropriate modification of the welding technique and sequence. Certain sequences, such as backstep, cascade, block, and wandering, minimize cracking near the bond and are used to advantage in poor-fit work. Whenever possible, welding should proceed toward the unrestrained end of a joint, because free movement of the parts will reduce the danger of weld metal cracking.

When postheat is applied immediately to a completed carbon steel or low-alloy steel weld, it will retard cooling, minimize the formation of underbead cracks, and slightly temper the structure. Figure 10-21 shows postheat being applied to a welded pipe, using electric induction coils. Although postheat can prevent cracks, it cannot remove cracks or porosity. Very highly hardenable

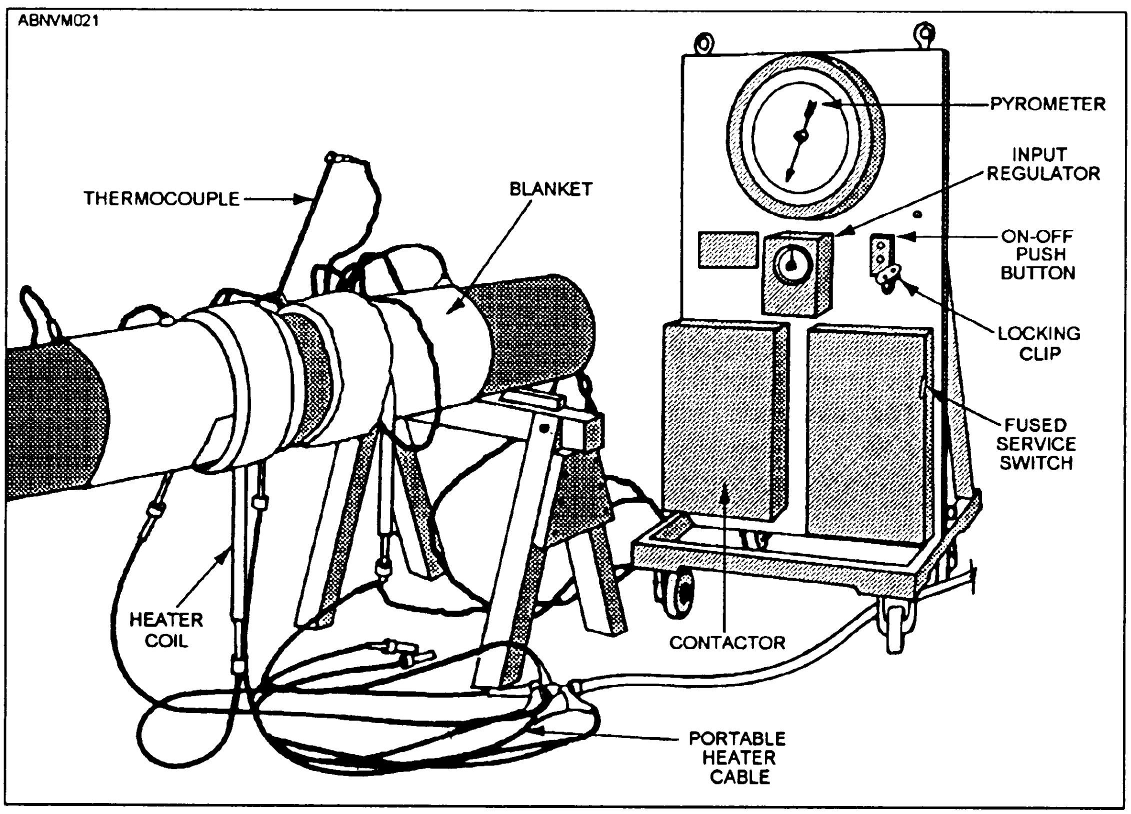


Figure 10-21.—Postheating welded pipe with electric induction coil equipment.

steels should be transferred directly to a stress-relief furnace without loss of preheat.

The peening of weld metal helps minimize cracking of weld metal and reduces distortion because it distributes the residual stresses created by welding.

Various specifications and codes require that the first and last layer of weld metal not be peened. Peening of the first layer could pierce the weld or displace the members being welded. Peening of the last layer can cause brittle fractures due to the cold working of the weld metal. Use peening on each weld bead or layer except the first and last. The effectiveness decreases as the thickness of the bead or layer increases. Peening becomes of doubtful value for deposits on one-fourth inch or thicker, except in special instances where the rigidity or weight of the weldments permits the use of heavy blows.

Peening equipment should be selected with care. The hammer, pneumatic tools, and so on, should be heavy enough in striking force to be effective without producing excessive work hardening, but not so heavy that bending moments are involved or cracks produced in the weld.

The general causes of weld metal cracking, base metal cracking, porosity, and inclusions are outlined in table 10-4.

GAS SHIELDED-ARC WELDING

This process uses a shielding gas to protect the electrode, arc, molten weld metal, and weld area from exposure to the atmosphere. The shielding gas is noncombustible and may or may not be inert (chemically inactive). The electrode may be nonconsumable, or it may be a consumable wire electrode that is fed automatically into the weld.

There are two different types of gas shielded-arc welding processes. One is the gas tungsten-arc (GTA) process, which uses a nonconsumable tungsten electrode. The other is the gas metal-arc (GMA) process, which uses a consumable wire electrode that is fed automatically into the weld.

These two processes were formerly known as tungsten inert-gas (TIG) welding and metal inert-gas (MIG) welding. The names were changed by the AWS because carbon dioxide is used as a shielding gas when welding mild steel by the GMA process, and carbon dioxide is not an inert gas.

A big increase has occurred in the use of the GTA and GMA processes for all types of structural and piping systems. This is especially true in aluminum fabrication. For that reason, we have given special attention to these two processes. Our discussion includes basic information on the characteristics of aluminum that affect its weldability, as well as on the effect of heat on the aluminum part being welded. The importance of surface preparation is explained. Detailed information is given on both the GTA and GMA processes. Practice exercises are provided to help you develop techniques in various operations used in each process.

BASIC THEORY OF ALUMINUM WELDING

Selection of the arc-welding method to use on aluminum depends largely upon the individual application. You need to consider thickness; design of the parts, components, or assemblies; and available equipment. The best welding methods for aluminum are the GTA and the GMA processes. Both use noncombustible gas (argon, helium, or a mixture of gases) to keep air away from the arc and molten weld pool and to eliminate the need for a welding flux. The gas shield is transparent; the welder can see the fusion zone and make neater and sounder welds. Aluminum can be welded in any position by either method.

The GTA process is best for welding aluminum sections less than one-eighth inch in thickness. This method can also be used on heavier sections, but the GMA process is usually chosen for its higher welding speed and economy.

General Considerations

The factors that affect the welding of aluminum and the properties of aluminum weldments include melting point, thermal conductivity, thermal expansion and contraction, oxidation, gas porosity, and the effects of welding.

Pure aluminum melts at 1210°F, and weldable aluminum alloys start to melt at 1050°F. This compares with steel, which melts at about 2800°F and copper at about 1980°F. Unlike these metals,

Table 10-4.—Causes and Cures of Common Welding Problems

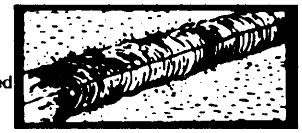
ABNVM022

porous welds

WHY
1. Short arc with extension of low hydrogen and stainless
2. Insufficient puddling time
3. Impaired bas metal
4. Poor electrode
5. Improper shield coverage

WHAT TO DO
1. Check impurities in base metal
2. Allow sufficient puddling time for gases to escape
3. Use proper current
4. Weave your weld to eliminate
5. pin holes
5. Use proper electrode for job
6. Hold longer arc
7. Check shield gas

cracked welds



WHY
1. Wrong electrode
2. Weld and parts sizes unbalanced
3. Faulty welds
4. Faulty preparation
5. Rigid joint

WHAT TO DO
1. Design structure to eliminate rigid joints
2. Heat parts before welding
3. Avoid welds in string beads
4. Keep ends free to move as long as possibe
5. Make sound welds of good fusion
6. Adjust weld size to parts size
7. Allow joints a proper and uniform gap
8. Work with amperage as low as possible

poor penetration

WHY
1. Speed too fast
2. Electrode too large
3. Current too low
4. Faulty preparation

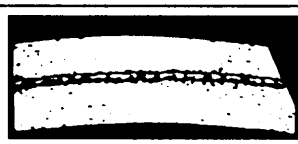
WHAT TO DO
1. Use enough current to obtain desired penetration- weld slowly
2. Select electrode according to welding groove size
3. Leave proper gap at bottom of weld

poor appearance

WHY
1. Faulty electrode
2. Overhang
3. Improper use of electrode
4. Wrong arc voltage and current

WHAT TO DO
1. Use a proper welding technique
2. Avoid overheating
3. Use a uniform weave
4. Avoid overly high current

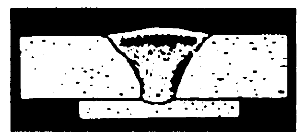
warping



WHY
1. Shrinkage of weld metal
2. Faulty clamping of parts
3. Faulty preparation
4. Overheating at joint

WHAT TO DO
1. Peen joint edges beforewelding
2. Weld more rapidily
3. Avoid excessive space between parts
4. Preform parts before welding
5. Use proper sequence
6. Clamp or tack parts properly -back up to cool
7. Adopt a proper welding procedure
8. Use high speed, moderate penetration process

poor fusion



WHY
1. Wrong speed
2. Current improperly adjusted
3. Faulty preparation
4. Improper electrode size

WHAT TO DO
1. Adjust electrode to match joint
2. Weave must be sufficient to melt sides of joint
3. Select proper curerent and voltage
4. Keep weld metal from flowing away from plates

undercutting

WHY
1. Faulty electrode or gun manipulation
2. Faulty electrode usage
3. Current too high

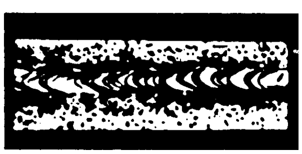
WHAT TO DO
1. Use a uniform weave in butt welding
2. Avoid using an overly large electrode
3. Avoid excessive weaving
4. Use moderate current, weld slowly
5. Hold electrode at safe distance from vertical plane in making horizontal fillet weld

brittle welds

WHY
1. Wrong electrode
2. Faulty preheating
3. Metal hardened by air

WHAT TO DO
1. Preheat at 300° to 500° F if welding on medium carbon steel or certain alloy steels
2. Make multiple layer welds
3. Stress relieving after welding
4. Use low hydrogen processes for increased weld ductility

spatter



WHY
1. Arc blow
2. Current too high
3. Arc too long
4. Faulty electrodes

WHAT TO DO
1. Clean parts in weld area
2. Adjust current properly
3. Adjust voltage
4. Pick suitable electrode

magnetic blow

WHY
1. Magnetic fields cause the arc to deviate from its intended course

WHAT TO DO
1. Use steel blocks to alter magnetic path around arc
2. Divide the ground into parts
3. Weld in same direction the arc blows
4. Use short arc length
5. Locate the ground properly on the work
6. Use A-C welding

there is no color change in aluminum during heating. However, it is possible to know when the aluminum is near its melting point and at welding temperature by watching the weld pool. The GTA weld pool, for example, develops a glossy appearance, and a liquid pool or spot forms under the arc when the metal becomes molten.

Aluminum conducts heat three times faster than iron, so you need a higher heat input to weld the aluminum. On the other hand, copper has a higher thermal conductivity than aluminum; therefore, less heat is required to weld aluminum than copper. It is usually helpful to preheat heavy sections of aluminum to reduce heat loss and, when using the

GTA process for joining such sections, to get better welding results.

Aluminum welds decrease about 6 percent in volume when solidifying from the molten state. This contraction may cause excessive weld joint distortion unless correct allowances are made before welding.

Thermal expansion of aluminum is approximately twice that of steel and one-third greater than copper. The surrounding surface expands due to the heat of welding. Thermal expansion of the adjacent aluminum may reduce the root opening on butt joints during the welding. Then, when the metal cools it contracts. This contraction, coupled with shrinkage of filler metal on cooling, may put the weld in tension and cause cracking. Excessive restraint of the component sections during cooling of the weld may also result in weld cracking.

Speed is also a factor in preventing distortion. Welding at a slow rate may cause greater area heating, thus creating more expansion and subsequent contraction.

Weldable aluminum alloys are of two types: the work-hardenable alloys, such as EC (electrical conductor grade), 1100, 3003, 5052, 5083, and 5086; and the heat-treatable alloys, such as 6061, 6062, 6063, and 7039.

Although alloys in the 2000 and 7000 series are also heat-treatable, most of them are not recommended for arc-welded fabrication because weldments are low in ductility. Better properties are obtained with the resistance-welding method. A notable exception is alloy 7039, now employed for armor plate and other critical applications. Welding qualities of alloys in the 2000 and 7000 series with either resistance or GMA processes are excellent. As-welded (GMA) strengths are upward of 48,000 psi, and ductility of these welds ranges from 8 to 12 percent elongation, in 2-inch increments.

Mechanical properties can be improved in heat-treatable alloys by heat treatment at temperatures above 900°F, followed by a low-temperature aging treatment above 300°F.

Aluminum alloys lose hardness and strength when reheated to high temperatures. When heated above 900°F, the aluminum alloys revert to the annealed condition almost immediately. The degree of loss is a function of time and temperature. We mentioned earlier that the weld metal is over 1050°F when deposited; therefore, welding causes some annealing of the parent metal. With the heat-treatable alloys, welding also lowers the ductility of the joint.

Preheating is necessary if the mass of the parent metal causes heat to be conducted away from the joint so fast that the welding arc cannot supply the heat required to produce fusion. Insufficient heat causes poor fusion of the weld bead and inadequate melting of the parent metal. Preheating of the parts being joined helps to produce a satisfactory weld, reduces distortion or cracking in the finished product, and increases welding speed.

Preheating is necessary in GTA welding of heavy plate. For the heat-treatable alloys, such as 6061, preheat should be used carefully. Too high a temperature or too long a preheat period can decrease the as-welded strength of the joint. Recommended preheat temperatures for various thicknesses of aluminum plate and tube are shown in table 10-5.

In GMA welding, preheat is seldom required regardless of plate thickness. This is one advantage of the GMA process over GTA. Another advantage is the greater welding speed of GMA.

Residual stresses created in aluminum alloy by the heat of welding may become excessive, due to the total amount of heat input, thickness of metal, and design of the weldment. In extreme cases, such stresses may cause early failure of the weldment. One common method of modifying residual stresses is by peening (localized working of the metal by hammering) to effect limited distribution of the stresses. However, peening usually is not advisable on thin sections. For these and certain other cases, stress relieving by thermal treatment is recommended, where required.

All aluminum alloys can be completely annealed by heating them to the proper temperatures for specified periods of time. Annealing of the metal relieves all residual stresses. The temperatures required for substantial stress relief have an adverse effect on the mechanical properties. This may lower the resistance to corrosion in some alloys.

For aluminum-magnesium alloys (5000 series), high residual stresses may be reduced by heating the

Table 10-5.—Preheat Temperatures for Welding Sheet, Plate, and Tubular Aluminum Sections (Butt Joints)

Tubular Sections			
Outside Diameter Inches	Wall Thickness Inches	Approximate Preheat Degrees F	
		GTA	GMA
1-3	1/3	None	NR*
4-6	1/8	Optional—400	NR
1-3	l/4	None	None
4-6	l/4	400	None

Sheet and Plate		
Thickness	Approximate Preheat Degrees F	
	GTA	GMA
l/8-1/4	None	None
l/2	600	None
3/4		None
1	NR	None
2	NR	Optional—500
3	NR	Optional—500

*Not recommended

Note: These preheat temperatures are only for use as a guide. Most weldors prefer to increase the welding current and thereby avoid preheating. Preheating is another operation and increases overall costs. Also, if welding the heat-treatable alloys such as 6061, it should be realized that the temperature and length of preheating time can affect the as-welded strength of the joint. It is seldom necessary to preheat when using the GMA process.

alloys at temperatures below 650°F, the temperature for complete annealing. The principal limitation on post-weld heating is whether the weldment can fit inside the available oven. Heating the entire weldment in a furnace is recommended. Local heating for stress relieving is effective in some cases, but only where testing or performance data proves its effectiveness.

The aluminum-magnesium alloys (5000 series) can usually be stress relieved by post-weld heating them at 450°F for approximately 4 hours. As previously mentioned, complete annealing is achieved upon heating these alloys to 650°F. Cooling rate is unimportant.

Aluminum and its alloys rapidly develop an oxide surface film upon exposure to air. This oxide has a melting point in excess of 3600°F or about 2400°F above the melting point of pure aluminum. Temperature differential allows the aluminum to melt before the oxide film. When this happens, the film prevents fusion between the filler metal and its base plate. Therefore, the oxide film must be disrupted or removed by a chemical cleaner, flux, mechanical abrasion, or by the action of the welding arc.

Particles of oxide entrapped in the weld will impair ductility of the weldment. The joint should be cleaned with a stainless-steel wire brush immediately before welding to reduce the oxide level.

The GTA and the GMA welding processes have a major advantage over other methods, in that no fluxes are required. The action of the welding arc breaks up the oxide film. The noncombustible gas shield envelops both the arc and weld pool, preventing oxidation from recurring while the metal is molten.

Molten aluminum readily absorbs available hydrogen. When the weld pool solidifies, most of the hydrogen is released because it is practically insoluble in solid aluminum. This released hydrogen may become entrapped and cause porosity in the weld, which may impair its strength and ductility. Also, hydrogen may get into the molten weld metal from surface oils or from moisture on the filler wire. To reduce weld porosity, the metal surfaces must be carefully cleaned and care must be taken to maintain the cleanliness of the filler wire supplied by the manufacturer.

Cleaning the surfaces to be welded is of major importance in all aluminum joining, regardless of the welding process. This cleaning should be done just before welding. Cleanliness cannot be overemphasized. Oxide, grease, or oil films remaining on the edges to be joined will cause unsound welds. Unsoundness (porosity caused by gas, dross inclusions, ships, and so on) reduces the mechanical and electrical efficiency of the weld. Mildly alkaline solutions, and commercial degreasers that do not produce toxic fumes during welding, are used to remove surface contaminants before welding. One common method of cleaning is for the welder to wipe the edges of the joint with a cloth that has been dipped in a solvent, such as alcohol or acetone. All welding surfaces should be dried after cleaning to prevent porosity in the weld metal. Avoid use of carbon-chlorine solvents.

Oxide films should be removed from the surface of the aluminum by a suitable abrading process such as brushing with a clean, stainless-steel wire brush immediately prior to welding. If you are ever in doubt whether to wire brush, DO IT. Black, sooty-surfaced welds mean insufficient brushing.

Preparing Aluminum for Welding

The choice of joint design for welding aluminum depends upon the thickness of the material and the process used for joining. On relatively thin materials, one- to three-sixteenths inch thickness, the square butt joint is usually satisfactory for both processes. For thicker metal, either a single-vee bevel or double-vee bevel may be necessary.

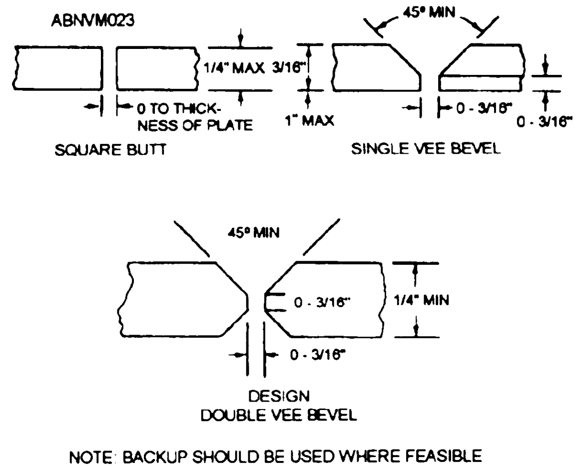


Figure 10-22.—Recommended joint designs for common thickness of plate.

The joint design and root openings required for GTA welding are determined by the thickness of the aluminum to be joined and the structural requirements of the weldment. Design varies from a square butt for one-eighth inch sheet to a 45-degree minimum included-angle vee joint for one-half inch or thicker plate. For tubular sections having a wall thickness greater than one-eighth inch, the edges should be beveled with a minimum 60-degree included angle and have a zero to one-sixteenth inch square butt lip. Recommended joint designs for common thicknesses of plate and pipe are shown in figures 110-22 and 10-23. For one-eighth inch thick and up, some root opening is recommended to ensure complete penetration.

The joint design and root openings required for GMA welding are determined by metal thickness and structural requirements as in GTA welding. Aluminum sheet up to one-fourth inch thick can be welded manually with complete penetration using a square butt design. For manual welding, material greater than one-fourth inch thick may have a

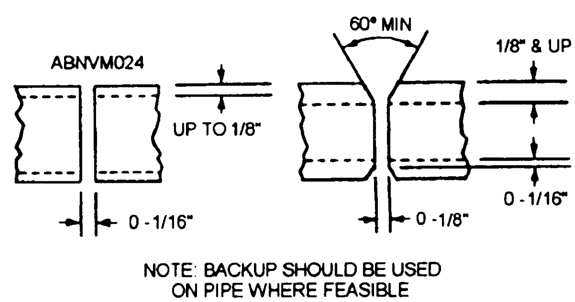


Figure 10-23.—Recommended joint design for pipe.

single-vee groove or a double-vee groove, as shown in figure 10-24. The edges of tubular sections are prepared the same as the edges of plate of corresponding thickness.

The welding of tubular sections employs the same techniques as those used for plate and pipe, with the exception that a backup is not used when welding is to be done from both sides. In this case, the back-chipping technique is used to ensure high-quality welds in the finished product. Backup plates are recommended wherever possible to control weld penetration. These plates also permit faster welding speeds.

Good joint fit-up makes welding easier, saves filler metal and shielding gas, and helps to assure quality welds. If jigs are not used to hold the joint members in their correct position, tack welding may be necessary. Tack welds should be short in length, one-fourth to one-half inch. They should also be small in size, one-eighth to three-sixteenths inch, depending upon the size of the metal. In addition, tack welds should be sufficient in number and correctly placed to maintain proper alignment of units or components being welded. The number of tacks to be made is determined by the workpiece to be welded.

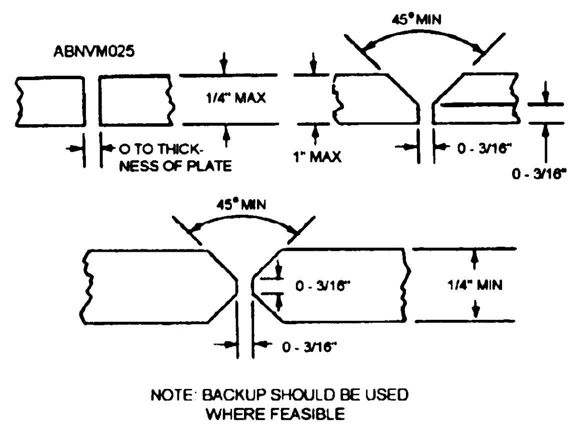


Figure 10-24.—Single-vee and double-vee groove welds.

GAS TUNGSTEN-ARC (GTA) WELDING PROCESS

The GTA process is widely used for welding relatively thin aluminum sections. In this process, an arc is established between a nonconsumable tungsten electrode and the aluminum parts to be welded with a shield of gas enveloping the arc and weld pool. The arc melts the aluminum base metal, and a bare filler rod of suitable alloy is manually added to the molten pool. Welding can be done rapidly from all positions. No flux is required in GTA welding because the action of the arc breaks up the oxide film and allows good weld-metal flow. A shield of gas, either argon or helium or a mixture of argon and helium, surrounds the electrode and the weld pool to prevent oxidation during welding.

Since the heat of the tungsten arc is concentrated in a small area, it is much faster than oxyacetylene welding. Distortion in GTA welds is also appreciably less than for oxyacetylene welds.

Welding Power Source

The heat for any arc-welding process is generated by the arc between the electrode and the base metal. The welding current for GTA welding is supplied by the ac/dc transformer-rectifier welder (fig. 10-25). This machine will deliver ac

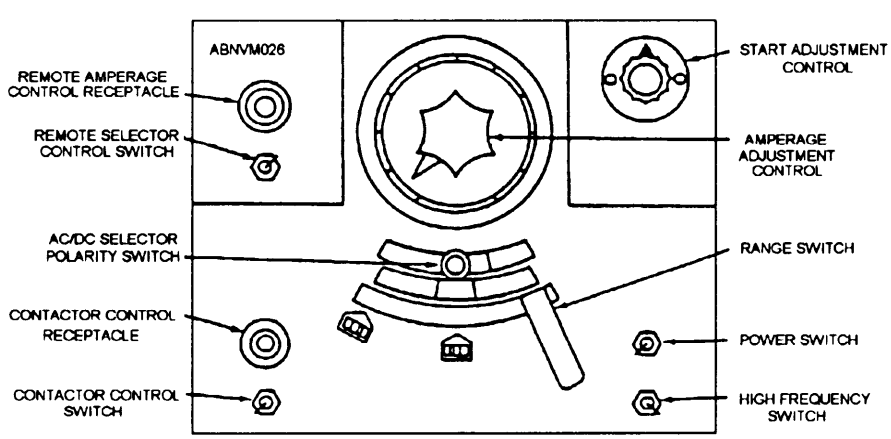


Figure 10-25.—Equipment for GTA welding.

high-frequency, dc reverse polarity (DCRP), and dc straight polarity (DCSP) welding current. Except for high frequency, ac welding is only authorized for use on tenders and shore facilities. Exceptions will require approval.

High-frequency ac is recommended for the welding of aluminum. It offers both the advantages of DCSP and DCRP welding. Theoretically, ac welding can be called a combination of DCSP and DCRP welding, as shown in figure 10-26.

In ac welding, when the current passes through zero (fig. 10-26), the arc is broken. To restart the arc, a high-voltage, high-frequency, low-power additional current is used. This establishes an ionized path for welding current to follow, when the arc is struck at zero current.

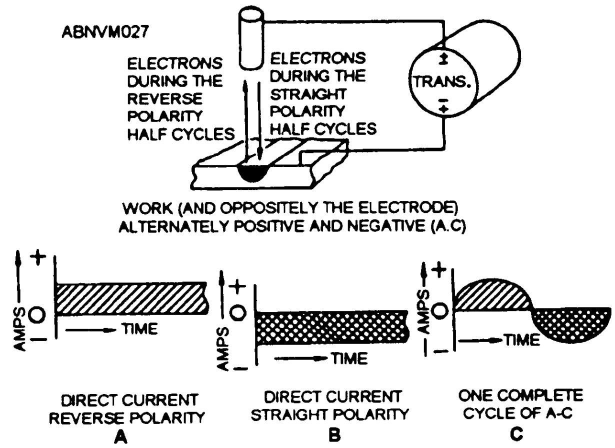


Figure 10-26.—Ac welding as a combination of dc straight and reverse polarity welding.

In any GTA welding operation, selection of the proper current is of utmost importance. Table 10-6 may be used as a guide for the selection of current for welding some of the more common metals.

Table 10-6.—Current Selection for GTA Welding

Material	Alternating Current	Direct Current	
	with high frequency stabilization	Straight Polarity	Reverse Polarity
Aluminum-up to 3/32 inch thich	1	2	N.R.
Aluminum-over 3/32 inch thich	1	N.R.	N.R.
Aluminum castings	1	N.R.	N.R.
Brass alloys	2	1	N.R.
Silicon copper	N.R.	1	N.R.
Monel	2	1	N.R.
Stainless steel	2	1	N.R.
Hard surfacing alloys	2	1	N.R.

Key: 1. Excellent Results
2. Good Results
N.R. Not recommended

Welding Equipment and Supplies

In addition to the ac power source, the following equipment is needed for GTA welding:

- GTA welding torch. (Note that the word *torch* is commonly used for this GTA welding device. It is also termed *electrode holder*. However, throughout this discussion the word *torch* will be used.)
- Gas supply, regulator-flowmeter, hose, and fittings
- Filler metal
- Water supply and fittings
- Helmet or eye shield, and protective clothing
- Stainless-steel wire brush

For currents above 200 amperes, cooling the torch and power cable is necessary because of heat generated by the arc and the current passing through the cable. For welding currents below 200 amperes, air-cooled torches are satisfactory. A sectional sketch of a GTA water-cooled torch is shown in figure 10-27.

Water used to cool the welding torch should be clean to prevent clogging or flow restriction. Overheating can melt the silver-brazed metal joints in the torch and the plastic water tube that sheaths the electric cable. A control mechanism is available that does not allow the welding current to start unless the water is flowing. Some GTA welding equipment is provided with a solenoid valve that automatically shuts off the water supply when the welding stops. This prevents excessive cooling and moisture condensation inside the torch. Moisture can contaminate the electrode and cause porosity in the weld during the initial weld period. When GTA equipment is to be used in the field and if water is not available, a small water tank and pump can be used to circulate water between the tank and the torch. The GTA welding torch carries the welding current and directs the gas to the weld area. The torch must be properly insulated for the maximum current ranges to ensure operational safety. Current is transmitted from the ac transformer through the power cable to a collet holding the tungsten electrode. Gas ports surrounding the electrode permit the gas to enter the nozzle or cup.

The electrode should extend beyond the end of the gas cup a distance of l/8 to 3/16 inch. Selecting the right size electrode for each job is important to prevent electrode damage and poor welds caused by too high or too low a current. Excessive current will cause tungsten particles to transfer to the weld, while insufficient current allows the arc to wander erratically over the end of the electrode. With correct current the electrode will have a stable hemispherical end. Recommended electrode sizes

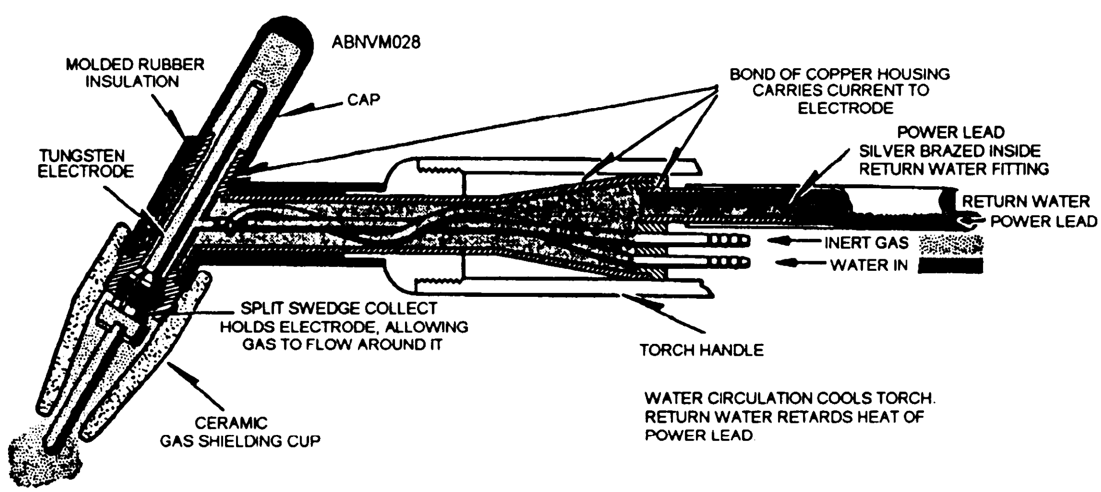


Figure 10-27.—Sectional sketch of a GTA water-cooled torch.

for various ranges of welding current are shown in table 10-7.

We will not describe in detail the advantages and disadvantages of the various types of electrodes made of pure tungsten, thoriated tungsten, or tungsten-zirconium alloy. Many welders prefer pure tungsten for GTA welding with ac. Thoriated tungsten is preferred for automatic GTA welding using dc straight polarity current. A note of interest here is that tungsten electrodes are usually color-coded on one end. A medium green indicates that the rod is pure tungsten. A yellow color indicates a 1 percent thoriated tungsten rod. A light red color indicates a 2 percent thoriated tungsten rod. A tan color indicates that the rod is zirtung (tungsten zirconium).

The gas cup or nozzle of the torch can be either ceramic or metal. Ceramic nozzles are generally unsatisfactory for welding at high-current levels because the nozzle may melt at the tip and partially close the orifice. On the other hand, metal nozzles of too small diameter will short out the high-frequency current if the work is touched by the nozzle. Torch manufacturers usually recommend the type and size of nozzle for different current ranges. Generally, the nozzle diameter should be equal to or slightly greater than the molten weld pool.

Dual Action of the AC Arc

The first function of the ac arc is to provide the heat necessary to melt the base and filler metals. The second arc function is to break up and remove the surface oxides from the aluminum. This is called the "cleaning action," and takes place during that part of the ac cycle when the electrode is positive. The cleaning action is either a result of the electrons leaving the base plate or the gas ions striking the surface or a combination of both.

Shielding Gas

Initially the arc breaks up the oxide on the area where it is directed. The gas shields the arc and weld pool, preventing oxidation from reoccurring. The gas also shields and prevents oxidation of the hot tip of the tungsten electrode; and because of this, the flow of gas should not be stopped until the tungsten electrode tip has cooled. Shutoff can be either manual or automatic; the latter is preferred. Another function of the gas shield is to provide a more easily ionized path, thus aiding smooth transfer of current. Either argon or helium can be used for shielding the arc in the GTA process. Helium requires a higher gas flow, but gives greater penetration and faster welding speeds than argon. This deeper penetration is obtained because the arc in the helium atmosphere is hotter than in the argon atmosphere. Argon is preferred by most welders because the cleaning action is greater and the arc more stable. The flow of gas necessary for good GTA welding depends on the welding current, size of nozzle, joint design, speed of welding, and freedom from draft in the area where the welding is being done. This last factor can affect gas coverage considerably. Recommended gas flows are shown in table 10-8.

Table 10-7.—Recommended Current Ranges for Thoriated and Nonthoriated Tungsten Electrodes

Electrode Diameter Inches	Current, Amperes	
	Standard Tungsten Electrodes	Thoriated Tungsten Electrodes
0.04	10-60	15-80
l/16	40-120	60-150
3/32	100-160	140-250
1/8	150-210	225-350
5/32	190-275	300-450
3/16	250-350	400-550
l/4	300-490	500-800
5/16	450-600	

Table 10-8.—Recommended Practices for GTA Welding of Aluminum

Material Thichness Inches	Welding Position	Joint Design (1)	Current Amps AC	Dia. of (2) Tungsten Electrode Inches	Argon (3) Gas Flow CFH	Filler Rod Dia. Inches	No. of Passes
1/16	Flat	Sq. Butt	70-100	1/16	20	3/32	1
	Horiz & Vert.	Sq. Butt	70-100	1/16	20	3/32	1
	Overhead	Sq. Butt	60-90	1/16	25	3/32	1
1/8	Flat	Sq. Butt	125-160	3/32	20	1/8	1
	Horiz & Vert.	Sq. Butt	115-150	3/32	20	1/8	1
	Overhead	Sq. Butt	115-150	3/32	25	1/8	1
1/4	Flat	60° Single Bevel	225-275	5/32	30	3/16	2
	Horiz & Vert.	60° Single Bevel	200-240	5/32	30	3/16	2
	Overhead	100° Single Bevel	210-260	5/32	35	3/16	2
3/8	Flat	60° Single Bevel	325-400	1/4	35	1/4	2
	Horiz & Vert.	60° Single Bevel	250-320	3/16	35	1/4	3
	Overhead	100° Single Bevel	275-350	3/16	40	1/4	3
1/2	Flat	60° Single Bevel	375-450	1/4	35	1/4	3
	Horiz & Vert.	60° Single Bevel	250-320	3/16	35	1/4	3
	Overhead	100° Single Bevel	275-340	3/16	40	1/4	4
1	Flat	60° Single Bevel	500-600	5/16-3/8	35-45	1/4-3/8	8-10

(1) See exercises for joint designs.

(2) For standard (non-thoriated) tungsten electrodes.

(3) Helium is not generally used on gas tungsten-arc welding; however, gas flow rates for it are slightly higher than for argon.

Filler Metal

Additional filler metal is not necessary in GTA welding when enough parent metal is provided by the joint design to form the weld bead. For other welds, it is often necessary to add filler metal. For filler metal in the form of straight length, bare rod is used for manual welding, while filler metal in wire form, spool wound is used for automatic welding.

Filler rods of EC, 1100, 4043, 5154, 5183, 5356, 5556, and other alloys are available in various diameters. Take care to see that a compatible filler metal is used in welding different aluminum alloys. Weld craters and longitudinal cracks may result from using incorrect filler alloy. Make a special effort to see that only clean rods are used. Dirty rods contaminate the weld. Store rods in a hot locker or warm dry area and keep them covered.

PRACTICE EXERCISES FOR GTA WELDING

Now that we have covered various fundamentals of GTA welding of aluminum, let us turn our attention to some practical exercises that will help you acquire skill in performing GTA welding operations. A thorough knowledge of the procedures covered in the following projects will aid you in assignments as the operator on GTA welding jobs.

Setting Up Equipment

This exercise in setting up equipment will acquaint you with the equipment and accessories commonly used in GTA welding. The basic equipment and accessories required for GTA welding of aluminum are as follows:

—Ac welding transformer with capacity range of 90 to 500 amperes having superimposed high-frequency current

—GTA welding torch and 0.040-inch, 1/16-inch, l/8-inch, 3/32-inch, 5/32-inch, 3/16-inch, and 1/4-inch diameter tungsten electrodes, collets, and suitable gas cup nozzles

—Argon gas, usually a cylinder with a regulator-flowmeter, a solenoid control valve interlocked with the welding circuit, or a manual cut-off valve (called an economizer) in the gas line before the torch

—Water supply, main shut-off valve, and solenoid control valve interlocked with the welding circuit

—Steel worktable and C-clamps

—Welding helmet, gloves, and protective clothing

—Stainless-steel wire brush for cleaning oxide from the surfaces on which weld metal will be deposited

NOTE: Reference to standard equipment in the following exercises will be briefly summarized, but anticipates all previously indicated items.

Specific information on the different makes of GTA welding equipment is not given in this training manual. We suggest the operator read the manufacturer's instruction pamphlets for specialized information.

Most GTA welding transformers are operated from a 220- or 440-volt ac power source. Normally, an Electrician's Mate is the only one allowed to connect or disconnect a transformer. However, you should know the electrical hookup and be aware that high voltages, if incorrectly handled, may cause a fatal injury.

The high-frequency current imposed on the welding current often affects radio reception unless the transformer is properly installed, grounded, and adjusted. Therefore, the manufacturer's instructions on these points should be carefully followed.

The power cable to the GTA welding torch, and the ground cable to the work, should be connected according to the manufacturer's directions. The welding torch should be hung in a safe location so that the tungsten electrode cannot touch anything grounded and thus complete an electrical circuit. The switch controlling power to the torch should always be in the "off" position when welding is not being done.

The following checks should be made before starting to weld with GTA units:

1. Be sure the torch is the right type and capacity for the current at which most of the welding will be done. Some manufacturers offer different torches for different ranges of welding current.

2. Check the size, appearance, and position of the tungsten electrode in the torch. It should be clean and silvery, and the diameter should be that recommended for the welding current to be used. A dirty, rough electrode surface usually means that the inert gas was shut off before the electrode cooled, that there was air leakage in the gas supply system or torch proper, or that the electrode tip was contaminated by touching metal. A dirty tungsten electrode can sometimes be cleaned satisfactorily with a fine emery cloth. If severely contaminated, the electrode should be replaced or the tip broken off and dressed on a grinding wheel. (NOTE: The dust produced from grinding thoriated electrodes is radioactive. However, this contamination normally does not exceed the maximum permissible concentrations. Even though the radioactive hazard of grinding thoriated tungsten is slight, care should be taken to grind electrodes on specially designed and constructed grinders.) When you are welding, the tip should be hemispherical in shape. The needlepoint tips used for stainless steel should not be used for aluminum. A contaminated and a good tungsten electrode are shown in figure 10-28. Note the hemispherical tip on the good electrode. The electrode should extend beyond the end of the gas cup a distance of l/8 to 3/16 inch. It must be securely held in the torch both for positioning and for good electrical contact. Because small diameter electrodes are easily bent, check to see that the electrode is straight and centered in the cup. If necessary, straighten or replace the electrode.

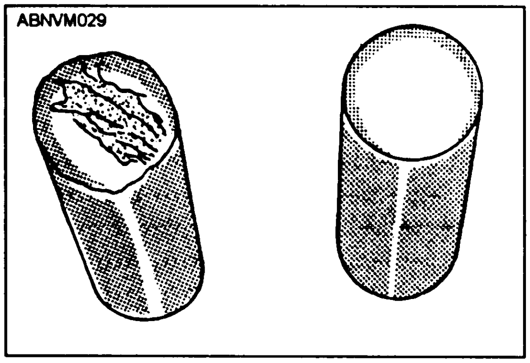


Figure 10-28.—Contaminated and good tungsten electrodes.

3. Check the connections on the gas supply for leaks with soapy water.

4. Select the proper gas cup size according to the torch manufacturer's instructions. Make sure the gas cup is free of spatter. Clean or replace it if necessary.

5. Check the ground cable connections to the workpiece. The connections should also be periodically checked after welding begins, as they tend to work loose. This causes the welding current to vary.

6. Preset the current range (see table 10-7) for the joint to be welded, and switch on the transformer, as shown in view A of figure 10-25.

7. Open the main shut-off valve on the cylinder of gas and adjust the flow, as shown in view B of figure 10-25. Table 10-8 lists the recommended flow for various welding currents.

8. Be sure the water supply to be used is not at a higher pressure than that recommended by the torch manufacturer. If satisfactory, the water shut-off valve is usually opened fully and the flow is controlled by the water ports in the gun.

9. Never look at a welding arc without a hand shield or welding helmet with the proper shade of protective glass, or your eyes will be injured. Eye fatigue indicates a different shade of glass is required or there is leakage around the protective filter glass. A No. 10 glass is satisfactory for most GTA welding at current ranges of 75 to 200 amperes. Gauntlet gloves and protective clothing must be worn as protection from hot metal. Bare skin should never be exposed to the rays of the welding arc because painful burns may result.

If you are teaching a person how to set up the equipment, you should demonstrate turning on the water and gas supply, switching on the transformer, presetting the gas flow and current range, and then shutting down the equipment. You should then have the person repeat the start-up and shut-down procedures until the procedures are thoroughly understood.

Establishing an Arc and Forming a Weld Pool

This exercise is intended to acquaint you with the correct technique of initiating an arc and forming the weld pool.

As material for this exercise, 1/4" by 6" by 12" plate of any aluminum alloy recommended for welding may be used. You will need a standard ac transformer, GTA welding torch equipped with 5/32-inch diameter tungsten electrode, argon gas, and necessary accessories. The procedure calls for regulating the argon gas flow 30 to 35 cubic feet per hour. Also, select a welding current of 175 to 225 amperes.

When using ac high-frequency current, the electrode does not need to come in contact with the workpiece to strike the arc. The high-frequency current will jump the gap between the tungsten electrode and the workpiece and establish the welding current path. To strike the arc, hold the torch in a horizontal position, as shown in figure 10-29, about 2 inches above the work surface.

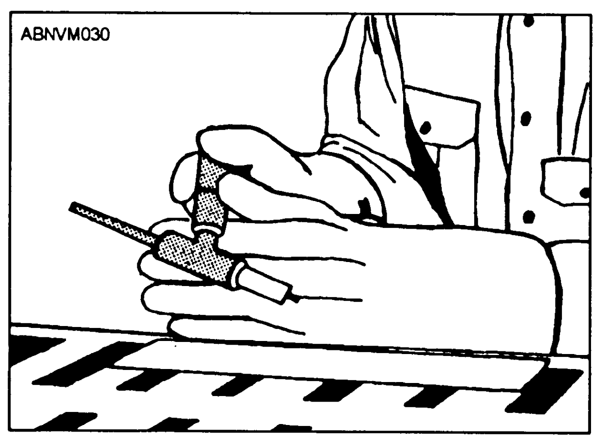


Figure 10-29.—Torch position for the starting swing to strike the arc.

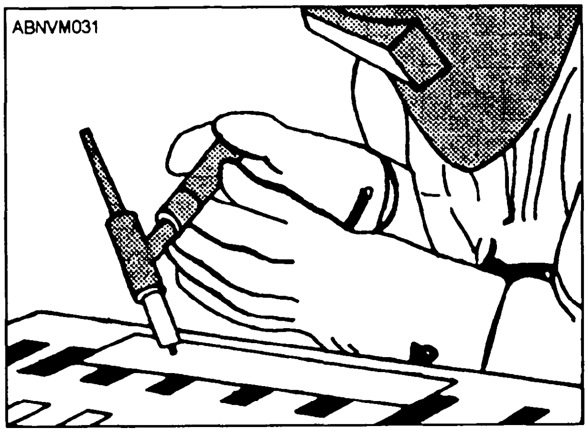


Figure 10-30.—Position of the torch at the end of the swing when the arc strikes.

Then, with a rapid motion, swing the electrode end of the torch down to within an eighth of an inch of the work surface. The arc will then strike. Figure 10-30 shows the torch position at the time the arc strikes. After the arc has been struck, hold the torch at a 90-degree angle to the workpiece surface and with small circular motions, as shown in figure 10-31, form a molten puddle. When the molten puddle has been formed, hold the torch at a 75-degree angle to the work surface and move the torch slowly and steadily along the joint at a speed that will produce a bead of uniform width. Move the torch slow enough to keep the puddle bright and fluid. No oscillating or other movement of the torch is necessary except the steady forward movement.

When the use of a filler metal is necessary, form the molten puddle as described in the previous paragraphs. When the puddle becomes bright and fluid, move the arc to the rear of the puddle and add the filler metal by quickly touching the rod to the front edge of the puddle. When the puddle becomes bright and fluid again, repeat these steps. Figure 10-32 shows the correct procedure for adding filler metal. This sequence is continued until the weld joint has been completed. The width and height of the weld bead is determined by the speed of travel, movement of the torch, and amount of filler metal added.

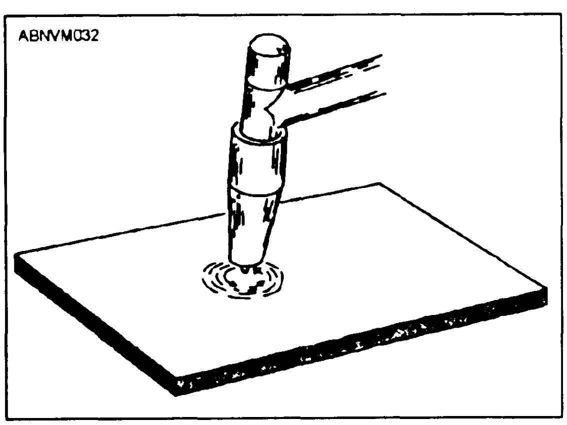


Figure 10-31.—Forming a molten puddle with a GTA torch.

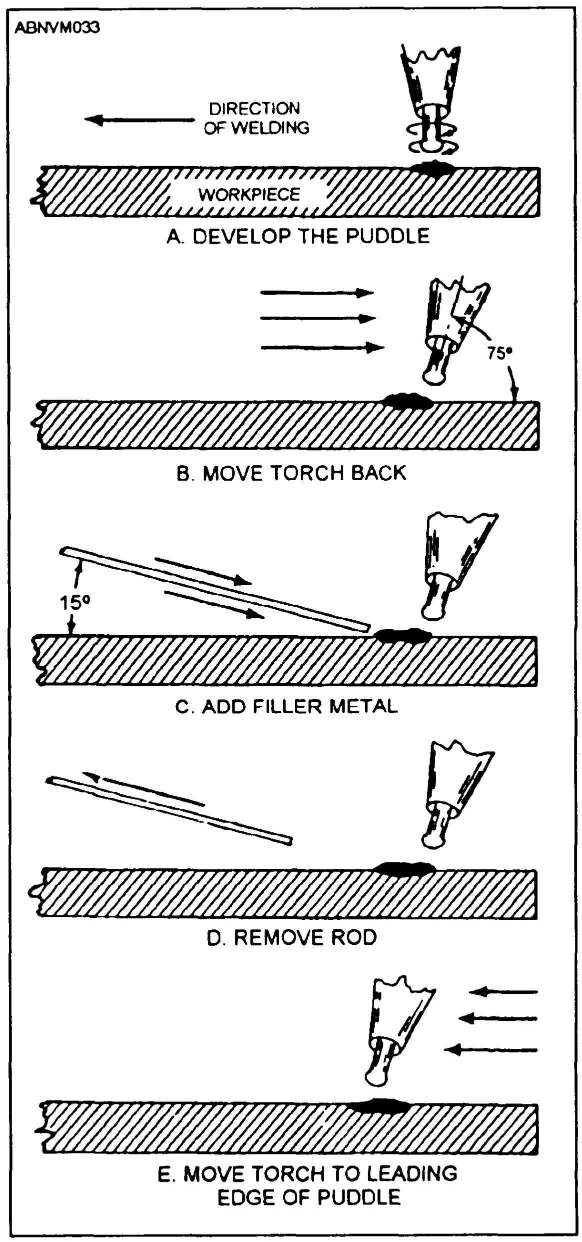


Figure 10-32.—Addition of filler metal (flat position).

When using dc straight or reverse polarity welding current, the same motion is used for striking the arc, but the electrode must come in contact with the workpiece to start the flow of welding current, unless the dc welder has high frequency to give it a self-starting arc. When the arc has been struck, withdraw the electrode approximately one-eighth inch from the work surface to avoid contaminating the electrode with the molten metal. To make the weld bead, follow the same steps as described for ac welding.

To stop an arc, snap the electrode quickly back to the horizontal position. This must be done rapidly so the arc will not damage the weld surface or the workpiece.

You will find that welding technique improves when you learn to weld in a comfortable position. Quality welding is dependent upon smooth, even manipulation of the torch and filler rod. This cannot be accomplished if you are in an awkward or uncomfortable position.

A common mistake often made by new operators in GTA welding is improperly feeding the filler rod into the arc. The arc heat should be used to form and hold the molten pool, and the filler rod should be melted by the leading edge of the pool. In this way, the weld metal will always be fused into the base metal of the workpiece. By watching the edges of the weld pool, you can learn to judge the pool's fluidity, buildup, and fusion into the parent material. Incorrect torch angle, improper torch manipulation, too high a welding current, or too low a welding speed can cause undercutting in the base plate along one or both edges of the weld bead.

The surface appearance and etched cross sections of three weld beads on a flat plate are shown in figure 10-33.

The welding current employed in each weld determines its quality. The weld bead shown in view A indicates that the current selected for welding is too high; view B indicates that the welding current used is correct; and view C indicates that the welding current is too low.

Weld beads made with sufficient and insufficient shielding gas are shown in figure 10-34. Insufficient shielding gas gives an unsound weld bead having a very poor appearance. Using too much shielding gas is wasteful.

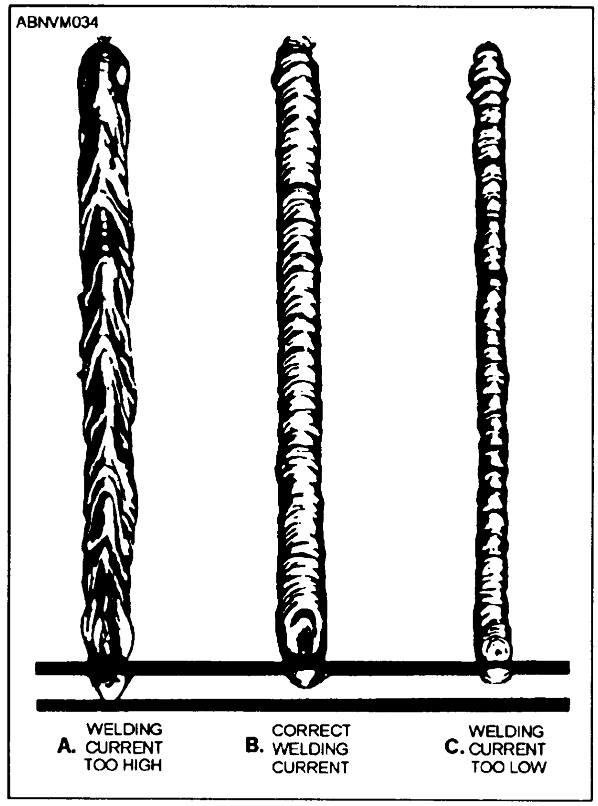


Figure 10-33.—Comparative GTA weld beads as determined by electrical current.

Good weld bead appearance resulting from using two different techniques of torch-filler rod manipulation is shown in figure 10-35. In view A, a bead was made using a two-step technique, namely, intermittent filler rod addition to the weld pool and intermittent torch movement. In view B, a bead was made by moving the torch forward in a relatively steady motion, feeding the filler rod intermittently as the pool required it. This latter technique gives improved weld bead appearance needing little or no finishing.

You should practice making weld beads on a flat plate until you are satisfied with the workmanship. In making satisfactory beads, practice is necessary to develop a "steady hand." If the appearance of weld beads made are equivalent to the ones shown in figure 10-36, and the sample proves satisfactory by visual examination, you should continue on to the next exercise. Should the sample show evidence of poor or careless workmanship with poor bead appearance, spatter, or cracks, as indicated in figure 10-37, you must practice until you make a weld bead that will meet visual inspection requirements.

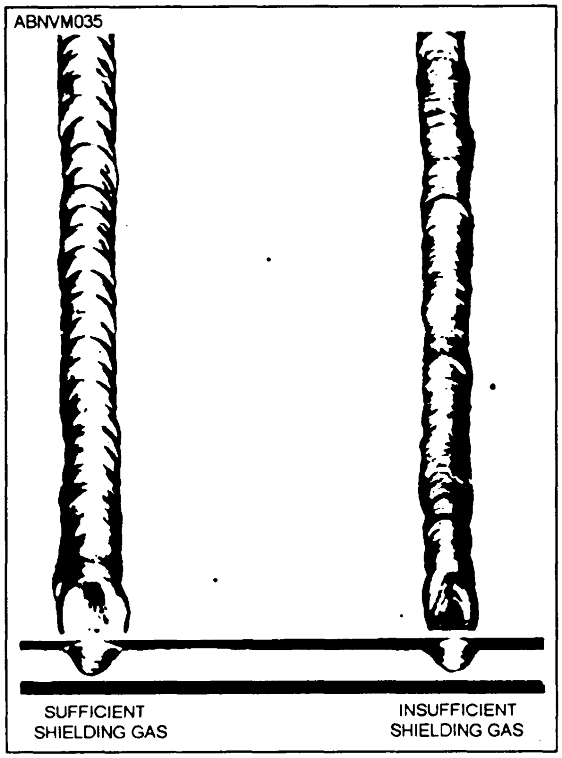


Figure 10-34.—Comparative GTA weld beads as determined by shielding gas.

Flat-Position Single-Pass Butt Welds

This exercise will help you learn the technique of making a single-pass butt weld in the flat position on aluminum. You should use 3/16" by 6" by 12" EC aluminum and 1/8-inch diameter 1100 alloy filler rod, or any other recommended combination of parent sheet-filler alloy. You will also need a 3/16 by 1" by 12" backing strap of EC aluminum or the same sheet-filler alloy.

The GTA welding torch should be equipped with a l/8-inch diameter tungsten electrode. Of course, you will need the ac transformer, argon gas, and necessary accessories.

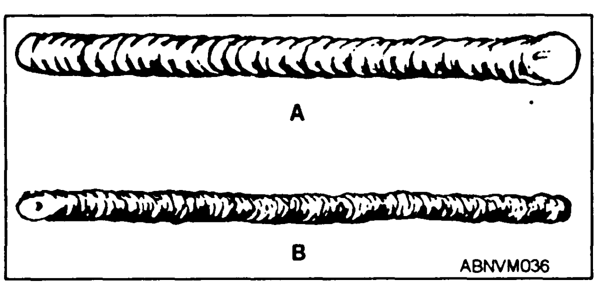


Figure 10-35.—Comparative GTA weld beads with filler rod manipulation.

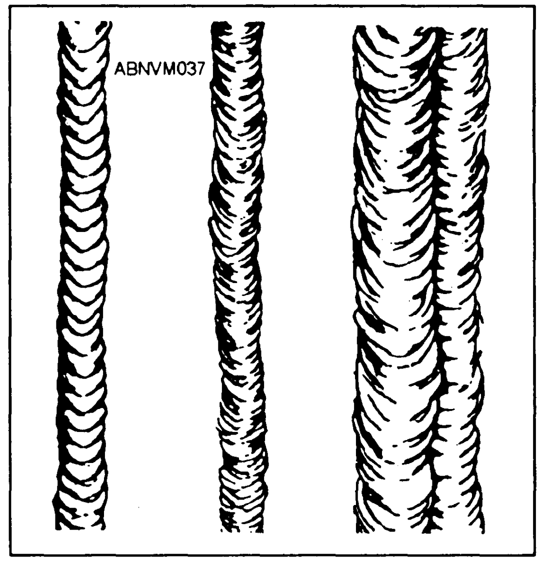


Figure 10-36.—Visual inspection standards for GTA welds.

The procedure for welding is to bevel abutting edges of sheet as indicated in figure 10-38. Clean all surfaces, including the backing strap, with solvent, and wipe dry. Brush the weld surface areas with a stainless-steel wire brush. Inspect and clean the filler rod if necessary. Regulate the argon gas flow 25 cubic feet per hour, and select a welding current of 175 to 210 amperes. Arrange the plates

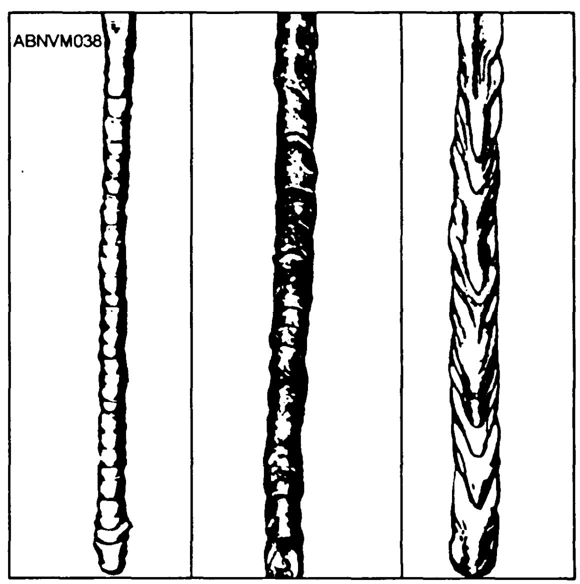


Figure 10-37.—Unacceptable GTA welds.

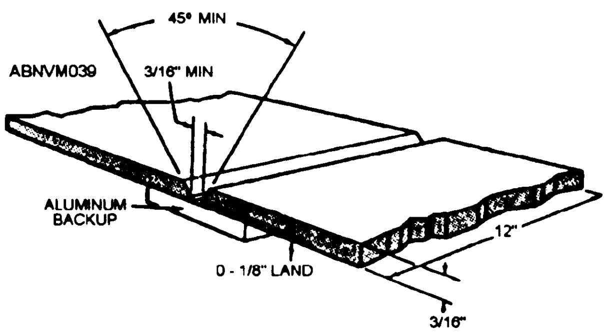


Figure 10-38.—Joint design flat-position single-pass butt welds in aluminum sheet.

as shown in figure 10-38 without jigs. Position the plate and backup strap with all units supported and level. Then tack weld.

In welding practice, remember that good GTA welding is dependent upon this definite procedure-form the molten pool in the parent sheet. Then feed the filler rod intermittently to the leading edge of the pool as the torch is being moved forward. DO NOT feed the filler rod into the arc. You should practice making single-pass butt welds until they are satisfactory. Workmanship must pass visual inspection standards.

Horizontal-Position Multipass Fillet and Butt Welds

This exercise will help you learn horizontal-position welding. Use 1/2" by 6" by 12" EC aluminum plate and 3/16-inch diameter 1100 alloy filler rod, or any recommended parent plate-filler alloy combination. You will also need cleaning materials and backing strap, if they are used.

The ac transformer with superimposed high-frequency current, a GTA welding torch equipped with 3/16-inch diameter tungsten electrode, argon gas, and necessary accessories are the items of equipment needed.

The procedure is to bevel the abutting edge of plates, as shown in figure 10-38. Clean all areas, including the backing strap, if one is used. Brush surfaces with a stainless-steel wire brush to remove oxide film, and between passes if contamination is apparent.

Regulate argon gas flow at 35 cubic feet per hour, and select a welding current of 250 to 320 amperes.

Tack weld the assembly in the flat position, and then arrange units as shown in figure 10-39. Use a suitable jig to hold parts steady.

Rules for quality welding in the flat position must be followed for out-of-position GTA welding. Cleanliness, good joint fit-up, preheat, sufficient shielding gas, and correct welding current are important. In addition, you will find it advisable not to use high welding current or to deposit large weld beads. Direct the arc so that there is no overheating at any one area that produces sagging or undercutting. The filler metal addition, bead size, and sequence have to be placed so that there is complete fusion between passes.

The welding of a fillet joint and a butt joint in a horizontal position is shown in figure 10-40, views

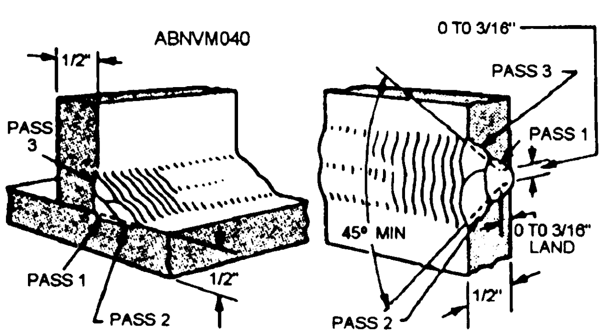


Figure 10-39.—Jolt design and weld pass sequence horizontal-position multipass fillet and butt welds.

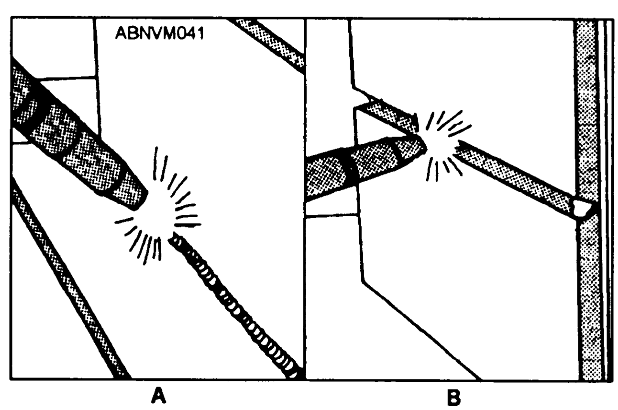


Figure 10-40.—Welding a fillet and butt joint in the horizontal position.

A and B. The correct positioning of the torch and addition of the filler metal at the weld pool edge to prevent undercutting when making a horizontal position fillet weld is shown in figure 10-41.

Vertical-Position Multipass Fillet and Butt Welds

This exercise will brief you on the technique of vertical position welding. You will need 1/2" by 6" by 12" EC aluminum plate and 3/16-inch diameter 1100 alloy filler rod or any other recommended parent plate-filler rod combination. You will also need a backing strap, if one is used.

The equipment needed is the ac transformer with superimposed high-frequency current, a GTA welding torch equipped with 3/16-inch diameter tungsten electrode, argon gas, and the necessary accessories.

Prepare the abutting edges of plate as shown in figure 10-22. Clean and dry the joint area thoroughly. Brush with a stainless-steel wire brush to remove oxide where the filler metal will be deposited. Examine and clean the filler rod, if needed.

Regulate the argon gas flow at 35 cubic feet per hour, and select a welding current from 250 to 320 amperes.

Position sections as shown with all units supported. Tack weld in the most convenient position. Holding jigs may be used. Follow the weld pass sequence as shown in figure 10-42.

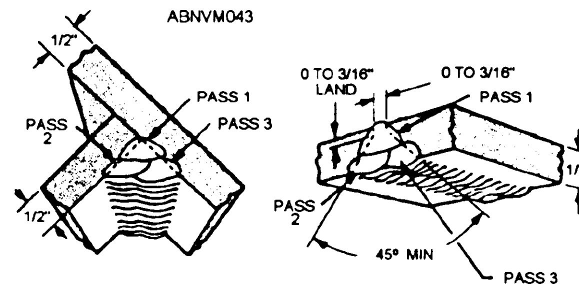


Figure 10-42.—Joint design and weld pass sequence vertical-position multipass fillet and butt welds.

Butt and fillet welds in the vertical position are made as shown in figure 10-43.

All of the factors presented concerning out-of-position welding also apply here. Do not use too high a welding current or deposit too large a weld bead. If the molten pool is too large, it will be difficult to control. Bead size, filler metal addition, and bead sequence should be carefully handled to ensure complete fusion between passes. Some welders find that a slight weave in vertical welding will smooth out the bead. Practice your work until it passes satisfactory visual inspection.

Overhead-Position Multipass Fillet and Butt Welds

This exercise will acquaint you with the technique of overhead-position welding. The

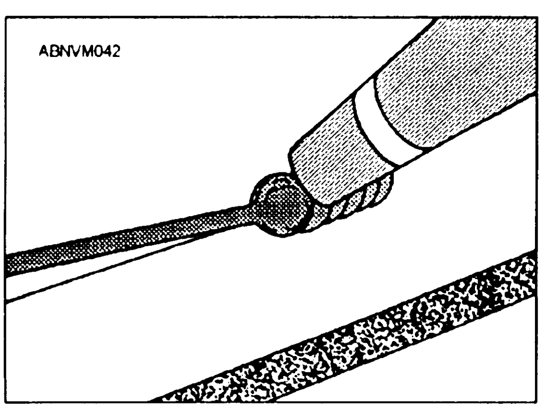


Figure 10-41.—Correct position of the welding torch and proper addition of the tiller metal to form a weld pool.

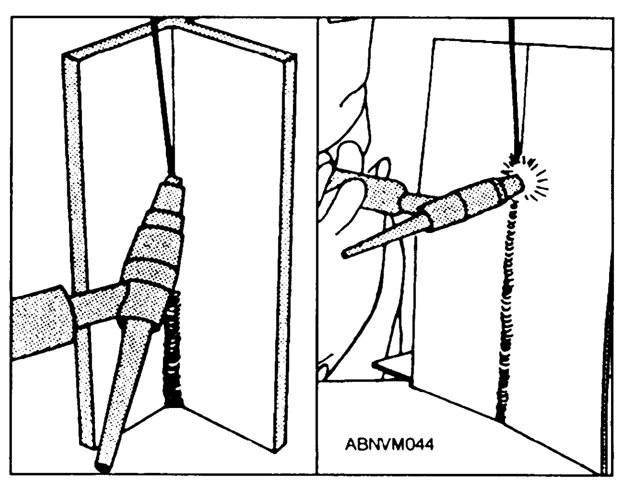


Figure 10-43.—Butt and fillet welds made in the vertical position.

materials, gas flow, and equipment needed for this exercise are the same as those described for vertical-position multipass fillet and butt welds.

Bevel the edges of abutting plates as shown in figure 10-44. Tack weld the backing strap. Clean and dry all joint surfaces with cleaner. Wire brush to remove joint area oxides, and also any apparent weld contamination after each pass.

Tack weld the parts in the most convenient position. Position the sections as shown in figure 10-44 with all units supported. Use holding jigs, if necessary. Follow the weld pass sequence as numbered.

Overhead multipass butt and fillet welds are shown in figure 10-45. Here, as in vertical welding, a slight weave may or may not be used. A lower welding current and travel speed are used as compared to flat-position welding. Conversely, a higher flow of shielding gas is used. Take care to avoid sagging and poor penetration by adding too much filler and carrying too large a pool. Let the established pool wet out enough before adding more filler. Most inexperienced welders find overhead welding awkward. Therefore, try to get in as comfortable and relaxed a position as possible when welding. This will help with steady, even torch and filler rod manipulation.

The new operator should practice both fillet and butt welding in the overhead position until satisfied with the work. If the weld passes visual inspection, continue on to the next exercise.

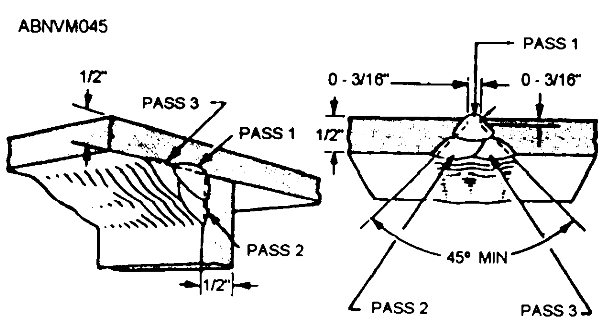


Figure 10-44.—Joint design and weld pass sequence overhead-position multipass fillet and butt welds.

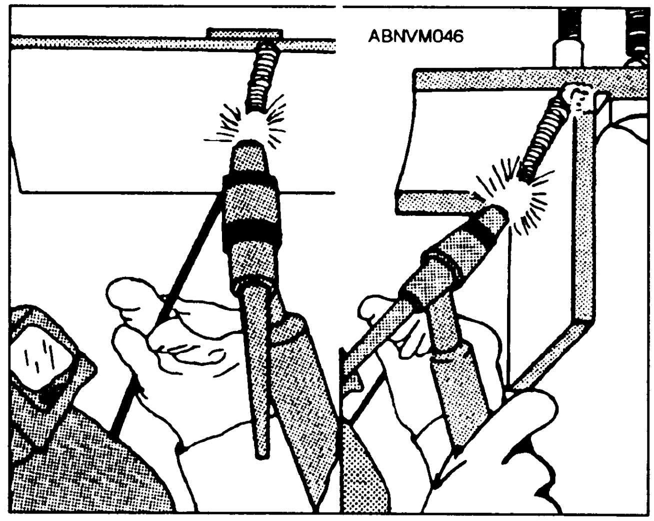


Figure 10-45.—Making overhead multipass groove and fillet welds.

Horizontal Fixed-Position Multipass Welding

This exercise will help you acquire the technique of welding aluminum pipe in the horizontal fixed position, with or without backup. Use 2 1/2-inch diameter, schedule 80 aluminum pipe; l/8-inch diameter, 4043 alloy filler rod, or any other recommended parent pipe alloy-filler rod combination; a backing ring for backup; and cleaning solution or solvent.

With the ac transformer, you will need a GTA welding torch equipped with l/8-inch diameter tungsten electrode, argon gas, and necessary accessories. You also will need a jig for holding pipe in position and a pipe and backing ring.

The procedure involves beveling pipe edges as indicated in joint design and weld pass sequence shown in figure 10-46. Clean, dry, and brush the weld areas and backup ring. Insert the ring in the proper position after the pipe sections are clamped on the jig. Clean the filler rod, if required.

Regulate the argon gas flow at 30 cubic feet per hour, and select a welding current of 160 amperes.

Position sections as shown in figure 10-46, with all units supported. Tack weld in the most convenient position. Follow the weld pass sequence as shown.

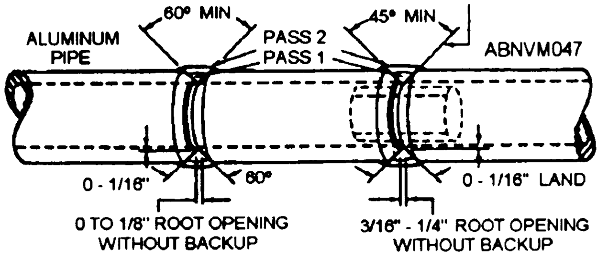


Figure 10-46.—Joint design and weld pass sequence horizontal fixed-position multipass (GTA) welding.

Most welders prefer to use a backup ring for pipe welding when possible because it makes the operation easier. With backup, the joint fit and penetration control are not so critical. You should, however, learn to make the weld without a backup ring.

Horizontal fixed-position pipe welding is often considered a test to qualify for welding in any position. It includes welding in the flat, vertical, and overhead positions. Figure 10-47 shows the technique of torch and filler rod handling.

GAS METAL-ARC (GMA) WELDING PROCESS

The GMA welding process is also known as gas consumable electrode welding (fig. 10-48). It uses a dc (reverse polarity) and a shield of argon or helium or a mixture of both. A small diameter aluminum wire serves both as electrode and filler metal and is fed automatically from the welding gun at high speed. Commercially available equipment for GMA welding is designed to initiate gas coverage and automatically feed the aluminum electrode into the weld area when the arc is struck. A welding pool is formed immediately when the arc is established. Welding progresses by moving the welding gun along the line of the joint at a rate to build up a bead of the desired dimensions. The electrode and weld pool are protected from oxidation by the shield of gas during welding. No flux is required.

GMA Welding Equipment

Numerous types and models of GMA welding equipment are used in the Navy. They all have the same basic requirements. Each must have a source of DCRP welding current, a wire feed unit for feeding the wire filler metal, a control unit that controls the automatic feed of the wire filler metal and shielding gas, and a welding gun for directing the wire filler metal and shielding gas to the weld area. Figure 10-49 shows one type of GMA welding equipment that is used quite often for short run welds and welds in hard-to-get-to places that are inaccessible to larger welding guns.

The 200 dc amp rectifier welder shown in figure 10-49 was designed specifically for the GMA welding process and is a constant potential power source. The constant potential power source compensates for changes in arc length, thus providing more uniform welding.

The welding gun shown in figure 10-49 contains the wire drive motor and drive roll assembly, the control switch for control of the wire feed and gas flow, and a replaceable l-pound spool of wire filler

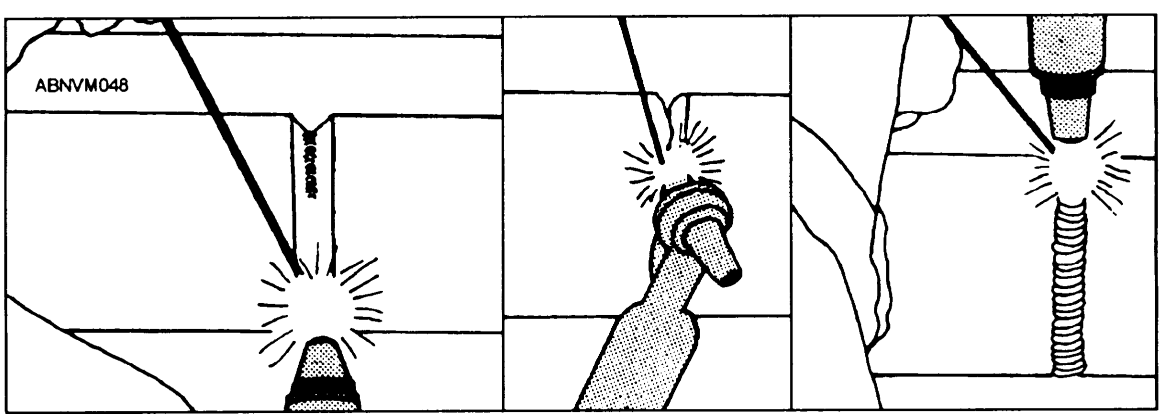


Figure 10-47.—Techniques of torch and filler rod handling for tubular sections.

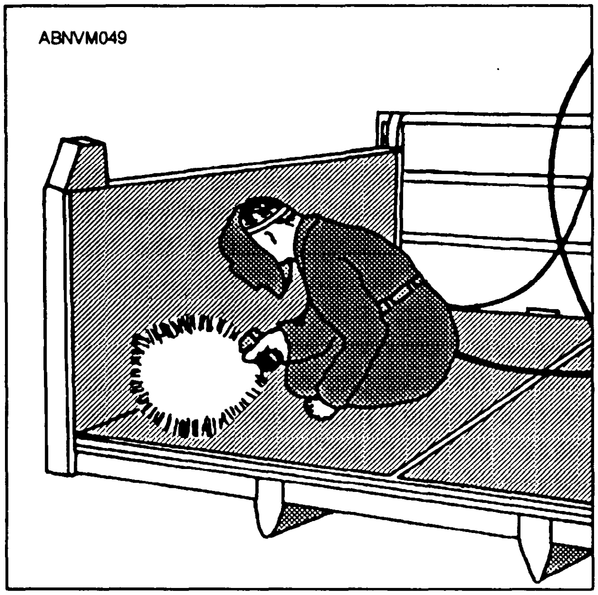


Figure 10-48.—CMA welding aluminum truck bed.

metal. The welding gun is connected directly to the dc rectifier welder. This eliminates the need for a separate control unit and wire drive assembly. Wire filler metal in sizes 0.030, 3/64, and l/16 inches may be used with this gun. The weight of the gun, including a l-pound spool of wire, is about 3 pounds.

Another GMA welding unit is shown in figure 10-50. It consists of a 250-amp dc rectifier welder, the welding gun, and a canister. This equipment differs from that shown in figure 10-49 in that the welding gun does not contain the spool of filler metal. The filler metal is on a 12-inch diameter spool that is inside the canister. The filler metal is fed through a lo-foot long plastic guide liner to the drive rolls in the gun and then to the weld area. The dc rectifier welders shown in figures 10-49 and 10-50 are connected to a 440-volt ac electrical supply source. These welders may be used with a 220-volt ac supply source by making the necessary electrical changes according to the manufacturer's technical manual.

In addition to the equipment already mentioned, the following supplies and equipment are needed for the GMA welding of aluminum:

- Gas supply, regulator-flowmeter valve, hose, and fittings
- Filler wire
- Helmet or eye shield, and protective clothing
- Stainless-steel wire brush

DCRP is most often used for GMA welding of aluminum. In DCRP welding, the electrons flow from the plate to the filler wire. This provides the heating effect necessary on the end of the filler wire electrode to form molten aluminum droplets. These droplets, in turn, are transferred into the weld pool. The GMA process deposits filler metal at higher rates than the GTA process, making faster, more

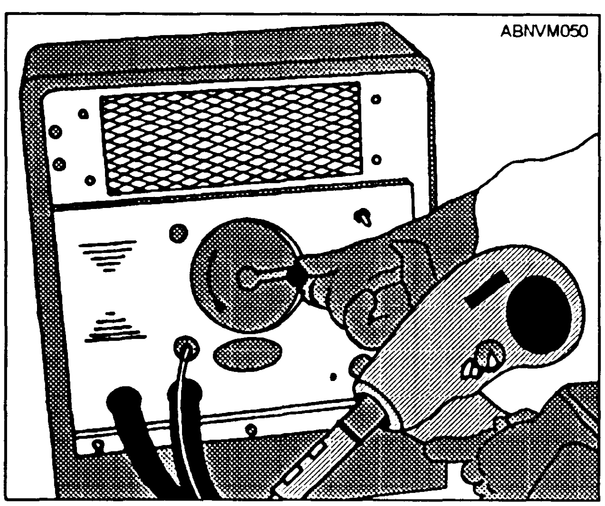


Figure 10-49.—GMA welding equipment (AIRCO products).

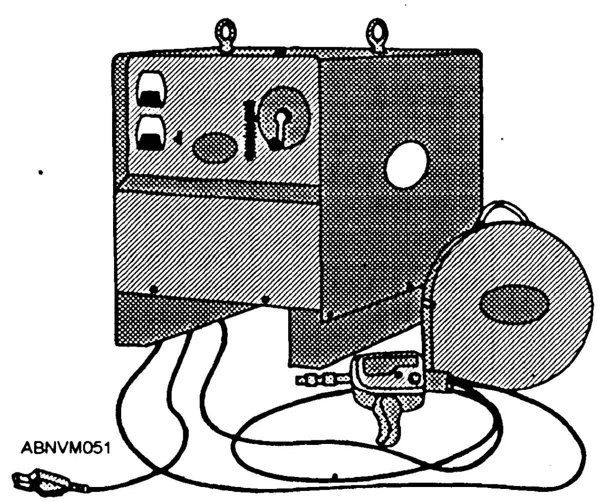


Figure 10-50.—Heavy-duty GMA welding equipment (AIRCO products).

economical welds with less heat effect on the workpiece.

Dual Action of the Arc

The reverse polarity arc supplies heat to melt the consumable filler wire and the workpiece. The arc also breaks up the surface oxide on the aluminum. This cleaning action is due to the electrical characteristics of the DCRP arc. Arc action is not intermittent as in ac GTA welding, but is continuous because there is no change in current direction using dc GMA welding.

Shielding Gas

The GMA welding gun deposits molten aluminum where directed on the workpiece. The gas shields the arc and weld pool while the filler wire is being melted and transferred in spray or droplet form to the pool. Another purpose of the gas shield is to provide a more easily ionized path than air.

Helium, argon, or mixtures of the two are suitable for GMA welding of aluminum. At any given current, the helium shielded arc has a higher voltage than the argon arc. A smoother, more stable arc is obtained with argon. Pure argon is used most widely on aluminum plate less than three-fourths inch thick. Combinations of argon and helium are often employed for welding heavy plate. This combination is used particularly for out-of-position welding to obtain the “hotter arc” characteristics of helium with the stabilizing effects of argon. Mixtures of 75 percent helium and 25 percent argon are commercially available. Other gas mixtures, for example, 60 percent helium and 40 percent argon, are mixed by combining flows from separate tanks of helium and argon. Helium additions of over 10 percent markedly change the arc characteristics.

The flow of gas necessary for good quality GMA welding depends upon the gas used, welding current, diameter of gun nozzle, joint design, welding position, speed of welding, and freedom from draft

Table 10-9.—Recommended Practices for GMA Welding of Aluminum Alloys

Material Thickness Inches	Welding Position	Joint Degree (1)	Current Amps DC	Arc Voltage	Filler Wire Dia. Inches	Argon (2) Gas Flow CFH	No. of Passes
l/8	Flat	None	110-130	20	3/64	30	1
	Horiz. & Vert.	None	100-120	20	3/64	30	1
	Overhead	None	100-120	20	3/64	40	1
l/4	Flat	None or Single Bevel	200-225	26-28	l/16	40	1
	Horiz. & Vert.	Single Bevel	170-190	26-28	l/16	45	2 or 3
	Overhead	Single Bevel	180-200	26-28	l/16	50	2 or 3
3/8	Flat	Single or Double Bevel	230-300	26-28	l/16	50	1 ot 2
	Horiz. & Vert.	Single or Double Bevel	180-225	26-28	l/16	50	3
	Overhead	Single or Double Bevel	200-230	26-28	l/16	50	5
l/2	Flat	Single or Double Bevel	280-320	26-30	3/32	50	2 or 3
	Horiz. & Vert.	Single or Double Bevel	210-250	26-30	l/16	50	3 or 4
	Overhead	Single or Double Bevel	225-275	26-30	l/16	80	8 to 10
1	Flat	Single or Double Bevel	320-375	26-30	3132	60	4 to 5
	Horiz. & Vert.	Single or Double Bevel	225-275	26-30	l/16	60	4 to 6
	Overhead	Single or Double Bevel	225-275	26-30	l/16	80	15 or more
2 (3)	Flat	Single or Double Bevel	350-425	26-30	3/32	60	12 or more
3 (3)	Flat	Single or Double Bevel	350-450	26-30	3/32	60	20 or more

(l) See exercises for Joint Designs.

(2) Gas flows for helium are slightly higher than for argon. Lower flows are possible as mentioned in Part I-Basic Theory.

(3) Preheat optional.

in the welding area. This last factor can affect gas usage and weld quality considerably, so it is recommended that the welding area be essentially draft-free. When welding in the field, suitable shielding with curtains or other type of windbreak should be provided to prevent natural air currents from interfering with the gas flow. Recommended gas flows for GMA welding are shown in table 10-9.

Filler Metal

Filler wire of EC, 1100, 4043, 5154, 5183, and 5356 and others are available in 0.030-, 3/64-, l/16-, and 3/32-inch diameters. It is necessary that the correct alloys be used for the specific welding job. The recommended alloy of filler wire for the various alloys is shown in table 10-10. The recommended filler wire diameters for welding various metal thicknesses and in different current ranges are listed in table 10-11.

The wire that you use must be clean. Unsound welds result from wire that has been contaminated by oil, grease, dust, or shop fumes. Your best welding results are obtained by using wire that has just been taken out of its carton. Wire should be stored in a hot locker or in a warm dry area and should be kept covered. If welding is stopped for any length of time, remove the wire and place it in the original carton to prevent possible contamination.

Table 10-10.—Recommended Filler Materials for GMA Welding of Various Aluminum Alloys

Parent Metal Sheet, Plate or Tube	Filler Alloy
EC	EC/1100
1100	1100/4043
2219	2319
3003	1100/4043
3004	5356/4043
5005	5356/4043
5050	5356/4043
5052	5138/5356
5154	5138/5356
5083	5138/5356
5086	5356/5138
5454 (l)	5554/5356
5456	5556/5138
6061	5356/4043
6063	5356/4043
7039	X5039/5183

(1) For high temperature applications, first choice for filler metal is alloy 5554 otherwise, use 5356 or 5183 for higher strength weldments.

Table 10-11.—Recommended Welding Current Ranges for Various Diameters of GMA Filler Wire

Filler Wire Diameter Inches	Welding Current Amperes
0.030	75-150
3/64	120-210
l/16	165-300
3132	240-450
l/8 (l)	400 and up (2)

(1) Normally used for automatic welding.

(2) Maximum welding current dependent on the power source.

PRACTICE EXERCISES FOR GMA WELDING

Before welding with GMA equipment, be sure that all controls are properly adjusted, all connections are correctly made, and all safety precautions are being observed. Wear protective clothing, including a helmet with a suitable filter lens. Hold the welding gun as shown in figure 10-51. Support the weight of the welding cable and

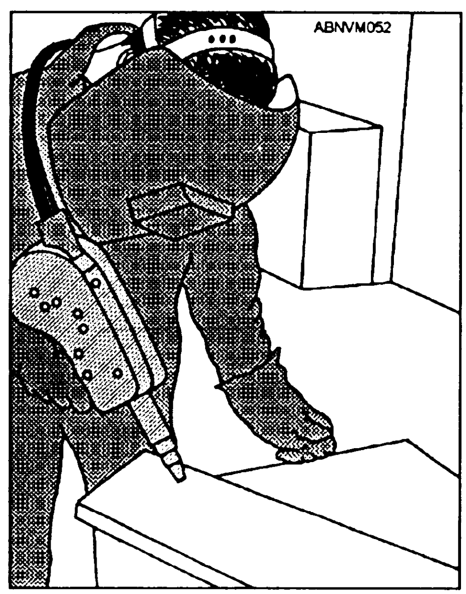


Figure 10-51.—Positioning the GMA gun prior to welding.

gas hose across your shoulder to ensure free movement of the welding gun. Hold the gun close to, but not touching, the workpiece. Lower your helmet and squeeze the trigger on the gun. Squeezing the trigger starts the flow of shielding gas and energizes the welding circuit. The wire-feed motor is not energized until the wire electrode comes in contact with the workpiece. Move the gun toward the work, touching the wire electrode to the work with a sidewise scratching motion as shown in view A of figure 10-52. To prevent sticking, pull the gun back quickly, about one-half inch, the instant contact is made between the wire electrode and the workpiece. The arc will strike as soon as contact is made and the wire-feed motor will feed the wire automatically as long as the trigger is held.

To break the arc, just release the trigger. This breaks the welding circuit and also de-energizes the wire-feed motor. The wire electrode may stick to the work when you strike the arc, or at any time during welding. If that happens, release the trigger and clip the wire with a pair of pliers or side cutters.

A properly established arc has a soft, sizzling sound. The arc itself is about one-fourth inch long, or about one-half the distance between the gun nozzle and the work. If the arc does not sound right, adjust the wire-feed control dial or the welding machine itself. For example, a loud, crackling sound indicates that the arc is too short and that the wire-feed speed is too fast. Correct this by moving the wire-feed dial slightly counterclockwise. This decreases wire-feed speed and increases arc length. A clockwise movement of the dial has the opposite effect. With experience, you will be able to recognize the sound of the proper length of arc.

Use the forehand technique for welding. Hold the gun at an angle of 5° to 20° from the vertical position, as shown in view B of figure 10-52. A right-handed person welds from right to left. The forehand technique provides the best coverage of shielding gas to the weld area, and the operator has a better view of the weld joint. A left-handed person holds the gun in the same position relative to the surface of the base metal, but welds from left to right.

You should first learn to strike and establish an arc and to adjust the wire feed and welding current to obtain the proper arc characteristics. Then you should learn to run a bead. To run a practice bead, select the proper current setting, gas flow, and correct size filler wire as recommended in table 10-9; then, proceed as follows:

1. Hold the gun in the proper position, close to but not touching the surface of the work, and squeeze the trigger.

2. Lower your welding helmet and strike the arc.

3. Hold the gun at the starting point until a puddle forms.

4. As soon as you see a puddle, move the gun forward steadily at a rate that permits the work and the electrode to melt at the same time. Keep the arc in the pool of weld metal. Do not direct it into

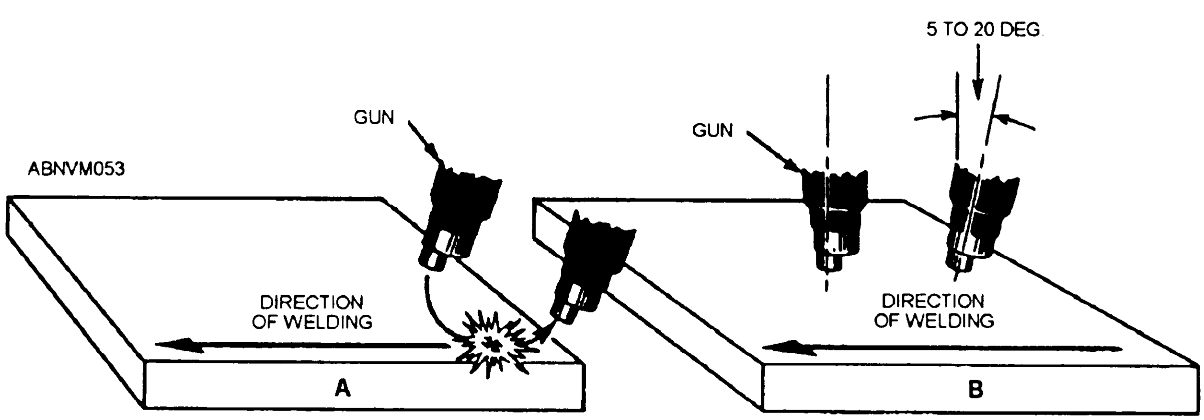


Figure 10-52.—GMA welding. (A) Striking the arc. (B) Gun angle.

the base metal. A thin, irregular bead will result if you move forward too rapidly. Undercutting may result if you move the gun forward too slowly. A good bead is uniform in width and height. The ripple is uniform, and there is no overlap or undercut at the edges.

Some of you may want to move the gun along the line of weld with a steady forward motion. Others prefer to run a bead with a reciprocating technique like that shown in figure 10-53. When you use this technique, strike the arc and then slowly move the gun forward along the line of weld about one-half inch and then back about one-fourth inch. Continue this one-half inch forward and one-fourth inch backward motion along the line of weld. If you want a wide bead, use a side weave. Here, the gun is moved uniformly back and forth across the line of weld while steadily moving along the line of weld. The width of the bead determines the amount of sidewise movement.

Although GMA welding does not require the use of a flux, it does require that the base metal be clean. Aluminum and aluminum alloys should be cleaned with an approved compound, or with a stainless-steel wire brush. Any grease should be removed with a solvent before cleaning with a compound. Stainless-steel wire brushes that have picked up grease should be cleaned with a solvent before they are used to clean aluminum for welding.

Once you get the feel of welding with GMA equipment, you will probably find that the techniques are less difficult to master than many of the other welding procedures. However, there are some pitfalls. Porous welds may result from the following causes:

- Low arc voltage (less than 26 volts)
- Low welding current

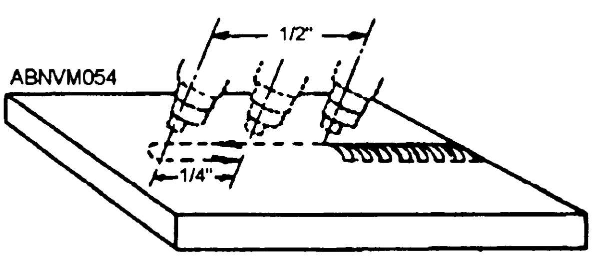


Figure 10-53.—Reciprocating technique for GMA welding.

- Inadequate shielding gas flow resulting from a low cylinder pressure, from restrictions in the gas passages of the equipment, or from improper adjustment of the flowmeter
- Excessive weaving or whipping of the welding gun
- Poor fit-up of parts
- Improperly cleaned base metal, or dirty welding wire
- Nonuniform wire-feed speed

Welder fatigue is often the cause of poor weld quality and low output. You will learn that the quality and quantity of your work improves as you learn to weld comfortably. Out-of-position welding is usually more awkward than flat position; therefore, arrange the work for flat position welding whenever possible for economy and quality.

Satisfactory weld results also depend on good maintenance of the GMA equipment. Maintenance procedures are outlined in the manufacturer's technical manual furnished with the equipment. Weld beads made with too low, too high, and the correct current are shown in figure 10-54.

Notice the lack of penetration and "ropy" appearance of the weld bead made with insufficient welding current. Also, note the deep penetration

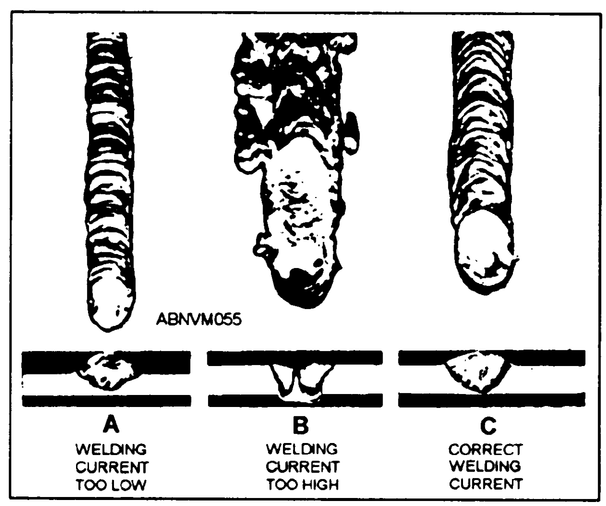


Figure 10-54.—Weld bead characteristics determined by welding current.

and flat appearance of the bead made with excessive welding current.

Weld beads made with sufficient and insufficient shielding gas are shown in figure 10-55. Inadequate shielding gas gives an unsound weld bead having a dirty appearance. Using too much shielding gas is wasteful and may cause weld turbulence and porosity. Note the appearance and penetration of the bead made with the proper current and gas flow. Recommended flows of shielding gas for various thicknesses of plate are shown in table 10-9.

If the sample weld shows evidence of poor or careless workmanship, having spatter and cracks, or has bead appearance as indicated in views A and B of figure 10-54 or view B of figure 10-55, it is unsatisfactory. Continue to practice until you can make a weld that will pass visual inspection. Practice making weld beads on flat plate until satisfactory workmanship results. Practice is necessary to develop a "steady" hand. If the appearance of your weld beads is equivalent to the ones shown in figure 10-56, the sample is satisfactory to visual examination.

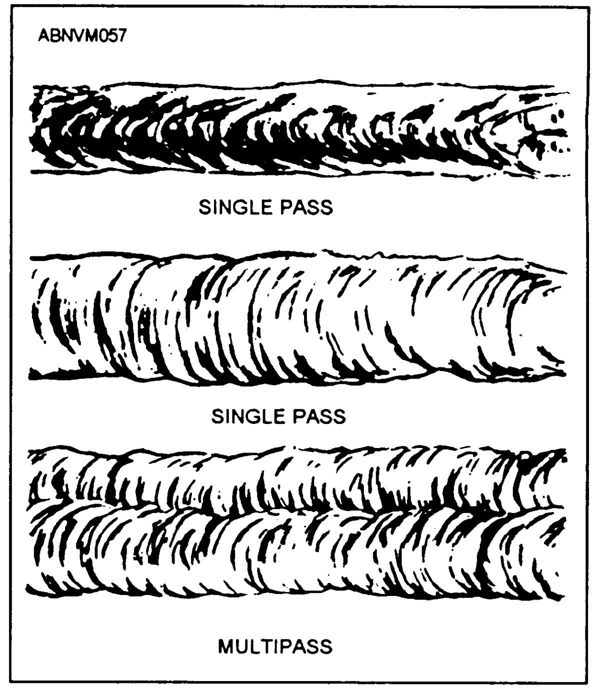


Figure 10-56.—Acceptable single-pass and multipass GMA welds.

To be proficient as a welder, you must be able to make all the various types of welds in the flat, vertical, horizontal, and overhead positions. The following exercises will aid you in learning the techniques employed in making different types of welds in all positions.

Flat-Position Single-Pass Butt Welds

This exercise will help you make a single-pass butt weld in aluminum plate. You will need 3/8" by 6" by 12" EC aluminum plate and l/16-inch diameter 1100 alloy filler wire, or any other recommended parent plate-filler wire alloy combination. You will also need a backing strap 1/4" by 1 1/2" by 12", cut from the parent plate or thinner aluminum alloy section compatible with the workpiece. In addition, you will need a suitable solvent or cleaner for removing dust or grease. Use the standard equipment and necessary accessories. Saw or machine bevel the abutting plate surfaces, allowing for land. Thoroughly clean the weld surface areas, including the backing strap. Regulate the gas flow at 50 cubic feet per hour, and select a welding current of 230 to 300 amperes.

Aluminum plates should be prepared and placed as shown in figure 10-57. When so placed, there should be a slight gap between the two aluminum

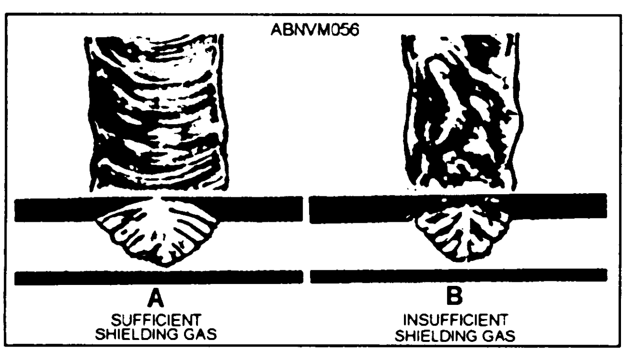


Figure 10-55.—Weld bead characteristics determined by shielding gas.

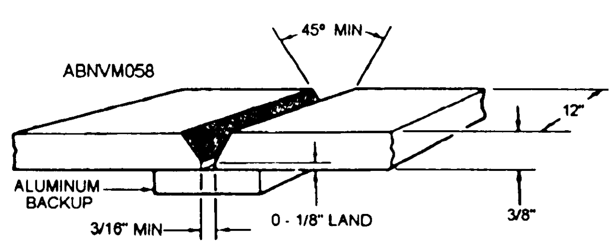


Figure 10-57.—Joint design flat-position, single-pass butt welds in aluminum plate.

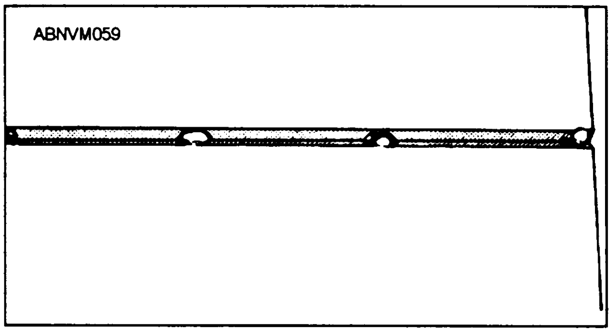


Figure 10-58.—Plates tack-welded and aligned for GMA welding.

sections to permit good root fusion in the butt weld. Ordinarily, when using a backing strap, the gap between the parts to be welded should be not less than the diameter of the filler wire. Slightly more space is preferable. After the plates are aligned and rigidly supported, tack weld, as shown in figure 10-58, before making the single weld pass. Bring the gun into the forehand welding position, as shown in figure 10-51. Hold the gun 5° to 20° from the vertical, pointing in the direction of travel. After the arc is initiated, move the gun forward at the proper angle and speed as shown in figure 10-59.

The angle of the gun is dependent upon both the speed of travel and the position of the joint. Adjust this angle to give the proper cleaning action, depth of penetration, and bead contour. When welding unequal sections, direct the arc against the heavier piece to obtain equal fusion in the two edges.

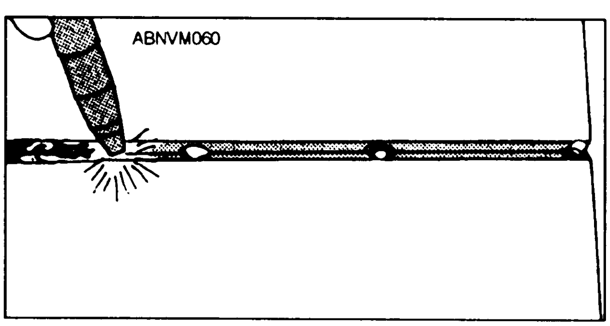


Figure 10-59.—Moving the welding gun forward at the proper angle.

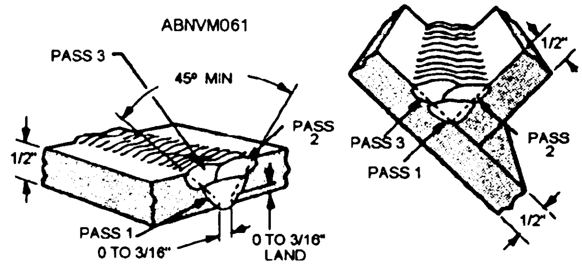


Figure 10-60.—Joint design and weld pass sequence flat-position multipass butt welds in aluminum plate.

The correct arc length is very important. Too short an arc will cause porosity; too long an arc will result in lack of fusion. A proper arc is between one-eighth inch to three-eighths inch long, depending on the current, joint, and filler wire alloy. The correct arc length, when struck, will produce a smooth sizzling or hissing sound.

Practice making single-pass butt welds, according to the procedure outlined, until your weldments can pass the usual inspection standards. Defective tack welds or defective sections of the main weld can be chipped out and the area rewelded.

Flat-Position Multipass Butt Welds

This exercise will help you make multipass flat-position GMA butt welds in aluminum plate. The material requirements include 1/2" by 6" by 12" EC aluminum plate and 3/32-inch diameter 1100 alloy filler wire, or any other parent plate-filler wire alloy combination recommended for welding; a compatible aluminum alloy backing strap, if used, and degreasing solvent or solution.

Prepare the abutting plate edges by milling or sawing to the proper angles, shown in figure 10-60. Clean the weld area and backing strap, if used. Use solvent, and wipe dry. When more than a single pass is made, wire brush after each pass if contamination is visible. Regulate the gas flow at 50 cubic feet per hour, and use a welding current of 280 to 320 amperes.

One method of weld pass sequence is shown in figure 10-60. You should always watch the weld pool. This is the only way to determine if there is proper penetration and fusion. The fluidity of the

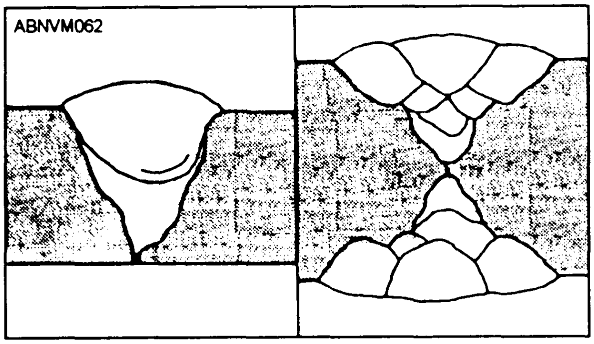


Figure 10-61.—Gross section of two welds showing poor root fusion and too heavy a root face.

molten pool, especially near its edges, is important. The gun angle used for making multipass butt welds in the flat position is the same as that used in making single-pass butt welds. It is sometimes necessary to lower the welding current when making later successive passes because of heat buildup. Clean between passes with a stainless-steel wire brush for improved welding results. Etched cross sections of two welds, shown in figure 10-61, illustrate poor root fusion caused by too heavy a root face and/or inadequate joint spacing. Welding with too low a welding current or too high a welding speed may also cause this condition.

Gross porosity in a weld is clearly shown in figure 10-62. Insufficient shielding gas, improperly cleaned plate, or dirty filler wire will cause such porosity.

Voids in multipass butt welds are often caused by dirty plate, dirty filler wire, or improper welding technique. (See fig. 10-63.)

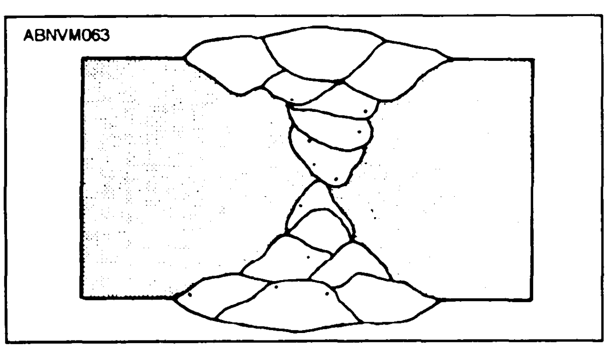


Figure 10-62.—Grass porosity in a multipass butt weld.

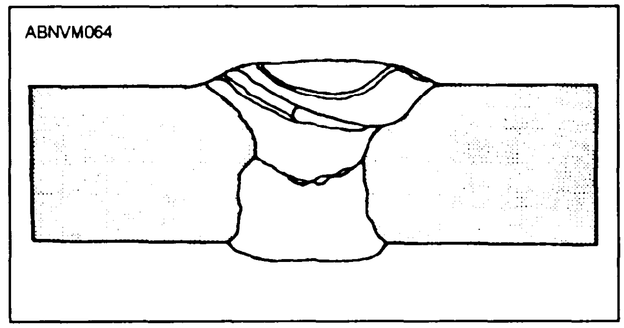


Figure 10-63.—Voids in multipass butt welds.

Cross sections of good multipass GMA butt welds are shown in figure 10-64. The welds have good root fusion and are free from weld skips, inclusions, and porosity.

Practice the weld joints shown in figure 10-60 until your workmanship is satisfactory. Take care that you do not melt or fuse the backup when making the root pass of a joint using a steel orcopper backup. If this does happen, the root pass

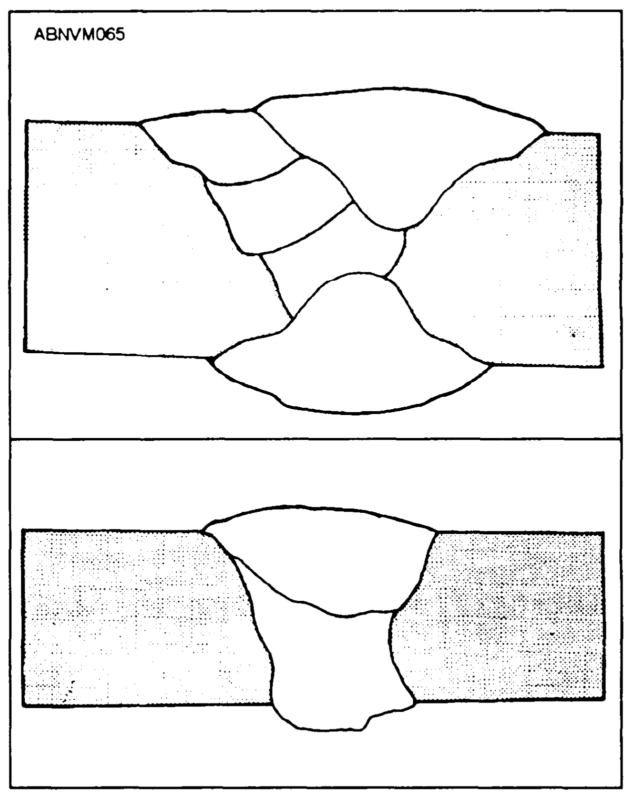


Figure 10-64.—Cross section of good multipass GMA welds free from defects.

may become contaminated with steel or copper and will be less ductile.

In addition, complete an extra weldment without backup. If there is a lack of penetration, make a seal or finishing bead along the root of the weld. When high-quality welds are required, the fused back side of the joint may be chipped or burred out to sound metal, making a groove suitable for welding. This is shown in figure 10-65.

Horizontal-Position Multipass Fillet and Butt Welds

This exercise will help you learn horizontal-position GMA welding. You will need 1/2" by 6" by 12" EC aluminum plate and l/16-inch diameter 1100 alloy filler wire, or any other recommended parent plate-filler wire alloy combination. You will also need a cleaning solvent or solution.

The equipment will be the dc rectifier, GMA welding gun, filler wire, gas, and necessary accessories. You will also need a jig to hold the plates in position.

Prepare the abutting edges of the plate by machining or grinding to the proper angles, shown in figure 10-39. Clean and dry the weld areas. Brush with a stainless-steel wire brush before the initial weld pass is made, and also after each successive pass if contamination is apparent.

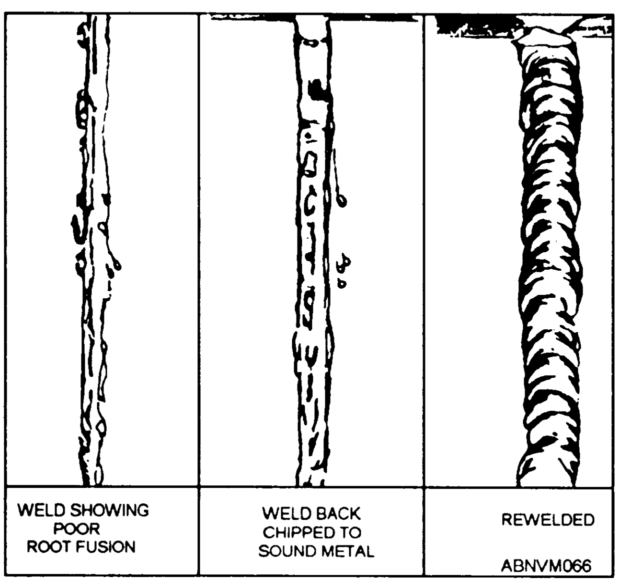


Figure 10-65.—Chipping out the fused back side of a joint to make a high-quality weld.

Regulate the gas flow at 50 cubic feet per hour, and use a welding current of 210 to 250 amperes.

Follow the pass sequence as indicated in figure 10-39. Make certain that sections are properly fitted and jigged.

All rules for quality welding in the flat position must be followed for out-of-position GMA welding. Cleanliness, good joint fit-up, sufficient shielding gas, correct welding current, and so on, are important. You should not use a high welding current or deposit too large a weld bead. Welding wire one-sixteenth inch in diameter is recommended when butt welding one-half inch thick plate in the horizontal position. This compares to 3/32-inch diameter welding wire for the same thickness of plate in the flat position.

Take special care to direct the arc so that you do not overheat any one area. This may cause sagging or undercutting. The welding speed, bead size, and bead sequence have to be such that there is no lack of fusion between passes. The welding of a fillet and a butt joint in the horizontal position is shown in figure 10-66. Practice welding these two joints until your workmanship is satisfactory.

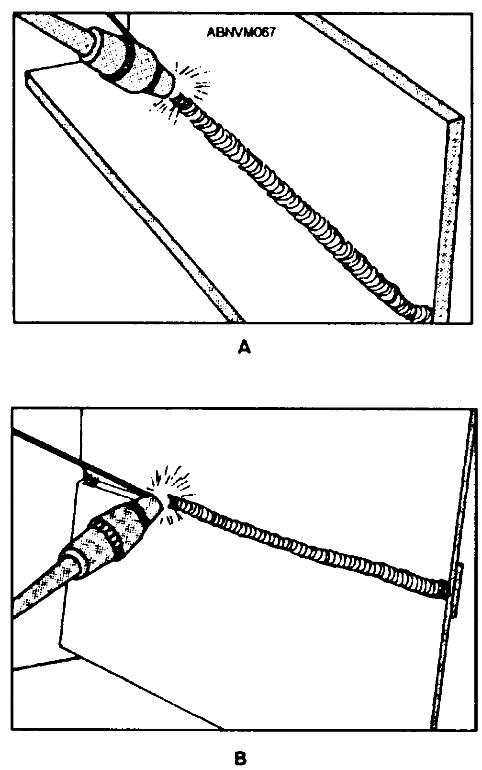


Figure 10-66.—Welding a fillet and butt joint in the horizontal position.

Vertical-Position Multipass Fillet and Butt Welds

This exercise will help you learn vertical-position GMA welding. The materials and equipment needed are the same as those described for horizontal-position welding. The gas flow and current range are also the same. Machine or grind the abutting plate edges to the angles shown in figure 10-42. Thoroughly clean and dry the weld areas. Clean with a wire brush between passes if contamination shows in the weld area.

Follow the weld sequence shown in figure 10-42. Make all welds in the upward direction. Take care to fit the parts to be welded with the root space shown.

Fillet and butt welds made in the vertical position are shown in figure 10-67. Note that the welding is done upward. All factors concerning out-of-position horizontal welding also apply here. Do not use too high a welding current or deposit too large a weld bead. If the molten pool is too large, the effects of gravity will make it difficult to control. Bead size, weld speed, and bead sequence must be such that there is no lack of fusion between passes. Some welders find that a slight side-to-side weave, approximately one-eighth inch, when done smoothly and evenly, is helpful in vertical welding.

Overhead-Position Multipass Fillet and Butt Welds

This exercise will help you learn overhead-position GMA welding. The materials and equipment are the same as those used for horizontal- and vertical-position welding. However, in overhead-position welding, the gas flow is regulated to flow at 60 cubic feet per hour, and the welding current is selected at 225 to 275 amperes.

Prepare edge angles of abutting plates by machining or grinding as shown in figure 10-44. Clean and thoroughly dry the weld areas, using solvent to degrease the metal. Surfaces on which weld metal will be deposited should be wire brushed to remove aluminum oxide coating. Brush with a stainless-steel brush after every pass if there is contamination. Follow the weld sequence shown in figure 10-44. Figure 10-68 shows a welder making overhead multipass fillet and butt welds.

Here, as in vertical welding, a slight weave may or may not be used. A lower welding current and travel speed are used as compared to flat-position welding. Conversely, a higher flow of shielding gas is used. Take extreme care to avoid sagging and poor penetration. Trying to deposit too much metal and carrying too large a weld pool is the direct cause of such conditions. Most inexperienced welders find overhead welding awkward. Assume as comfortable and relaxed a position as possible, and

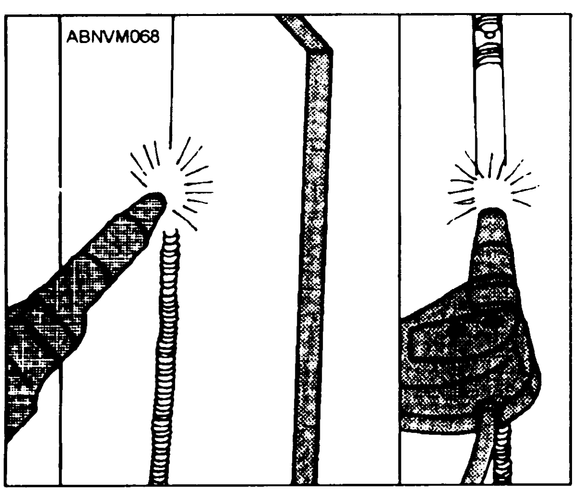


Figure 10-67.—Welding fillet and butt joints in the vertical position.

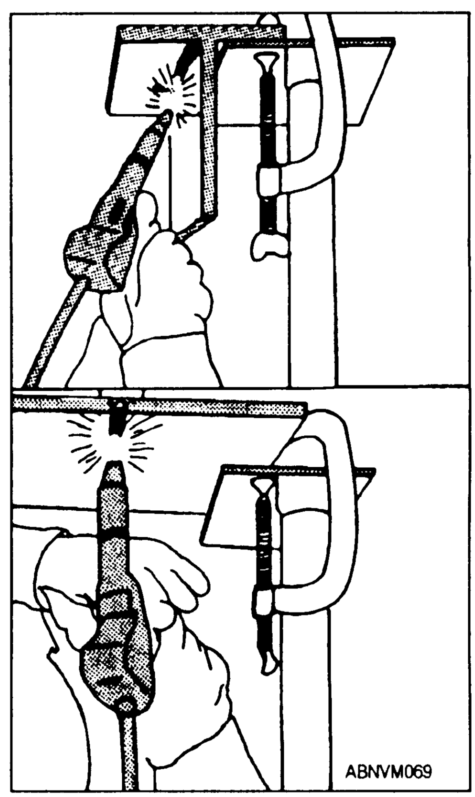


Figure 10-68.—Welding overhead multipass fillet and butt welds.

this will help you with the steady gun handling necessary for quality welding. Practice until your overhead welds pass visual inspection.

Horizontal Fixed-Position Multipass Welding

This exercise will help you learn GMA welding of aluminum pipe, with and without backup, in the horizontal fixed position. For this exercise, use 5-inch diameter standard aluminum pipe 6061 alloy and 1/16-inch diameter 4043 or 5356 alloy filler wire, or any recommended parent metal-filler wire alloy combination. You will also need a backing ring. Equipment requirements include a dc generator or rectifier, a GMA welding gun, filler wire, gas, and necessary accessories. You will also need a jig for holding the pipe in the welding position.

Pipe edges should be angled to the degree indicated in figure 10-69. Insert a backup ring and place the assembly in a holding jig; or, place two abutting sections in the jig if a backing ring is not used. Thoroughly clean and dry the weld area.

Wire brush the tile surface to remove the protective oxide coating. Brush again after each pass if contamination appears. Regulate the gas flow at 60 cubic feet per hour, and select a welding current of 150 to 190 amperes. Follow the weld sequence as shown in figure 10-69.

Horizontal fixed-position welding is often considered a test to qualify for welding in any location. You must weld in the flat, vertical, and overhead positions. Manipulation of the GMA gun for welding pipe in the horizontal fixed position is shown in the photographic sequence in figure 10-70.

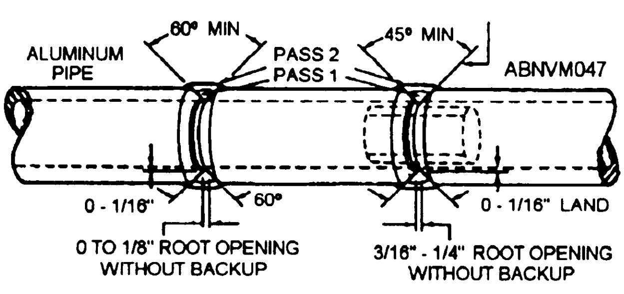


Figure 10-69.—Joint design and weld pass sequence horizontal fixed-position multipass GMA welding.

Since this welding involves flat, vertical, and overhead welding, you should be able to weld satisfactorily in all of these positions before attempting fixed-position welding. Determining factors for quality welds, previously discussed, also hold true here.

Most welders prefer to use a backing ring for pipe welding, when possible, because it makes welding easier and faster. With backup, the joint

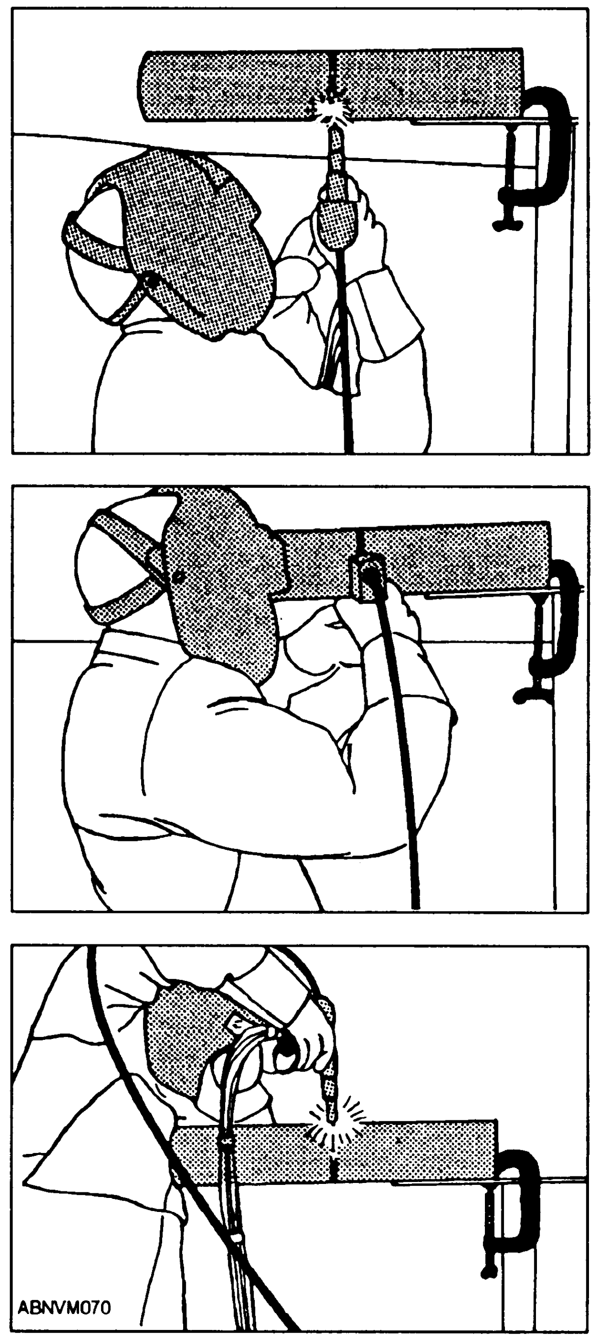


Figure 10-70.—CMA gun manipulation for welding pipe in the horizontal fixed position.

fit-up and the control of penetration are not as critical.

SAFETY

Safety must be observed in GTA and GMA welding as in any other welding process. In addition to the safety precautions listed in chapter 1 of this manual, the following general precautions should also be observed:

1. The welding area must be properly ventilated without excessive drafts that can affect the welding arc and shielding gas. Carbon tetrachloride or other chlorinated hydrocarbons should NOT be used for cleaning aluminum before welding. Alcohol and acetone are recommended as chemical cleaners, but surfaces cleaned with these materials should be thoroughly dried before welding. Welding should not be done in any area where fumes from such solvents are present.

2. The ac transformer used for GTA welding or the dc generator rectifier for GMA welding is normally fed from a 220- to 440-volt circuit. These voltages can cause severe or fatal injuries: **DO NOT** work on any wiring in an energized circuit. The deck where welding is being done must be dry.

3. Welding transformers or rectifiers must have a power ground so that welders cannot get a shock from stray current.

4. Do not lay the torch on the work or worktable. Hang it up in a safe place so the electrode is not touching metal that may be grounded.

5. Do not change a tungsten electrode before it has cooled or while the transformer switch is in the "on" position. Do not change spools of filler wire while the generator or rectifier is on.

6. Do not use defective welding cable. If any of the connections are operating hot, you may have a poor electrical connection.

7. Use a welding helmet when looking at the arc. Use the correct shade of lens, usually No. 10 for GTA and No. 12 for GMA. If your eyes become irritated, see the doctor immediately. If not treated promptly, the irritation caused by burning rays of the arc becomes very painful and feels like hot sand in the eyes. The doctor will give you eye drops that will relieve unnecessary suffering.

8. Wear suitable clothing as protection from the spatter or molten particles and to shield your body from rays of the arc.

9. Do not strike an arc on a compressed gas cylinder.

10. Do not weld in the vicinity of inflammable or combustible materials. Degreasing of aluminum with alcohol or other inflammable solvents in an improperly ventilated welding area creates a fire hazard.

11. Do not weld on containers that have held combustible or inflammable materials without first exercising the proper precautions.

12. Do not weld in confined spaces without adequate ventilation or individual respiratory equipment. Do not weld on workpieces without wiping off the degreasing solvent.

13. Mark metal "HOT" because aluminum does not change color when heated.

14. Do not chip or grind without safety goggles and a suitable face shield.

15. Do not move individual cylinders unless the valve protection cap, where provided, is in place and tight.

16. Do not drop or abuse cylinders in any way.

17. Make certain that cylinders are well fastened in their stations so that they will not fall.

18. Do not use a hammer or wrench to open cylinder valves.

19. Never force connections that do not fit.

20. Never tamper with cylinder safety devices.

21. Always protect hose and welding cable from being trampled or run over. Avoid tangles and kinks. Do not leave the hose and cable so they can trip people.

22. Protect the hose, cable, and cylinders from flying sparks, hot metal, hot objects, and open flame.

23. Do not allow hose to come in contact with oil or grease; these rot the rubber and cause a hazard.

24. Be sure the connections between the regulators, adaptors, and cylinder valves are gas tight. Test them with soapy water under gas pressure.

25. When welding is to be stopped for an extended length of time, release the pressure-adjusting screws of the regulators.

26. When welding is to be stopped for a longer time, close the cylinder valves and then release all gas pressure from the regulators and hose.

27. If the equipment is to be taken down, close the cylinder valves, make certain that all gas pressures are released from the regulators and hose, and see that the pressure-adjusting screws are turned in the counterclockwise direction.

28. Use flat black paint on bulkheads and overhead of weld areas to reduce ultraviolet light reflected from GTA or GMA welding areas.

OTHER ELECTRIC WELDING PROCESSES

In addition to the shielded metal-arc process and the two shielded gas processes already described in this chapter, there are two other welding processes that you should know about. These are stud welding and resistance welding. Each of these processes is summarized briefly in the following sections.

STUD WELDING

Stud welding is a relatively simple electric welding-arc process that is used to end-weld studs to plate or other pieces. Stud welding was first developed to fasten wooden decking to steel plates, but it has become widely used for a variety of other applications. The equipment required for stud welding includes (1) a stud welding gun, (2) a timing device to control the time of current flow, (3) a source of dc power for welding, and (4) a supply of specially designed metal studs and ferrules. A typical portable stud welding gun is shown in figure 10-71. Figure 10-72 shows the connections between the various units in the system.

The heat necessary for coalescence is produced by an electric arc that is drawn between the metal stud (held in the gun) and the other workpiece part. When the stud and the other piece have reached the required temperature, they are brought together under slight pressure from a spring in the gun. The process requires relatively little skill, since many factors are controlled automatically. When you press the trigger of the gun, the arc is established and controlled, the welding time is controlled, and the stud is plunged against the plate at the proper time and held in place until the weld is completed.

If you have problems getting sound welds, check these three common errors made while stud welding.

- Improper amperage supplied to the stud gun from the power source. Welding of 5/8-inch studs requires amperage settings of up to 750 amps. Most stud guns require special power sources that can deliver such high amperages. Most shop welding machines cannot deliver enough amperages to properly weld studs over l/4 inch.

- Improper welding time selected. Consult owner's manual or process instruction for proper weld time selection.

- Base metal not cleaned properly. Remove all rust, paint, oil, or grease from weld area and grind to bare metal.

RESISTANCE WELDING

Of all the electric welding processes discussed in this chapter, resistance welding is the only one that cannot be considered as an arc process. Electrodes are used in resistance welding, but they do not create an arc. Instead, the electrodes (there are usually two of them) are pressed against the workpieces. Current is applied, and the heat necessary for coalescence is produced by the resistance of the workpieces to the flow of a low-voltage, high-amperage current.

Among the processes included in the resistance welding group are spot welding, seam welding, and projection welding. The discussion here is confined to spot welding, since this is the only type of resistance welding that is commonly used aboard ship. Figure 10-73 shows a type of spot welding

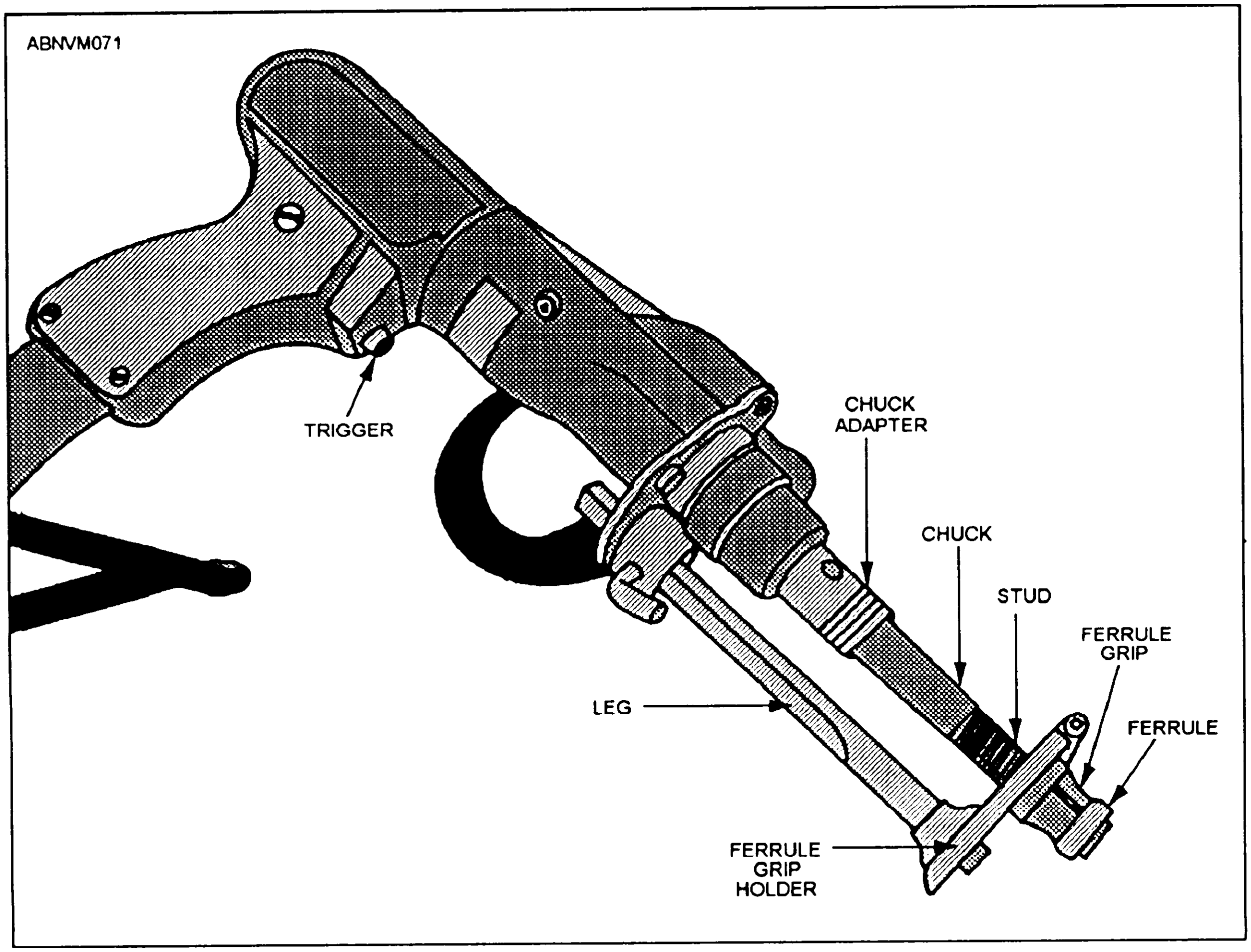


Figure 10-71.—Stud welding gun.

machine that is commonly used on repair ships. The machine serves to (1) transform the available power supply to a suitable welding current; (2) apply

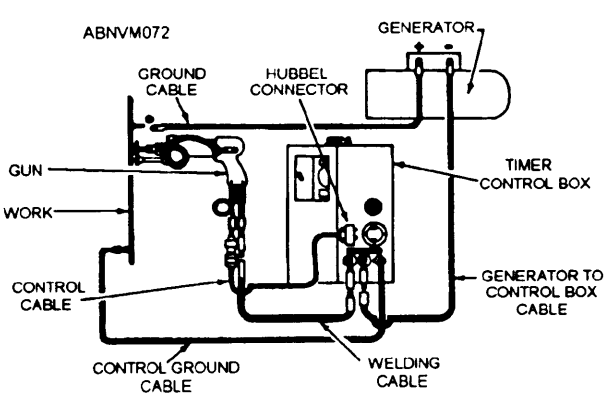


Figure 10-72.—Connection diagram for stud welding.

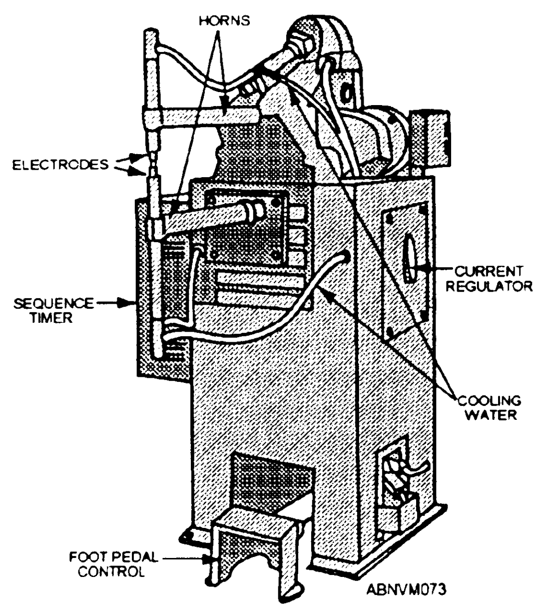


Figure 10-73.—Spot welding machine.

pressure to the work; (3) transmit current to the work; and (4) control the intensity and the duration of both current and pressure.

As may be seen in figure 10-79, the electrodes are held in arms (often called horns). The work is placed between the two electrodes, and the machine is adjusted for the control of current, pressure, and time. The electrode in the lower horn supports the work, provides backing as pressure is applied by the electrode in the upper horn, and completes the welding circuit from the transformer that is located in the machine. A foot pedal control permits the operator to start the welding sequence while using both hands to position the work between the electrodes. When the foot pedal is depressed, the upper electrode moves down into contact with and applies pressure to the work. At the instant the foot pedal is depressed, a preset, automatic timing device takes over. First, the timer provides for SQUEEZE TIME, during which pressure is built up in the pressure system and is applied to the work. Next, at the end of squeeze time, the timer provides WELD TIME, which controls the duration of current flow. Finally, the timer provides HOLD TIME, during which pressure is maintained on the electrodes after current flow stops. Hold time permits the weld nugget to cool and solidify under pressure. The weld that results depends on many factors, including current, pressure, and timing settings; the condition of the electrodes; and the surface condition of the workpiece. Each kind and thickness of material requires an individual setup. These adjustments are based on tables of resistance welding data furnished by the manufacturer.

ARC CUTTING

Arc cutting is a melting process rather than a burning process. The heat of the arc is used to melt the metal along the line of cut. This method does not produce cuts of the quality produced by oxyacetylene cutting, but it has the advantage of being applicable to almost all metals (including nonferrous metals).

Two arc-cutting procedures are commonly used. CARBON-ARC CUTTING is done with a carbon or graphite electrode. SHIELDED METAL-ARC CUTTING is done with a covered metal electrode. DC and straight polarity are preferred for both of these types of arc cutting. Conventional arc welding power sources are used for both of these types of arc cutting.

The procedure for arc cutting is shown in figure 10-74. When cutting thin plate (under one-half inch), you do not need to manipulate the electrode except as required to maintain the arc and to advance the arc as the cut progresses (fig. 10-74, view A). When cutting heavier plate, manipulate the electrode with an up-and-down motion in the cut so as to displace the molten metal; keep the electrode at an angle to the plate (fig. 10-74, view B) so that the bottom of the plate is cut slightly before the top. In general, metal-arc cutting is better than carbon-arc cutting through heavy sections. Metal-arc cutting is also generally preferred for rivet cutting and for hole piercing. Gas tungsten-arc cutting is an arc-cutting process used for cutting aluminum alloys. A high-temperature, high-velocity arc is established between the tungsten arc and the workpiece. A shielding gas mixture of hydrogen and argon emerges from the nozzle at a sufficiently high velocity to blow the molten metal from the cut. Most of the safety precautions concerning arc welding that are given in chapter 1 of this training manual also apply to arc cutting. Be sure that you are entirely familiar with all appropriate safety

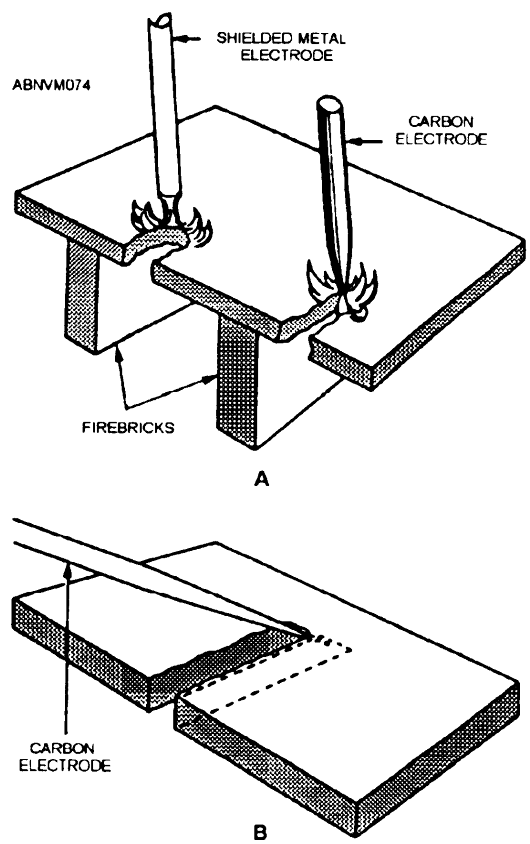


Figure 10-74.—Techniques for arc cutting. (A) Thin plate. (B) Heavy plate.

precautions before attempting any arc-cutting operation.

Air carbon-arc cutting is a method of cutting or gouging metal by melting it with the heat of an electric arc and blowing away the molten metal with a high-velocity jet of compressed air. The flow of compressed air is parallel and external to the carbon electrode. Because it does not depend upon oxidation of the metal, air carbon-arc cutting is very effective in cutting nonferrous metals.

The air carbon-arc gun shown in figure 10-75 is used to clamp a carbon-graphite electrode in such a position that air emitted from orifices in the gun nozzle is directed parallel to the electrode. The air then strikes the molten metal immediately behind the arc. The gun also contains an air control valve and the cable that carries both the current and the air. This cable is connected to a dc welding machine delivering reverse polarity current, and also to a source of compressed air.

The carbon electrodes used for this cutting process are copper coated to increase their life, provide a uniform cut, increase their current-carrying capacity, and reduce the radiated heat. The carbon electrodes, used with the gun shown in figure 10-75, may vary in diameter size

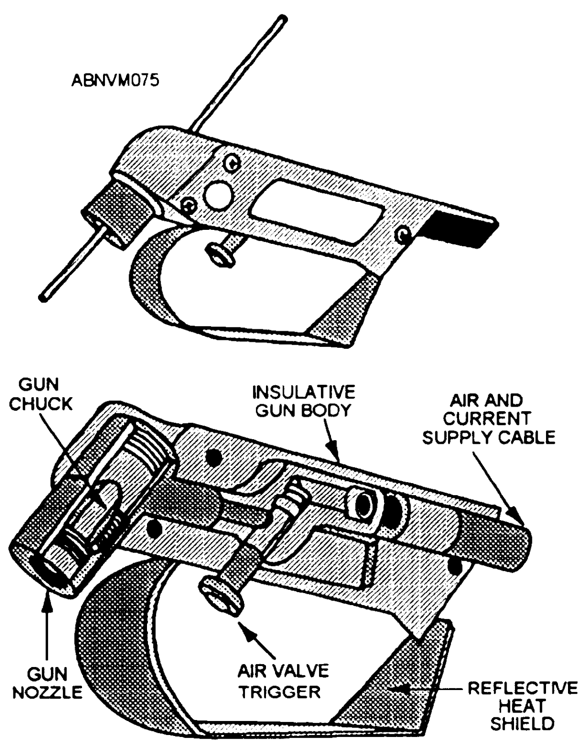


Figure 10-75.—Air carbon-arc gun.

from 5/32 to 3/8 inch. The amperage settings for these rods should be according to the recommendations of the manufacturer, but may vary from a minimum of 75 amps for the 5/32-inch rod to a maximum of 800 amps with the 3/8-inch rod.

The compressed air for this process is supplied by the ship’s low-pressure air system or by an appropriate air compressor. Most cutting applications require 80 to 100 psi air pressure, although pressures as low as 40 psi can be used for light work. On heavy work, pressures up to 125 psi may be necessary. The air supply hoses for this process should have a minimum inside diameter of one-fourth inch, and there should be no restrictions of the air flow through the hoses.

To make a cut, hold the gun with the electrode at the desired angle of cut and strike an arc between the end of the electrode and the metal to be cut. The jet of compressed air is then turned on by depressing the air valve trigger. After being depressed, the trigger may be turned a quarter turn in either direction for continuous flow of air. The air jets are directed immediately behind the point of arcing, and the electrode is moved forward as the molten metal is blown away by the air jets. Speed of travel is determined by the electrode size, type of metal being cut, amperage setting, and air pressure used. Proper speed of travel produces a good clean cut and is recognized by a smooth hissing sound.

Air carbon-arc cutting offers certain advantages over oxyacetylene cutting. The heat penetration is shallower with this process, and the volume of metal adjacent to the cut which is subjected to a high rise in temperature during cutting is also less. As a result, there is less warpage and distortion of the metal being cut.

In all cutting operations, be careful that hot slag does not come in contact with any combustible material. Globules of hot slag can roll along a deck for quite a distance. Do not cut within 30 or 40 feet of unprotected combustible materials. If combustible materials cannot be removed, cover them with sheet metal or another noncombustible material.

Many of the safety precautions discussed in chapter 1 of this training manual apply to cutting as well as to welding. Be sure that you are entirely familiar with all appropriate safety precautions before attempting any cutting operation.

SUMMARY

You have been introduced to welding equipment, its use, and the safety precautions associated with the equipment. Various processes and techniques were also discussed to give you an insight to welding and arc-cutting operations. However, knowing both the equipment and the safe operation of this equipment is only the first step. Your ultimate goal is to put your knowledge to use.

CHAPTER 11

NONDESTRUCTIVE TESTS AND INSPECTIONS OF WELDS

LEARNING OBJECTIVES

Upon completion of this chapter; you will be able to do the following:

- Describe the various types of nondestructive tests (NDTs) performed on welded or brazed joints.
- Discuss some of the equipment used to perform NDTs
- Describe the various nondestructive testing symbols used.
- Discuss the procedures for hydrostatic and operational tests of ships' systems and piping systems.

INTRODUCTION

A component is only as good as its weld. If the weld is not sound and is subject to cracking under normal wear and use, then the material that has been welded is of no use. Nondestructive tests (NDT) ensure that the welds, castings, forging, and components are of good quality. This chapter will discuss the various NDT methods used.

When tests are specified, the specifications or standards will outline in detail (1) which part is to be inspected, (2) the testing procedure that must be used, (3) the extent of the part that will be inspected, (4) the qualifications of the persons making the test, (5) the qualifications of the persons evaluating the results of the test, (6) the acceptance levels that the test must show, and (7) the materials and equipment to be used.

Unspecified tests (tests not in the standards) may be made, but they cannot be considered as final acceptance tests unless they are specifically approved by the Naval Sea Systems Command. Welders are not permitted to inspect their own welds for final acceptance.

There is no standardized waiver of any specified test regardless of the type of organization making or repairing the item. This should be understood by all concerned.

Official (acceptance) tests must be performed by personnel with current certification by the Naval Sea Systems Command. These include radiography, liquid penetrant, ultrasonic, and magnetic particle tests. If you are not certified, you may still take part in radiographic tests (RTs) made under the direct supervision of a qualified radiographer if you have had formal training in the *Radiological Affairs Support Manual*, NAVSEA SO420-AA-RAD-010 (RAD-10), rules and regulations. Under these conditions, you may help prepare an item for testing and assist with radiographic exposures according to RAD-10 radiation protection rules.

In the following pages, we will discuss the use of radiography and ultrasonic testing (UT) and some of the limitations of each. We will also provide some information on the uses and limitations of magnetic particle (MT) and liquid penetrant (PT) inspections. The last section of this chapter discusses hydrostatic testing of components.

Before you begin any NDT of welds, you should make a visual inspection (VT) to detect undercutting, weld, spatter, arc strikes, cracks, and other obvious surface defects.

RADIOGRAPHY

To determine the quality of a weld, we must examine the interior of a weld for defects. To detect internal defects, the Navy relies heavily on an inspection method known as radiography. In this method, a beam of radiant energy is passed through the metal and recorded on a radiographic film, which is similar to photographic film. The source of the energy is an X-ray tube of radioactive isotope (Iridium-192). X-ray machines that are practical for use on ships are generally of medium power; that is, they can penetrate metal that is about 3 inches thick. The source used must be according to the guidelines of MIL-STD-271, *Requirements for Nondestructive Testing Methods.*

The action of the penetrating radiation, or "beam," works almost exactly as a beam of sunlight or electric light through air. But instead of being stopped or reflected, as light is by metal or solids, it penetrates the solid and travels through it. Some of the radiation is scattered or absorbed by the solid, and does not get through. A thin section of metal will "pass" more radiation than a thick section. A radiographic film is placed on the side of the metal opposite the source. The image on the film (after development) will show black where more radiation passed through and will show lighter shades or clear white where less radiation, or no radiation, passed through. A hole or other defect in the metal, of even a few thousandths of an inch, will allow more radiation to pass through than passes through the solid metal. The film will show a shadow that is darker at the defect and lighter AROUND the defect.

Radiography is used where the full thickness of a part must be inspected, or seen. For best results, use only enough energy to get the picture on the film. The exposure time is figured from factors such as the type of energy, type and thickness of material, film type, screens, distance, and required image density. A thick piece of metal will need a longer exposure time than a thin piece.

X-RAY EQUIPMENT

The X-ray equipment used for radiography on some repair ships, tenders, and at shore stations is the 275-kilovolt-peak (LVP), 10-milliamperage (mA) portable X-ray machine. Figure 11-1 shows that the machine consists of three principal units plus electrical cable and water hose.

Power Supply

The power supply and cooling unit shown in view A converts 220-volt or 440-volt, three-phase, 60-cycle

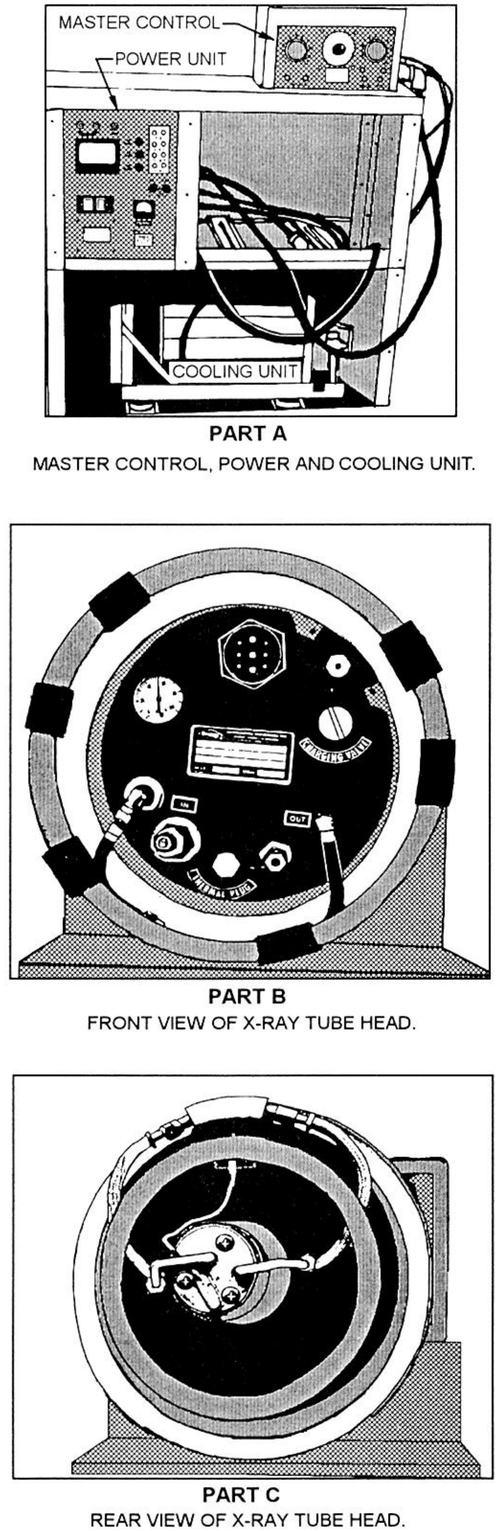


Figure 11-1.—Portable X-ray unit for a radiographic inspection of metals.

current from the power source to 2,000-cycle, single-phase current. It also circulates a coolant through the X-ray tube head (views B and C) by means of a radiator, water pump, and interconnecting hose.

Master Control

The master control (fig. 11-1, view A), when properly set up with the power supply and tube head (fig. 11-2), provides the means for energizing and adjusting the kilovoltage and milliamperage of the tube head. A timer automatically indicates the elapsed exposure time, and de-energizes the tube at the completion of the exposure. Indicating instruments show the kilovoltage and milliamperage of the X-ray beam emerging from the X-ray tube window.

Transformer

A transformer within the head assembly converts low voltage to the kilovoltage required for the production of X rays by the X-ray tube located in the head. The unit also contains a heat exchanger and blower for removing heat from the transformer and X-ray tube parts. The head is charged with an insulating gas (sulfur hexafluoride) to prevent electrical leakage. The tube that actually produces the X rays is a vacuum tube containing a negative and a positive terminal. The negative terminal is a filament that provides a source of electrons. The positive terminal is a target at which the stream of electrons is focused. A high voltage applied to the tube drives electrons from the cathode, or negative terminal, to the anode, or positive terminal. The higher the voltage, the greater the speed of the electrons; resulting in a higher range of radiation.

PRINCIPLES OF X-RAY GENERATION

The principle of X-ray generation is illustrated in figure 11-3. Heat and X rays are generated when rapidly moving, negatively charged particles

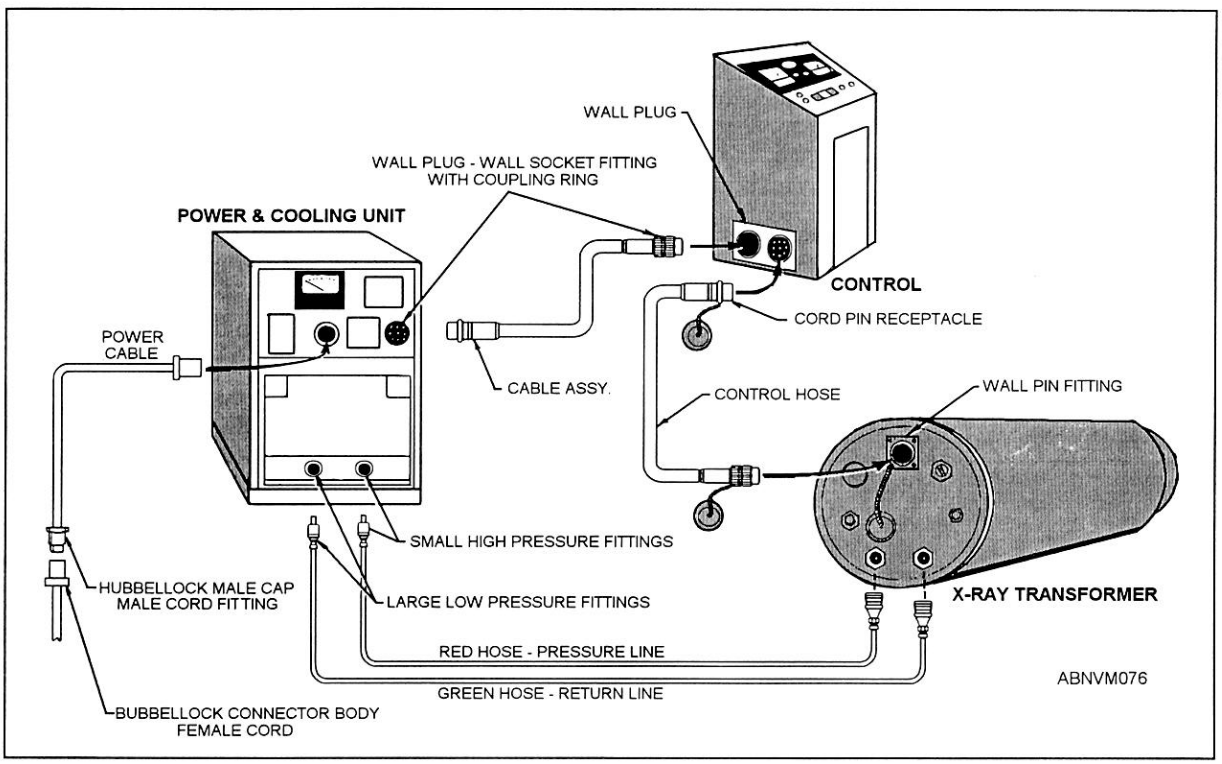


Figure 11-2.—Connections for portable X-ray machine.

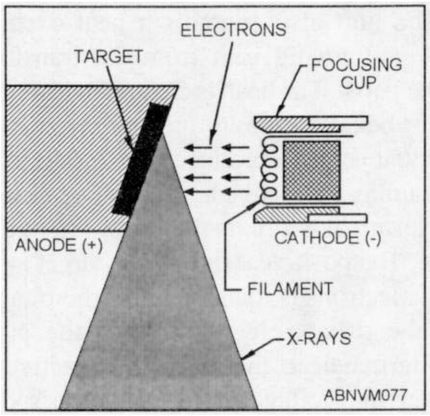


Figure 11-3.—Principle of X-ray generation.

(electrons) collide with a mass of matter. The collision transforms the energy of motion (kinetic energy) of the electron into radiant energy. The faster the particles are moving, the shorter the wavelength of the X rays. The greater the current (milliamperes), the greater the intensity of the radiant energy produced. Most of the kinetic energy is transformed into heat. Only a small portion is transformed into electromagnetic waves (X rays) with the ability to travel in straight lines without displacing the matter through which they pass.

Figure 11-2 shows how the several units of the portable X-ray equipment are interconnected. You can find a complete description of this setup, as well as the details for the operation and care of the equipment, in the handbook furnished with the machine. This equipment should be operated only by qualified personnel who have had the required special training on this equipment.

The diagram in figure 11-4 illustrates the fundamentals of radiographic exposure and the setup of the film, specimen, and radiation source. Note that the film assembly is placed as close as possible to the test specimen, while the X-ray source is some distance away. A definite space ratio must be maintained between the specimen and the X-ray source if a satisfactory radiograph is to be obtained.

Screening

Almost all industrial radiographs are made with lead intensifying screens. Normally, lead intensifying screens decrease the exposure time required by increasing the effects of the X rays on the film. These screens perform two functions. First, they absorb long rays from the X-ray tube and the scattered rays from the object being radiographed and from the surrounding area. Second, the primary X rays striking the screens cause the screens to emit secondary rays that react on the film in the same manner as do the primary rays. This intensifies the amount of radiation striking the film. The film and screens are packaged in a lightproof device known as a cassette, which is positioned snugly against the specimen that is to be radiographed.

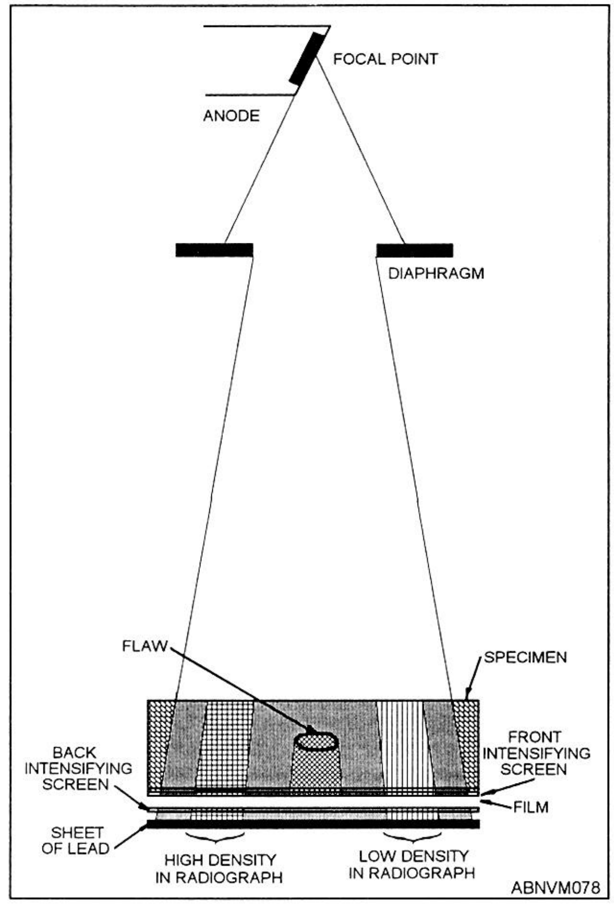


Figure 11-4.—Shematic diagram for making a radiograph.

Other Factors

Many factors govern the results obtained in radiography. The principal factors are the kind and thickness of the test specimen, the type of film used, the focal distance between the specimen and the radiation source, the voltage applied, the exposure time, and the location, size, and orientation of the defect. Each of these factors has a bearing on the radiograph produced.

RADIOACTIVE SOURCE

Radioactive sources disintegrate with a time scale rate expressed in terms of half-life. This may be days for Iridium-192. Any source aboard ship must be considered as "live" or potentially dangerous to health, because the source cannot be turned on and off as can an X-ray machine. NO person is to use (expose) radioactive sources unless the use and users are licensed by NAVSEA.

SAFETY PRECAUTIONS

X rays and gamma rays are potentially very dangerous to health. Therefore, the operator must be thoroughly familiar with and use all prescribed safety precautions when using radiation-producing equipment. When operating radiographic equipment, all personnel, including the operator, must be at a safe distance from the source of radiation. A heavy bulkhead or lead shielding is usually provided between the radiation source and the operating personnel. The first step before you begin the operation is to clear all personnel from the area in which the radiograph is to be made. The area must then be roped off. Remember that secondary radiation scattered from the test piece or nearby and overhead objects is potentially as dangerous as the direct radiation from the beam itself.

Distance

The best radiation safety precaution is distance between personnel and the radiation source. This is true because the intensity of radiation varies inversely with the square of the distance from the radiation source. X rays, like a beam of light, cover an increasingly larger area with lessened intensity as they travel from the source. This principle, known as the inverse square law, is illustrated in figure 11-5. When the distance (D) from the radiating source is doubled (2D), the area covered by the beam (Cl) is quadrupled (C2). At the same time, though, the intensity per unit of area is only one-quarter of the value at the original distance. Thus, with sufficient distance, the area covered by the beam may be tremendously large, but its intensity per unit area will be slight. The intensity at any given distance, however, depends upon the intensity of the radiation source.

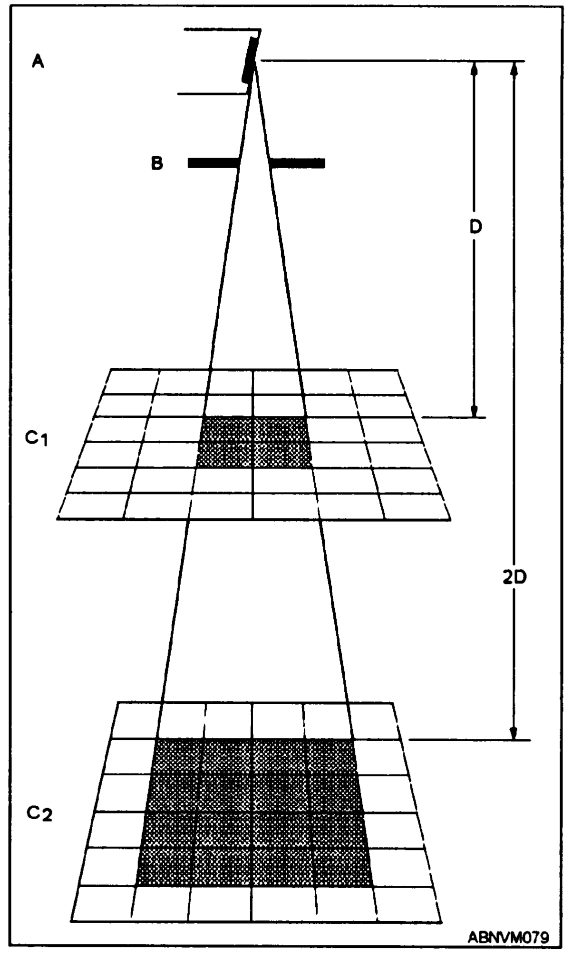


Figure 11-5.—Diagram illustrating inverse square law.

Time

An important factor in minimizing exposure to radiation is to reduce the amount of time material is exposed to X rays. It stands to reason that if the exposure time is reduced, the amount of radiation will also be reduced. Mathematical calculations are used to determine the amount of exposure required for different types and thicknesses of metals.

Shielding

Shielding also reduces radiation exposure. If a shield is placed between the operator and the source of radiation, the amount of radiation received by the operator will be reduced. The denser the shielding material, the better the protection provided. Lead is the best shielding material available due to its dense structure. Steel bulkheads, decks, overheads, and machinery also provide good shielding provided that they form a solid partition between the source and the operator.

RADIOGRAPHIC LIMITATIONS

Some of the limitations of the use of radiography are pointed out in the information that follows. The greatest limitation is the shortage of qualified film interpreters. The accessibility of the item to be radiographed is an important limitation. Accessibility controls the placement of both the radiation source and the film, which, in turn, controls the amount of distortion involved. The distortion factor will be discussed later with the interpretation of radiographs.

Other limitations are the thickness and type of material being radiographed. A 300 kVP X-ray machine that can penetrate 3 inches of steel in a reasonable length of time can only penetrate approximately 2 inches of various copper-base alloys using the same kVP rating. The thickness range for steel, using Iridium-192 is 1/4 inch to 2 1/2 inches. The thickness range for copper-base alloys is approximately the same as steel.

INTERPRETATION OF RADIOGRAPHS

The interpretation of radiographs is guided by radiographic standards set by the Naval Sea Systems Command and published in MIL-STD-2035, *Nondestructive Testing Acceptance Criteria.* Copies of these standards are available aboard each ship or station that have radiographic equipment. A decision on whether or not a part is acceptable is based on a comparison of the radiograph of the part with the appropriate radiographic standards. The standards provide specific guidance on the size, number, and dispersion of various defects, and on what decisions for either acceptance or rejection should be made by a qualified radiographic inspector.

You must be familiar with what is and what is not acceptable, and with the design of the part. Unless all sections of the metal radiographed are of uniform thickness, a radiograph of a perfectly sound section of metal will vary in density. Thin sections and cored internal cavities appear as darker areas on the radiograph. Density differences caused by the design must not be confused with density differences caused by defects. Film should be viewed only in an enclosure where all background light is prevented from causing reflections on the film. The light source for viewing should have enough intensity to allow you to view film that ranges in density from gray to black. The light intensity source should have a variable control, a cooling fan, and masking facilities. All radiographs are required to be within given density ranges. A densitometer is used to measure the density ranges of a film to ensure compliance with the requirements.

Shadow Formation

Remember, a radiograph is a shadow picture. Like any shadow cast by an object in a visible light source, the radiograph of a specimen containing a defect is subject to distortion. The shadow cast by your body depends on the relative position of your body to both the light source and the surface upon which the shadow is cast. In the same way, the different positions of the source of radiant energy, the defect, and the film determine the extent to which the shadow cast by the defect is distorted.

The principles of shadow formation are shown in figure 11-6. Note that enlargement and distortion arise in several different ways. First, view A shows that enlargement occurs unless the surface upon which the shadow is cast is flush with the object itself. The greater the distance between the object and the surface upon which the shadow is cast, the greater the enlargement. Second, views E and F show that if the angle of the radiating beam or the surface upon which the shadow is cast is other than at a right angle (90”) to the object or film, the shadow is distorted as well as enlarged. A third kind of distortion occurs when the radiating source is not an ideal point source, as shown in views A, E, and F, but radiates from a beam area containing innumerable points, as shown in B, C, and D. As a consequence, a halo effect results, as shown in B, C, and D, which adds to the distortion stemming from other causes. You can minimize this halo effect by keeping the proper focal distance between the test specimen, the radiating source, and the surface upon which the shadow is cast.

Keep the principles of shadow formation in mind. Remember that the size of the shadow cast by any defect other than a spherical defect is influenced by the way the beam is aimed at the defect. For example, if the defect is cylindrical and the beam is parallel to the long axis of the cylinder, the shadow cast is that of a circle. On the other hand, if the beam is parallel to the diameter of the cylindrical defect, the shadow has a rectangular shape. In other instances, what appears to be a hairline crack may in reality be a cold shut. It is sometimes possible to overcome this difficulty by radiographing the specimen twice, with the direction of the radiating

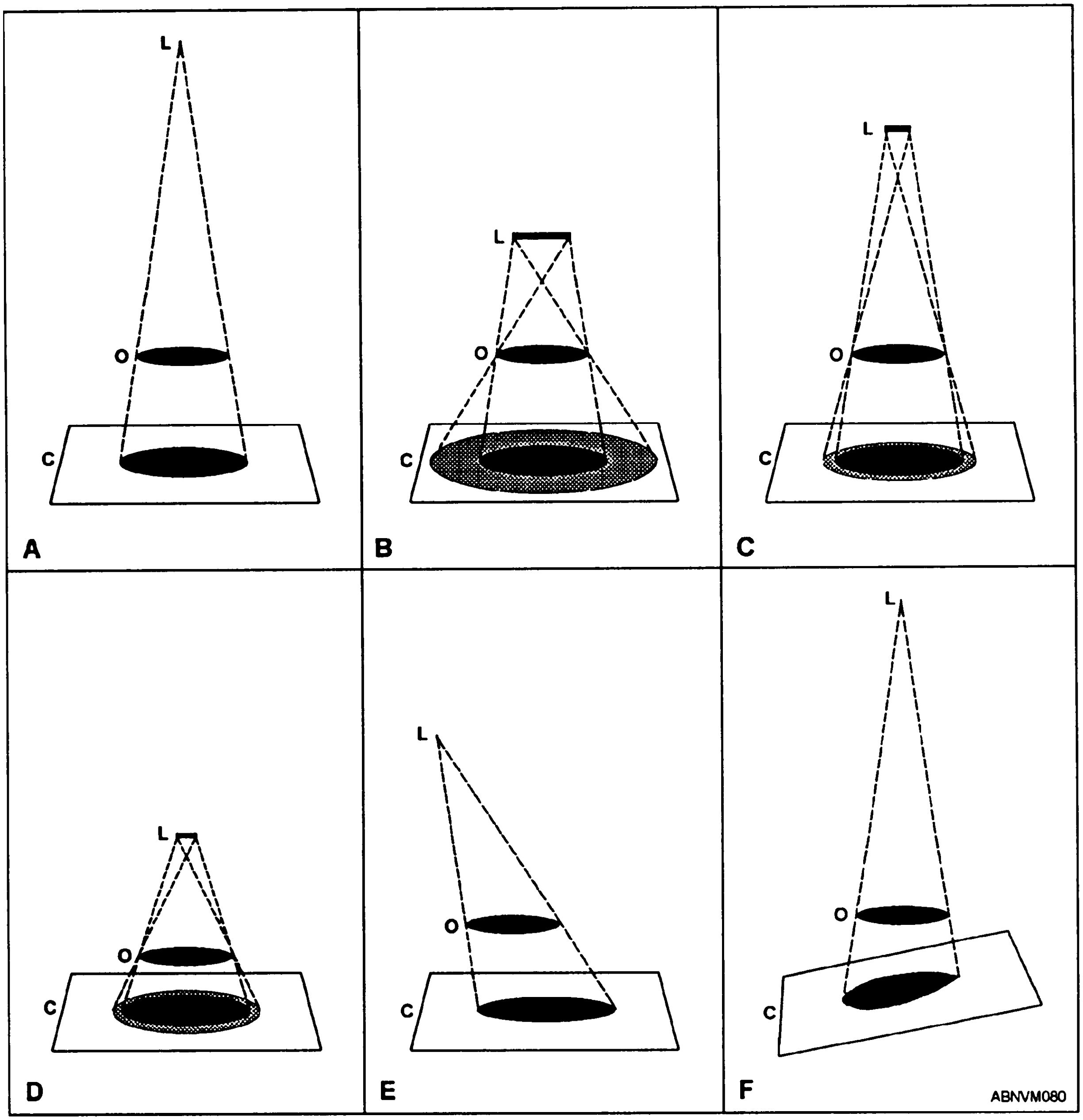


Figure 11-6.—Principles of shadow formation.

sources varied 90° from each other. Unfortunately, many parts do not lend themselves to this procedure.

Defects

The defects most frequently detected in steel welds through the use of radiography are slag inclusion, porosity, cracks, and incomplete fusion. Sand inclusions, porosity, shrinkages, and hot tears are some of the defects revealed in steel castings. These defects are less dense than the surrounding steel. Therefore, they absorb a smaller portion of the beam passing through the metal, and they show up on the radiograph as darkened areas. The characteristics of the more common defects revealed by a radiograph are briefly described as follows:

- Surface roughness appears as irregular light and dark areas having contours identical to the combined surfaces.

- Gas cavities are indicated by round dark areas.

- Inclusions may appear as regular or irregular light or dark areas, depending on the density of the included material.

- Shrink porosity is indicated by a lacy, honeycombed, discontinuous pattern, while individual shrink cavities appear as localized dark spots, usually with a branching, or tree-like, pattern.

- Cold shuts appear as dark lines or bands that tend to be curved. When two streams of molten metal that are significantly different in temperature meet and do not fuse together, the flow is known as a cold shut.

- Cracks are shown as dark lines of various widths, while hot tears are seen as dark lines containing many branches.

Standard radiographic plates are valuable guides in determining the acceptability of a weld. However, the individual who views the plates must depend a great deal on training and experience. Further, the individual must be sure that the radiograph plate was properly exposed and developed. If it is not, a radiograph showing characteristic defects may, in fact, be sound. If there is doubt, the part should be rejected or submitted for further radiographic inspection.

Frequently, an unacceptable weld can be salvaged by chipping or grinding out the defects and rewelding. When this is done, the area must be re-radiographed to determine the acceptability of the repaired area. Before you start to grind or chip, though, be sure that the defects are real to avoid grinding into or through a perfectly good section.

In addition to the use of radiographs to determine acceptability, an analysis of radiographs can lead to a correction of the conditions leading to the defects. By comparing the results of the inspection procedures with your knowledge of the causes of defects, you can improve the overall quality of the product and rejects can be reduced or eliminated.

MAGNETIC PARTICLE INSPECTION

Magnetic particle (MT) inspection can be used for the detection of weld defects in metals or alloys in which magnetism can be induced. While the test piece is magnetized, finely divided iron powder is applied to it. As long as the magnetic field is not disturbed, the iron particles will form a regular pattern on the surface of the test piece. If the magnetic field is disturbed by a crack or some other defect in the metal, the pattern is interrupted and the particles cluster around the defect.

CIRCULAR AND LONGITUDINAL MAGNETIZATION

The test piece may be magnetized either by passing an electric current through it, as shown in view A of figure 11-7, or by passing an electric current through a coil of wire that surrounds the test piece, as shown in view B of figure 11-8. When an electric current flows in a straight line from one contact point to the other, magnetic lines of force are in a circular direction, as shown in view A of figure 11-7. When the current flow is through a coil around the test piece, the magnetic lines of force are longitudinal through the test piece. In order for a defect to show up as a disturbance in the pattern of the iron particles, the direction of the magnetic field must be close to a right angle to the major axis of the defect. Since the orientation of the defect is unknown, a minimum of two current directions must be used during the test. In figure 11-7, circular magnetism is induced in the test piece so that the piece may be inspected for lengthwise cracks. Longitudinal magnetism (fig. 11-8) is induced so that the piece may be inspected for transverse cracks. In general, magnetic particle inspection is satisfactory for detecting surface cracks and subsurface cracks that are not more than 1/4 inch below the surface.

MT INSPECTION EQUIPMENT

The type of MT inspection unit most commonly used in the Navy is the portable unit shown in view B of figures 11-7 and 11-8 It is a high-amperage, low-voltage unit having a maximum magnetizing current output of 1,000 amperes, either alternating or direct current. It is ready to operate when it is plugged into the voltage supply specified by the manufacturer. The unit consists of magnetizing current source, controls, indicating meters, three 10-foot lengths of flexible cable for carrying the current to the test piece, and a prod kit. The prod kit includes an insulated prod grip fitted with an ON-OFF relay or current control switch, a pair of heavy copper contact prods, and two 5-foot lengths of flexible cable. Cable fittings are designed so that either end of any cable may be fitted to the unit, to the prods, or to any other cable. The unit has

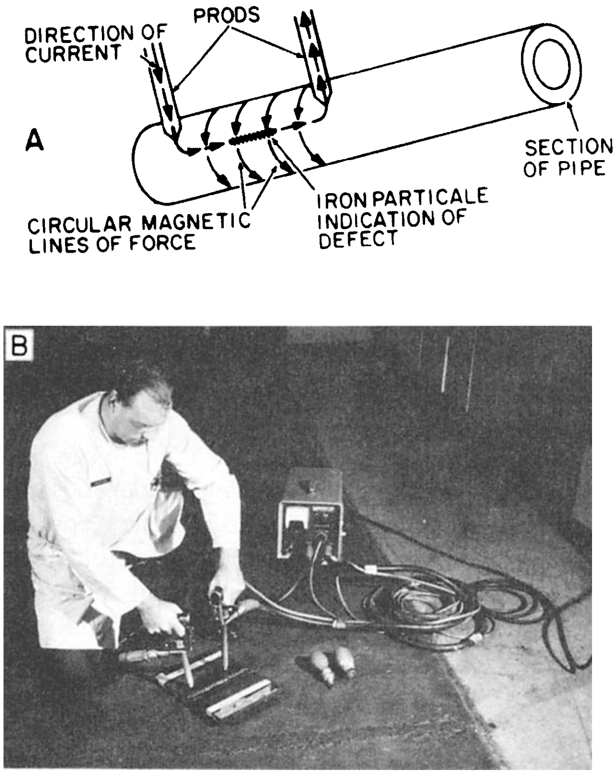


Figure 11-7.—Circular magnetization—prod method.

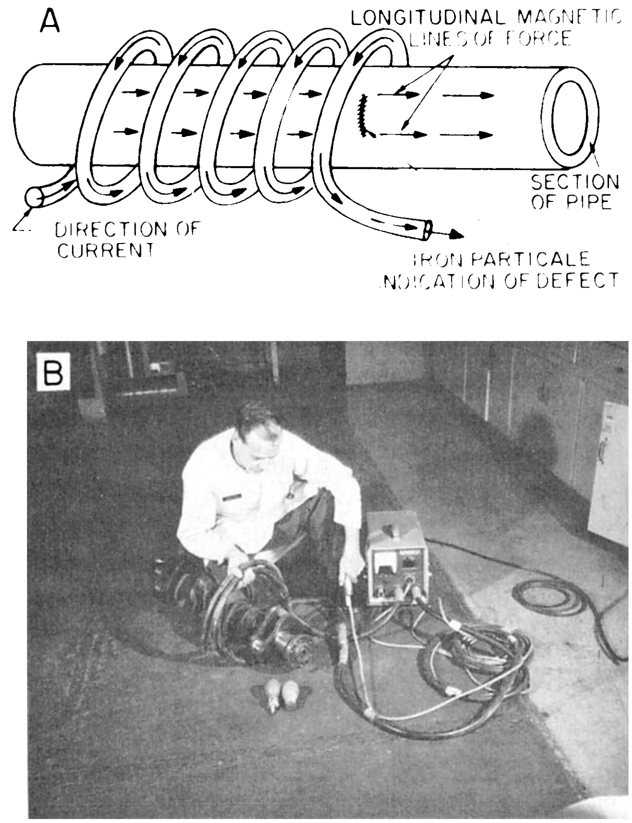


Figure 11-8.—Longitudinal magnetization—coil method.

three outlets on the front, which makes it easy to change from alternating to direct current or vice versa. The outlet on the left is labeled ac, the center is COMMON, and the right is dc. One cable will always be plugged into the COMMON outlet. The other cable is plugged into the ac or dc outlet, depending upon what type of current the test requires. For most work, alternating current magnetization will locate fatigue cracks and similar defects extending through to the surface. Direct current is used when a more sensitive inspection is required to locate defects that are below the surface.

The unit can be used to produce alternating or direct current in either of two ways:

- View B of figure 11-7 shows prods attached to the flexible cable and used as contacts through which current is passed into and out of a portion of the test piece. This sets up a circular magnetization in a local area between the prod contact points.

- View B of figure 11-8 shows a flexible cable wrapped around the work. This forms a coil which, with the passage of current, induces longitudinal magnetism in the part of the workpiece that is surrounded by the coiled cable.

Either of these two methods may be used, but the prod method is probably the easiest to apply. It will detect surface defects in most instances. With the prods, however, only a relatively small area of the test piece can be magnetized at any one time. This magnetized area is limited to the distance between prod contact points and to a few inches on each side of the current path. To check the entire surface, it is necessary to successively test adjacent areas by changing the location of the prod contact points after a given area has been tested. Each area of the test piece must be inspected twice; once with the current passing through the metal in one direction and again with the current passing through the metal in a direction at right angles to the direction of the first test. One of the advantages of the prod method is that the current can be easily passed through the metal in any direction. Therefore, if you think a given area is defective, you can conduct magnetic field tests in various directions to locate the defect.

The prod method is used by adjusting the unit for a current output suitable for the magnetizing and testing to be performed for any particular kind of metal. The amperage setting will depend on the distance between prod contact points. The prod kit supplied with the unit has a space between prod contact points of 4 to 6 inches. For this space and a material thickness of less than 3/4 inch, a current setting between 300 and 400 amperes is satisfactory. When the material thickness is 3/4 inch and over, use 400 to 600 amperes. You can get the same magnetic field force with less amperage if the prod contact points are closer together. When you hold the prods constantly at the same spacing, you can use a greater amperage to induce a field of greater strength.

After adjusting the unit, place the prods in position. Hold them in firm contact with the metal and turn on the current. Then apply magnetic particles to the test area with the duster bulb and observe any indicator patterns. With the current still on, remove the excess particles from the test area with a blower bulb and complete the inspection. Do not move the prods until after the current has been turned off; otherwise the current will arc, and you would have a flash similar to that occurring in arc welding.

DEFECT IDENTIFICATION AND REPAIR

MT inspection will help you locate hairline cracks that are otherwise invisible. The particles form an unmistakable outline of the defect. Large voids beneath the surface are more easily detected than small voids, but then, any defect below the surface is more difficult to detect than one that extends through to the surface. Since false indications occur frequently, you must be able to accurately interpret the particle indications to make correct repairs to the weld.

Defect Identification

Some of the factors that help you to interpret the test results include the amount of magnetizing current applied, the shape of the indication, the sharpness of the outline, the width of the pattern, and the height or buildup of the particles. Although these characteristics do not determine the seriousness of the indication, they do serve to identify the kind of defect indicated.

A crack is indicated by a sharp, well-defined pattern of magnetic particles with a definite buildup. This indication is produced by a relatively low magnetizing current. Seams are revealed by a straight, sharp, fine indication. The buildup of particles is relatively weak, and the magnetizing current must be higher than that required to detect cracks. Small porosity and rounded indications or similar defects are difficult to detect if you are inexperienced. A high magnetizing current continuously applied is usually required. The particle patterns for these defects are fuzzy in outline and have a medium buildup.

Defect Repair

Whether or not an indicated defect is to be chipped or ground out and repaired by welding depends on the specifications governing the job. Surface cracks are always removed and repaired. Indications of subsurface defects are evaluated by the inspector. If the indication is positive, it is usually best to grind or chip down to the solid metal and make the repair. Unless you have had considerable experience and can differentiate accurately between true and false indications, it is best to use the magnetic particle inspection only to locate surface defects. The magnetic particle inspection is almost foolproof for this purpose. After the defects have been repaired, the areas should be reinspected to ensure that the repair is sound.

Demagnetization

The final step is to demagnetize the workpiece. This is especially important when the workpiece is made of high-carbon steel. Demagnetization is essential when direct current has been used to induce the magnetic field. It is not as necessary when alternating current has been employed in the test. In fact, the usual demagnetization procedure involves placing the workpiece in an ac coil or solenoid and slowly withdrawing it while the current passes through the coil.

Demagnetization can be done with the portable unit if a special demagnetizer is not available. To demagnetize with the portable unit, form a coil of flexible cable around the workpiece. Be sure that the cable is plugged into the unit for the delivery of alternating current. Set the current regulator to deliver a current identical to that used for the inspection, and turn on the unit. Then gradually decrease the amperage until the ammeter indicates zero. If the piece is large, it may be necessary to demagnetize a small portion of the work at a time.

You can use a small compass to check for the presence of a magnetic field. When the compass is held near the workpiece, deviation of the needle from its normal position indicates the presence of a magnetic field. If a magnetic field is present, the workpiece will require demagnetization.

LIQUID PENETRANT INSPECTION

Liquid penetrant (PT) inspection is used to inspect metals for surface defects similar to those revealed by the MT inspection. Unlike the MT inspection, which can reveal subsurface defects, the PT inspection reveals only those defects that are open to the surface. Both ferrous and nonferrous metals can be inspected by the use of the PT inspection.

Seven groups of penetrant are listed in MIL-STD-271. According to MIL-STD-271, group 1 penetrant material should be used for all welds. The use of a group other than group 1 penetrant material for welds requires approval of the authorized representative of NAVSEA. The application of all PT inspections must be according to the appropriate MIL-STD or NAVSEA document. Instructions prescribed for each penetrant should be followed carefully according to the applicable procedure, since there are some differences in the procedures and safety precautions required for various penetrants.

PT INSPECTION PROCEDURES

The following procedures should be followed when you use liquid penetrants to inspect a weld.

Surface Preparation

First, you must prepare the surface. Remove all slag from the surface. Except where a specific finish is required, it is not necessary to grind the weld surface as long as the weld surface is in accordance with applicable specifications and as long as the weld contour blends into the base metal without undercutting. If a specific finish is required, PT inspections may be made before the finish is made. This will detect defects that extend beyond the final dimensions, but a final liquid penetrant must he made AFTER the specified finish is made.

Surface Cleaning

After surface preparation, you should clean the surface of the material, including areas adjacent to the inspection area, very carefully. You can clean the surface by swabbing it with a clean, lint-free cloth saturated in a solvent, such as acetone or isopropyl alcohol, or by dipping the entire piece into a solvent. After you have cleaned the surface, remove all traces of the cleaning materials. It is extremely important that all dirt, grease, scale, lint, salt, and other materials are removed. Make sure that the surface is completely dry before the liquid penetrant is used.

Application

You must maintain the temperature of the liquid penetrant and the workpiece between 50° and a maximum of 150°. Do NOT attempt to use liquid penetrant when this temperature cannot be maintained. Do NOT use an open flame to increase the temperature, since liquid penetrant materials are flammable.

When the material is clean and dry, coat the surface with the liquid penetrant. The penetrant may be sprayed on, brushed on, or the entire piece may be immersed in the penetrant. You must allow time for the penetrant to get into all cracks, crevices, or other defects that are open to the surface. Wet the surface of the piece with the penetrant and keep it wet for a minimum of 15 to 20 minutes. The time limits will vary depending upon which group of penetrant is being used. Follow the instructions prescribed by the appropriate MIL-STD or NAVSEA document concerning the length of time the surface must be kept wet.

When the surface has been kept wet with the penetrant for the required length of time, remove the excess penetrant from the surface with a clean, dry, lint-free cloth or absorbent paper towel. Then, dampen a clean, lint-free cloth or absorbent paper towel with penetrant remover and wipe the remaining excess penetrant from the test surface. Dry the test surfaces after removal of excess penetrant only by normal evaporation, or with the clean, lint-free cloth or absorbent paper towel previously mentioned. When you are drying the surface, be very careful so that you do not contaminate the surface with any oil, lint, dust, or other materials that would interfere with the inspection.

After the surface has been dried, you must apply another substance called a “developer.” The developer (powder or liquid) must be allowed to stay on the surface for a minimum of 7 minutes before the inspection is started. It can be left on no longer than 30 minutes; this leaves a total of 23 minutes to evaluate the indications.

Let's stop for a moment and examine what takes place when these penetrant materials are applied. First of all, the penetrant applied to the surface of the material will seep into any passageway open to the surface, as shown in view A of figure 11-9. The penetrant is normally red in color and, like penetrating oil, it seeps into any cracks or crevices that are open to the surface. Next, the excess penetrant is removed from the surface of the metal with the penetrant remover and a lint-free absorbent material. Only the penetrant on top of the metal surface is removed (view B, fig. 11-9); thus, only the penetrant that has seeped into the defect is left.

Finally, the white developer is applied to the surface of the metal. (See view C, fig. 11-9.) The developer, an absorbing material, will actually draw the penetrant from the defect. Therefore, the red penetrant indications in the white developer represent the defective area. The amount of red penetrant drawn from the defective area will give an indication of the size and sometimes the type of defect.

Defect Interpretation

When liquid penetrants are used, the lighting in the test area must be bright enough so that you can see any indications of defects shown on the test surface. These indications must be carefully interpreted and evaluated. There are normally some insignificant indications in all inspections. Most of them are caused by failure to remove all excess penetrant from the surface. At least 10 percent of the areas that are questionable on the accuracy of the indications should have the penetrant and the developer removed from the surface. Then the area must be retested to determine whether defects are actually present, or whether the indications are merely caused by excess penetrant. If the second PT inspection does not reveal indications in the same locations, it is usually safe to assume that the first indications were not really indications of defects.

All penetrant inspection materials must be removed as soon as possible after the final inspection has been made. Use water or solvents, as appropriate.

SAFETY

You must observe a number of safety precautions while working with liquid penetrant materials. Since the materials are flammable, they must not be used near open flames, and they must not be applied to any surface that is at a temperature higher than 150°F. Many of the solvents are also poisonous in the vapor form and highly irritating to the skin in the liquid form. Handle all penetrant inspection materials with respect for their hazardous nature.

ULTRASONIC TESTING

In addition to radiography, ultrasonic tests (UT) are also used to inspect the interior of metal and welds. Defects lying throughout the thickness or depth of a weld are easily detected.

Several techniques for the ultrasonic testing of metals have been developed within the past few years and are now widely used in the Navy.

Some of the defects detectable by ultrasonic inspection are cracks, lack of fusion, slag inclusions, porosity, lamination, and incomplete penetration. The following section gives only basic information on the principle of ultrasonic weld inspection. More information can be found in MIL-STD-271.

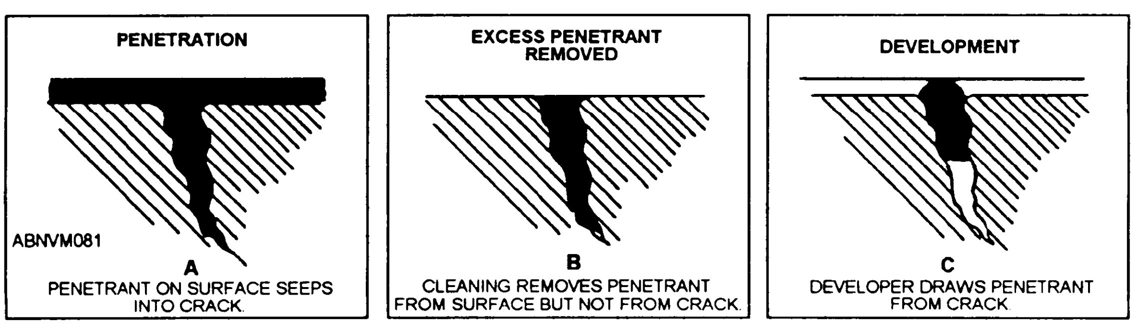


Figure 11-9.—Principles of liquid penetrant inspection.

ULTRASONIC PRINCIPLE

The term *ultrasonic* means vibrations or sound waves whose frequencies are greater than those that affect the human ear (greater than about 20,000 cycles per second). The Navy uses equipment that has, for practical purposes, a frequency range between 500,000 and 10,000,000 cycles per second.

UT Equipment

The UT equipment, shown in figure 11-10, includes a transmitter/transducer and CRT screen. These are the two basic components of all UT equipment regardless of make or model.

TRANSDUCER.—High-frequency electric energy from the transmitter is transformed into high-frequency mechanical energy by the transducer. The transducer is held against a piece of metal with some oil or glycerin (called a couplant) between the contacting surfaces to prevent air from remaining between them.

The high-frequency mechanical energy, in the form of high-frequency sound, is transmitted into and through the metal. After entering the metal, the sound travels in straight lines in what is known as the beam path. When the beam strikes the far surface of the piece or strikes the boundary of a defect, the beam reflects back toward the transducer. When the beam is reflected, it leaves the metal in the same area it entered, travels through the couplant, and enters the transducer where it is converted back to electrical energy. It is then relayed to an amplifier. The beam is then presented on a cathode ray tube (CRT) screen as vertical deflections of the base line. Figure 11-11 is a block diagram showing this principle.

CRT SCREEN.—The CRT screen shows a base line of light along the lower part of the screen. The initial pulse bounce between the transducer and the metal is shown as a peak rising from this line at the left or start position. It takes a certain amount of time for a signal or beam to travel through the metal, and approximately the same amount of time to bounce back. This time is calibrated along the base line as distance, or as the distance traveled by the beam front in a certain time. If a test piece has a certain thickness and no defects, the CRT screen will show the start position peak somewhere on the left of the base line and another peak (back reflection) to the right of the base line at a distance proportional to the thickness of the piece. The relationship of the actual thickness of the test piece to the distance shown on the base line may be determined from the calibration settings on the instrument. These two peaks will be relatively high on the screen and will represent the beam entrance into the piece and reflection from the opposite surface, respectively. If there were a defect between the two surfaces, SOME of the beam would BOUNCE from the boundaries of the defect and would show on the CRT somewhere along the base line at a distance relative to the two surface indications, usually as a smaller peak.

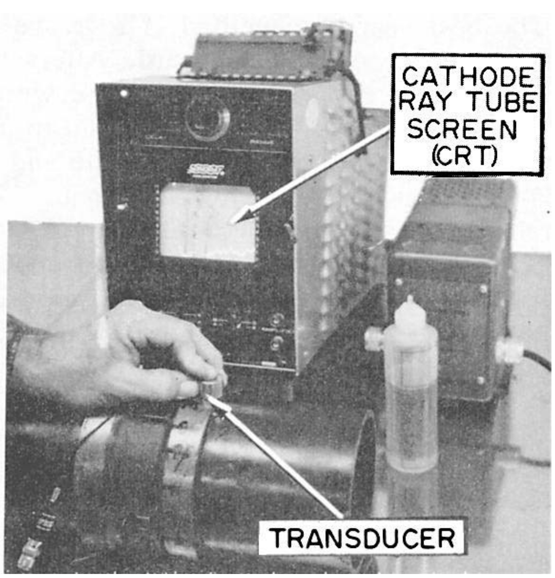


Figure 11-10.—Ultrasonic testing equipment.

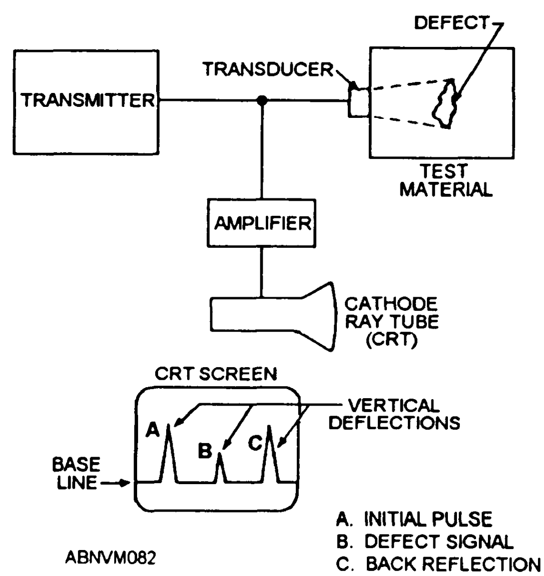


Figure 11-11.—Principle of ultrasonics.

If the defect shows at a point one-half of the distance along the base line (fig. 11-11) from the entrance peak, then the defect will actually lie one-half of the thickness of the piece from the entrance surface. If the piece is 1 inch thick, then the defect will lie 1/2 inch below the surface. If the defect peak is high, the defect is large (in a plane 90° from the beam); and if the peak is small, then the defect is small. If the defect is larger than the beam diameter, the defect surface will bounce back ALL the beam, and the back reflection peak will disappear. If the defect is smaller than the beam diameter, some of the beam will be stopped and bounced by the defect, and some will go on and be bounced by the back of the piece. The CRT will then show the near-surface peak, the small intermediate peak, and a slightly reduced peak (at the back or far side of the piece) at the right, or designated l-inch point, on the base line.

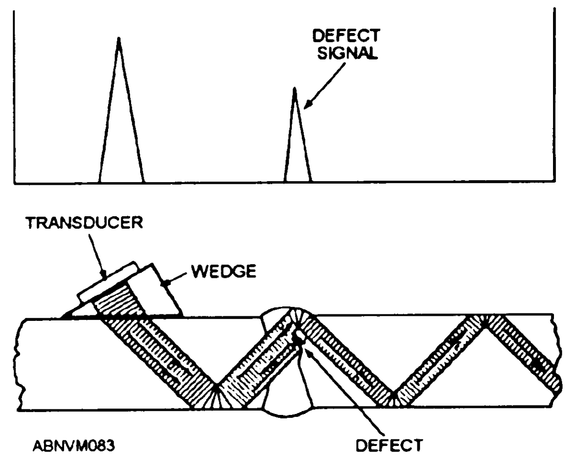


Figure 11-12.—Angle beam testing.

Calibration Block

You need to determine the size of a defect, and where possible, evaluate the nature of the defect. This means that some reference or standard for comparison (commonly called a calibration block) is absolutely necessary. The most common practice is to use a sample piece of material with a hole drilled in it and compare defect signals obtained from the calibration block. Calibration is the most important part of ultrasonic testing, since it is essentially a comparison test.

ULTRASONIC WELD INSPECTION

Detecting, locating, and measuring defects are the major requirements for weld inspection.

When testing welds for defects, you should use the greatest possible direct reflection of sound. This is easily done if the defects have a boundary that lies parallel to the plane upon which the transducer rests, and the face of the transducer lies flat upon that plane. Such placement results in a longitudinal (compressional) beam with its axis normal to the surface boundary. To obtain the greatest direct reflection, sound should strike a surface boundary or defect boundary that lies at right angles to its direction of travel. Since most weld defects are rotated 90° from the surface, you will need a way to change the direction of the sound beam. You can do this by securing a Lucite wedge to the transducer. This is known as the angle beam method, shown in figure 11-12.

As you can see in figure 11-12, the sound beam passes through the wedge and enters the part to be tested at an angle. The sound beam will continue to bounce at this angle until it is completely scattered or absorbed by the material. Weld inspections are performed when the sound has made only one or two bounces. If a flaw is present in the weld, as indicated in figure 11-12, some of the sound beam will reflect back and show up as an indication on the CRT screen.

The best scanning method is to move the search unit forward and backward. Alternately approach and move away from the weld a distance sufficient to permit the sound to pass through the full thickness of the plate and the weld in an upward and downward path. The search unit is also moved parallel to the weld itself, as shown in figure 11-13. In this manner, you will scan the complete volume of the weld, following the same pattern along the weld, as shown by the dotted line in figure 11-13.

NONDESTRUCTIVE TESTING SYMBOLS

Nondestructive testing symbols specify the type of test to be used and the extent to which the test will be

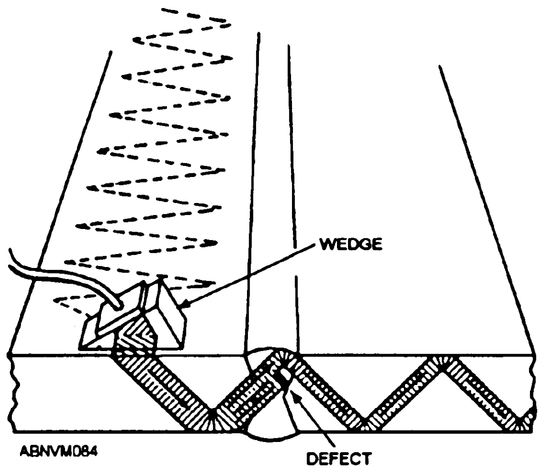


Figure 11-13.—Scanning a weld.

performed. The four basic nondestructive testing symbols are as follows:

TYPE OF TEST	SYMBOL
Radiographic	RT
Magnetic Particle	MT
Liquid Penetrant	PT
Ultrasonic	UT

An assembled nondestructive testing symbol consists of the following elements:

REFERENCE LINE	TAIL
● Arrow	Extent of test
● Basic testing symbol	Specification, process,
● (N) Number of tests	or other reference

Each of these elements should be used as necessary. They will have standard locations with respect to each other, as shown in figure 11-14.

The arrow connects the reference line to the part to be tested (fig. 11-15). The side of the part to which the arrow points is called the arrow side of the part. The side opposite the arrow is called the other side.

The location of testing symbols is shown in figure 11-16. Tests to be made on the arrow side of the part are indicated by a test symbol on the side of the reference line toward the reader, as shown in view A. Tests to be made on the other side of the part are

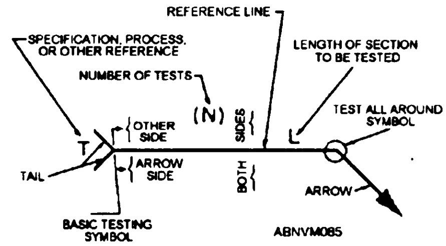


Figure 11-14.—Standard location of elements on a nondestructive testing symbol.

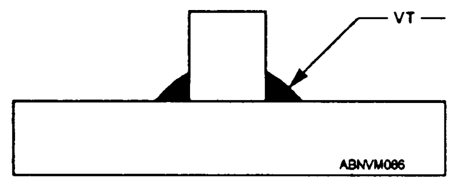


Figure 11-15.—Arrow connecting the reference line and part being tested.

indicated by the test symbol on the side of the reference line away from the reader, as shown in view B. Tests to be made on both sides of the part are indicated by test symbols on both sides of the reference line, as shown in view C. When nondestructive testing symbols have no arrow-side or other-side significance, the testing symbols are centered on the reference line, as shown in view D.

When a specification, process, classification, or other reference is used with testing symbols, the reference is placed in the tail, as shown in figure 11-17. Specification, process, classification, or other reference need not be used on testing symbols when the testing procedure is prescribed elsewhere.

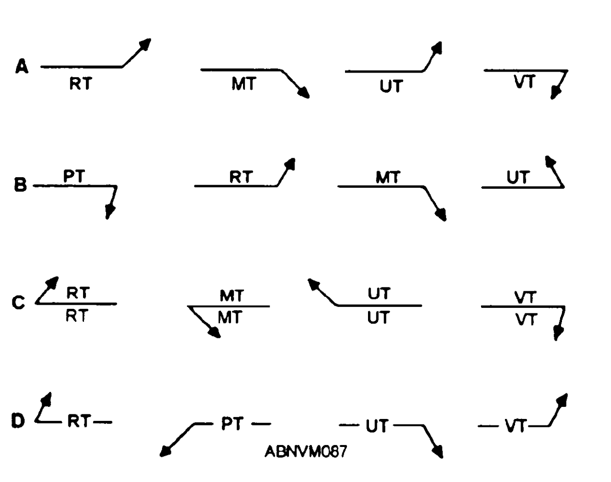


Figure 11-16.—Location of testing symbols.

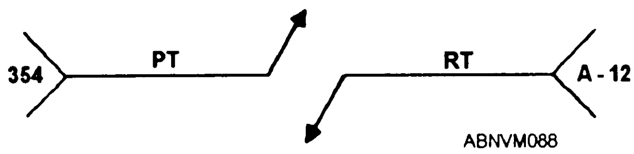


Figure 11-17.—Location of specification, process, classification, or reference.

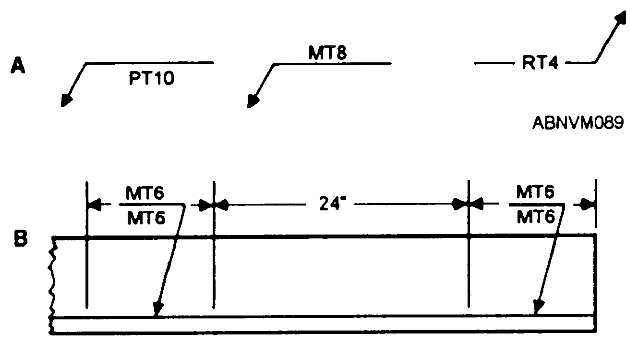


Figure 11-18.—Specifying length and exact location of area to be tested.

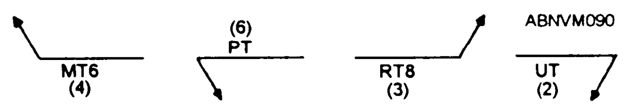


Figure 11-19.—Specify number of tests to be made at random.

The length of the section to be tested is specified as shown in figure 11-18. To specify tests of welds or parts where only the length of the section need be considered, the length in inches is shown to the right of the basic test symbol (fig. 11-18, view A). To show the exact location of the section to be tested as well as its length, dimension lines are used as shown in view B. When the full length of a part is to be tested, no length dimensions need be shown on the testing symbol.

If a number of tests are specified to be taken at random, the desired number of tests are placed in parentheses, as shown in figure 11-19.

To specify tests that are to be made all around a part, the test-all-around symbol is used with the basic test symbol, as shown in figure 11-20.

Nondestructive testing symbols may be combined with the standard welding symbols previously discussed. This feature increases the scope of all welding symbols. The length of a section to be tested can be indicated, and individual areas for testing can be specified by means of these symbols. Figure 11-21 shows the combining of nondestructive testing symbols and welding symbols.

Figure 11-20.—Specify tests to be made all around.

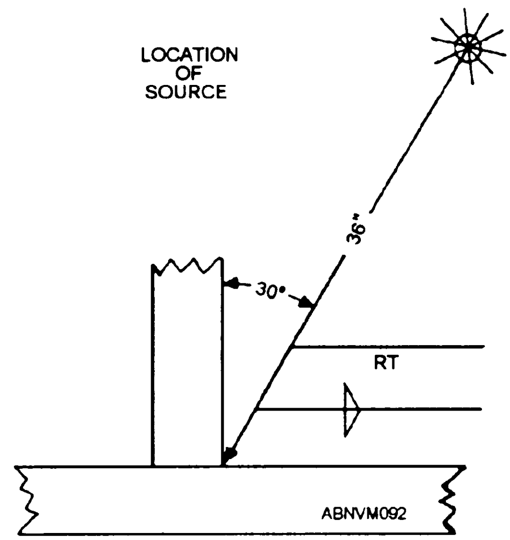


Figure 11-21.—Combining nondestructive testing symbols and welding symbols.

HYDROSTATIC TESTING

Fluid systems are hydrostatically tested during initial construction, subsequent to repairs, and periodically to verify the integrity of the system. All piping sections that have been removed for repairs and newly fabricated sections must be hydrostatically tested before installation to make sure that there will be no leaks under operating conditions. Operational tests are also preformed, instead of hydrostatic tests, after certain repairs involving mechanical joints. The basic purpose of all such tests is to ascertain that the system can perform its intended function safely and reliably. This section will discuss hydrostatic tests, operational tests, and the equipment used to conduct these tests.

HYDROSTATIC TESTS

Hydrostatic testing of piping systems is accomplished whenever repairs are made to piping system or any related components. Hydrostatic testing of ships' systems is required every 8 years, and should be conducted before or during the early stages of a scheduled major overhaul of the ship. Regardless of the reason for testing, all hydrostatic testing is accomplished in the same general manner using the same equipment. Hydrostatic testing of systems or components is commonly referred to as "H" pressure tests. These tests of piping systems should be at a pressure of 135 percent above the maximum system design pressure, but in no case less than 50 psi. The line drawing in figure 11-22 shows a simple hydrostatic test setup and associated equipment.

Hydrostatic Testing Equipment

Shop hydrostatic testing of piping systems or components should be conducted in an area that can be secured from all traffic. This area should also provide the operator protection in event of component failure. When hydrostatic testing the ship's piping system, set up the equipment in an area that can be secured from all unwanted traffic. The equipment required for hydrostatic testing includes a pump, two pressure gauges, two relief valves, a cutoff valve, blank flanges, gaskets, and clamps.

PUMPS.—There is no specific requirements for the type of pump to be used for hydrostatic testing. The pump must be large enough to deliver the required pressure and water volume to the system being tested. Pneumatic pumps are the most common type of pump used for hydrostatic testing and are operated by the ship's compressed air system. These pumps are usually rated in gallons per minute.

PRESSURE GAUGES.—When performing hydrostatic tests, use two independent pressure gauges. These two gauges will indicate actual hydrostatic test pressure. One of the gauges will be the master gauge and the other will be the backup gauge. Use the master hydrostatic test gauge readings as the true hydrostatic test pressure throughout the test.

Master Gauge.—Master test gauges are used to indicate actual hydrostatic test pressures. The scale range of the master test gauge should be greater than the maximum test pressure, but should not exceed 200 percent of the maximum test pressure. Master test gauges shall have a valid calibration label according to NAVSEA OD 54845, Metrology Requirements List.

Backup Gauge.—A backup gauge is used to check and verify the accuracy of the master test gauge. Like the master gauge, the backup gauge is also subject to actual test pressure. The scale range of the backup test gauge should also be greater than the maximum test pressure, but should not exceed 200 percent of the maximum test pressure. Backup test gauges shall also have a valid calibration label according to NAVSEA OD 54845, Metrology Requirements List.

RELIEF VALVES.—Relief valves provide for overpressure protection of the system or component, equipment, and safety of personnel. The relieving capacity, at test pressure of relief valves used for

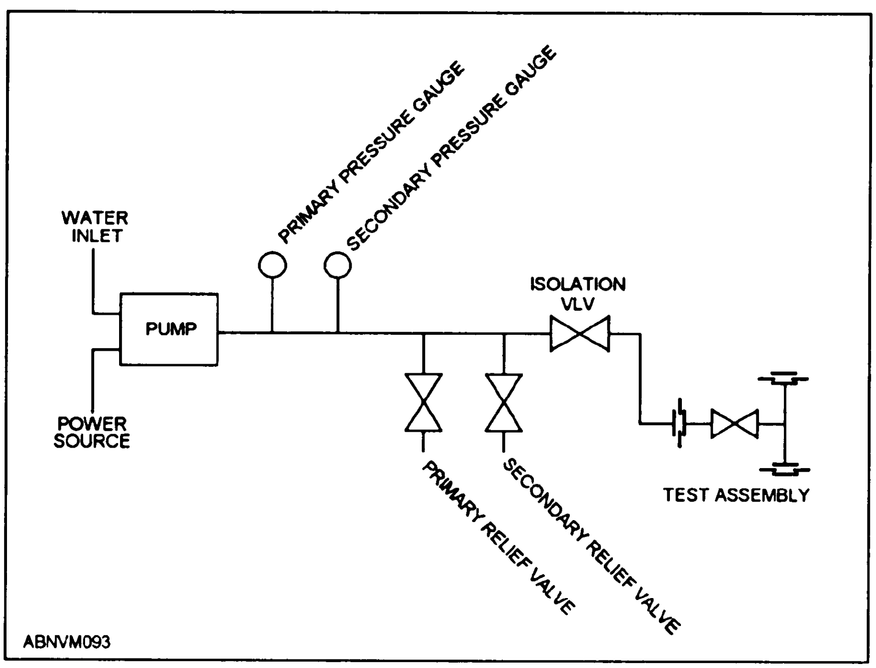


Figure 11-22.—Hydrostatic test equipment and set up.

over-pressure protection and their inlet and discharge piping, shall be greater than the capacity of the source being used to pressurize the system. Relief valves are classified as either the primary or secondary relief valve.

Primary Relief Valve.—The primary relief valve must be of the manual type that can be operated from the control station. Usually the primary relief valve is a manually operated valve with a drain to a sump or other suitable drainage system. The person controlling the source of pressure (pump operator) cannot also be a relief valve operator.

Secondary Relief—The secondary relief valve may be either manually or automatically operated. The secondary relief valve is usually located next to the primary relief valve on a hydrostatic testing unit but may also be remotely located. If the secondary relief valve is of the manual type, another operator must be stationed to operate this valve.

If the secondary relief is of the automatic type, test the set point of the relief valves to be used. If necessary, adjust the set point no more than 30 days before the relief valves ae to be used for the hydrostatic test. In conducting a 135 percent test, the set point of the relief valve shall be no greater than 100 lb/in^2 or 10 percent above the test pressure, whichever is less.

Hydrostatic Testing Equipment Setup

After assembling all required testing equipment and checking calibration dates, you are ready to set up the equipment for your test. Whether testing in the shop or a ship's system, the setup of the equipment is similar. Both shop and system testing will be discussed in this chapter.

SHOP HYDROSTATIC TEST SETUP.—Most shop testing is done in areas that are specifically designed and built for hydrostatic testing. These areas have installed pumps, gauges, and relief valves permanently mounted in the area. The operating station is isolated from the testing area to provide protection to the operator in case of failure of the component being tested.

When setting up a component for testing, each outlet of the component must be blanked off with blank flanges or other suitable blank fittings. One fitting should be drilled and tapped, and fitted with a nipple of suitable size for connecting the hose from the hydrostatic pump. Use appropriate bolts to secure the flanges or fittings with gaskets to all openings of the pipe. After blanking off all openings of the pipe, completely fill it with water through the nipple fitted to the one blank flange.

SYSTEM HYDROSTATIC TEST SETUP.—System setup is similar to the hydrostatic testing done in the shop. You will use a portable pump with the required gauges and relief valves incorporated into the pump control panel or on a separate manifold. You should also take the following precautions when hydrostatically testing shipboard systems:

- When setting up a component for testing, each outlet of the component must be blanked off with blank flanges or other suitable blank fittings. One fitting should be drilled and tapped, and fitted with a nipple of suitable size for connecting the hose from the hydrostatic pump.
- Protect equipment, tanks, gauges, and machinery that would be subjected to a test pressure higher than their specified test pressure by disconnecting from the system, or isolating from the test.
- Provide expansion joints with temporary restraints, if required, or isolate them from the test.
- Eliminate air pockets before any system is pressurized for a hydrostatic test to prevent the pressurization of gases in the system.
- Verify that all valves and equipment in or connected to the portion of the piping system to be pressurized are in the required position or condition.

Testing Procedures

After obtaining and setting up the equipment, you are ready to begin testing of the component. Generally, the sequence for testing is as follows:

1. Establish required prerequisites and initial conditions.
2. Align the system for testing.
3. Station the operator, manual relief valve operator, and inspector. Two manual relief valve operators may be required if a manual

relief valve is used for the secondary relief valve.

4. Establish communication between the operator, relief valve operator, and the inspector if their stations are separated.
5. Pressurize the system slowly and incrementally, checking for leaks at each increment.
6. Increase pressure to hydrostatic test pressure.
7. Perform required inspections.
8. Depressurize, remove temporary equipment, and restore the system to its original configuration.

In the following section, we will look at component pressurization, inspection requirements, and testing durations.

PRESSURIZATION.—During hydrostatic tests of systems havin a maximum system pressure in excess of 300 lb/in^2, raise the test pressure in increments of approximately 25 percent of the final test pressure. At each increment, make a check for leaks before proceeding to the next higher pressure increment. The final test pressure should be +2 to -0 percent of the final test pressure but should not exceed 50 lb/in^2. For test pressures less than 100 lb/in', a +1 to -0 percent tolerance is acceptable.

If any of the following events occur, you should take immediate action to terminate the test and depressuize the component:

- Pressure gauge fails to respond to changes in test pressure or gauge ruptures during the test.
- Pressure gauge readings do not agree within 2 percent of maximum test pressure or are not accurate within 2 percent of maximum test pressure.
- Changes in test pressure cannot be held constant.

VISUAL INSPECTIONS.—Visual inspections are required at specified intervals as the pressure is increased to the test pressure. Repaired areas that are being tested should remain uninsulated to allow examination for leakage.

TEST DURATION.—The test duration for hydrostatic testing of ships' systems and of repaired assemblies are different, although the end requirements of the hydrostatic testing is the same for both the repaired piping assembly and ships' systems. You will follow different testing parameters for each test.

Testing Ships' Systems.—For testing of a ship's system maintain the test pressure during hydrostatic tests for at least 1/2 hour before inspection. If the inspection is done prior to 1/2 hour, the system may not be pressurized evenly and you may get an indication of leakage due to valve packing and joint setting occurring. Test pressure should be maintained at 135 percent of system design pressure but not less than 50 lb/in^2 for the duration of the test. Some systems may require tests more or less than 135 percent. Always refer to the operator's manuals, systems' drawings, or other applicable documentation for correct test pressures.

Testing Repaired Piping Assemblies.—Always test piping or piping assemblies (except halocarbon refrigerant piping) removed for repair or replacement before reinstallation. Test pressure, in most cases, will be 135 percent of the system design pressure, but in no cases less than 40 lb/in^2. Hydrostatic test pressure will be held for a minimum of 15 minutes before inspection. Hold this pressure while a complete inspection of the piping assemble is made. Special attention should be given to renewed parts and repaired sections. Some assemblies may require tests of more or less than 135 percent. Always refer to the operator's manuals, systems, drawings, or other applicable documentation for correct test pressures.

ACCEPTANCE CRITERIA FOR HYDROSTATIC TESTS.—The criteria for an acceptable hydrostatic test is that there should be no leakage or permanent deformation of the pressure-containing parts. This acceptance criteria is determined by visual examination. The following are exceptions to the no leakage criteria for acceptable hydrostatic testing of ships' systems only:

- The leakage does not become hazardous to personnel.
- The leakage can be adequately contained to protect equipment.
- The leakage is within the capacity of the hydrostatic test pump to maintain pressure throughout the test.

Piping assemblies that have been repaired or replaced require zero leakage.

Do not consider the test complete until all specified inspection points have been recorded as satisfactory and test pressure has been maintained. Correct or repair all leaks. Rehydro all repaired assemblies or portion of affected assemblies to the required test pressure.

OPERATIONAL TESTS

Operational pressure tests (commonly called "J" pressure tests) are performed periodically to determine the integrity (leak tightness) of a system. Operational tests are nothing more than visually inspecting the system or repaired piping assembly while operating the system at design pressure. Operational pressure tests are also performed instead of hydrostatic tests after certain repairs involving mechanical joints. The basic purpose of an operational test, as with a hydrostatic test, is to ascertain that the system perform its intended function safely and reliably.

Periodic operational pressure tests should be conducted under operating pressure (with the service fluid) on all shipboard piping systems once a quarter. At least once a year, conduct this test by pressurizing the system one section at a time, to detect leaking valves and to ensure proper operation of all the valves in the system.

SUMMARY

This chapter has given you a basic knowledge of radiographic tests, magnetic particle inspections, liquid penetrant tests, ultrasonic inspections, hydrostatic tests, and nondestructive testing symbols. Use this knowledge along with the appropriate NAVSEA technical manuals and publications, and on-the-job experience under a qualified supervisor. You will soon perform these tests in a professional manner and with reliable results.

CHAPTER 12

SHEET METAL LAYOUT AND FABRICATION

LEARNING OBJECTIVES

Upon completion of this chapter; you will be able to do the following:

- *Define some of the basic terms used in the layout and fabrication of sheet metal*
- *Describe the basic techniques used to perform various sheet metal layout operations and define the three types of plans*
- *Recognize the various methods of pattern development*
- *Describe some of the tools and equipment generally found in the sheet metal shop, and describe their use and operation*
- *Describe the safety procedures and equipment used in sheet metal fabrication*

INTRODUCTION

As a Hull Maintenance Technician (HT), you may be assigned to lay out and fabricate ventilation ducts, drip pans, and other items made from sheet metal. In this chapter, we will look at the tools and methods that you will use for jobs of this sort. We will also look at pattern development, the transfer of a pattern to sheet metal, and the fabrication of the sheet metal projects.

NOTE: You will not be able to do the layouts in this chapter unless you learn each step of each process as you go along. Later in the chapter, you will simply be instructed to carry out many of the procedures you were taught earlier in this chapter. Before you can fabricate an item, you must have a plan and be able to read it. Your plan may be a sketch, a drawing, or a blueprint. Later on, you will be expected to make your own sketches and drawings.

A SKETCH is a rough outline of the structure to be fabricated, giving dimensions and details of the job to be done. The sketch includes such information as angles to be used and the type of material required.

A DRAWING is similar to a sketch, but it is made with mechanical drawing instruments and it is drawn to scale.

A BLUEPRINT is a duplicate of a drawing or sketch. Usually, only accurate drawings are blueprinted. These blueprints are furnished by the manufacturers of the machinery installed aboard your ship and also by the command concerned with the building and maintenance of the ship on which you are serving.

If you have not done so, this is a good time to study Blueprint Reading and Sketching, NAVPERS 12077-E You must be able to read plans accurately, and this book will help you to read almost any type of plan. A satisfactorily completed job is your objective, and the plans are essential guidelines. As you study this chapter, you may find that you also need to review portions of Use and Care of Hand Tools and Measuring Tools, NAVEDTRA 12085, and Mathematics, Volume 1, NAVEDTRA 10069-Dl.

USING LAYOUT TOOLS

The tools you will use most often to lay out sheet metal jobs and patterns are the scratch awl, flat steel square, circumference rule, straightedge, dividers, trammel points, prick punch, and center punch. When you make your practice layouts, you will probably be restricted in the amount of sheet metal you can use. If at all possible, use template paper instead of metal. This material has a rosin-coated surface that is well adapted to scribe and divider marks. If this type of paper is not available, use heavy brown wrapping paper or discarded chart paper, which you can get from the navigator or quartermaster. When you use paper, substitute a 4H pencil for the scribe and a pencil divider for your regular layout dividers. Take good care of your scribes, pencils, dividers, and rules because the accuracy of your work depends upon them. After you have made a few practice layouts, the importance of accurate measurements should be clear to you. You will have a feeling of satisfaction when your layout turns out as you planned it. If it does not quite fit, you were probably careless somewhere in your layout.

Figure 12-1 shows the correct way to scribe a line on metal using a scratch awl and rule. When you scribe your line, hold the scale or straightedge firmly in place. Set the point of the scriber as close to the edge of the scale as possible by tilting the scriber outward. Exert pressure on the point and draw the line, tilting the tool slightly in the direction of movement. For short lines, use the steel scale as the guide. For longer lines, use a circumference rule or a straightedge. When you draw a line between two points, prick punch each point. Start from one prick punch mark and scribe toward the center. To complete the line, start from the other prick punch mark and scribe towards the center as before.

The FLAT STEEL SQUARE is useful for laying out sheet metal jobs. Before using it, or at least at periodic intervals, check the square for accuracy, as shown in figure 12-2. When your square is off, your work will be proportionately off, no matter how careful you are. In parallel line development, use the flat steel square to construct lines that are parallel to each other as well as perpendicular to the baseline. This procedure

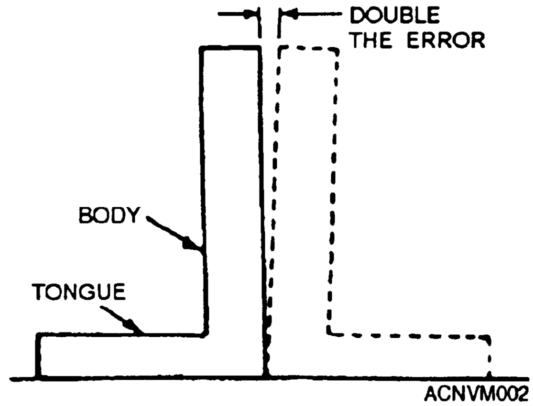


Figure 12-2.—Checking the square.

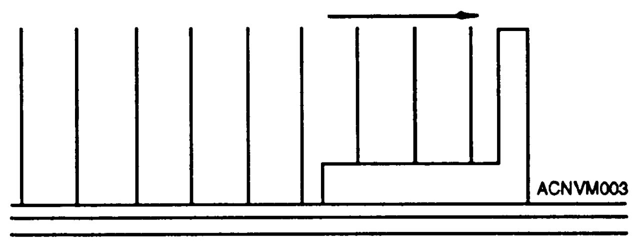


Figure 12-3.—Drawing perpendicular parellel lines.

is shown in figure 12-3. Just clamp the straightedge firmly to the base line. Slide the body of the square along the straightedge, and draw perpendicular lines through the desired points.

The COMBINATION SQUARE can be used to draw a similar set of lines, as shown in figure 124. Use

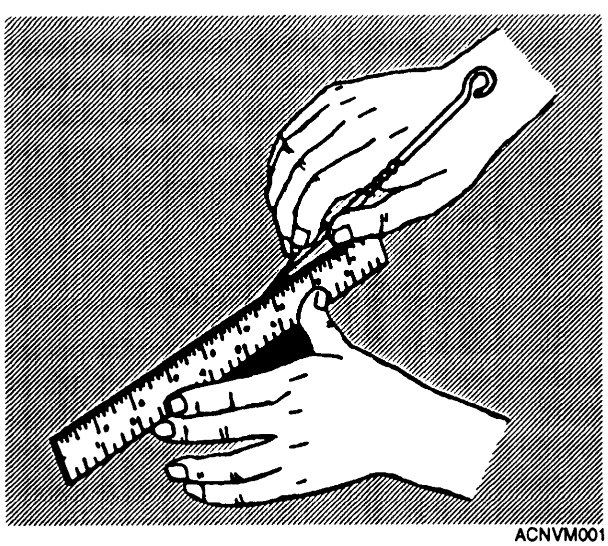


Figure 12-1.—Scribing a line.

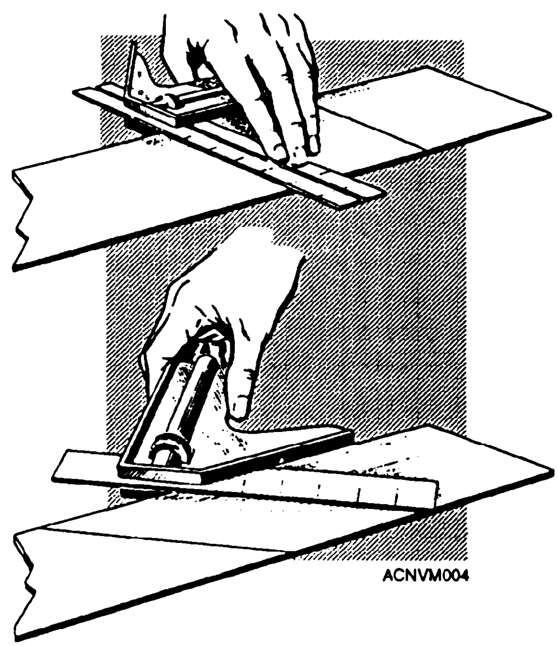


Figure 12-4.—Using a combination square.

an edge of the metal upon which you are working as the base line. One edge of the head of the combination square is 90 degrees and the other edge is 45 degrees. Lay either edge of the head on the edge of the metal to make either a 45- or 90-degree angle to the edge of the metal.

Combination squares are delicate instruments and will be of little value if they receive rough handling. Stow your tools properly when you are not using them. Keep them clean and in tiptop shape, and you will be able to construct 90-degree angles, 45-degree angles, and parallel lines without error.

Use a protractor to construct lines for angles other than 45 or 90 degrees. Mark the vertex of the angle on the base line with a prick punch. (See fig. 12-5.) Set the vertex of the protractor on the mark, and then scribe a V at the desired angle (in this illustration, 70°). Scribe the line between the vertex and the point located by the V and you have constructed an angle of 70°.

When you mark a point with the PRICK PUNCH, use very light taps with a small ballpeen hammer. The smaller the mark you make (so long as you can see it), the more useful and accurate that mark becomes.

Use DIVIDERS to scribe arcs and circles, to transfer measurements from a scale to the layout, and to transfer measurements from one part of the layout to another. Careful setting of the dividers is of extreme importance. When you transfer a measurement from a scale to the work, set one point of the dividers on the scale mark and accurately adjust the other leg to the desired length, as illustrated in figure 12-6.

To scribe a circle or an arc, grasp the dividers between the fingers and the thumb, as shown in figure 12-7. Place the point of one leg on the spot that will be the center of the circle or arc. Exert just enough pressure to hold the point at the center, slightly inclining the dividers in the direction in which they are to be rotated. Then rotate your dividers with both legs touching your work to make your circle or arc.

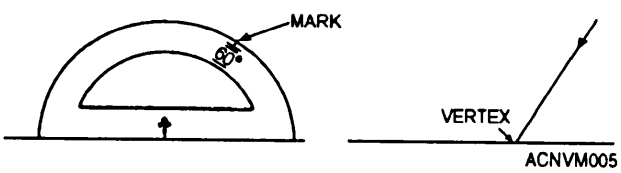


Figure 12-5.—Constructing an angle with the protractor.

When you need to scribe a circle with a radius larger than your dividers, you will have to use TRAMMEL POINTS. The points are adjusted as shown in figure 12-8. Set the left-hand point on one mark, sliding the right-hand point to the desired distance, and tighten the

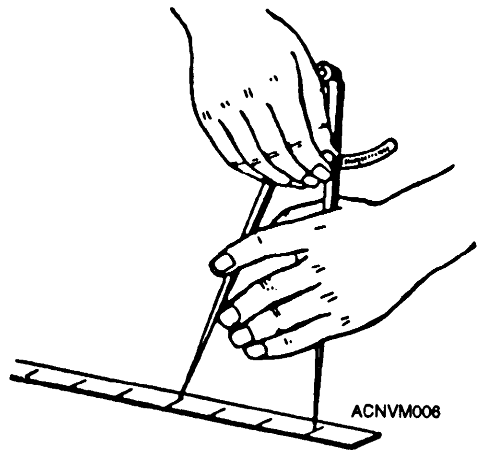


Figure 12-6.—Setting the dividers.

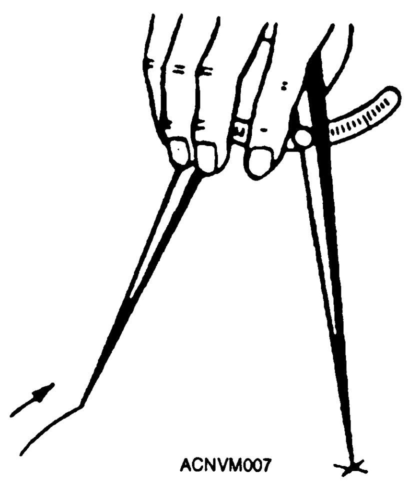


Figure 12-7.—Scribing an arc or circle with dividers.

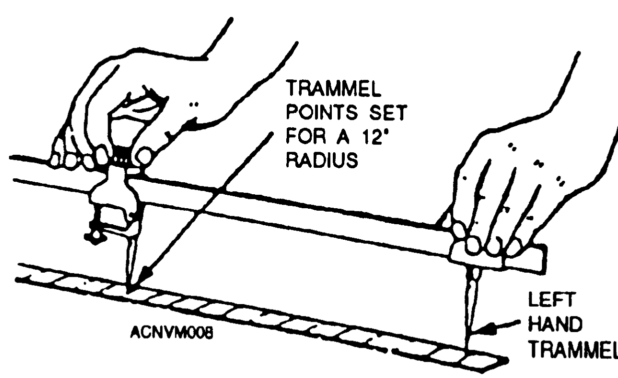


Figure 12-8.—Setting trammel points.

thumbscrew. Then scribe the arc or circle in the same manner as with the dividers.

MAKING SIMPLE LAYOUTS

A STRETCHOUT is a pattern on a flat sheet that has not been formed into a three-dimensional object. Figure 12-9 shows three-dimensional objects being formed from flat patterns. When jobs are laid out, you will need to add allowances for edges and scams.

A DRIP PAN is one of the objects you will have to make. Some of these pans, or boxes, will be used around the machinery in your shops. Take a look at them and see how they were made. Some have welded seams. Others are riveted and soldered. The welded seam is the fastest and easiest to lay out, but the riveted and soldered seam is by far the better of the two for sheet metal work. The various methods of seaming will be discussed later in this chapter.

Break out your layout tools. Select a piece of sheet metal or template paper about 1 foot square. Lay out a pan, or box, similar to that shown in figure 12-10. Make the sides about 1 l/2 inches in height, and the bottom about 9 inches square. Don't forget the tab if you are going to join the seam by riveting. The angle for the notch of the tab is 45 degrees (fig. 12-11). If this notch is not cut, you will have difficulty forming the side of the box. When you have the drip pan, or box, laid out, form the pan by breaking (bending) the side up 90 degrees. If you have made all of your measurements accurately, and have made your breaks on the line, the upper edge will be even all around, like the one shown in figure 12-11.

The STRETCHOUT OF A CYLINDRICAL JOB will be rectangular in shape, as shown in figure 12-12. One dimension of the rectangle will be the height of the cylinder, and the other dimension will be its circumference. When you are given measurements for a cylindrical job, however, you will be given the diameter rather than the circumference of the cylinder. You will have to find the circumference yourself.

The circumference may be determined by computation or with a circumference rule.

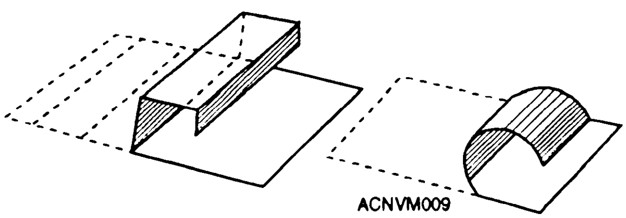


Figure 12-9.—Forming square and cylindrical shapes from flat patterns.

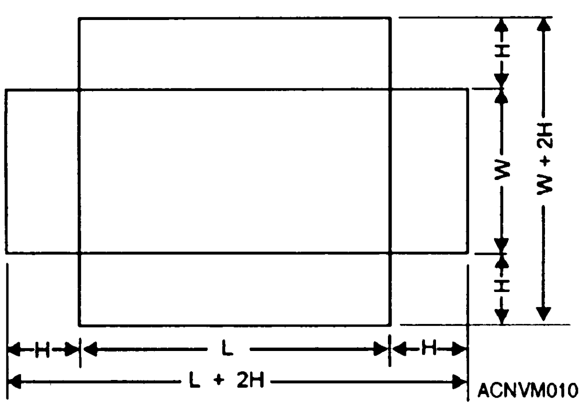


Figure 12-10.—Layout of a box or a drip pan.

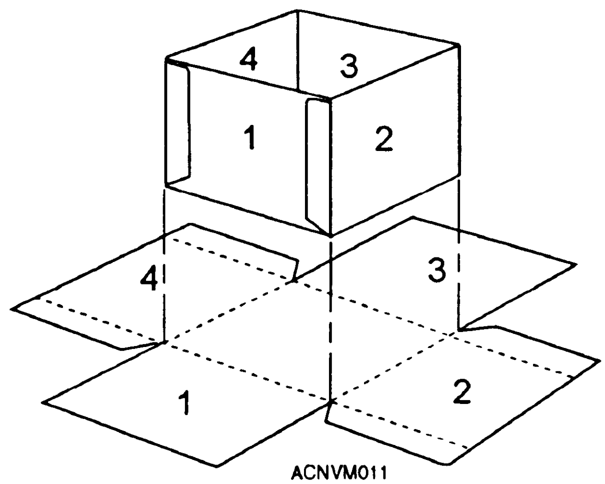


Figure 12-11.—Layout of a box.

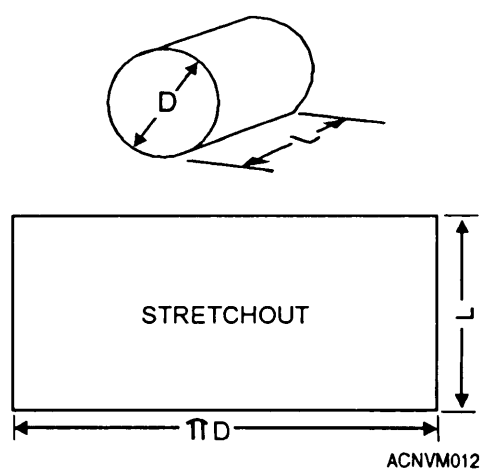


Figure 12-12.—Stretchout of a cylinder.

If you compute the circumference, multiply the diameter by pi (π), or 3.1416. This formula is read as $C = \pi D$. If the measurement is not critical, you can round off pi to 3.14 or 3 l/7. Either way, the formula will give you one dimension of your stretchout. The height or length is your other dimension.

Another method is by the use of the circumference rule. The upper edge of the circumference rule is graduated in inches in the same manner as a regular layout scale, but the lower edge is graduated, as shown in figure 12-13.

The lower edge gives you the approximate circumference of any circle within the range of the rule. You will notice in figure 12-13 that the reading on the lower edge directly below the 3-inch mark is a little over 9 3/8 inches. This reading would be the circumference of a circle with a diameter of 3 inches and would be the length of a stretchout for a cylinder of that diameter. The dimensions for the stretchout of a cylindrical object, then, are the height or length of the cylinder and the circumference. Do not forget that you will have to allow for the scams.

A VARIATION OF THE CYLINDRICAL JOB is a flat-sided structure with rounded ends (fig. 12-14).

To figure the stretchout for this shape, you will need two dimensions. The first is simply the length of the shape, which we will say is 12 inches. The second is the circumference, which is computed as follows. Use the formula $C = \pi D + 2W$. D is the diameter of the circle that you would have if both curved ends of the shape were put together. W is shown in figure 12-14. We will assume that D = 5 inches, and W = 6 inches.

$$C = \pi D+2W$$

$$C = 3.14 \times 5+2 \times 6$$

$$C = 15.7 + 12$$

$$C = 27.7$$

We find that the circumference is 27.7 inches. Therefore, our stretchout measures 27.7 inches by 12 inches.

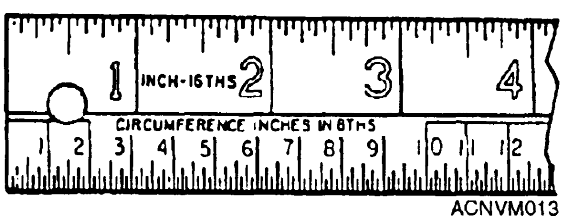


Figure 12-13.—Circumfcrcncc rule.

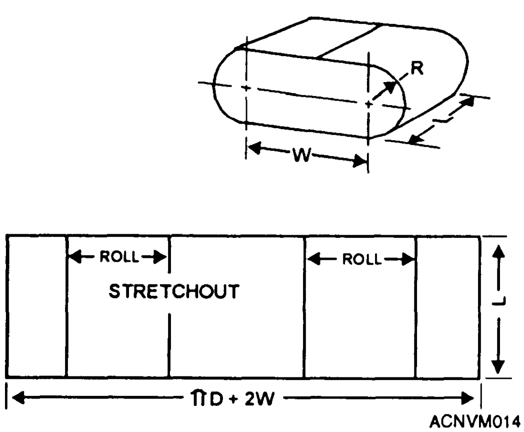


Figure 12-14.—Variation of a cylinder.

USING GEOMETRY FOR LAYOUTS

Following are the procedures in using geometry for making various types of layouts.

CONSTRUCT A 90-DEGREE OR RIGHT ANGLE. This is no problem at all if you have a true steel square. We will describe three methods that you may use to erect a perpendicular to produce a right angle when you do not have a usable true steel square.

1. For the first method, break out your dividers, a scriber, and a straightedge. Draw a base line like the one labeled AB in figure 12-15. Set the dividers for a distance greater than one-half AB, then, with A as a center, scribe arcs like those at C and D. Then, without changing the setting of the dividers, use B as a center, and scribe another set of arcs at C and D. Draw a line through the points where the arcs intersect and you will have perpendiculars to line AB, forming four 90-degree or right angles. Not only have you constructed a

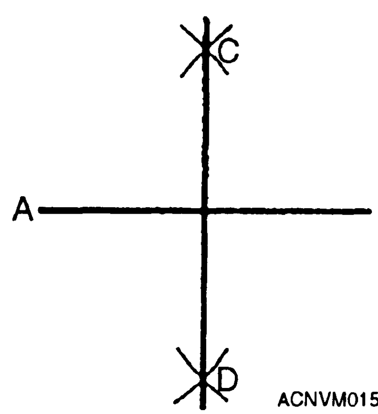


Figure 12-15.—Constructing a 90-degree angle by bisecting a line.

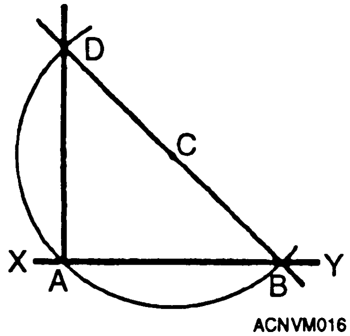


Figure 12-16.—Constructing a 90-degree angle at a given point.

perpendicular, but you also bisected, or divided, line AB into two equal parts.

2. Use a pair of dividers to CONSTRUCT A RIGHT ANGLE AT A GIVEN POINT. You will find this skill quite useful in making layouts. Figure 12-16 illustrates one method for constructing a right angle at a given point.

Suppose you have line XY with A as a point at which you need to erect a perpendicular to form a right angle. Select a point within the proposed angle that you wish to construct. In figure 12-16 that point is C. Set the dividers equal to CA, and using that distance for a radius, swing an arc BAD with C as a center. Lay a straightedge along the points B and C and draw a line that will intersect the other end of the arc at D. Now, draw a line connecting the points D and A and you have constructed a 90-degree angle.

3. Figure 12-17 shows another way to construct a perpendicular at a given point on a line:

Step 1: Take your dividers and place the point at point B on line XY.

Step 2: Lay arcs on line XY at equal distances from B on line XY. These arcs become points S and T on line XY.

Step 3: Before your next arcs are made, increase the distance between your divider points. Set your divider point at S on line XY. Lay arcs directly above and below P on line XY. These arcs become points W and M. Repeat this procedure from T on line XY without adjusting your dividers. You will have intersecting arcs at W and M.

Now draw a perpendicular between the intersecting arcs at W and M. You will have a right angle at B on line XY.

The three methods described in the preceding paragraphs may be used to form 90-degree comers in

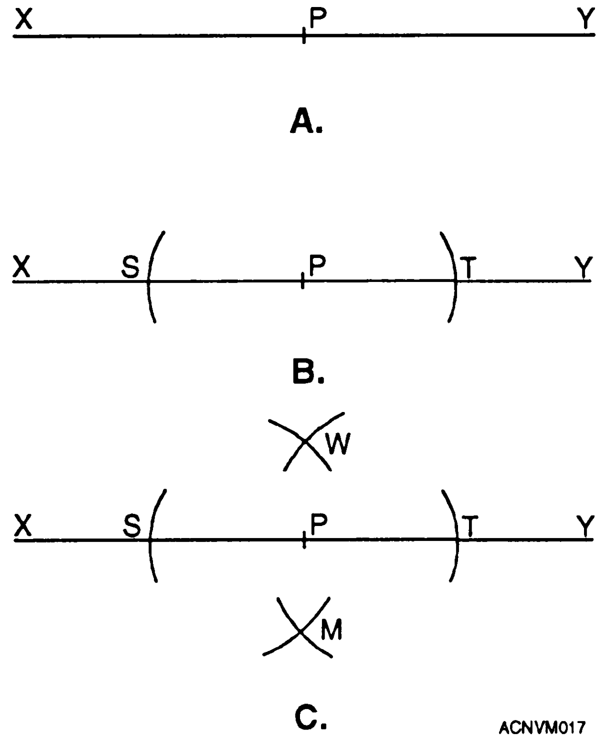


Figure 12-17.—Constructing a 90-degree angle by bisecting a line at a given point.

stretchouts that are square or rectangular, such as a drip pan or a box.

TO LAY OUT A DRIP PAN WITH A PAIR OF DIVIDERS, you will need dividers, a scriber, a straightedge, and a sheet of template paper. You know the length, width, and height or depth to which the pan must be made. Now proceed as follows:

Step 1. Draw a base line. (See fig. 12-18.) Select a point on this line for one corner of the drip pan layout. Erect a perpendicular through this point to form a 90-degree angle (W in fig. 12-18).

Now, measure off on the base line the required length of the pan (L in fig. 12-18). At this point erect another perpendicular. You now have three sides of the stretchout. Draw the fourth side parallel to the base line, connecting the two perpendiculars that you have erected. The fourth side will be drawn at a distance from the base line equal to the width of the drip pan.

Step 2. Now, set the dividers to mark off the depth of the drip pan. You can use a steel scale to measure off the correct radius on the dividers. Using each corner for

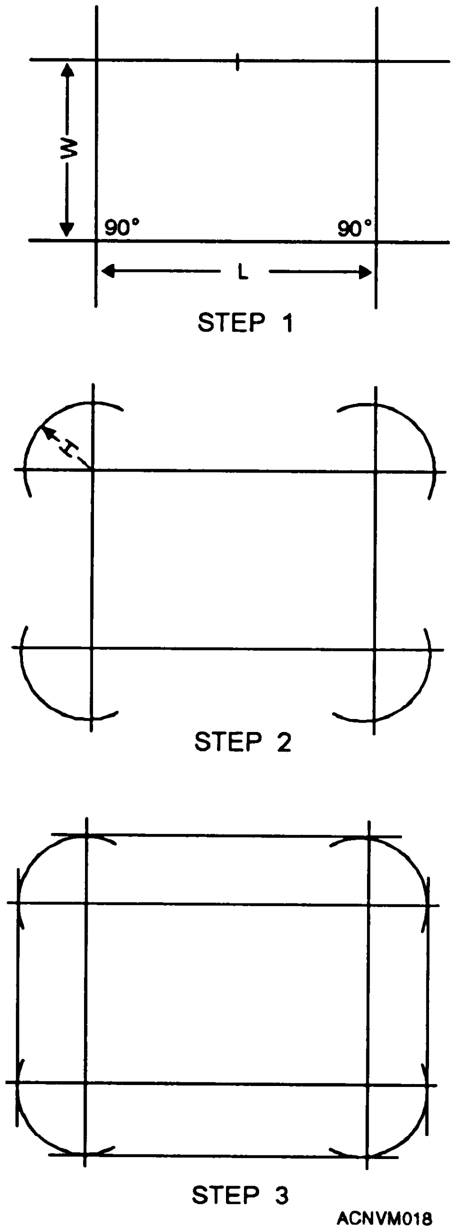


Figure 12-l8.—Laying out a drip pan with dividers.

a point, swing a wide arc like the one shown in the second step in figure 12-18.

Step 3. Extend the end and side lines as shown in the last step in figure 12-18, andcomplete the stretchout by connecting the arcs with a scriber and straightedge.

Step 4. Now lay out tabs like those shown in figure 12-11. Their size is determined by the diameter of the rivet, which in turn is determined by the thickness of the sheet. All that remains to be done now is to transfer the pattern to the sheet, cut the metal, and form it.

You have seen how a pan can be laid out without a steel square by the use of geometric construction. You bisected a line, erected a perpendicular from a given point on a line, and drew parallel lines by geometric construction. Use those geometrical principles to do a lot of layout problems rapidly and accurately.

You should also know how to BISECT AN ANGLE. Angle ABC (fig. 12-19) is given. With B as a center, draw an arc cutting the sides of the angle at D and E. With D and E as centers, and with a radius greater than half of arc DE, draw arcs intersecting at F. A line drawn from B through the point F bisects the angle ABC.

DIVIDE A LINE INTO ANY GIVEN NUMBER OF EQUAL PARTS. You need only a straightedge and a compass. Figure 12-20 illustrates the dividing of a line into 10 equal parts. To divide line AB into 10 equal parts, draw random line CB from B at a convenient acute angle to AB. Set a compass to a spread less than one-tenth of the length of CB, and lay off this spread 10 times from B on CB. Project the intermediate points of intersection on CB to AB by lines parallel to the line between the 10th point of intersection and A. The projected points of intersection divide AB into 10 equal Parts.

DIVIDE OR STEP OFF THE CIRCUMFERENCE OF A CIRCLE into six approximately equal parts. Set the dividers for the radius of the circle and select a point

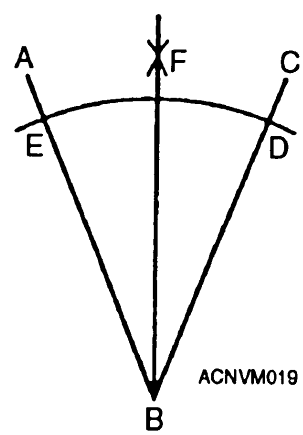


Figure 12-19.—Bisecting an angle.

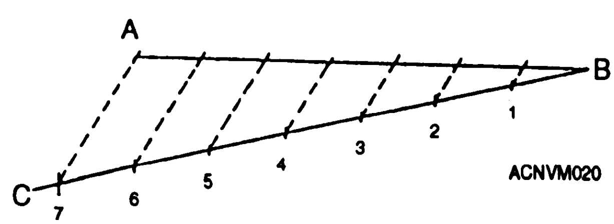


Figure 12-20.—Dividing a line into any number of equal parts.

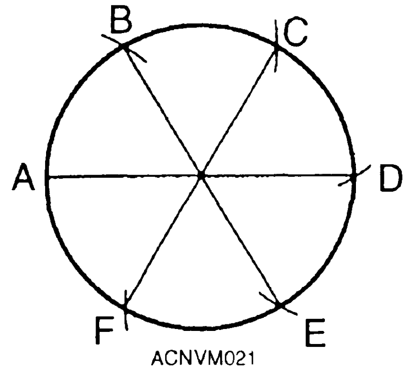


Figure 12-21.—Dividing a circle into six equal parts.

on the circumference for a beginning point. In figure 12-21, point A is selected for a beginning point. With A as a center, swing an arc through the circumference of the circle like the one shown at B in the illustration. Use B, then, as a point, and swing an arc through the circumference at C. Continue to step off in this manner until you have divided the circle into six equal parts. If the points of intersection between the arcs and the circumference are connected as shown in figure 12-21, the lines will intersect at the center of the circle, forming angles of 60 degrees.

If you need an angle of 30 degrees, all you have to do is to bisect one of these 60-degree angles by the method described earlier in this chapter. Bisect the 30-degree angle and you have a 15-degree angle. You can construct a 45-degree angle in the same manner by bisecting a 9O-degree angle. In all probability, you'll have a protractor to lay out these and other angles. But since you may not always have a steel square or protractor available, it's a good idea to know how to construct angles of various sizes and to erect perpendiculars.

LAY OUT A SQUARE OR RECTANGULAR ELBOW WITH A PAIR OF DIVIDERS. Take a look at figure 12-22. View A shows you what the completed job should look like. Now, to make your layout for this job, draw the base line OZ shown in view B. Set the dividers for a distance equal to the width of the cheek. This distance forms the throat radius. This rule will not always apply, as it must often be governed by the amount of space available to make the turn with the elbow. Now, with O as a center, scribe the arc YU. To get the heel radius, add the width of the cheek to the throat radius. Using 0 as a center, scribe the arc ZT. These layouts, when cut, will form the cheeks, or sides, of the elbow. The next operation is to lay out the heel and throat pieces. These arc the other two of the four

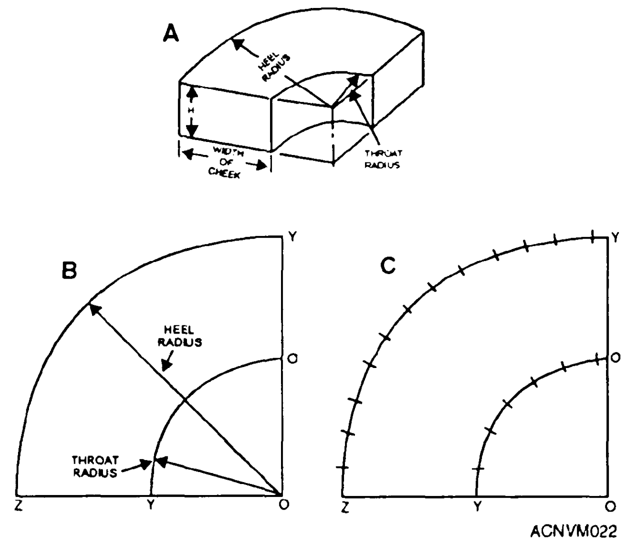


Figure 12-22.—Layout of a square or rectangular elbow.

sides of the elbow, the throat being the inside piece and the heel the outside piece. Set the dividers at exactly 1 inch, and step off the heel and throat arcs as shown in view C of figure 12-22. If there is a distance of less than 1 inch left at the end of the arc, measure it with another pair of dividers or a scale. To make the stretchout of the heel and throat, lay out one piece of metal equal to the height of the elbow (H in view A, fig. 12-22) and equal in length to the number of steps taken with the dividers, plus the fraction of an inch left over. One stretch out will be the heel and the other the throat. You can assemble this elbow by welding, in which case you do not need to allow for tabs. But welding will cause a thin section to warp, so you may need to use some of the other standard methods for joining this type of work.

ALLOWING FOR EDGES

So far, your practice jobs have been laid out to be formed with the edges left as they are. Very few of your jobs in the shop will actually be fabricated in this manner. Edges are formed to improve the appearance of the work, to strengthen the piece, or to eliminate a raw edge that could cut someone. These edges may be formed from the metal itself by inserting wire or by attaching a band or angle iron. The kind of edge that you will use on any job will be determined by the purpose, size, or strength of the edge needed.

The SINGLE-HEM EDGE is shown in figure 12-23. This edge can be made in any width. In general, the heavier the metal, the wider the hem is made. The allowance for the hem is equal to its width (W in fig. 12-23).

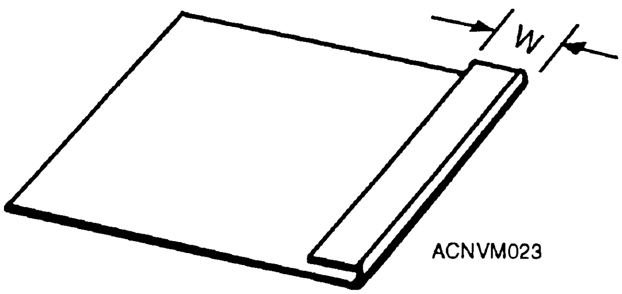


Figure 12-23.—Single-hem edge.

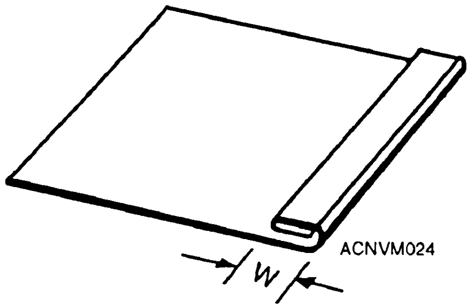


Figure 12-24.—Double-hem edge.

The DOUBLE-HEM EDGE (fig. 12-24) is used where additional strength is needed or when a smooth edge is desired inside as well as outside. The allowance for the double-hem edge is twice the width of the hem.

A WIRED EDGE (fig. 12-25) will often be specified in plans. Objects such as ice-cube trays, funnels, garbage pails, and other articles formed from sheet metal are manufactured with wired edges to strengthen and stiffen and to eliminate sharp edges. The allowance for a wired edge is 2 l/2 times the diameter of the wire used. For example, if you are using wire that has a diameter of l/8 inch, multiply l/8 by 2 l/2 and your answer will be 5/16 inch. This is the amount you will allow when laying out sheet metal for the wired edge.

ALLOWING FOR SEAMS

When you made your layout for a drip pan or box, you were told to allow for a tab for seaming with rivets. This method of joining sheet metal is known as lap seaming.

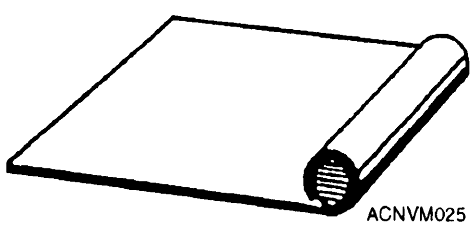


Figure 12-25.—Wired edge.

LAP SEAMS are shown in figure 12-26. They may be of three kinds: the plain lap seam; the offset, or "joggled," lap seam; or the corner lap seam. Lap seams may be joined by drilling and riveting, by soldering, or by a combination of both riveting and soldering. To figure the allowance for a lap seam, you must first know the diameter of the rivet that you plan to use. The center of the rivet must be set in from the edge a distance of two and one half times its diameter. The total allowance, then must be five times the diameter of the rivet that you are going to use. Figure 12-27 shows the manner in which a plain lap and a corner lap are laid out for seaming with rivets. For corner seams, allow an additional 1/16 inch for clearance.

GROOVED SEAMS are useful in the construction of cylindrical shapes. There are two types of grooved seams-the outside grooved seam and the inside grooved seam (fig. 12-28). The allowance for a grooved

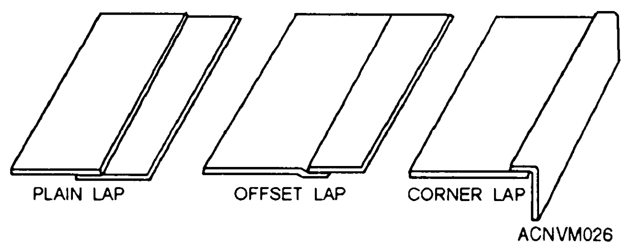


Figure 12-26.—Lap seams.

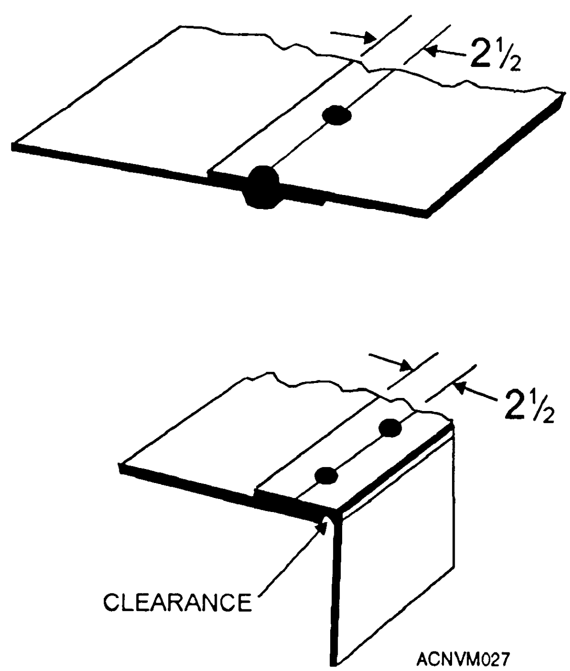


Figure 12-27.—Layout of lap seams for riveting.

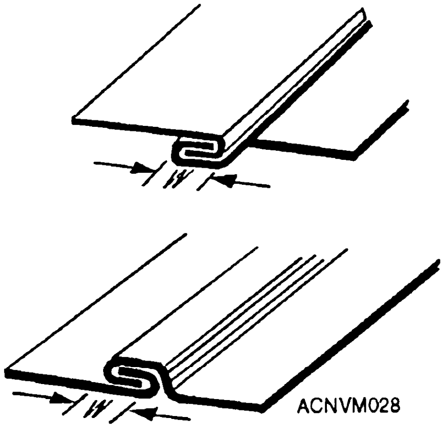


Figure 12-28.—Grooved seams.

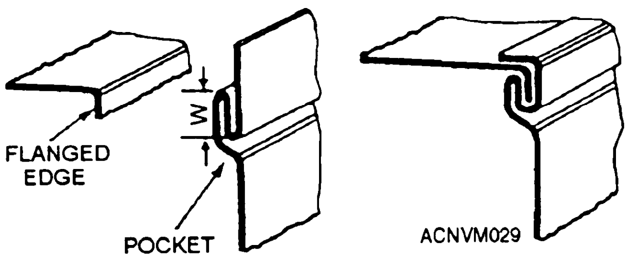


Figure 12-29.—Pittsburgh lock seams.

seam is three times the width (W in fig. 12-28) of the lock, one-half of this amount being added to each edge. For example, if you are to have a 1/4-inch grooved seam, 3 × l/4 = 3/4 inch, which is the total allowance; l/2 of 3/4 inch = 3/8 inch, which is the allowance you will add to each edge.

The PITTSBURGH LOCK SEAM (fig. 12-29) is a very useful corner seam that is used to advantage in rectangular ventilation lines, elbows, and boxes. At first glance, the seam appears to be quite complicated, but like lap and grooved seams it consists of only two pieces. The two parts are the flanged edge and the pocket with the projected edge, which is known as the locking flange after it has been bent over. After the pocket is formed, the flanged edge is inserted into the pocket, and the projected edge is then bent over the flanged edge. It then forms the locking flange that completes the Pittsburgh lock seam.

The allowance for the pocket and projected edge or locking flange is W + W + 3/16 inch. W is the width or depth of the pocket with 3/16 inch for the locking flange. The width of the flanged edge is l/l6 inch less than W to ensure a good tight fit. For example, if you are laying out a l/4-inch Pittsburgh lock (fig. 12-30, top view), your total allowance should be l/4 inch + l/4 inch + 3/16 inch, or 11/16 inch for the edge on which

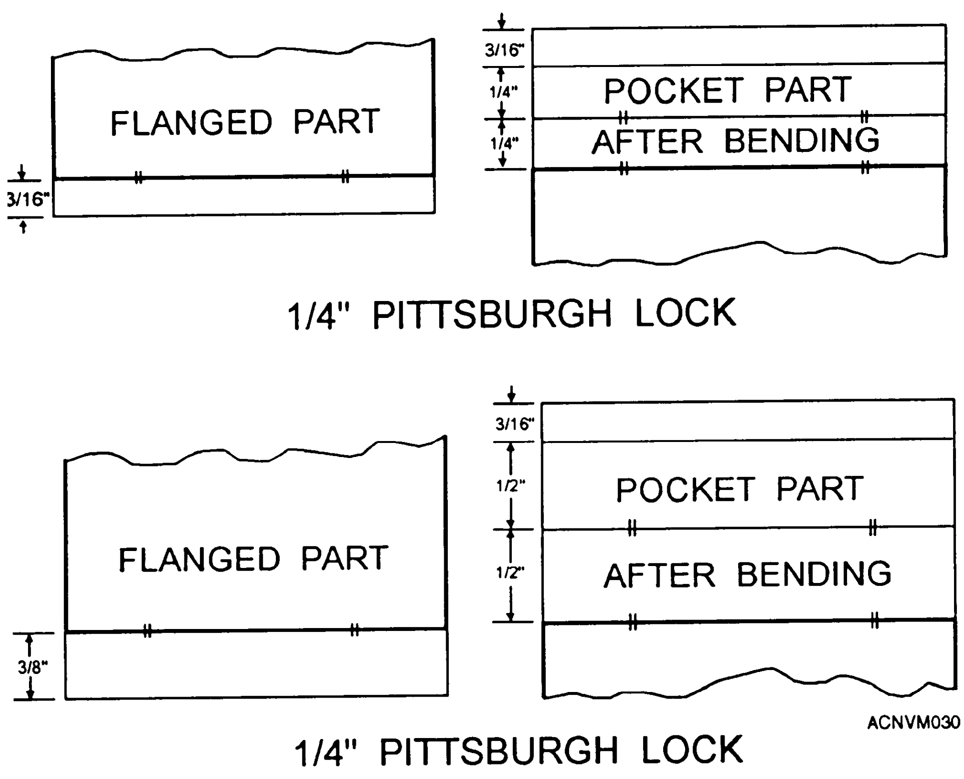


Figure 12-30.—Layout of Pittsburgh lock seam.

you are laying out the pocket, and 3/16 inch on your top piece for the flanged edge.

LAYING OUT NOTCHES

Notching is the last but not the least important step to be considered when you lay out a job. A notch is the spot on a piece of sheet metal that is cut out to allow the forming of a bend without the metal binding. Before you can mark a notch, you will have to lay out the pattern and add the seams, laps, or stiffening edges. If the patterns are not properly notched, you will have trouble when you start forming, assembling, or finishing the job.

There is no definite rule for selecting the proper notch for the job. But as soon as you can visualize the assembly of the job, you will have no trouble determining the shape of the appropriate notch. If the notch is made too large, a hole will be left in the finished job. If the notch is too small, or not of the proper shape, the metal will overlap and bulge at the seam or edge. Do not worry too much if your first notches do not come out very well; practice and experience will take care of that.

A SQUARE NOTCH is probably the first one you will make. That is the kind you were instructed to make in your practice layout of a box or drip pan. Take a look around the shop to see just how many different kinds of notches you can see in the sheet metal shapes.

SLANT NOTCHES are cut at a 45-degree angle across the corner, when a single hem is to meet at a 90-degree angle. Figure 12-31 shows the steps in forming a slant notch.

A V-NOTCH is used to seam the ends of boxes. You will also use a full V-notch when you construct a bracket with a toed-in flange or for similar construction. The full V is shown in figure 12-32.

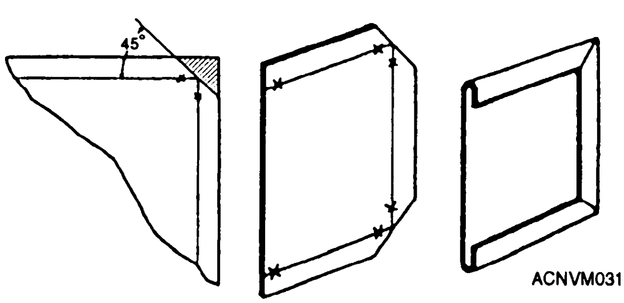


Figure 12-31.—Slant notch.

Your first 90-degree bends will be on line ADB, and the next ones will be on line CDE. But before you can make your bends, you will have to make your notch.

To make your notch, lay out your dimensions for the length and the width. Make sure you include the width the flange in your layout. Next lay out line ADB, which will be the width of the flange. Then lay out line CDE where your main bend will be, as shown in part V of figure 12-32. Next, bisect angles ADE and BDE on the flange, as shown in part W. Your final step prior to bending is to cut out your V-notch (angle FDG), as shown in part X of figure 12-32. Views Y and 2 show the bends being made.

When you are making an inside flange on an angle of MORE or LESS than 90 degrees, you will have to use a modification of the full V-notch to get flush joints. The angle of the notch will depend upon the bend angle. A modified V-notch is shown in figure 12-33.

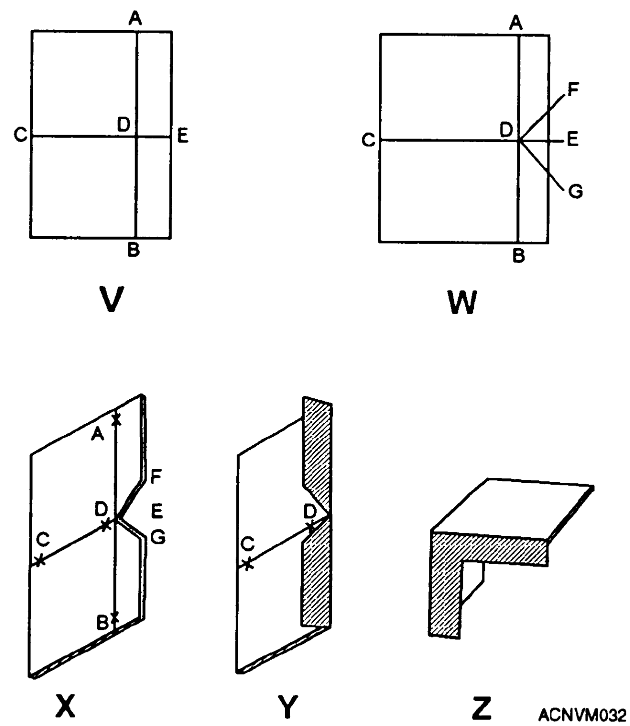


Figure 12-32.—V-notch.

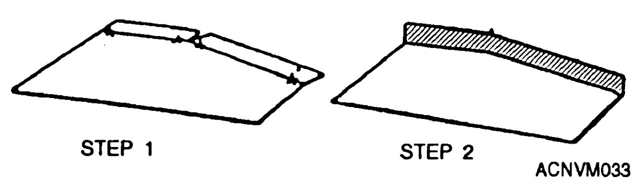


Figure 12-33—Modified V-notch.

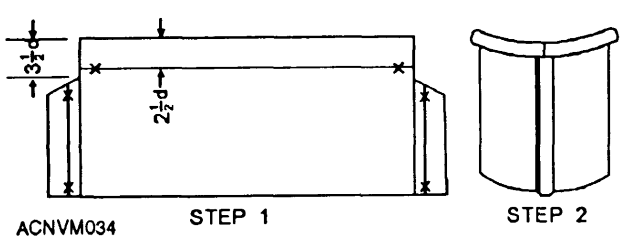


Figure 12-34.—Wire notch in cylindrical layout.

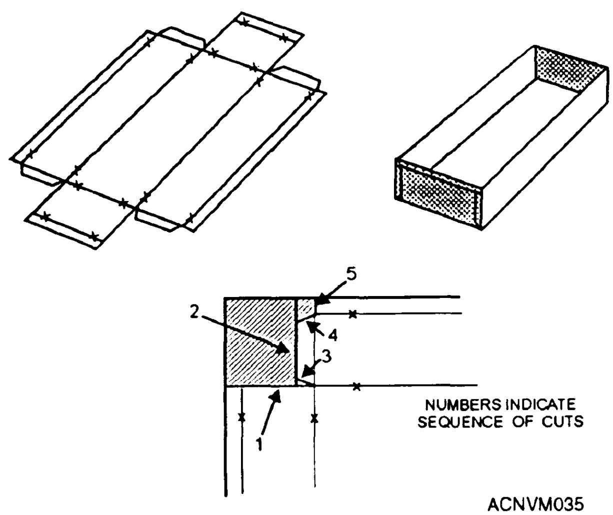


Figure 12-35.—Notching for an ice-cube tray.

A WIRE NOTCH is a notch used with a wired edge. The wire-edge cut-back allowance from the edge of the pattern will be one wire's diameter more than the depth of the allowance for the wired edge (2 1/2d), or 3 l/2 times the diameter of the wire (3 1/2d). The allowance on each side of the stretchout for the grooved seam is equal to 1 1/2 times the width of the seam (1 1/2W). That portion of the notch next to the wired edge will be straight, as shown figure 12-34. The shape of the notch on the seam will depend upon the type of seam used. The grooved seam shown in figure 12-34 requires a 45-degree notch.

Most of your work will require more than one type of notch. For example, in figure 12-34, notches are required for the wired edge and the grooved seam.

You will find another combination of notches when you lay out and make an ice-cube tray. The tray itself is similar to the drip pan you have already laid out, but the upper edge will require a wired edge. In this job, you will have to use the wire notch, the modified V, and the square notch (fig. 12-35).

PATTERN DEVELOPMENT

If all work that you were assigned to do consisted of laying out and fabricating drip pans, boxes, lockers, and straight sections of cylindrical and rectangular ventilation lines, your work would be much easier. Your layout would consist of nothing more than straight-line angular development, allowances for seams and edges, and visualizing the notch needed. But you will have to construct ventilation systems, or at least make repairs to those systems. This work calls for elbows and tees, which cannot be laid out unless you know how to do parallel line development.

PARALLEL LINE METHOD

Parallel line development assumes that a line that is parallel to another line is an equal distance from that line at all points. The main lines of a structure to be laid out by parallel line development are parallel to each other. Objects that have opposite lines parallel to each other, or that have the same cross-sectional shape throughout their length, are developed by this method.

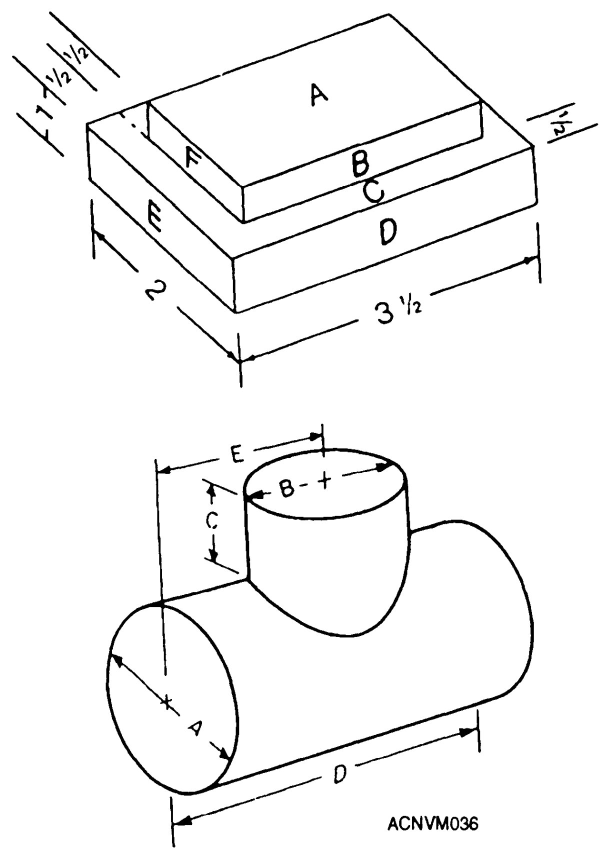


Figure 12-36.—Overall view of some objects fabricated by the parallel line method.

This includes such shapes as the cylinder and prism and their many variations.

You will have to use certain fixed principles as follows:

1. First, draw a plan and an elevation of the desired shape showing the parallel lines of the solid in their actual lengths.

2. Visualize the pattern from an angle in which the top, front, and side views are all present, as shown in figure 12-36.

3. Draw a stretchout or girth line perpendicular to the parallel lines of the solid. Each space contained in the section or plan view will be placed on the stretchout lines (fig. 12-37).

4. Draw measuring lines perpendicular to the stretchout lines of the pattern.

5. Draw lines from the points of intersection of the miter line, in the right view, intersecting similarly numbered measuring lines drawn from the stretchout, to show the outline of the development.

6. Trace a line through the points thus obtained to give the desired pattern.

Now, let us develop a layout of an intersected pipe following the parallel line method, step by step. A pipe like this could be used as a ventilation pipe on a slanting roof. Follow the instructions, checking each step with

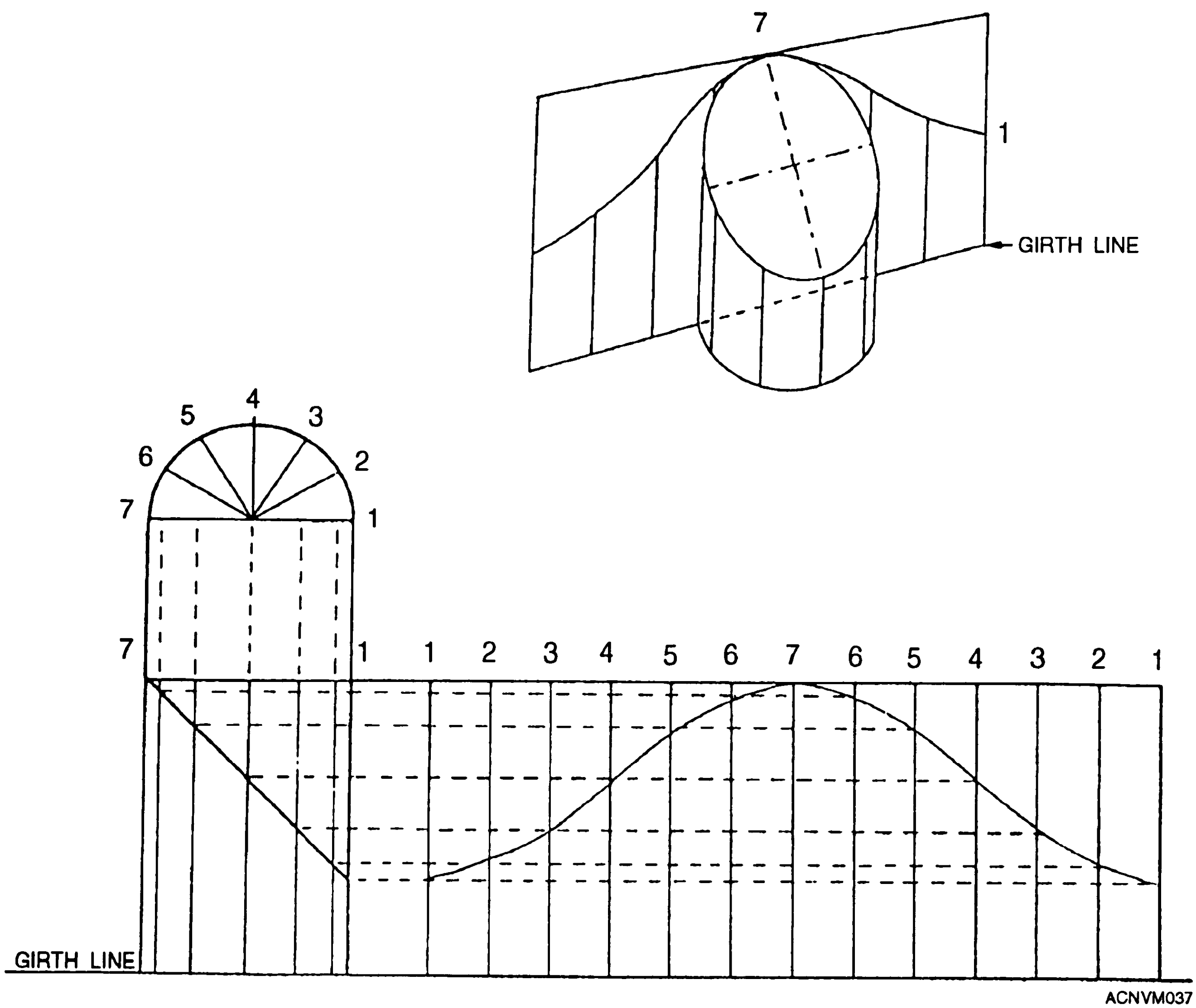


Figure 12-37.—Stretchout showing a girth line.

the illustration shown in figure 12-38. Then break out your layout tools and a sheet of template paper and try your skills at drawing an intersected pipe layout.

First, construct a base line. After the base line, draw your miter line at the same degree of angle as that of the slanting roof or inclined plane, as shown in figure 12-38. The elevation is the front view. Line AB represents the diameter of the pipe. The distance between line AB and the miter line is the height of the pipe, which will vary around the circumference of the pipe.

Now determine the center of line AB, and construct a center line as shown in figure 12-38. Set your dividers for one-half the distance of line AB. Develop the plan by the following steps:

1. Construct line 1-7 parallel to and just above AB. Using the point at which the center line of the elevation intersects line 1-7, swing an arc with the dividers and complete the half-plan as shown.

2. Step off the circumference of the half-plan with the dividers into six equal parts. To do this, place one leg of your dividers at point 1. With the same measurement used to scribe the half-plan, scribe a mark on the arc at point 3. Then from point 3 scribe a mark at point 5. You now have three equal parts. Bisect these three sections as an arc and you end up with your required six equal parts.

3. Set your straightedge at right angles to the center line. With the straightedge as a base line, use the flat steel square to draw lines parallel to the center line by the method shown earlier in figure 12-3. The parallel lines must be drawn from the points where the arcs intersect the circumference of the half-plan to the miter line (fig. 12-39).

4. with the straightedge draw EF (an extension of line AB), and step off twice the distance you stepped off in the circumference of the half-plan.

5. Draw line GH the same length as EF parallel to EF so that lines drawn from G to E and from H to F will both be perpendicular. The distance between line EF and line GH will be equal to the greatest height of the elevation.

6. Through the points located on the extended line, by stepping off with the dividers, draw parallel lines at right angles to the line extended from AB.

7. Number these lines in the proper order as shown (from 1 to 7 and back to 1).

You are now ready to transfer the miter line CD in the elevation to the stretchout and thus form the

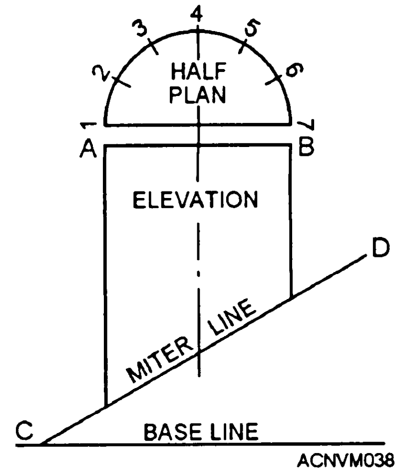


Figure 12-38.—Elevation and plan of intersected pipe.

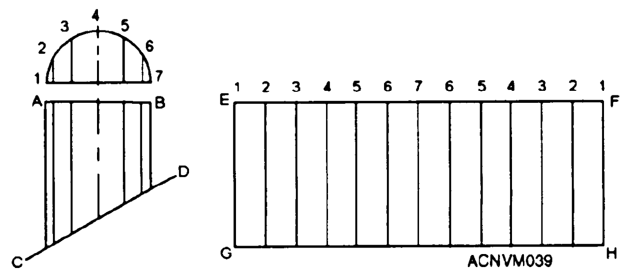


Figure 12-39.—Development of layout for intersected pipe.

stretchout for the elevation. You may use either of two methods:

- Measure and transfer the measurement from the elevation to the stretchout with your dividers.
- Project the points in the elevation to the stretchout by parallel projection lines (broken lines).

Whichever method you use, the stretchout will be the same. However, your measurements must be accurate. Try both methods and make a habit of using the one that comes easiest to you.

To develop your pattern by the use of dividers, follow these step-by step instructions, working from figure 12-39.

1. Take your dividers and set them to the distance of line 1 where it intersects line AB to its intersection on line CD.

2. Transfer this measurement to the two lines numbered 1 in the stretchout. Use line EF as your base line for the measurements on the strecthout, and scribe an arc on line 1.

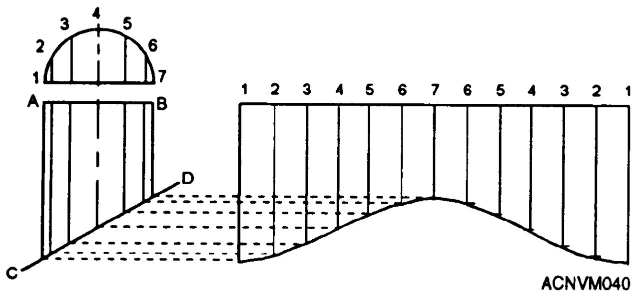


Figure 12-40.—Transfering from elevation to stretchout to making the pattern.

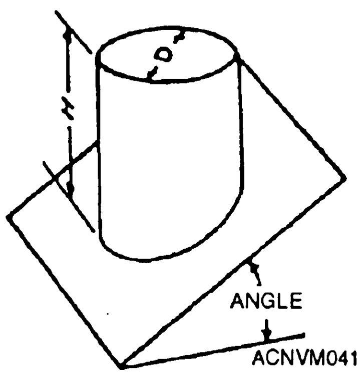


Figure 12-41.—Pictorial view of pipe intersected at an angle.

3. Then, measure line 2 in the elevation, and transfer this measurement to the two lines marked 2 in the stretchout. Repeat this procedure for lines 3, 4, 5, and 6.

4. Since there is only one line 7 in the stretchout, you will need to transfer the measurement of line 7 in the elevation to the stretchout only one time.

5. Finally, connect the points at which the arcs have intersected each of the elements, with a curve running from line A to the opposite line 1. Smooth out your curved line, add the allowances for seams, and the pattern is completed. If this final line has serious irregularities, you have made a mistake in your measurements. Your final stretchout should look exactly like the one made by projection in figure 12-40.

To obtain the pattern by projection, you simply project parallel broken lines from the points of intersection on the miter to lines with the same number in the stretchout. These broken lines are drawn at right angles to the numbered lines and parallel to line AB. They are drawn from the point where the numbered lines intersect the miter CD to the point at which they intersect the most distant line in the stretchout with the same number. Again, the pattern is completed by connecting the points of intersection on the stretchout with a curved line. Remember, the more care you take in drawing the elevation, stepping off the half-plan, and transferring the measurements from the elevation to the stretchout, the more accurate your pattern will be. Figure 12-41 is a pictorial view of the plan you have just laid out.

The parallel line method can also be used to develop an elbow of any desired diameter, depth of throat, or number of pieces. Figure 12-42 shows the development

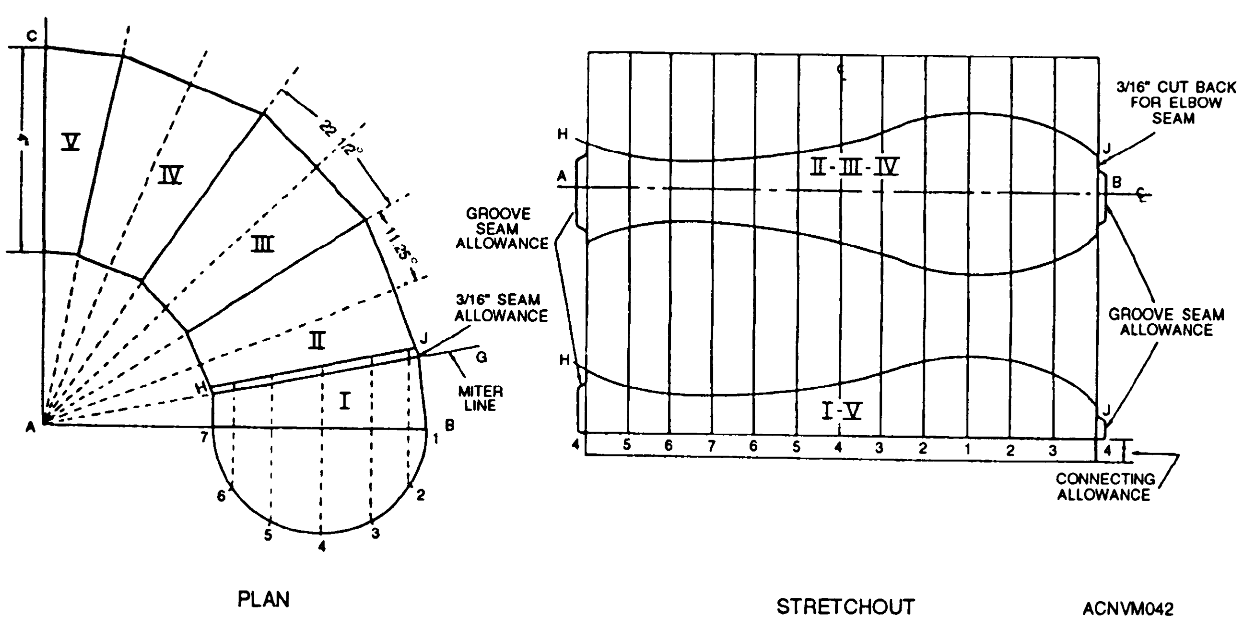


Figure 12-42.—Development of a five-piece 90-degree elbow.

of a five-piece 90-degree elbow. Take a pair of dividers and a straightedge and develop a five-piece 90-degree elbow using this method.

1. Using figure 12-42 as a guide, scribe horizontal line AB. From point A, scribe line AC to form angle CAB, which should be equal to the degree of angle that the elbow is to be. In this cast, we will use 90° for our elbow.

2. Set the dividers for the throat radius and scribe the arc, using A as the vertex.

3. Set your dividers for the heel radius, and using A as the vertex, scribe the heel arc. (The heel radius is determined by adding the diameter of the elbow to the throat radius.)

4. Divide the heel arc BC into equal spaces. To determine the number of spaces to use and the degree of angle per space, follow this rule: Multiply the number of pieces in the elbow by 2 and subtract 2. This will give you the number of equal spaces. Then, divide the degree of the elbow by the number of equal spaces. You now have the degree of angle for each space on the heel arc.

SAMPLE:

$5 \times 2 = 10 - 2 = 8$

$90° \div 8 = 11.25°$ of angle per space.

5. Now, draw lines from the vertex A to the points stepped off on the heel arc, making pieces I and V equal to one space each on the heel arc. Pieces II, III, and IV are made equal to two spaces each on the heel arc. They are twice the size of I and V.

6. Using AB for the base line, construct the half-plan.

7. Step off the circumference of the half-plan into equal spaces, and number the dividing lines from 1 to 7. For a larger diameter, use a greater number of equal spaces. The more spaces you use, the more accurate your plan will be.

8. Use AG for the miter line. You have now completed your elevation for making the stretchout of piece II, which will be the same for III and IV, and for making the stretchout of piece I, which will be the same as V.

9. To join the elbow together, you must make allowance for your elbow seam. Add the allowance from line AG up and draw line HJ.

10. Extend line AB to the right of the elevation to make the stretchout.

11. Set your dividers equal to one of the numbered divisions in the half-plan.

12. Step off twice the number of equal spaces in the stretchout that you have in the half-plan.

13. Erect perpendiculars from the base line of the stretchout and number them as shown in figure 12-42. The number with which you begin and end in your stretchout will determine the location of the seam in the finished elbow. The best location for a seam on an elbow is on the side, so you would number from 4 up to 7, then down to 1 and back up to 4. Numbering from 1 to 7 and back to 1, as was shown in the previous development, would place the seam on the heel. A layout done in this manner is undesirable because it would require more time and material to complete the seam. Numbering from 7 to 1 and back to 7 is also undesirable. This method would put the seam in the throat of the elbow; normally it would be too small to make a strong seam. The location of the scam is a matter of preference and is determined by the job you are laying out.

14. To transfer the pattern from the elevation to the stretchout using dividers, follow these steps:

a. Using line 4, measure its distance between lines AB and HJ with your dividers.

b. Using this distance, mark off three spaces on each of the three lines that are numbered as 4 in the stretchout. Start from the base line of the stretchouts.

c. The point on each line 4 that would divide the second and third space in half forms the center of the stretchout. To make the center line AB for the stretchout, draw a line to connect these three points.

d. Now, using the point where the center line and the numbered lines (elements) in the stretchout intersect, scribe arcs cutting each of the lines the same length as the corresponding lines in the elevation between the base line AB and line HJ.

e. Connect these points with smooth lines that will be curved. Your stretchout is now completed. Piece I in the stretchout (the lower piece) is the pattern for pieces I and V in the elbow, and piece II in the stretchout is the pattern for pieces II, III, and IV.

Figure 12-43 is a pictorial view of the five-piece elbow you have just laid out.

You have seen that you must draw an elevation and a plan view. For the intersected pipe and the elbow, it was necessary to draw only one elevation and plan view. However, some developments will require two or more elevations. An example of this type of development is the T-joint (fig. 12-44).

To develop the T-joint, you must draw a side elevation and an end elevation as well as plan views. For the side elevation, draw the object exactly as you would see it, looking directly at the side of the T. For the end elevation, draw the object exactly as you would see it if you were looking through the opening.

Follow these steps to construct the side and end elevation as shown in figure 12-44:

1. Draw a horizontal center line.

2. Construct two vertical parallel lines perpendicular to the center line, leaving sufficient space between them to lay out the side and end elevations. These lines will form the center lines for the elevations.

3. Draw the plan view above the constructed elevations, as shown in figure 12-45.

4. Step off the circumference of the plan view into seven equal spaces with your dividers.

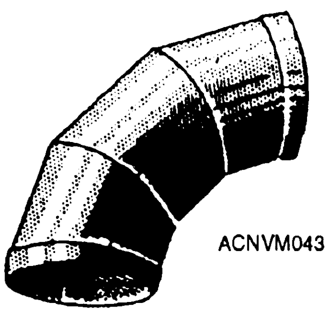


Figure 12-43.—Pictorial view of 8 five-piece elbow.

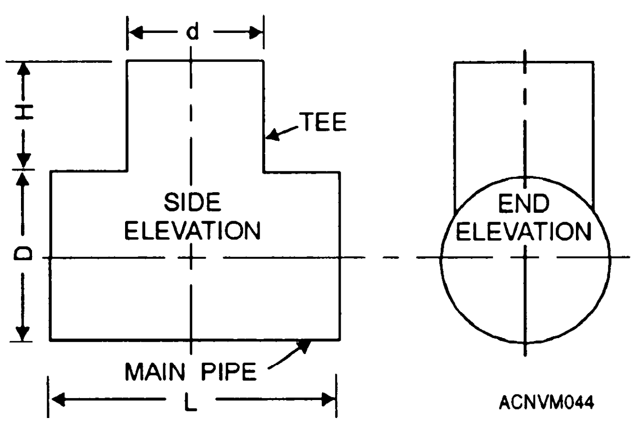


Figure 12-44.—Side and end elevation of a T-joint.

5. Number the elements of the plan as shown. The plan is numbered from 1 to 4 and back to 1 because each quarter section of the intersection, or miter, of the two pieces is the same as any other quarter section in the elevation. If the intersection of the T was other than a 90-degree angle, you would number from 1 to 7 as you did in developing the pattern for the elbow. As you can see, the number 4 element on the front view is in the center. If you rotate the T to look at the end view, the number 4 element is also rotated to represent its fixed position as the front and center element.

6. Extend lines parallel to the center lines in each of the views from the numbered points. In the end view, these lines will be drawn to the main pipe. To determine the lower end of the lines in the side elevation, proceed as follows: Place the straightedge at right angles to the number 4 vertical element of the end view. Draw a broken horizontal line from the number 4 element of the end view to the number 4 vertical element of the side view. Connect the other like-numbered elements in the same manner. Remember that there are two elements numbered 3, 2, and 1 in the side elevation to be connected.

7. Draw a curve through the intersections you have just located on the side view.

8. Now look at figure 12-46. To the right of the elevations, draw a stretchout equal in length to the

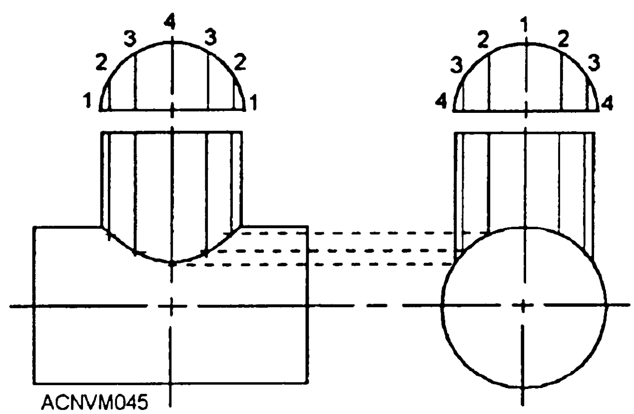


Figure 12-45.—Transferring elements to obtain miter line.

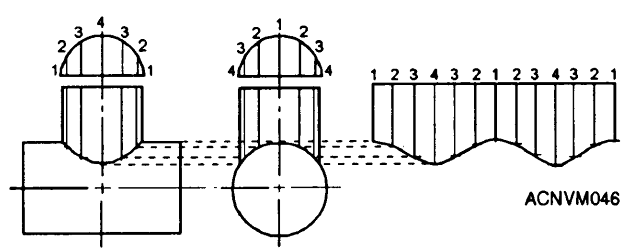


Figure 12-46.—Stretchout of the T.

circumference of the upper section of the T, or equal to twice the distance that you stepped off in the half-plan. The height of the stretchout, obtained by projection, is equal to the maximum height of the T. The height is equal to the length of the longest element in the side elevation—in figure 12-46, element number 4.

9. Step off, locate, and number the element lines in the stretchout.

10. Project the points of intersection locating the miter in the side elevation. Draw the curve through these points.

11. Now, using the circumference and length of the main pipe for dimensions, draw the stretchout for the main pipe as shown in figure 12-47.

12. Bisect the length of the stretchout with an element line, and number that line 1.

13. Set your dividers for the distance from 1 to 2 in the half-plan in the elevation. Using this radius and the point at which line 1 intersects the right-hand edge of the stretchout, scribe an arc on either side of 1 on the edge of the stretchout. Number each of these points 2. Now, setting the dividers for the distance from 1 to 3 in the half-plan of the elevation, scribe arcs, using 1 as a center, on either side of element 1 in the stretchout. Number both of these points 3. Repeat the procedure to get the points for the number 4 elements in the stretchout.

14. Through each of the points located, draw the element lines parallel to line 1.

15. Project the elements of the side elevation view to the correspondingly numbered elements in the stretchout. Connect the intersecting points with curved lines to outline the hole.

16. Add seams to the stretchout as required. Remember, the amount you will allow for seams will depend upon the method you plan to use for joining.

When the layout is completed, transferred to sheet metal, and formed, you should have a shape that looks like the one shown in figure 12-48.

You have been shown how to develop patterns for a drip pan or box by the straight line angular method of development, and methods for making stretchouts for elbows, pipe intersection angles, and T-joints by the parallel line method. Each of these methods has many more applications and you will use them often. However, you would not be able to develop some of the patterns that you will run into without a working knowledge of the method for radial line pattern development.

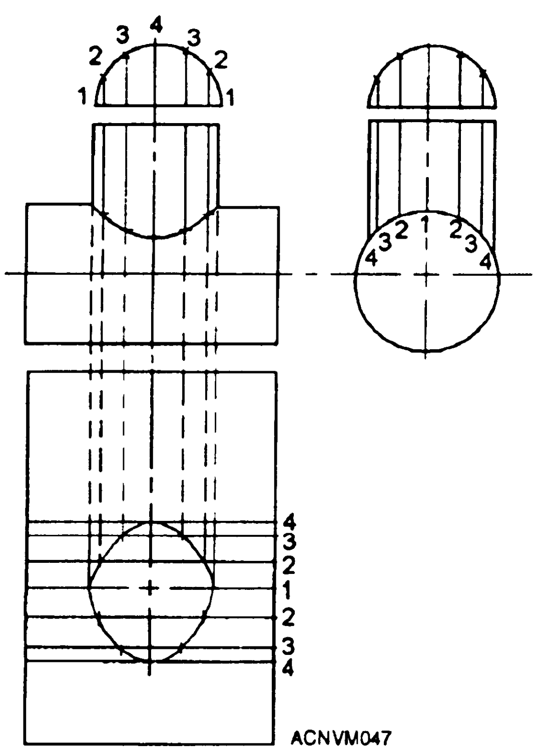


Figure 12-47.—Stretchout of the main pipe in the T-joint.

RADIAL LINE METHOD

The radial line method of pattern development uses some of the features of parallel line development. You will recognize them when you lay out a frustum of a right cone. You are familiar with the shape of a cone. A right cone is one that would stand straight, up and down, when resting on its large end. In other words, a center line drawn from the point, or vertex, to the base line, would form right angles with that line. The frustum of

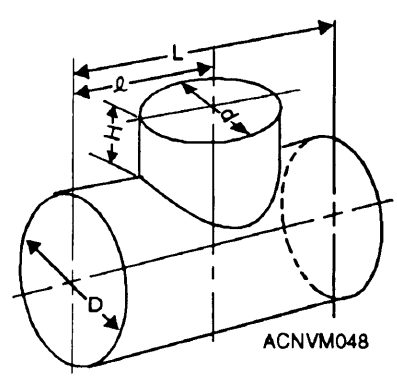


Figure 12-48.—Pictorial view of a T-joint.

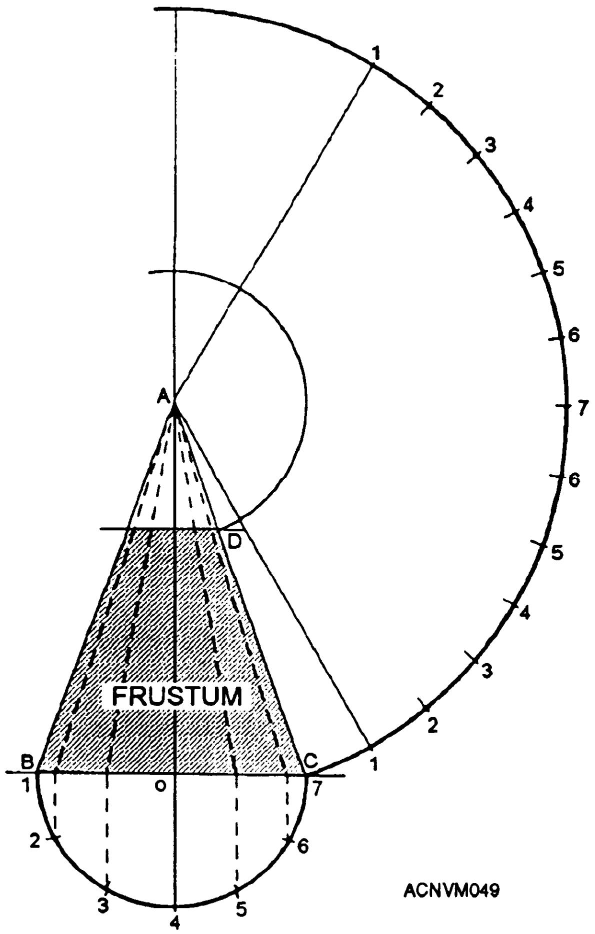


Figure 12-49.—Radial line development of frustum of a cone.

a cone is that part that remains after that point, or top, has been removed.

To develop a pattern for the frustum of a cone, check the following steps one-by-one with the illustration shown in figure 12-49.

1. Draw a front view of a cone, using such dimensions as your job at hand requires. Letter the vertex A, the base BC, and the axis AO.

2. At point D, and parallel to line BC, draw a line that cuts the top from the bottom of the cone. The bottom portion is called the frustum.

3. Draw a half-plan (using center 0 and radius OB) beneath the base of the frustum. Step the half-plan off into an equal number of spaces, and number them as shown in the illustration.

4. Set your dividers the distance of line AC, and using the vertex A as a center, scribe an arc of indefinite length.

5. Set your dividers equal to the distance of the step-offs on the half-plan, and step off twice as many spaces on the stretchout as you have in the half-plan.

6. Number the step-offs from 1 to 7 and back to 1, and draw connecting lines from vertex A to the number 1 at each end of the stretchout.

7. With vertex A as the center, set your dividers along line AC the distance of line AD, and scribe an arc that intersects both lines drawn from A to 1.

The area enclosed between the large and small arcs and the number 1 lines is the pattern for the frustum of a cone. Add allowances for seaming and edging and the stretchout is complete.

To develop a pattern for a cone cut at any angle, you need merely to elaborate the development of the pattern for a frustum. Such a pattern is shown in figure 12-50.

To develop a pattern for a cone cut at any angle, follow the method given here step by step:

1. Draw a cone with line ED cutting the cone at the required angle, as shown in figure 12-50.

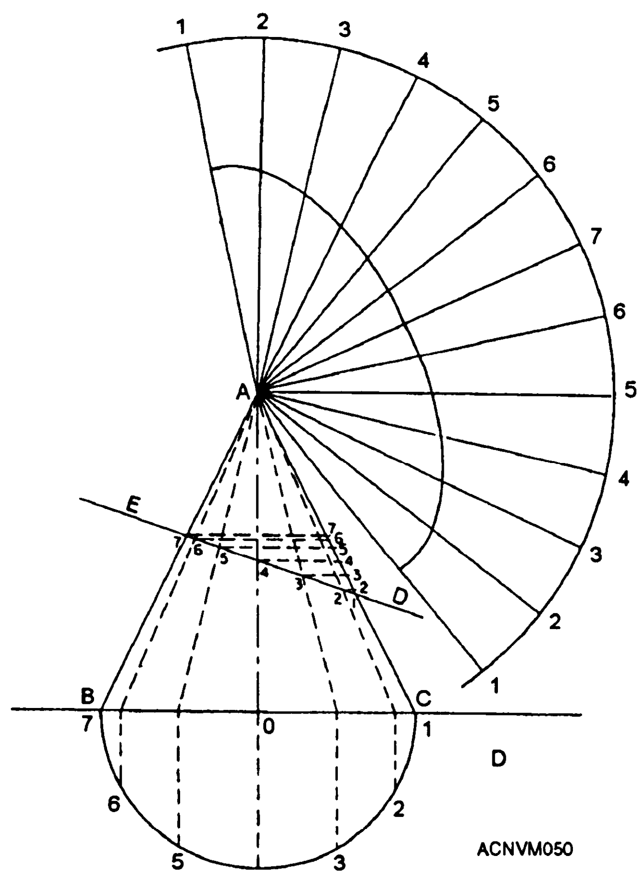


Figure 12-50.—Developement of a cone cut at any angle.

2. With center 0 and radius OB, draw a half-plan beneath the base line BC. Divide the half-plan into an equal number of parts and number them as shown.

3. From these points on the half-plan, draw lines perpendicular to the base line BC. From the points at which these lines intersect line BC, draw lines to vertex A.

4. Number the points of intersection on line DE, as shown in figure 12-50.

5. From the points of intersection of line DE, draw lines parallel to the base line BC and number the points of intersection on line AC.

6. With vertex A as a center and with dividers set to a distance equal to AC, draw an arc for the stretchout of the bottom of the cone.

7. Set the dividers equal to the distance of the step-offs on the half-plan and step off twice as many spaces on the arc as on the half-plan. Number the step-offs 1 to 7 and back to 1, as shown in figure 12-50.

8. Draw connecting lines from these points to vertex A.

9. Using vertex A as a center, transfer distances Al through A7 on line AC to each of the corresponding lines in the stretchout.

10. Join these points of intersection on the stretchout and a curved line to enclose the pattern of the cone.

11. Add allowances for seaming and edging, and the pattern is complete.

Thus far we have studied three principal methods of sheet metal development: angular, parallel line, and radial line development. Through the use of these three methods you can solve a large number of sheet metal layout problems. However, patterns for some objects are not readily developed by these methods. For example, a transition piece that changes the cross-sectional area of a duct from one geometric shape to that of another must be developed by triangulation rather than by the previous methods.

TRIANGULATION METHOD

It is often necessary to change the shape or area of a duct or pipe. This change is accomplished by transition pieces and other special fittings.

Most of the lines of the orthographic views on a transition piece are not shown in their true length because the lines slant away from the surface shown in the view. Because of this, you will have to find the TRUE LENGTH of some of the lines.

The true length of lines on transition pieces is found by triangulation. Using triangulation, the surface of the orthographic front view or elevation is divided into a number of triangles. Then the true length of each side of all triangles can be determined. This true length is then transferred to the development.

The general procedure for triangulation pattern development is as follows:

1. Construct the front view elevation and plan view in full scale.

2. Step off the plan view into four equal spaces.

3. Project the points stepped off on the plan view to the elevation (front view). Then draw the divisional lines.

4. Determine the true length of all the sides, edges, and divisional lines.

5. Develop the pattern from a center line, using the true length of all of the lines.

6. Sketch in the contours through the established points.

7. Add the necessary allowances for the seams.

The TWISTED SQUARE transition piece shown in figure 12-51 is quite simple to develop by triangulation.

Both of the openings, top and bottom, are parallel to each other. The centers of the openings are both on an axis perpendicular to the base. Because the openings are centered and have the same shape, the pattern could be obtained from a quarter-plan. However, a full-plan will be used here to illustrate the procedure. Here are the steps to be followed in making the layout:

1. Construct the elevation and plan views as shown in figure 12-5 1. The numbered lines indicate the elements that are shown in their true lengths. The lettered lines are those for which the true length must be found.

2. Extend the elevation's base line to the right of the elevation. Construct a perpendicular to the extension that is equal in length to the height of the elevation object. Mark these points A and H.

3. With your dividers, measure the distance from point 5 to point 6 in the full-plan view. From point A, on the extended base line, mark this distance to get point b. A line drawn from point b to point H is the true length of line b in the plan.

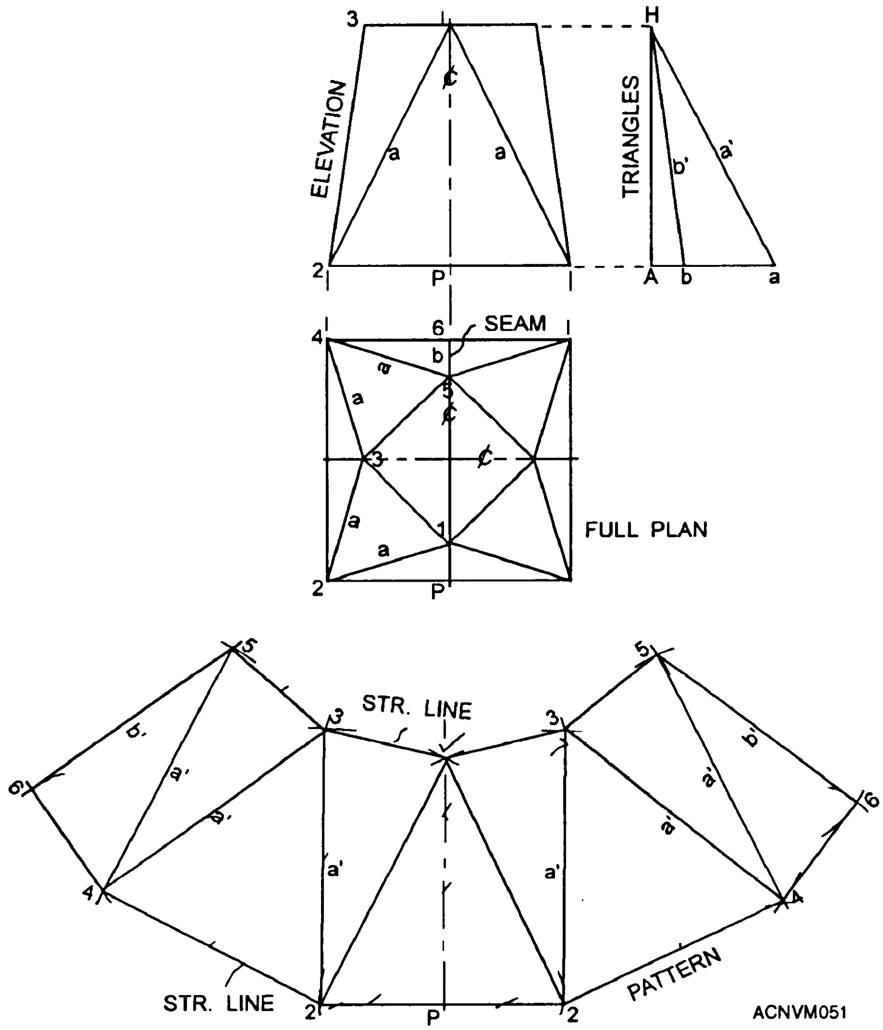


Figure 12-51.—Triangulation development of a twisted square.

4. Using the procedure for finding the length of line b, measure the distance between point 4 and point 5 to get the length of line a´.

5. Draw an extension to the vertical center line of the full-plan view. Construct a base line perpendicular to the center line. Mark the intersection of the two lines in the pattern as point P

6. Use your dividers to measure the distance from point P to point 2 in the full-plan view. Using this measurement as your radius and point P of your pattern as the pivot point, scribe an arc on each side of point P to get the true length of the base line. Label each of these points as point 2.

7. Using the true length of line a´ of step 3 as your radius, scribe an arc from each point 2 to intersect the center line to establish point 1 and your first triangle in the pattern.

8. Set your dividers for the distance between points 1 and 3 of the full plan. Using point 1 of the pattern for a pivot point, scribe an arc on each side of point 1.

9. With a´ as the radius, and using each point 2 as a pivot point in the pattern, scribe an arc to intersect each of two preceding arcs to establish points 3.

10. With 2-4 of the full plan as a radius, and using points 2 in the pattern for pivot points, scribe arcs at 4.

11. Set the dividers for the length of a´, and with points 3 in the pattern for pivot points, scribe arcs to establish points 4.

12. Set the dividers for the distance between 3 and 5 in the full plan. Using points 3 of the pattern for your pivot points, scribe arcs at 5.

13. With a´ as the radius and points 4 as the pivot points in the pattern, scribe your arcs establishing points 5.

14. Set your dividers to the length of line b´ in step 3. Now, using points 5 as the pivot points in the pattern, scribe your arcs at 6.

15. Set your dividers for the distance between 4 and 6 in the full plan. Using points 4 in the pattern as your final pivot points, scribe your arcs to establish points 6.

16. Draw straight lines between the established points, as shown in figure 12-5 1. Make your necessary allowances for the seams, and the pattern is completed.

Figure 12-52 illustrates the procedure for the development of a RECTANGULAR-TO-ROUND transition piece.

This is also a relatively easy development, and one that you can make on your own by following the drawing.

The OFFCENTER ROUND-TO-ROUND transition piece developed in figure 12-53 is a scalene conic section.

When the difference between the diameters of the top and bottom is small, as it often is, the vertex—if you could establish it—would fall in the next stop. When you have a scalene conic section to develop and that condition exists, you will have to develop the piece by the triangulation method. This type of development is shown in figure 12-53.

To develop the pattern, first draw the orthographic front view. Then swing in the half-circles at the top and the bottom. With the front view completed, follow these steps:

1. Divide the top half-circle into six equal parts to establish points A, B, C, D, and E.

2. Drop vertical lines from these points to intersect the top line of the front view at right angles. Number these points of intersection 1 through 7.

3. Divide the bottom half-circle into six equal parts to establish points F, G, H, J, and K.

4. Run vertical lines upward to intersect the bottom line of the front view at right angles. Number these points of intersection 8 through 14.

5. Construct the front view triangles as shown. Note that some of the lines are solid and some are broken. Make your lines the same way.

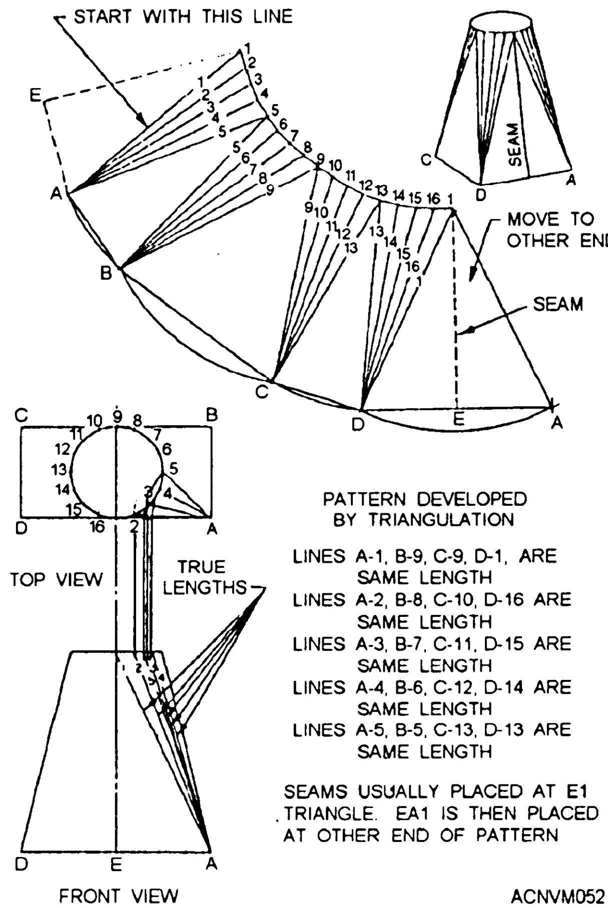


Figure 12-52.—Development of rectangular-to-round transition piece.

Now find the true length of each side of the triangles. The short side of each triangle that points downward is equal to one-twelfth the circumference of the TOP circle. The other two sides of each triangle are not shown in true length. Therefore, we must use triangulation to determine their true lengths. However, lines 1-8 and 7-14 are shown in their true length on the front view.

Work with the solid lines first. (See the top portion of fig. 12-53.) Set up two right angles to use as bases for true-length diagrams and work from point X and point Y. Take line 3-10 as an example. Set your dividers to the length of line 3-10 on the front view. Use point X as a center and swing an arc across line XZ. Then set the dividers equal to the DIFFERENCE between line G-IO and line B-3. Use X as a center and swing the arc to intersect line XY. A line connecting the two intersections is the true length of line 3-10.

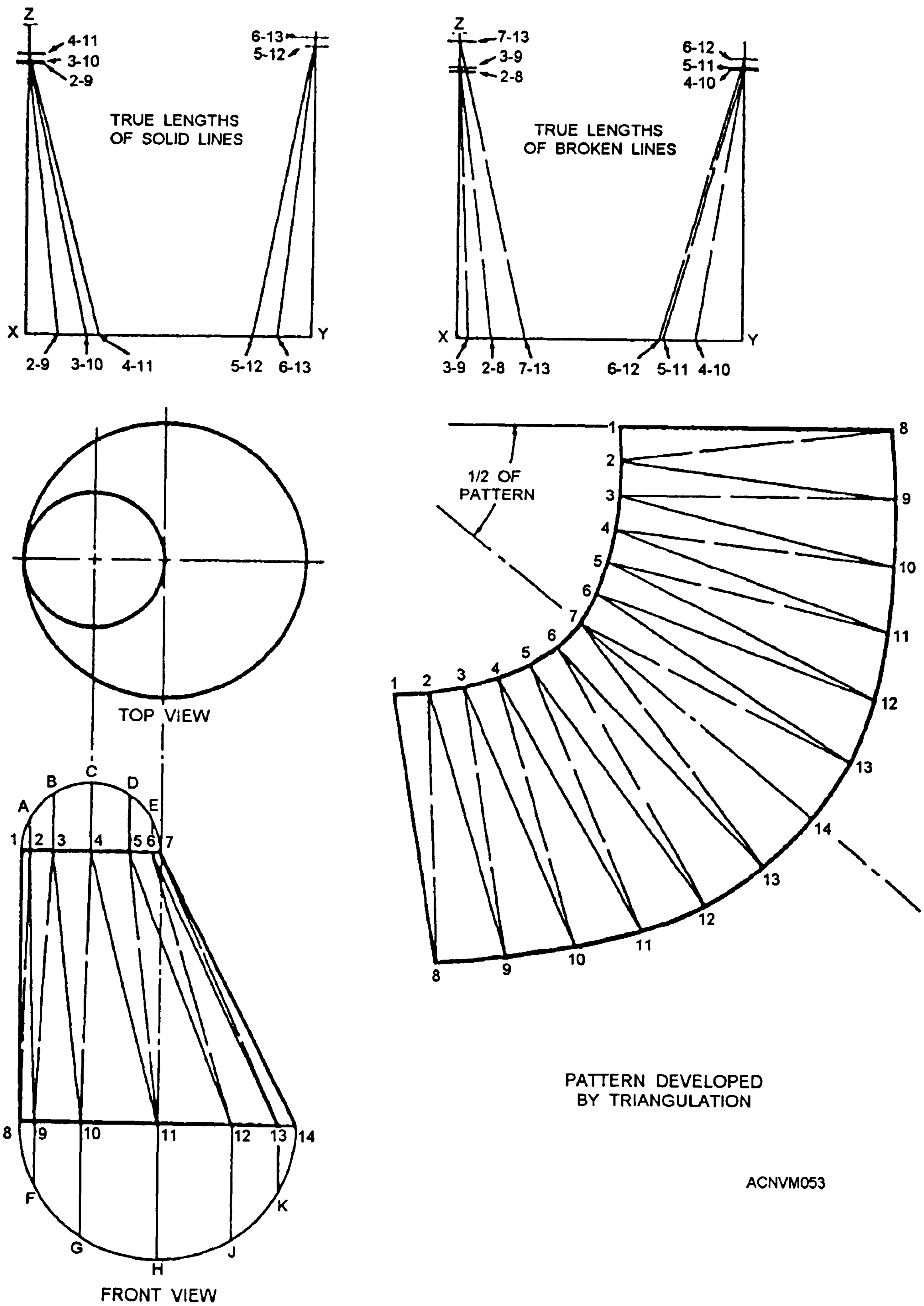


Figure 12-53.—Development of offcenter round-to-round transition piece.

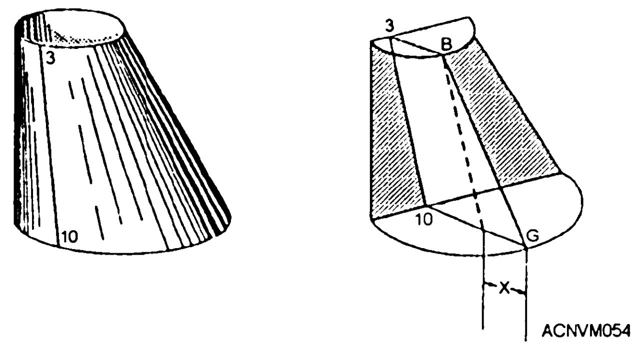


Figure 12-54.—Determining true length of a line.

Figure 12-54 shows why the difference between the lengths of line B-3 and line G-10 must be used as the length of the bottom leg of the triangle to get the true length of line 3-10.

If the half-plans of the front view (fig. 12-53) were bent forward 90 degrees and the entire front view revolved about 30 degrees to the right, the view would appear as shown in figure 12-54.

A perpendicular dropped from the top half-plan edge at B will be parallel to line 3-10 and intersect line G-10 as indicated. That intersection represents the proximity of the top edge to the bottom edge (top view, fig. 12-53). The distance between the point of intersection and point G (represented in the pictorial view by X shown in fig. 12-54) determines the length of the base leg required to plot the true length of line 3-10. Each line in the front view (fig. 12-53) is plotted, and the true length is obtained in the same manner.

With the true length of all the solid and broken lines established, lay out the development. First, draw a straight line that is almost vertical. Towards the top of the line, mark a point and label it point 1. Set your dividers for the length of line 1-8 in the front view of figure 12-53. Working from point 1 in the development, scribe an arc to locate point 8 as shown in figure 12-53. Using line 1-8 as a base line, you can now lay out the rest of the development. The first triangle to be laid out is 1-8-2. To obtain point 2 in triangle 1-8-2, use one equal spacing from the top half-circle of the front view. Using point 1 as a pivot point, scribe an arc. Then, using the true length of line 2-8, and using point 8 as the pivot point, scribe an arc across the first arc to locate point 2. Draw in your lines and you will have completed triangle 1-8-2. The next triangle to be developed is 8-2-9. To locate point 9, use one equal space of the lower half-circle from the front view of figure 12-53. Scribe an arc from point 8. Then, using the true length of line 2-9, strike an arc using point 2 as your pivot point. Point 9 is located where the two arcs intersect. Draw in your lines and your second triangle is completed. Continue this process until you reach line 7-14. At this point, you will have completed one-half of the pattern development. The other half is identical, so you will not have to lay out the other half.

TRANSFERRING THE PATTERNS TO METAL

Many of your patterns will be laid out right on the metal. However, there will be times when you will have to make the development on paper. Then, you must transfer the pattern to the metal that you plan to work. When you transfer these measurements, you must avoid mistakes or your piece will not come out as required.

Occasionally, you may cut out the pattern from template paper. Hold the pattern firmly in place and trace around the edges, as shown in figure 12-55. The break lines (where you bend the work) are located by using a prick or center punch and marking through the pattern on to the metal.

If you were in a large production shop where you made the same piece over and over again, you would make a metal pattern and use it to trace around and locate break lines and holes. Normally, your work is so varied that you will develop the stretchout when you need it. The future use of metal patterns is limited.

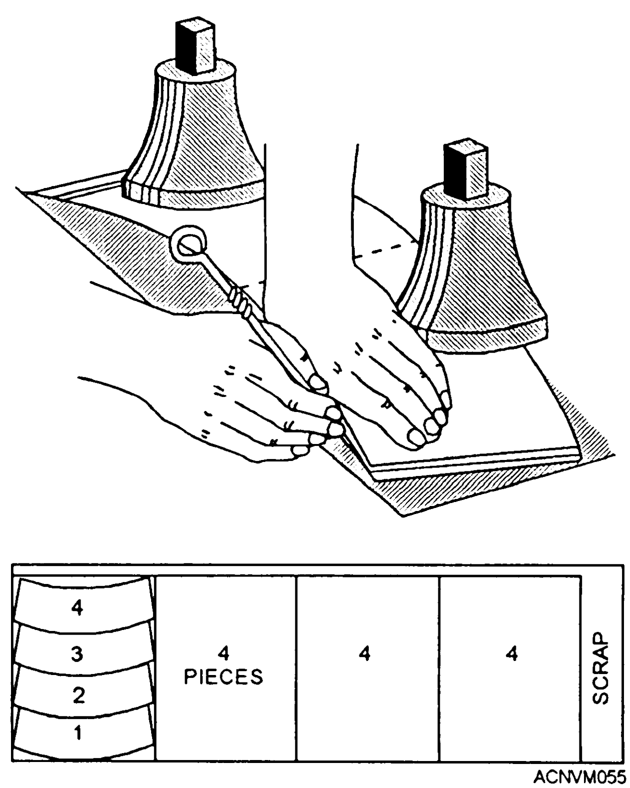


Figure 12-55.—Transfering patterns to metal.

Table 12-1.—Gauge and Decimal Measurement of Uncoated Low-Carbon Steel and Zinc-Coated Low-Carbon Steel

Gauge	Thickness (inches)
32	0.0097
30	0.0120
28	0.0149
26	0.0179
24	0.0239
22	0.0299
20	0.0359
18	0.0478
16	0.0598
14	0.0749
12	0.1046
10	0.1345

FABRICATING SHEET METAL

The various sheet metal alloys most commonly used aboard ship include zinc-coated low-carbon steel (often called galvanized iron), uncoated low-carbon steel, aluminum, Monel, copper-nickel alloy, copper, and brass.

Sheet metal will be identified by either a gauge number or by a decimal measurement. Table 12-1 shows the relationship between the gauge and decimal thickness for uncoated low-carbon steel and for zinc-coated low-carbon steel. Tables arc available for other materials. The gauge number of sheet metal is often stenciled on the metal. If by chance the gauge number does not appear on the sheet, you can find it by measuring the thickness of the material with a U.S. standard gauge for sheet and plate iron and steel. Then use table 12-1 to convert the measured thickness to its gauge.

CUTTING SHEET METAL

Several types of snips and shears are used to cut sheet metal. Snips are used to cut the lighter gauges of sheet metal. Bench shears, such as the type shown in figure 12-56, are used to cut heavier sheet metal.

Before using either the snips or the shears to cut sheet metal, make sure you have the right tool for the job.

Keep the blades at right angles to the work while you make the cut. The blades should be almost closed, but not quite, to their full length on each cut. If you close the blades all the way, the finished cut will tend to be jagged.

Figure 12-57 shows combination snips being used to cut an outside circle. The metal will be easier to handle during cutting if you cut away the excess metals on the corners first. When cutting out the circle, make a continuous cut, turning the metal as you cut.

Figure 12-58 shows the procedure for cutting out an inside circle with aviation snips. To start the cut,

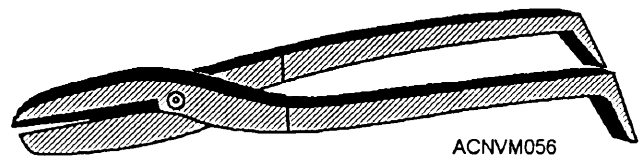


Figure 12-56.—Bench shears.

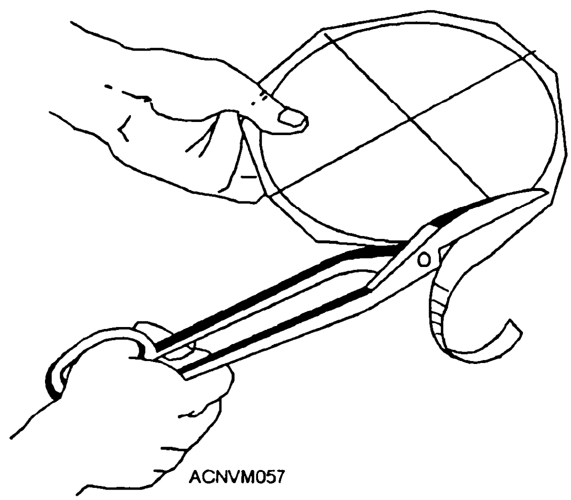


Figure 12-57.—Cutting an outside circle with combination snips.

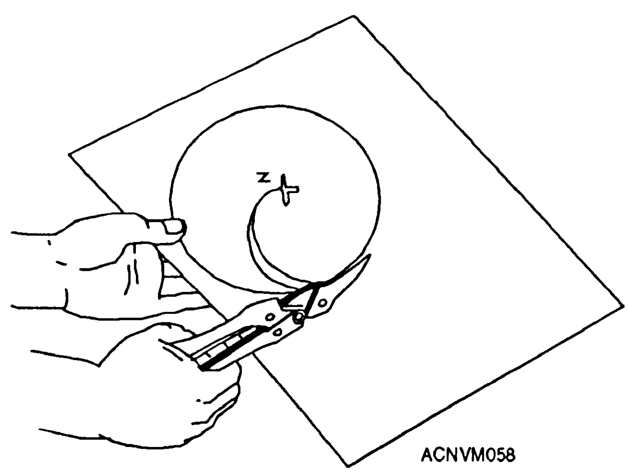


Figure 12-58.—Cutting an inside circle with aviation snips.

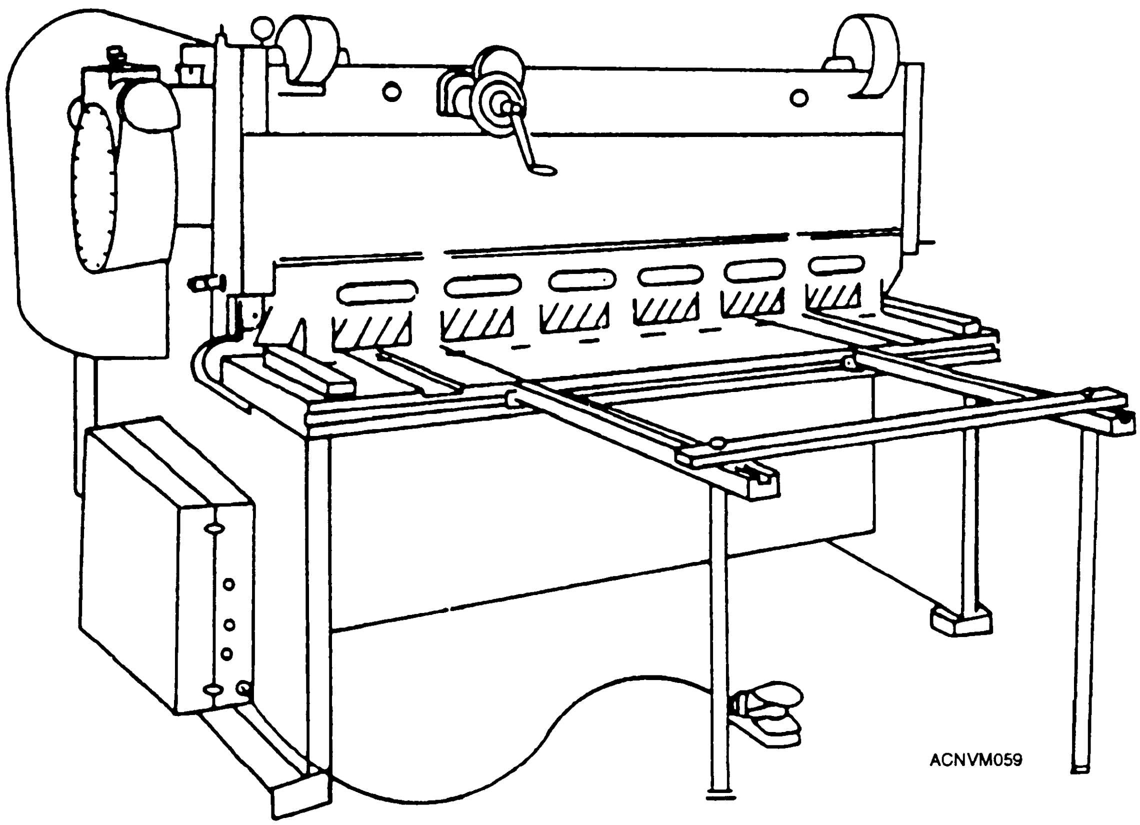


Figure 12-59.—Power-driven squaring shears.

punch a hole in the center of the circle to be cut. Then work your way out to the line of the circle and follow the line around until the cut is completed.

Unless otherwise specified, snips for cutting sheet metal are intended for use on mild steel of relatively light gauge. Stainless steel and other special alloy steels must be cut with special snips or shears that have special tool steel inlaid edges.

Some ships have squaring shears installed to use in making long straight cuts on heavy materials. The type of squaring shear installed depends on the nature and the amount of work to be done on that ship. Repair ships have large power-driven squaring shears such as the one shown in figure 12-59.

Squaring shears are designed for various capacities, which must never be exceeded. Nameplates indicating the maximum thickness of material to be cut are installed on each machine by the manufacturer. In general, the thickness specified by the manufacturer is for low-carbon or mild steel. If alloy steel must be cut, the thickness of the alloy steel also must not exceed that specified by the manufacturer.

Squaring shears are equipped with devices that serve as stops for sheets when more than one piece of the same size is required. The stops or gauges are located on the front, back, and sides of the bed of the shear. They can be adjusted to various lengths and angles.

Squaring shears are also equipped with hold-downs for clamping the sheet in place. The hold-downs used on powerdriven squaring shears are automatic. After the machine has been started and allowed to reach its operating speed, the metal is inserted; a foot treadle is then tripped, and the machine automatically clamps the sheet into position and makes the cut. Hand operated hold-downs are usually used on treadle-operated squaring shears. The sheet to be cut is inserted, the hold-down handle is adjusted, and the cut is then made by depressing the foot treadle. After the cut has been made, the hold-downs are released and the sheet can then be removed from the machine.

The principle of the shear is shown in figure 12-60. The lower blade of the shear is stationary and is attached in a parallel position to the bed of the machine. The upper blade, which is the movable blade, is attached to

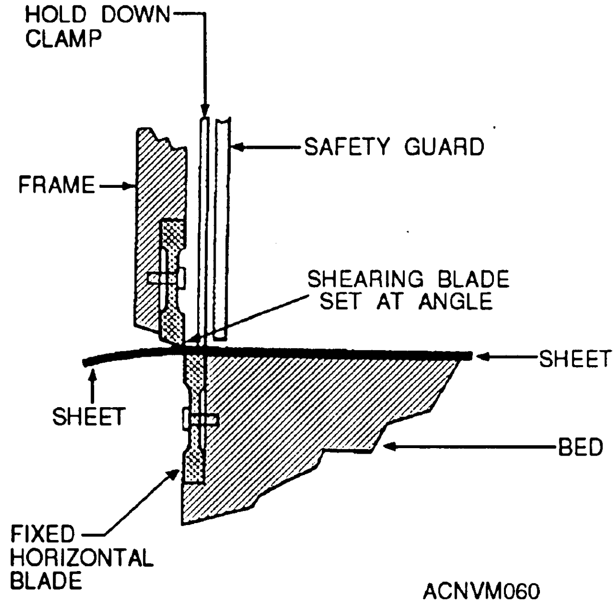


Figure 12-60.—Principle of a shear.

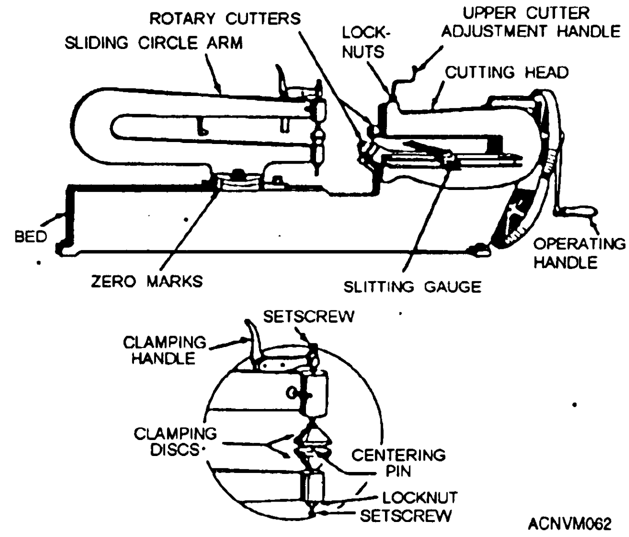


Figure 12-62.—Ring-and-circle shear.

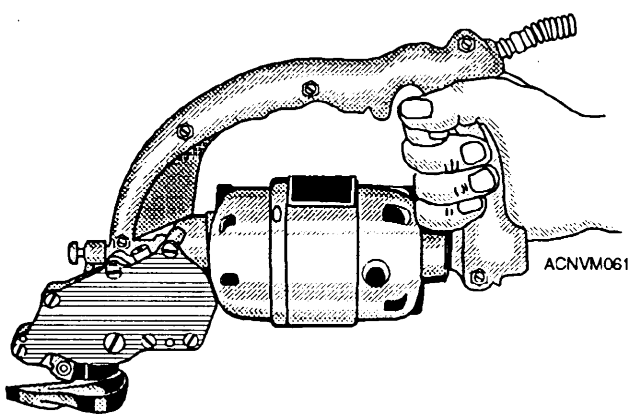


Figure 12-61.—Portable power-operated shearing tool.

a crosshead and at a slight angle to the position of the lower blade. The shearing action starts at one end of the sheet and continues across the sheet in much the same way that a pair of scissors cuts paper.

Portable, power-operated shears of the type shown in figure 12-61 are also used to cut sheet metal. They can be used to cut curves and notches as well as to make straight cuts. These tools cut metals of various gauges according to the capacity indicated on the nameplate.

There are special types of shears, some hand operated and some power driven, which are used on many ships for special types of cutting jobs. When available, these special shears can simplify your work.

Ring-and-circle shears are used to cut inside and outside circles. These shears may be hand operated, such as the one shown in figure 12-62, or they may be power driven. The following procedure is used to operate a ring-and-circle shear:

1. Select a piece of stock of the correct size, and locate the center of the piece. Mark the center with a prick punch.

2. Adjust the gauge arm of the machine to the radius of the desired circle.

3. Place the stock in the sliding circle arm. Locate the center of the stock by working the centering pin of the clamping device into the prick-punch mark.

4. Secure the metal in position by depressing the clamping handle.

5. Set the locknuts of the upper cutter adjustment handle so that the upper cutter, in its lowest position, produces a clean cut.

6. Lower the upper rotary cutter until it comes in firm contact with the metal.

7. If the shear is a hand-operated type, turn the operating handle. If it is a power-driven type, push the starting button. The blank feeds into the shear. Continue cutting until the disk is cut out completely.

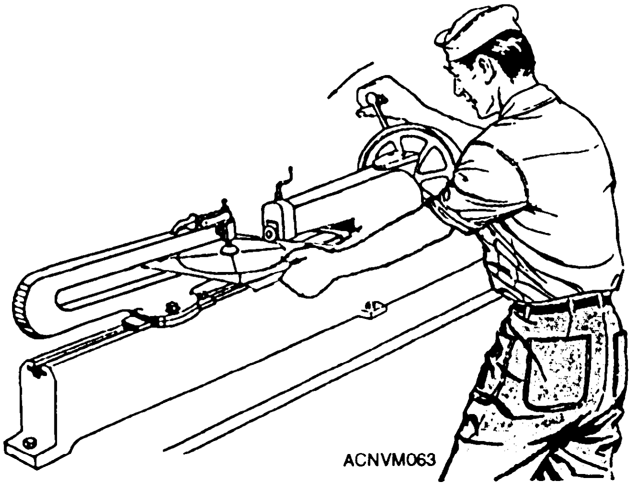


Figure 12-63.—Cutting a disk with the ring-and-circle shear.

The cutting of a disk with the ring-and-circle shear is shown in figure 12-63. To make a flange or ring, cut a disk in the manner just described. Then adjust the sliding circle arm to the new radius required for the inner circle. Make the inner cut by the same procedure used for the outer circle.

The ring-and-circle shear can also be used to cut straight or irregular curved sections as well as disks and rings. To cut light gauge material, the rotary cutters should be set to just touch, but not rub. To cut heavier gauge material, the cutters should be slightly separated. These adjustments should be made according to the instructions furnished by the manufacturer.

To cut a ring or a flange using only hand tools and a slitting shear or bench shear, follow the procedure shown in figures 12-64, 12-65, and 12-66.

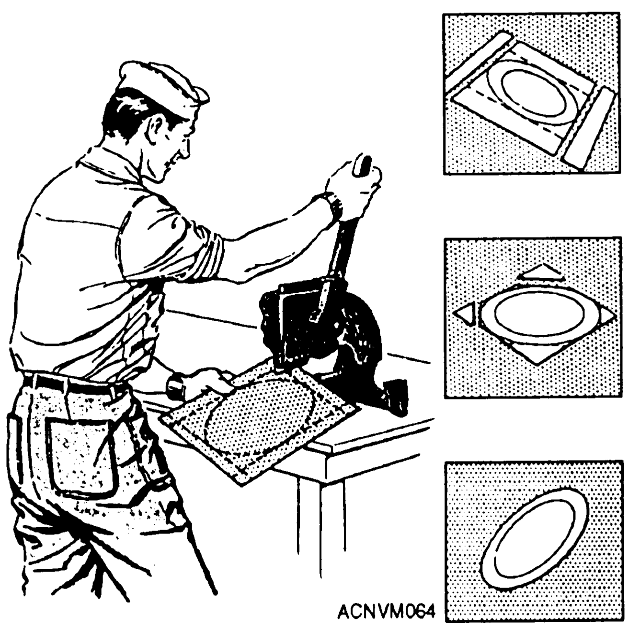


Figure 12-64.—Cutting outside of a circle with slitting or bench shear.

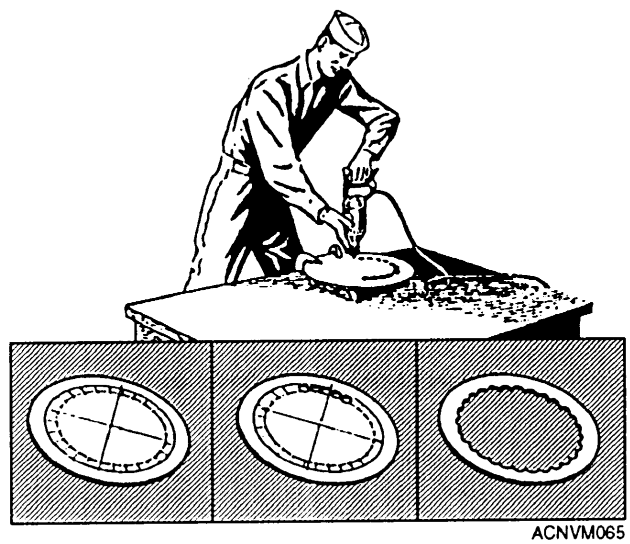


Figure 12-65.—Drilling holes around inner circumference.

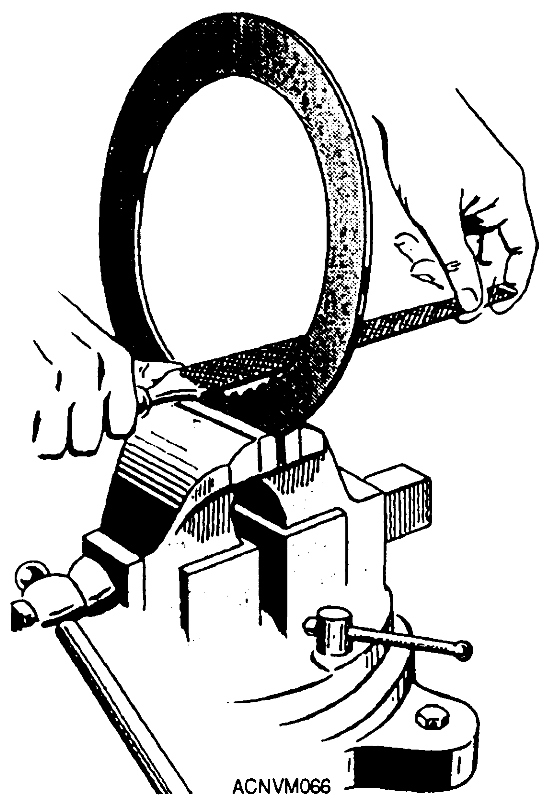


Figure 12-66.—Dressing the ring to final shape.

The steps used to make a ring by this method are as follows:

1. Scribe the inner and outer concentric circles using the desired radii.

2. Make a series of straight cuts on the slitting shears as close to the outer circumference as possible.

3. File or grind the outer circumference down to the scribed line.

4. Drill, punch, or chisel the inner material from the disk. Take care not to work too close to the inner scribed line.

A throatless shear is a heavy-duty machine that can take material up to l/4 inch in thickness. Smaller power-driven and hand-operated models are available. The throatless shear is normally used to cut out shapes that have an irregular curved edge. There are no guides on this type of machine. You control the cut by changing the direction of the sheet so that the blades cut along the lines scribed on the material.

There is a wide varity of equipment for cutting sheet metal. However, you may be assigned to a ship that does not have the equipment nor the room to keep it. In this case, you will have to depend on your normal shop tools. You can do a number of simple cutting operations on light sheet metal while the material is held firmly in a bench vise. Figure 12-67 shows the method used to cut sheet metal, held firmly in a vise, by using a chisel and hammer. Also you may use a hacksaw to make some of the cuts on the sheet metal held in a vise.

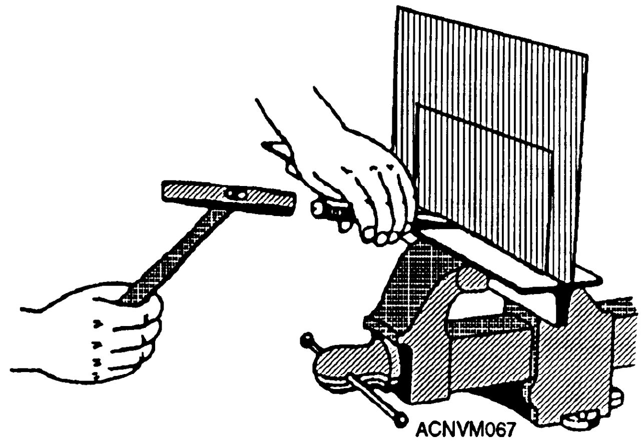


Figure 12-67.—Cutting light sheet metal with a cold chisel.

FORMING SHEET METAL

Sheet metal may be formed either by hand or with the aid of various special tools and machines. The hand forming of a bend is shown in figure 12-68.

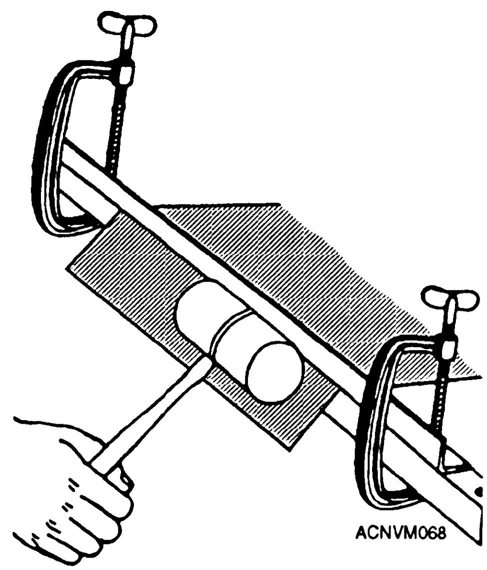


Figure 12-68.—Hand forming a bend in sheet metal.

The sheet is laid on a workbench or other flat surface, with the required amount projecting over the edge. A piece of angle iron is laid on top of the sheet with its edge even with the edge of the workbench. C-clamps are used to hold the angle iron and the sheet in place. Form the bend first by bending the entire length of the sheet with your hands. Then finish the bend by striking the bend area with a wooden mallet.

Sheet Metal Brakes

Sheet metal brakes produce more uniform bends than those made by hand. They also require considerably less effort. A standard cornice brake is shown in figure 12-69. Before you use this machine, two adjustments must be made.

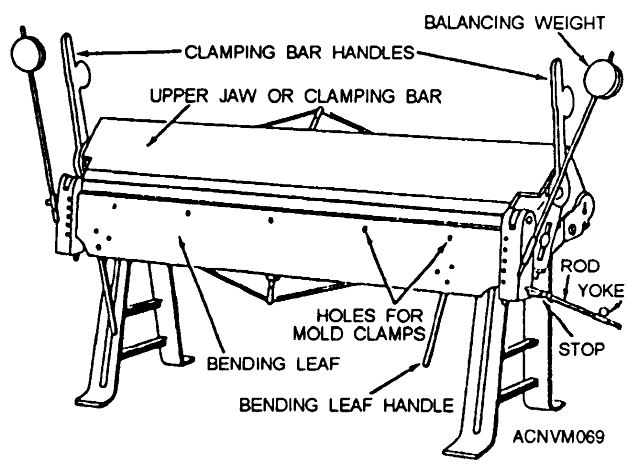


Figure 12-69.—Standard cornice brake.

1. Adjust the clamping adjustment screw for the gauge of sheet metal you are going to bend. The clamping device holds the work firmly in position, provided it is adjusted to the correct gauge. For example, if the clamping device is set for 18-gauge sheet and you are bending 24-gauge sheet, the sheet will most likely slip and the bend will be formed in the wrong position. If, on the other hand, you try to bend a thicker sheet while the machine is set for a thinner gauge, you may break the clamping handle of the machine.

2. Adjust the machine for the correct bend allowance. You can do this by moving the upper jaw to the correct position for the thickness of the metal and for the radius of the bend to be made. If the upper jaw is adjusted to the exact thickness of the metal, the bend will be sharp and will have practically no bend radius. If the jaw is set for a thickness greater than the metal, the bend will have a larger radius. If the jaw is set for a thickness less than the metal, the jaws of the machine may be sprung out of alignment and the edges of the jaws damaged.

After these two adjustments have been made, proceed as follows:

1. Scribe a line on the surface of the sheet metal where the bend is to be.

2. Raise the upper jaw with the clamping handle and insert the sheet. Bring the scribed line into a position even with the front edge of the upper jaw.

3. Clamp the sheet firmly in position. Check to make sure the scribed line is still in line with the front edge of the upper jaw.

4. Raise the lower leaf to the desired angle for the bend or flange. If you are bending soft and ductile metal such as copper, the bend will be formed to the angle to which you raised the lower leaf. If you are bending metal that has a good deal of spring to it, you will have to raise the lower leaf a few degrees higher. This will compensate for the tendency of the metal to spring back after it has been bent. The exact amount of springback that you will have to allow for will depend upon the type of metal you are bending.

5. Release the clamping device and remove the sheet from the brake.

The standard cornice brake is equipped with a stop gauge, consisting of a rod, a yoke, and a setscrew. These permit you to limit the travel of the bending leaf. This is a useful feature when you must make a lot of pieces with the same angle of bend. After you have made the first bend to the required angle, set the stop gauge so that the bending leaf will not travel beyond this angle. You can now make as many duplicate bends as are required.

The standard cornice brake is extremely useful for making single hems, double hems, lock seams, and various other shapes. As examples of how to actually use the standard cornice brake, we will consider first the forming of a single hem and then the forming of a Pittsburgh lock seam.

To form a single hem (fig. 12-23), proceed as follows:

1. Insert the sheet to be hemmed all the way into the brake. Line up the brake line with the front edge of the upper jaw.

2. Raise the lower leaf as far as it will go. If the stopgauge has been set, be sure the yoke is set far enough toward the end of the rod to permit the leaf to travel the maximum distance.

3. Lower the leaf, release the clamping device, and remove the sheet from the brake.

4. Close the left side of the brake, allowing the right side to remain open.

5. Insert the left hem edge of the sheet into the brake, holding the sheet with your left hand. Hold the sheet at an angle to the front edge of the brake.

6. Lower the upper jaw with your right hand. This action will flatten that portion of the hem that is between the jaws. The brake is thus being used as a press.

7. Raise the upper jaw and decrease the angle between the front edge of the brake and the edge of the sheet. When you decrease this angle slightly, you will bring another small portion of the hem under the jaws of the brake.

8. Continue lowering and raising the upper jaw until the entire hem has been flattened. Do the flattening operation in small sections. Do NOT attempt to flatten the entire hem in one operation. If you are working very springy metal, you may have to work the hem part of the way down with a mallet before you can finish it in the brake.

Figure 12-70 shows the procedure for making a Pittsburgh lock seam as follows:

1. Insert the sheet in the brake, making the first bend to just a little less than 90 degrees.

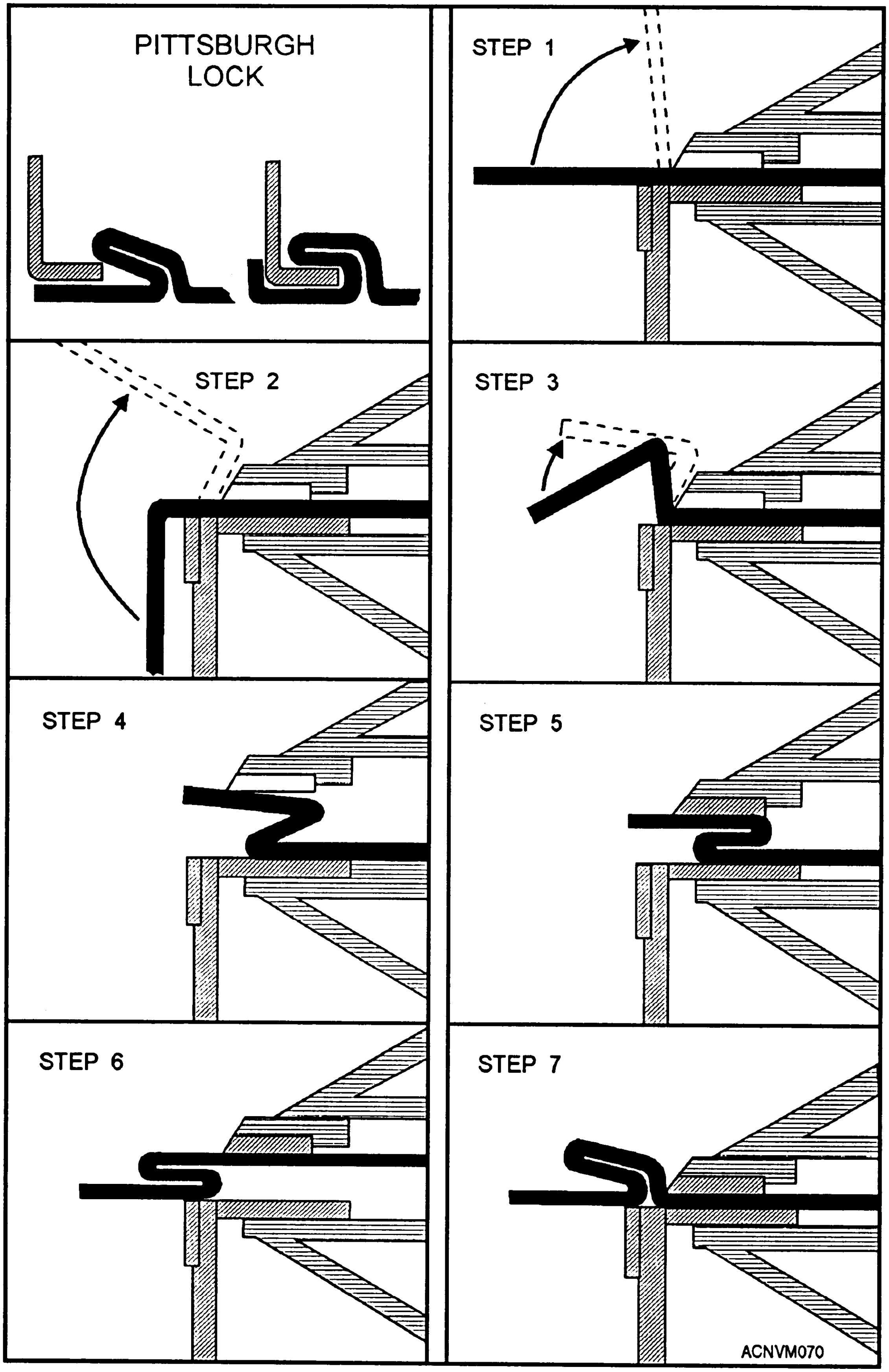


Figure 12-70.—Some steps in forming a Pittsburgh lock scam.

2. Remove the sheet. Insert the sheet, flanged edge down, all the way into the brake. Raise the lower leaf to make the maximum possible bend.

3. Remove the sheet from the brake. Turn the sheet so that the side with the 90-degree angle is up, and slide it into the brake until this angle is flush with the forward edge of the upper jaw. Raise the lower leaf through the maximum arc.

4. Raise the upper jaw and slide the sheet farther into the brake until the edge of the sheet once again is flush with the front edge of the upper jaw.

5. In the recess that will form the pocket of the seam, insert a strip of metal of the same gauge as the metal you are forming. One long strip running the length of the seam may be used, or several smaller lengths of stripping may be used. The stripping material should be about 1 inch wide.

6. Close the left-hand clamping device.

7. Use an easy up-and-down motion with the right-hand clamping device to start pressing the folds of the seam together. Complete the flattening operation in the manner described for flattening hems.

8. Turn the sheet over and line up the inner bent edge with the front edge of the upper jaw. Lower the upper jaw with the clamping handles.

9. The clamping procedure used in the preceding step will cause the formed edge of the seam to rise slightly. To bring this section back in line, work it down with a wooden mallet.

10. Bend the other portion that fits into the pocket to a 90-degree angle. Be sure the flange is the correct width.

11. Remove the strips from the pocket.

12. Insert the flanged edge into the pocket. Tap it firmly in place with a mallet. Bend the protruding edge over with a mallet, and the seam is finished.

Some brakes are equipped with molds, others are not. You will probably not have much occasion to use molds. However, they are useful for forming special shapes. The molds are fastened to the brake by means of friction clamps, in such a position that the work can be formed over them. Figure 12-71 shows sheet that is ready to be formed over a mold that is attached to a brake.

Occasionally one end of a sheet is bent at a sharper angle than the other end. The end that made the lower quality bend will then need to be adjusted. Normally this will be the right-hand end. After prolonged use on one end, that end is worn more than the other, thus requiring an adjustment.

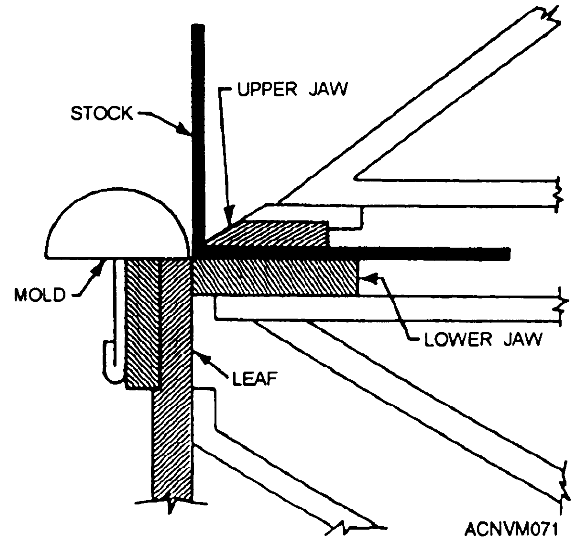


Figure 12-71.—Work ready to be formed over mold on standard cornice brake.

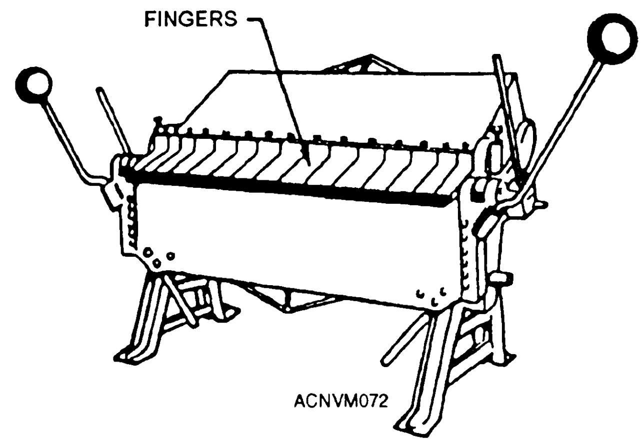


Figure 12-72.—Box and pan brake (finger brake).

The box and pan brake, normally called a finger brake, shown in figure 12-72, can do everything that the cornice brake can do and several things that the cornice brake cannot do.

The upper jaw of the finger brake consists of a series of steel fingers of varying widths, whereas the cornice brake has one long bar. The fingers are secured to the upper jaw by thumbscrews, as shown in figure 12-73.

The finger brake is particularly useful in forming boxes, pans, and other similar shapes. If these shapes were formed on a cornice brake, you would have to straighten part of the bend on one side of the box to

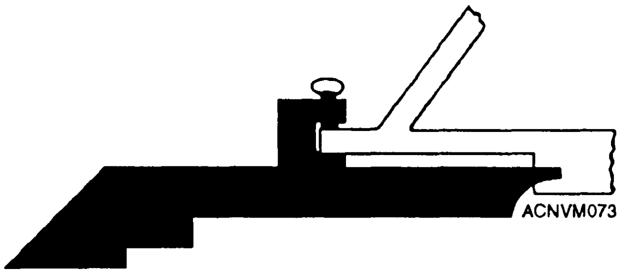


Figure 12-73.—Method of securing finger brake.

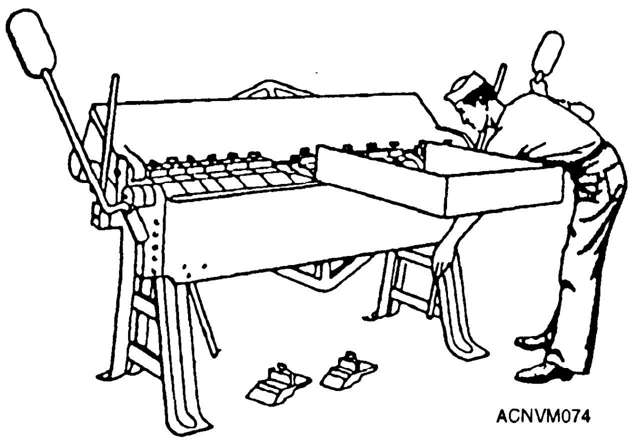


Figure 12-74.—Finger brake being used to form box (note fingers removed).

make the last bend. In the linger brake, you remove the fingers that are in the way and use only those fingers that arc required to make the bend (fig. 12-74). All fingers that are not removed for any operation must bc securely seated and fastened before the brake is used.

To maintain brakes in good condition, keep the working parts well oiled and be sure the jaws are free of rust and dirt. When operating the brakes, take care to avoid doing anything that would spring the parts, force them out of alignment, or otherwise damage them. Never use brakes for bending metal that is beyond their capacity such as thickness, shape, or type. Always bend short or small pieces in the center of the brake. Never try to bend rod, wire, strap iron, or spring steel sheets in a brake. Never hammer work while it is in a brake. If it is necessary to hammer the work, remove the work from the brake first.

Slip-Roll Forming Machines

Sheet metal can be formed into curved shapes over a pipe or a mandrel, but the slip-roll forming machine (fig. 12-75) is much easier to use and produces a more

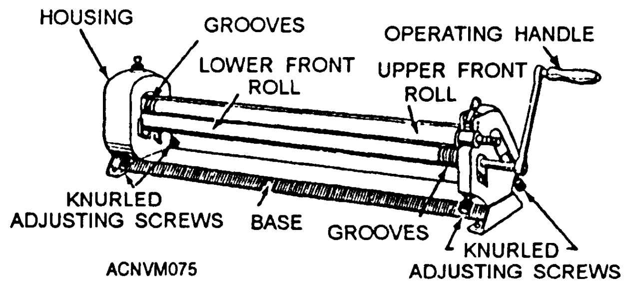


Figure 12-75.—Slip-roll forming machine.

accurate bend. Rolling machines are available in various sizes and capacities. Some are hand operated, as is the one shown in figure 12-75. Others are power operated.

The machine shown in figure 12-75 has two rollers in the front and one roller at the rear. Adjusting screws on each end of the machine control the height and angle of the rear roll and control the distance between the front rolls. By varying the adjustments, you can use the machine to form cylinders, cones, and other curved shapes. The front rolls grip the metal and pull it into the machine. Therefore, the adjustment of distance between the two front rolls is made on the basis of the thickness of the sheet.

To form a cylinder in the slip roll (fig. 12-76), follow this procedure:

1. Adjust the front rolls so that they will grip the sheet properly.

2. Adjust the rear roll to a height that is LESS THAN enough to form the desired radius of the cylinder.

3. Cheek to bc sure all three rolls are parallel.

4. Start the sheet into the space between the two front rolls. As soon as the front rolls have gripped the sheet, raise the free end of the sheet slightly.

5. Pass the entire sheet through the rolls. This will form part of the curve required for the cylinder.

6. Set the rear roll higher to form a shorter radius.

7. Rotate the sheet and pass it through the rolls again, feeding the opposite edge in first this time.

8. Continue rotating the sheet around and passing it through the rolls, each time adjusting the rear roll for a new radius, until a cylindrical shape has been formed.

9. Remove the cylinder from the slip roll. The top front roll has a device allowing you to release one end

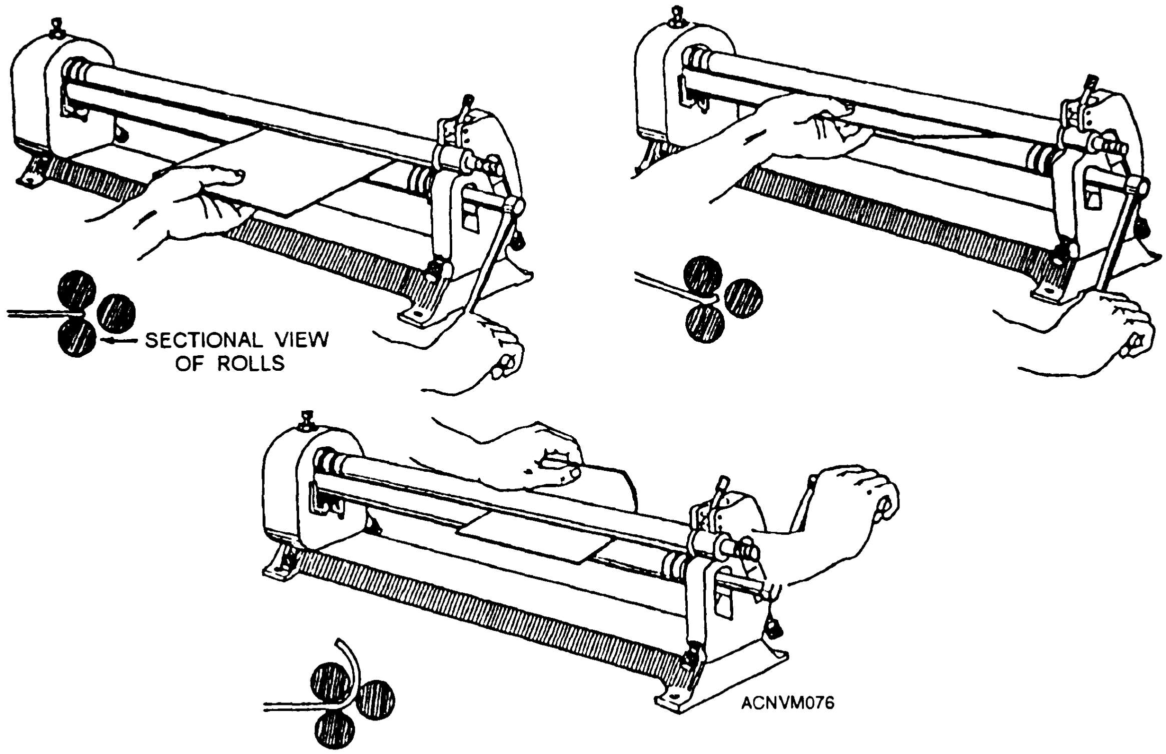


Figure 12-76.—Forming a cylinder on a slip-roll forming machine.

of the roll. Then you may raise the released end of the top front roll and slip the cylinder off.

Conical shapes can be formed by setting the back roll to an angle before running the sheet through it. Or they can be made with the rolls parallel, if you feed the sheet into the machine in such a way that the element lines of the cone pass over the rear roll in a line parallel to the rolls. The latter method of forming a cone is shown in figure 12-77.

The grooves at the end of the rolls can be used fo form circles out of wire or rod. They can also be used to roll wired edges, as shown in figure 12-78.

Metal Forming Stakes

Stakes are used to back up sheet metal for the forming of many different curves, angles, and seams in sheet metal. The stakes are available in a wide variety of shapes, some of which are shown in figure 12-79.

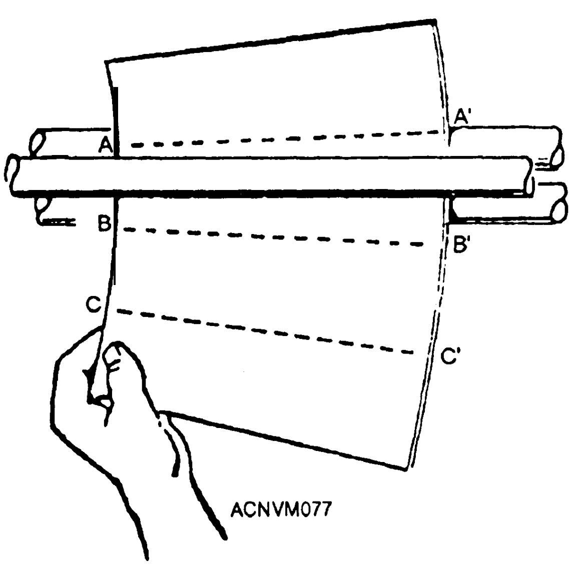


Figure 12-77.—Rolling a conical shape.

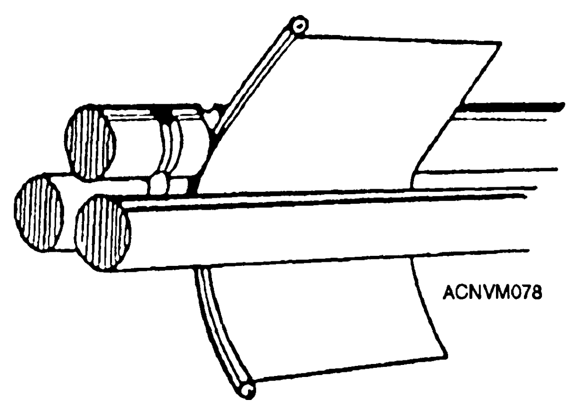


Figure 12-78.—Rolling a wired edge.

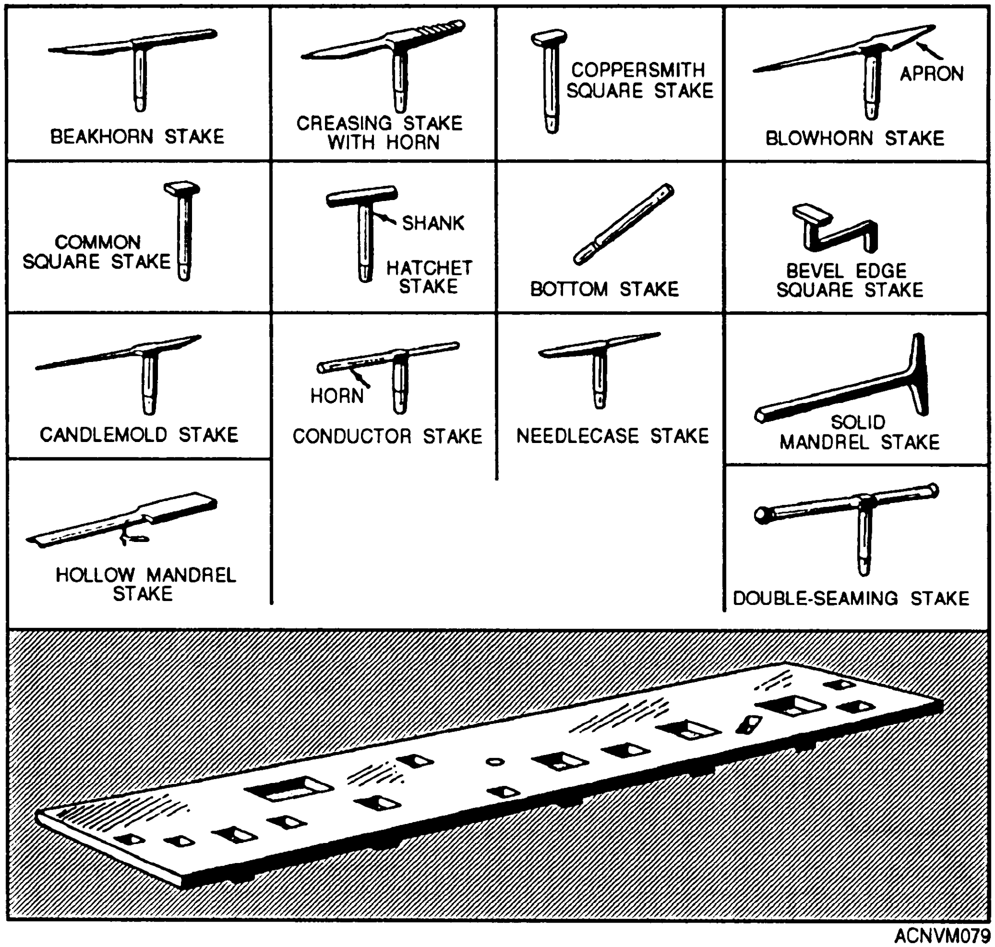


Figure 12-79.—Stakes and stake holder.

The stakes are held securely in a stake holder or stake plate (fig. 12-79) that is anchored in the workbench. The stake holder contains a variety of holes to fit a number of different types of stake shanks.

Stakes are not delicate, but they must be handled with reasonable care. They must not be used as backing when you are chiseling holes or notches in sheet metal, or when you are performing any other job that might damage the face of the stake.

The forming of a cone on a blowhorn stake is illustrated in figures 12-80 and 12-81. Figure 12-82 shows the forming of a bail (or handle) on a stake.

In forming sheet metal, you will often find it best to use a combination of several machines and some hand tools, rather than to do the whole job on any one machine. To form a cylinder with a grooved lock scam, for example, you would most likely use a brake, a slip-roll forming machine, a hand groover, and a hollow mandrel stake. The procedure for making a cylinder using these machines and tool is as follows:

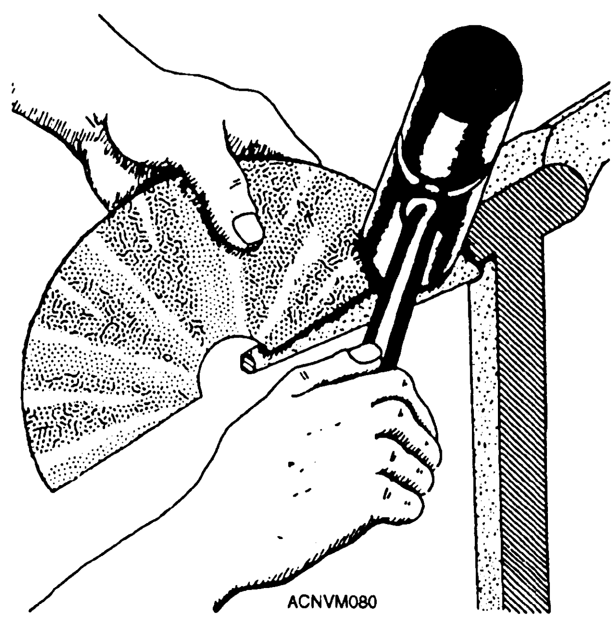


Figure 12-80.—Malleting a cone on a blowhorn stake.

1. Insert the sheet in the brake and form the first bend of the lock.

2. Rotate the sheet 180 degrees and then flip it over. Then form the bend for the other half of the lock, as shown in figure 12-83.

3. Adjust the rolls on the slip-roll forming machine, and roll the cylinder to shape.

4. Hook the seam together and slip the cylinder over a hollow mandrel stake, as shown in figure 12-84.

5. Select a hand groover of the proper size. The groover should be about 1/16 inch wider than the seam. Place the groover at one end of the seam and strike it with a hammer. Repeat the operation at the other end of the seam.

6. Complete the seam by moving the hand groover along the length of the seam and striking the head of the groover with a hammer or a mallet.

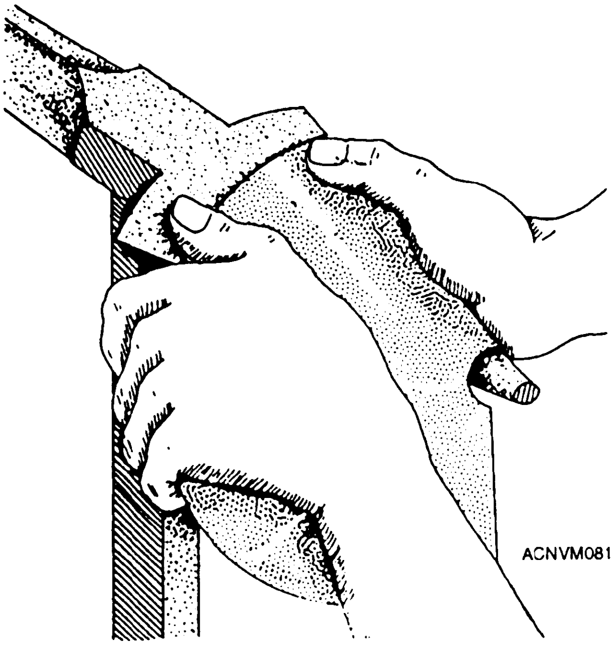


Figure 12-81.—Hand forming a cone on a blowhorn stake.

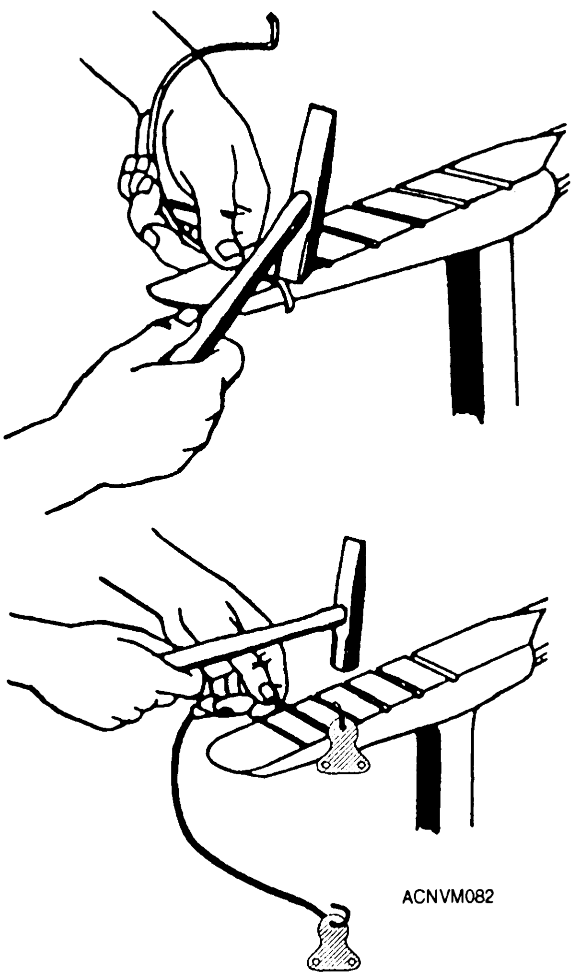


Figure 12-82.—Forming a bail on a hand stake.

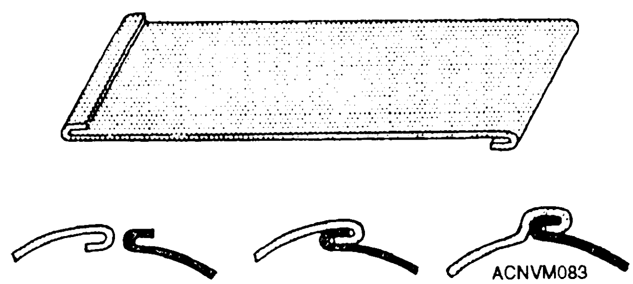


Figure 12-83.—Forming a grooved seam.

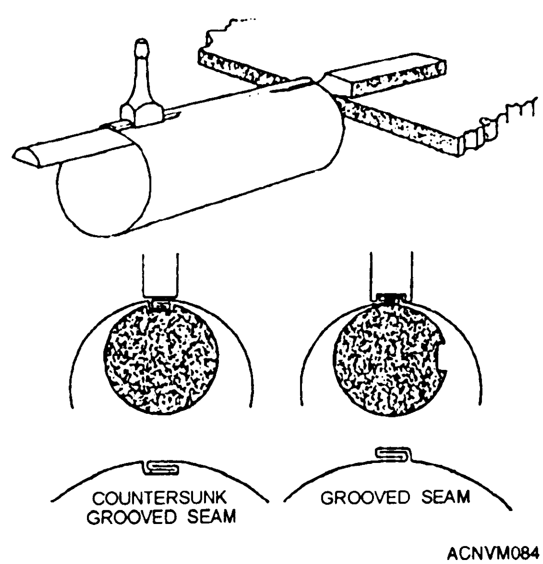


Figure 12-84.—Completing the grooved scam with a hand mandrel.

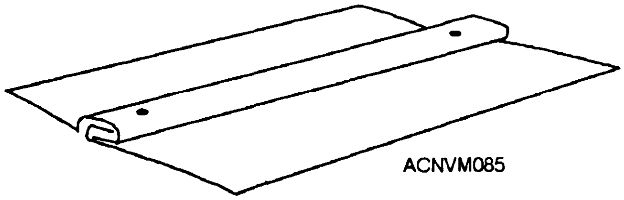


Figure 12-85.—Grooved scam locked with prick-punch indentations.

7. Secure the seam in position by making prick-punch indentations about l/2 inch in from each end of the seam, as shown in figure 12-85.

Specialized Metal Forming Machines

Large shops have rotary machines for burring, turning, wiring, beading, setting down, grooving, and crimping sheet metal. Some machines are of the combination type, having one head with several sets of rolls. A combination rotary head with burring rolls mounted is shown in figure 12-86. Sets of rolls for burring, turning, wiring, and elbow edging can be installed on this rotary head.

The burring rolls are used to turn an edge at right angles to form burrs or narrow flanges for seams and hems. A typical use of the burring rolls is for burring the disks that form the bottoms of some tanks and buckets.

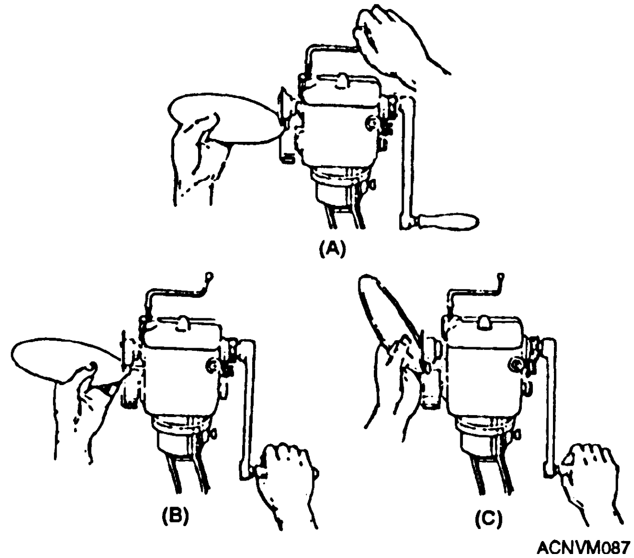


Figure 12-87.—Burring a disk.

Figure 12-87 shows the use of the burring rolls. The steps in burring a disk are as follows:

1. Adjust and align the rolls so that the inside edge of the top roll fits over the shoulder of the bottom roll. Make the clearance equal to the thickness of the metal. (Insufficient clearance will cause the top roll to act as a shear and damage the stock.)

2. Set the gauge to turn up the desired amount of metal. This is usually from l/8 inch to 3/16 inch.

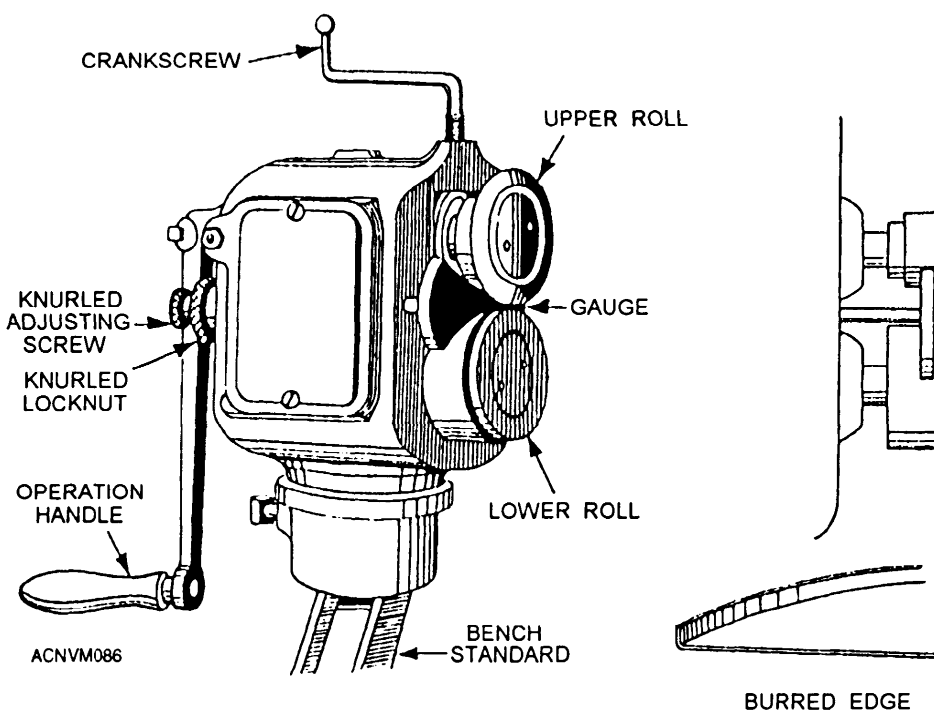


Figure 12-86.—Combination rotary machine (shown with burring rolls).

3. Place the disk in position, as shown in figure 12-87, and move the top roll down until it grips the stock and creases it slightly.

4. Crank the handle. Keep the edge of the disk tight against the gauge. Allow the disk to revolve as you turn the handle.

The first revolution should be made slowly so that you can get the burr established accurately. After you have made the first revolution, you can crank faster. Raise the disk slightly after each revolution.

Turning rolls (fig. 12-88) are used on the combination rotary machine for forming rounded flanges that are similar to burred edges except that they have radii. Several sets of turning rolls are usually provided. To use the turning rolls, be sure the rolls are properly aligned and the gauge is properly set. Then hold the edge of the metal firmly against the gauge during the first revolution.

Special wiring rolls are used to shape the metal around a wire. The edge of the metal is first turned on a brake or on the rotary turning rolls. The wiring rolls (fig. 12-89) are then used to complete the job. Wiring rolls may be used on either straight or curved edges. In making a wired edge, be sure to allow enough metal so that the wire will be completely covered; in general, the allowance for a wired edge is 1 1/2 times the diameter of the wire for thin metals, and slightly more than this for thicker metals.

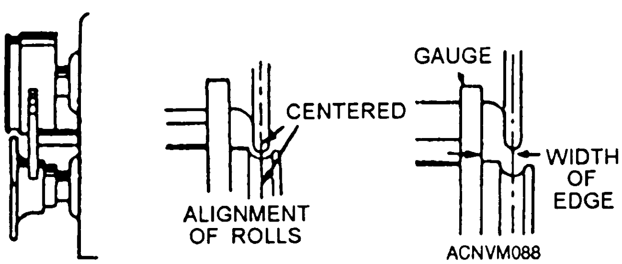


Figure 12-88.—Turning rolls for combination rotary machine.

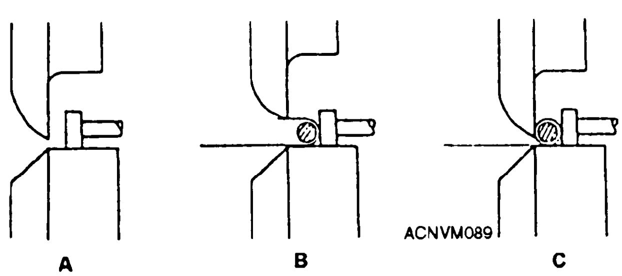


Figure 12-89.—Wiring rolls for combination rotary machine.

Elbow edging rolls are similar to turning rolls except that the elbow rolls have V-grooves in the lower rolls. Figure 12-90 shows a piece of an elbow being edged. One edge is turned in while the other is turned out. The pieces of the elbow are assembled and held together by interlocking the edges.

The setting-down machine, shown in figure 12-91, is used to close single seams. The beveled jaws grip the seam and mash it down tightly and smoothly.

Another specialized machine that you may have in your shop is the deep-throated beading machine (fig. 12-92). Several types of beading rolls may be used with

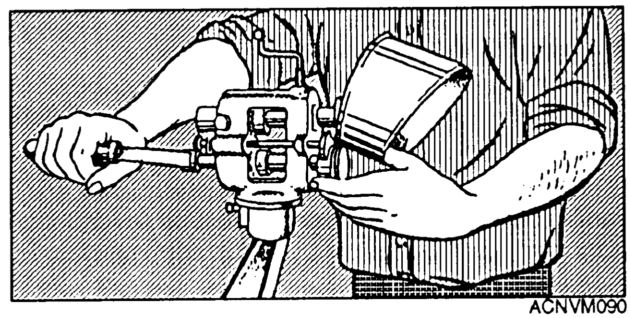


Figure 12-90.—Elbow edging rolls for combination rotary machine.

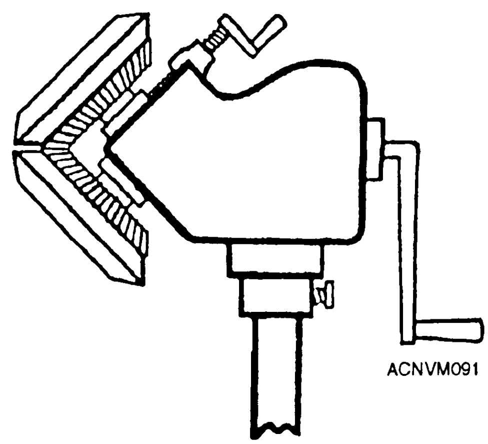


Figure 12-91.—Setting down machine.

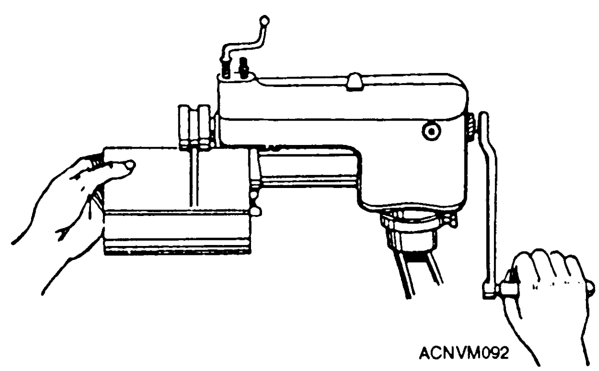


Figure 12-92.—Deep-throated beading machine.

this machine. Never allow seams to pass through the rolls of a beading machine. The machine would probably be sprung. Start the beading next to a seam and stop just before the seam is reached.

The crimping machine (fig. 12-93) is another specialized machine. It is used to corrugate the ends of a cylinder. Its diameter is reduced so that it can be fitted into another cylinder of the same diameter. Some crimping machines also have beading rolls next to the crimping rolls, as shown in the lower part of figure 12-93. The bead reinforces the cylinder and keeps it from slipping too far into the other cylinder. Be sure that you never run a riveted or grooved seam through the crimping machine.

RIVETING SHEET METAL

Once sheet metal has been cut and formed, it needs to be joined together. Most sheet metal seams are either locked or riveted. However, some are joined by brazing or welding. Lock seams are made primarily by the forming processes that have already been discussed. Welding and brazing are discussed in other chapters of this training manual. This section deals only with joining by riveting.

Rivets of different materials, sizes, and types are available. Rivets made of steel, copper, brass, and aluminum are widely used. However, rivets should be of the same material as the sheet metal they are joining.

For sheet metal work, you will probably use tinner's rivets, of the type shown in figure 12-94, more than any other kind of rivet. Tinner's rivets vary in size from the 8-ounce rivet to the 16-pound rivet. The weight of 1,000

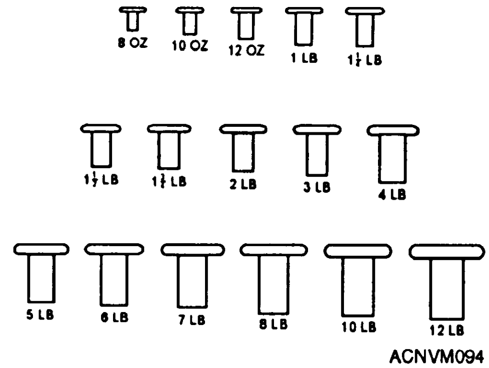


Figure 12-94.—Tinner rivets.

rivets indicates the size designation. If 1,000 rivets weigh 8 ounces, each rivet is called an 8-ounce rivet. The diameter and length of the rivets increase as the weight per 1,000 rivets increases. For example, the 8-ounce rivet has a diameter of 0.089 inch and a length of 5/32 inch, and the 12-pound rivet has a diameter of 0.259 inch and a length of l/2 inch. For special jobs that require fastening several layers of metal together, rivets with extra long shanks are used. Use table 12-2 as a guide for selecting the proper size rivets.

Rivet spacing is normally given on the blueprint or drawing. If the spacing is not indicated, space the rivets according to the service conditions the seam must withstand. For example, if the seam must be watertight, more rivets per inch are required than for a seam that does not need to be watertight. You must maintain a distance of at least 2 l/2 times the rivet diameter between the rivets and the edge of the sheet measuring from the center of the rivet holes to the edge of the sheet.

After the size and spacing of the rivets have been determined, mark the location of the centers of the rivet holes. Then pierce the holes by punching or by drilling.

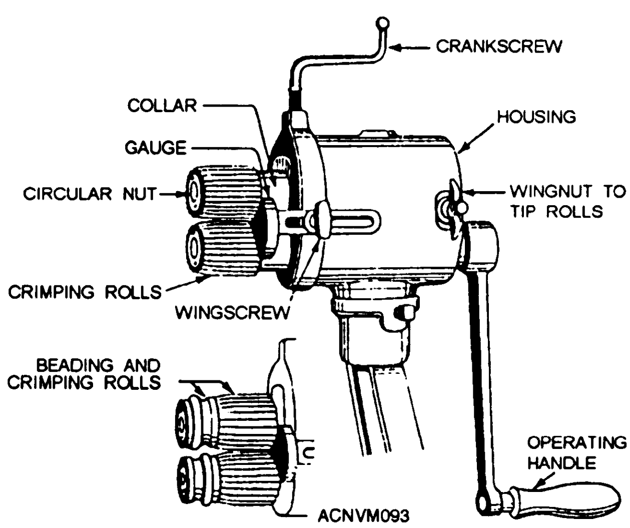


Figure 12-93.—Crimping machine.

Table 12-2.—Guide for Selecting Rivet Size for Sheet Metal Work

Gauge of sheet metal	Rivet size (weight in pounds per 1000 rivets)
26	1
24	2
22	2 l/2
20	3
18	3 l/2
16	4

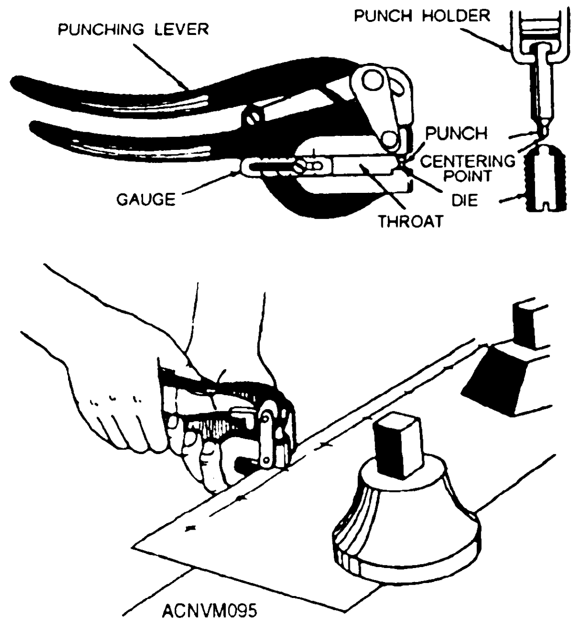


Figure 12-95.—A hand punch.

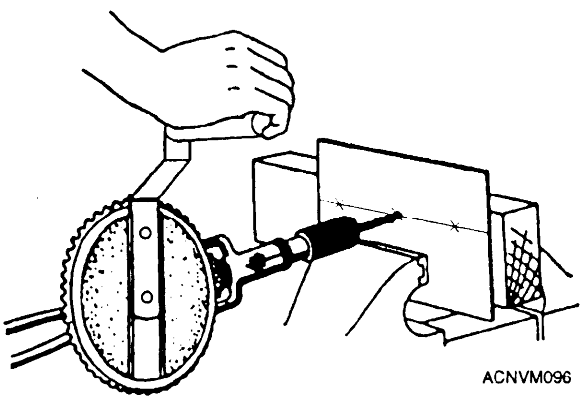


Figure 12-96.—Drilling holes with a breast drill.

If the holes are located near the edge of the sheet, a hand punch, similar to the one shown in figure 12-95, can be used to punch the holes. If the holes are farther away from the edge, you can use a deep-throated punch (either hand operated or power driven) or you can drill the holes. A breast drill used to drill holes for rivets is shown in figure 12-96. Drill the hole slightly larger than the diameter of the rivet to provide a slight clearance.

Riveting involves three operations: drawing, upsetting, and heading. These are illustrated in figure 12-97. A rivet set and a riveting hammer are used to perform these operations. The procedure for riveting sheet metal is as follows:

1. Select a rivet set that has a hole slightly larger than the diameter of the rivet.

2. Insert the rivets in the holes. Rest the sheets to be joined on a stake or on a solid bench top, with the rivet heads against the stake or bench top.

3. Draw the sheets together by placing the deep hole of the rivet set over the rivet and striking the head of the set with a riveting hammer. Use a light hammer for small rivets and a heavier hammer for larger rivets.

4. When the sheets have been properly drawn together, remove the rivet set. Strike the end of the rivet LIGHTLY with the riveting hammer. The process of spreading the end of the rivet to expand it so that it will hold the sheets together is known as upsetting the rivet. Do not strike the rivet too hard or else you might distort the metal around the rivet hole.

5. Place the heading die (dished part) of the rivet set over the upset end of the rivet and form the head. One or two hammer blows on the head of the rivet set

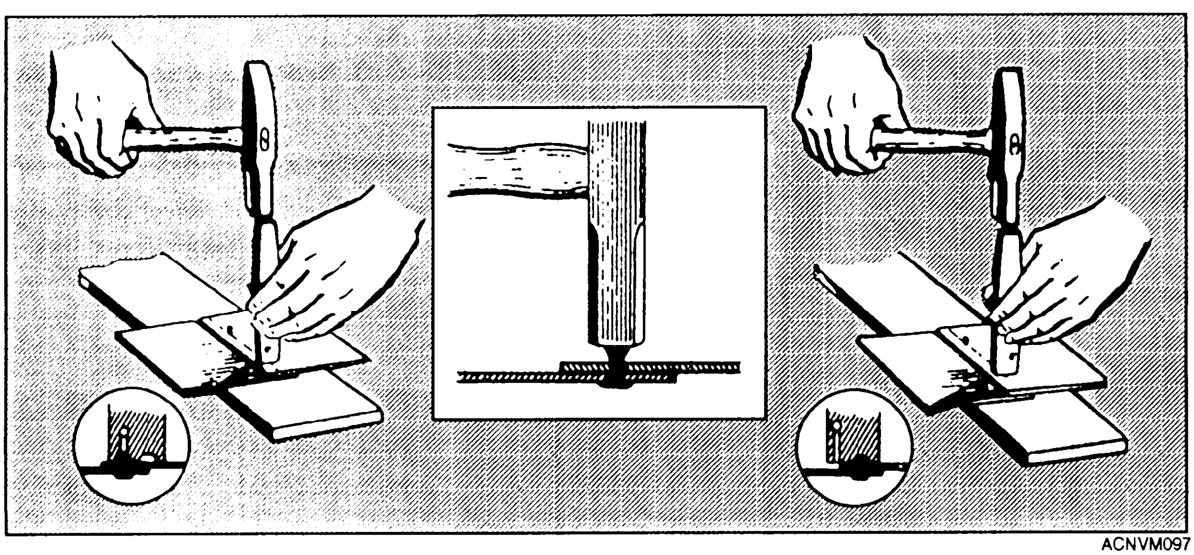


Figure 12-97.—Drawing, upsetting, and heading a rivet.

should be enough to form the head on the rivet. A correctly drawn, upset, and headed rivet is shown in the top part of figure 12-98. The lower part of this illustration shows the results of incorrect riveting procedures.

To rivet a seam when you cannot use a stake or a bench top to back up the rivet, use a hand dolly like the one in figure 12-99.

To rivet a seam of a cylinder, such as the one shown in figure 12-100, use a hollow mandrel stake or some other suitable bar as backing for the rivets. The procedure for riveting a seam in a cylinder is as follows:

1. Place rivets in the end holes, and slip the piece over the stake or bar.

2. Draw the seams together and upset the end rivets enough to hold the structure together.

3. Insert the center rivet. Draw, upset, and head this rivet.

4. Complete the seam by riveting from the center to one end and then from the center to the other end. Complete the drawing, upsetting, and heading of each rivet before you move on to the next rivet.

Besides the sheet metal rivets already discussed, you will also use the pop rivets like those shown in figure 12-101. These are high-strength, precision-made, hollow rivets assembled on a solid mandrel which forms an integral part of the rivet. They are especially useful for blind fastening, where there is either limited or no access to the reverse side of the work.

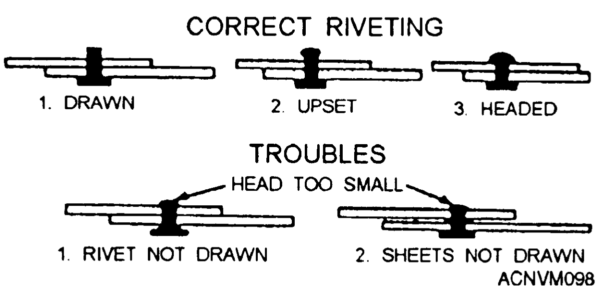


Figure 12-98.—Correct and Incorrect riveting.

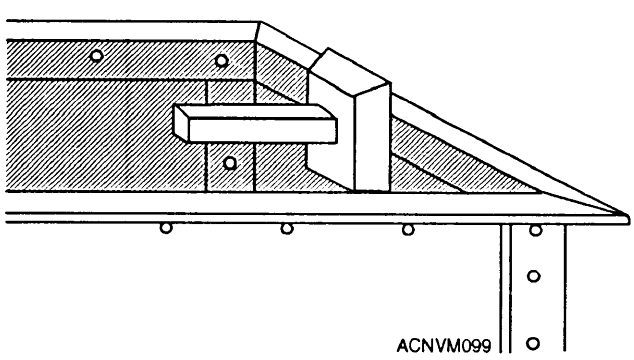


Figure 12-99.—Hand dolly used to back up rivets.

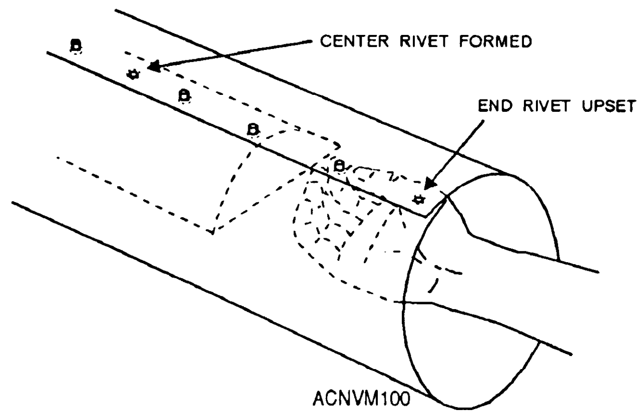


Figure 12-100.—Riveting a seam in a cylindrical section.

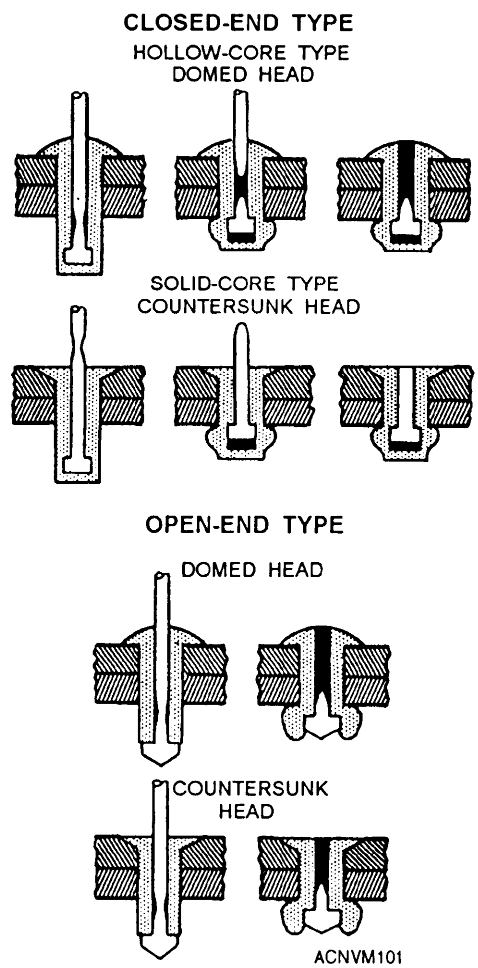


Figure 12-101.—Pop rivets.

Pop rivets are simple and easy to use. They require no complicated installations, expensive equipment, or skilled operators. Just drill a hole, insert and set the pop rivet from the same side, and high-riveting quality and strength is quickly accomplished.

There are two basic designs of pop rivets: closed end and open end. The closedend type of rivet tills the need for blind rivets, which seal as they are set. They are gas tight and liquid tight. They are installed and set from the same side just like the open-end type. As the rivet sets, a high degree of radial expansion is generated in the rivet body, providing hole-filling characteristics.

The open-end type of pop rivet resembles a hollow rivet from the outside. Because the mandrel head stays in the rivet body, the mandrel stem seals to a certain degree, but is now liquid tight.

Figure 12-102 shows two of the tools that are used for setting the pop rivets. These tools are lightweight and easy to use. For example, when using the small hand tool you need only to insert the mandrel of the rivet into the nosepiece, squeeze the handle, and the rivet is set. To operate the scissors type of tool, fully extend the lever linkage or gatelike mechanism. Then insert the rivet mandrel into the nosepiece of the tool. Place the rivet into the structure that is to be riveted. Apply firm pressure to the tool, making sure that the nosepiece remains in close contact with the rivet head. Closing of the lever linkage retracts the gripping mechanism, which in turn will withdraw the mandrel. The rivet is set when the mandrel head breaks.

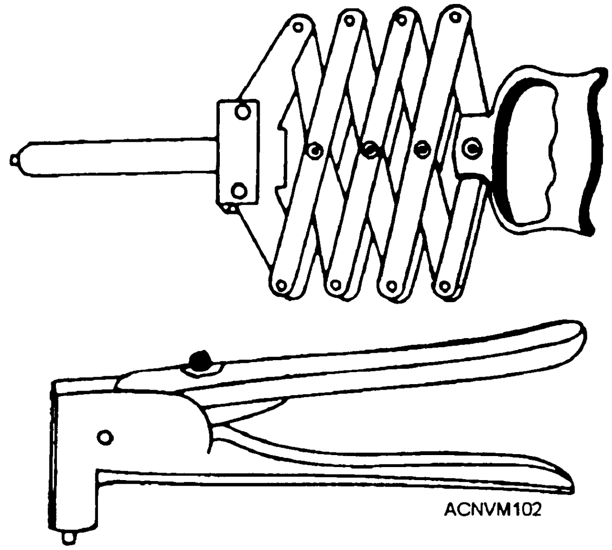


Figure 12-102.—Pop rivet tools.

Before inserting another rivet into the tool, make sure that the broken mandrel has been ejected from the tool. Fully extend the lever linkage and the mandrel will drop clear.

The scissors or expandable tool is unique because it can reach hard to get at areas and set the rivets with ease. This tool is particularly useful for installation of ventilation ducting.

Pop rivets that can be set by the tools shown in figure 12-102 are indicated by asterisks in table 12-3.

Table 12-3.—Pop rivet data

Rivet Material	Mandrel Material	Rivet Diameter (in inches)				
		3/32	7/64	l/8	5/32	3/16
		OPEN END RIVETS				
Aluminum	Aluminum	*		*	*	*
Aluminum	Steel	*		*	*	
Steel	Steel	*		*		
Monel	Steel		*	*		
Stainless	Stainless			*		
		CLOSED END RIVETS				
Aluminum	Aluminum			*	*	*
Aluminum	Steel			*		

SHEET METAL PRACTICE PROJECTS

As soon as you have learned the basic operations of laying out, cutting, forming, and joining sheet metal, you will be ready to try your hand at fabricating various objects. You should have no trouble in laying out and fabricating boxes, pans, cylinders, funnels, ells, tees, elbows, and many other sheet metal items, if you follow the procedures that were given in this chapter. It takes a lot of practice to develop a skill for sheet metal work. All your practicing should be done on scrap metal until you are good enough to turn out finished articles without wasting material.

Building a locker is a good practice project because it involves so many aspects of sheet metal layout and fabrication. The locker described here is fairly simple. You will have to develop your own plans for a more elaborate or an odd-shaped locker.

The first thing to consider in building a locker is the outside dimensions. Then decide on the thickness of metal you will use, the method of seaming, the number and location of shelves, and the type of door it will have. Plan out all of these details before you start your layout.

Figure 12-103 shows a locker that has one riveted shelf. The locker is assembled by using Pittsburgh lock seams and rivets. The door is flush to the front side and is swung on exposed hinges. A hasp and staple are used as a securing device.

Lay out the main body of the locker. Provide sufficient allowances for all of the scams and the doorjamb. One Pittsburgh lock seam is used for the main body of the locker, and another one is used for the back. The layout for the doorjamb is determined by the following factors:

1. The size of the door in its relation to the size of the locker. (The difference between the size of the door and the size of the locker controls dimension A in fig. 12-103.)

2. The thickness of the door. (This controls dimension B in fig. 12-103.)

3. The width of the stop (C in fig. 12-103). Normally the stop is about 3/8 inch to l/2 inch in width.

4. The allowance for the single hem (D in fig. 12-103). This allowance will be slightly less than that of the stop.

The next step is to lay out the notches. Square notches are used for the Pittsburgh lock scam. A combination of notches is required for the doorjamb. A is laid out at 45°, B at 90°, C at 45°, and D at 90° to the base line.

Now lay out the rivet holes for the seam and for fastening the shelf to the body of the locker. Then lay out the locker's back and shelf. Mark the locations of the rivet holes to match those on the main body of the locker. Be sure to provide for a stiffening flange on the front of the shelf when you lay out the shelf.

The next step is to lay out the door. Remember, all the layout lines will be on the inside of the sheet when it is folded up, so the actual door will be slightly larger than the layout. Make allowances for this so that the door will fit into the jamb. Also, the door must not make a tight fit. It must have clearance so that it can open and close freely. Generally, twice the thickness of the metal is allowed for this clearance.

After all the pieces have been laid out, trimmed, notched, and the rivet holes made, the next step is to form the locker to its shape. It does not matter which part of the locker you form first. The back has four 90-degree bends that will form the flanges of the Pittsburgh lock seam. Form the hem first on the shelf, then the stiffening flange. The tabs for riveting the shelf to the main body of the locker may be bent either up or down.

Form the pocket for the Pittsburgh lock seam on the main body of the locker. Then form the jamb on the opposite edge of the sheet. Follow these procedures for bending the jamb:

1. Transfer the lines of the jamb (indicated by X in fig. 12-103) to the reverse side of the sheet.

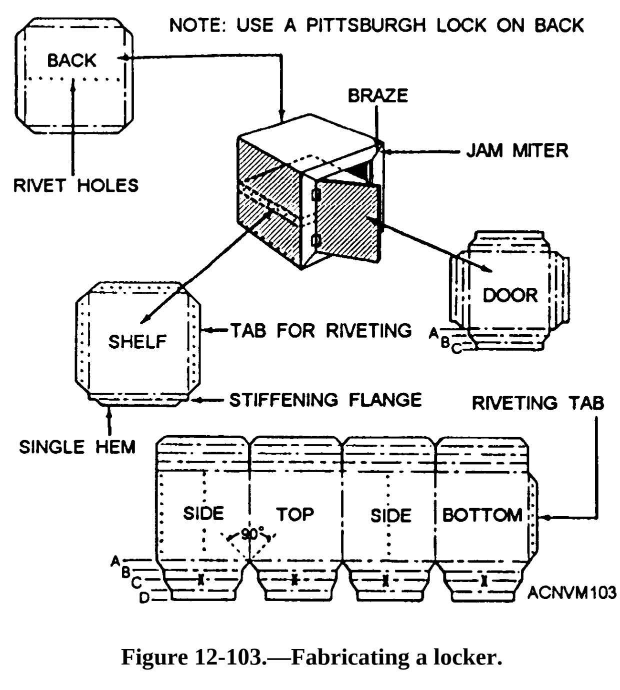


Figure 12-103.—Fabricating a locker.

2. Insert the sheet all the way into the brake, with the reverse side up and the layout lines down.

3. Completely form the single hem.

4. Remove the sheet from the brake and turn it over so that the layout lines are up. Reinsert the sheet in the brake and form the flange for the stop (C in fig. 12-103).

5. Remove the sheet again. This time, with the layout lines down, insert the sheet in the brake and form the depth of the jamb (B in fig. 12-103).

6. Slide the sheet out to the next line and form A (fig. 12-103).

The next step is to form the sides, top, and bottom of the locker. Start with the sheet all the way in the brake. Form the tab for riveting first, then slide the sheet out to the next brake line to form the bottom. Form one side, the top, and then the other side in the same way.

Form the door by making the single hem C all the way around. Then form flanges B and A on each section of the door.

Assemble the locker by riveting the side seam. Then install the back with the Pittsburgh lock seam. Solder or braze the jamb miters at the front of the locker and also at the corners of the door. (These miters and corners should NOT be welded. The extreme heat of welding will cause severe distortion of the structure.) File off any excess metal, and clean the soldered or brazed areas thoroughly to remove all traces of the flux.

Fit the door in the jamb. There should be enough clearance all around so that the door fits loosely. Insert thin strips of metal between the door and the jamb on all four sides to equalize the clearances. Then using either rivets or screws, fasten the hinges to the locker and to the door. Install a knob or handle on the door so that you can open and close it. The locker is completed.

MAINTENANCE AND REPAIR OF SHEET METAL STRUCTURES

The ventilation ducts and other sheet metal structures aboard ship are maintained and repaired by HTs. Such structures may require the fabricating of replacement parts, the patching of existing parts, and the overhauling of closures and other fittings. You will most likely repair or replace insulation and lagging, periodically clean the ventilation ducts, and do various other jobs.

In general, the principles of layout and fabrication that apply to making new objects also apply to making replacement parts. To replace a section of ventilation system ductwork, for example, you would make up a new section according to the layout and fabrication procedures described in the previous paragraphs.

Sometimes you will be able to patch ductwork rather than to manufacture a new section. Patches are installed by welding, brazing, or using sheet metal screws or pop rivets.

Many ducts throughout the ship are insulated to reduce the amount of heat and noise transferred between the duct and the surrounding spaces. When insulation and lagging are removed for the repair or replacement of a section, the area must be reinsulated and relagged.

Ducts are insulated by applying the specified insulating material, and tying the insulating material in place with galvanized steel wire or fibrous glass thread. The insulating material is then covered with lagging. The lagging is fastened with an adhesive.

Before applying insulation to bulkheads, inspect the area carefully and be sure that the protective coating of the metal is intact and that the surface is free of any oil, grease, or dirt. Insulation may be applied to bulkheads by one of two approved methods. In the first method, the studs are laid out and welded to the bulkhead and the insulation is then pushed onto the studs. In the second method, each piece of insulation is fitted into its proper place and the location of the studs is marked by punching through the insulation. The insulation is removed and the studs are welded to the marked spots. The insulation is then put on over the studs.

Detailed information concerning approved insulating materials and approved methods of using them may be obtained from NAVSEA plans and from *NSTM,* chapter 635.

SUMMARY

We have discussed the tools and procedures for sheet metal layout and fabrication. Study your pattern development methods and refer back to them while you are laying out your patterns. As with anything you do, experience will help you become more efficient in your work. However, accuracy is one of your major concerns. Double check your layout before you start making your cuts and bends. A little extra effort will save time and material.

CHAPTER 13

STRUCTURAL STEEL FABRICATION

LEARNING OBJECTIVES

Upon completion of this chapter you will be able to do the following:

- Describe some of the tools and equipment generally found in the shipfitter shop, and their use and operation.
- Describe the safety procedures and equipment used in structural steel fabrication.
- Describe the basic sections of a blueprint and interpret a blueprint using standard symbology.
- Identify the shapes and sizes of structural steel shapes.
- Understand the requirements for making repairs to ships' hulls and general structures.

INTRODUCTION

Structural steel repair is the broadest and most frequent type of repair done by HTs. It is the foundation upon which you will build your knowledge for the rest of the rate. In structural steel repair, you will use all the knowledge and skills learned in the preceding chapters. As a shipfitter working in the shipfitter shop or working in the HT shop on smaller ships, you will be called upon to weld, braze, cut metals, bend pipe, prep weld joints, fabricate general shipboard structures, and a host of other related tasks. This chapter will cover the basics of structural steel fabrication from reading and interpreting blueprints to making cuts in ships' hulls.

SAFETY

With any job you are tasked with, whether as a worker or as supervisor, safety should be your number one priority. As a shipfitter, you will be performing numerous tasks involving the operation of large equipment, working with heavy metal sections, and using heat producing equipment. Each of these jobs present unique safety considerations before, during, and after the job is complete. This section will address some of the common safety considerations for working in restricted access spaces and the handling and storage of structural steel. Other safety items for welding, cutting, brazing, and compressed gas storage have been covered in preceding chapters and will not be repeated in this chapter. Specific safety requirements for a specific type of machinery will be covered in the section of this chapter discussing that specific machine.

RESTRICTED ACCESS SPACES

As a shipfitter, you will be tasked to work in restricted access spaces such as voids and tanks. A restricted space is defined as a space with only one exit or where equipment or structural barriers prevent easy exit or entrance. When working in these spaces, there are several safety precautions to keep in mind to prevent injury or death of personnel. These safety precautions are as follows:

- Ensure the space has been certified gas free, if the space is unmanned and ventilation is nonexistent or the space is used to store hazardous material.
- Ensure proper ventilation is available to permit work in restricted access spaces. When

sufficient ventilation cannot be obtained without blocking the means of access, personnel in the confined space shall be protected by airline hose mask.

- Leave gas cylinders and heavy welding or cutting equipment outside the restricted access space.

- Station a watch outside the space to observe all workers at all times and to render assistance in an emergency.

- If entering a restricted access space through a manhole or other small opening, means shall be provided to remove personnel quickly in case of an emergency.

- If the access fitting to a restricted access space is remotely controlled, ensure measures are taken to secure and tagout (with a DANGER tag) remote control equipment to avoid accidental closing of the doors.

- If work in a restricted access space is suspended for any substantial period of time, remove all welding and torch leads, air hoses, and electrical cords from the space.

- When using gas-welding equipment, always close the torch valves and the gas supply to the torch, when not actually in use, to eliminate the possibility of the gas escaping through leaks or improperly closed valves. Torches shall remain in restricted spaces only for the period necessary to perform the required hot work.

STRUCTURAL STEEL STORAGE

The safe handling and stowage of structural steel shapes and plate has become a major safety concern in the past few years. There have been numerous mishaps on board ships and shore facilities involving the incorrect handling of steel shapes and plates. These incidents have caused loss of property, limb, and even life. One incident, on board a tender, caused the death of three people because of improperly stored steel plate. Always remember plate steel is extremely heavy. A 4 ft by 8 ft sheet of steel plate l/8 inch thick will weigh over 160 pounds. Multiply this by several sheets and not even the strongest man would be able to control its movement. Safety precautions for the storage and handling of structural steel plate are as follows:

—Store metal plates and shapes in properly designed and constructed racks. Plate metal should never be stored, standing on end, outside of storage racks.

—Storage racks will be orientated forward to aft, never port to starboard. Due to ships greater port to starboard movement at sea, plate stored in a port to starboard orientation could slide out of the rack and cause serious damage to material, equipment, or personnel.

—Ensure all storage racks have properly constructed doors or retaining devices to properly secure metal in the storage rack.

—Metal stored outside of racks should be stored flat on the deck. The metal should be secured with retaining devices to prevent the port to starboard or forward to aft movement of the material while at sea. The retaining device should be of proper strength and allow for the removal of an individual piece of metal without affecting the rest.

—When handling any kind of metal, wear gloves to protect your hands and prevent slipping.

—Use proper lifting procedures to prevent back injuries.

—To prevent injury from falling metal, never position any part of your body under a piece of metal being moved.

—If the material being moved is too heavy, get help before attempting to move the piece by yourself.

The attitude of metal workers towards safety is an important ingredient in a successful shop safety program. Aside from personnel injury, shop efficiency is lowered by damaged equipment and productivity is decreased. Be aware of all shop safety requirements. To be effective, the shop safety program must require 100 percent participation of all personnel.

BLUEPRINT READING

As an HT working in the shipfitter shop or any other shop manned with HTs, you will be required to use and interpret blueprints on a daily basis. You will also be required to make simple drawings and diagrams for planning or fabricating purposes. Having a good working knowledge of blueprints and drawings will greatly improve your productivity and efficiency.

Correctly interpreting blueprints will reduce mistakes and rework of jobs due to the wrong dimensions or improperly placed components.

This section will discuss the organization, lines and symbols, dimensions, and scales found on a blueprint. Views, detail drawings, and assembly prints will aid you in your job and will also be discussed in this chapter. Welding and NDT symbols, though a part of blueprints, have already been discussed in previous chapters. It isn't the intent of this section on blueprint reading to make you an expert on blueprints. But you should have the basic knowledge of blueprints to enable you to function in a shop environment until you gain further skill in reading blueprints. To gain further knowledge in blueprint reading, you should refer to *Blueprint Reading and Sketching,* NAVEDTRA 10077.

NOTE: Only standard blueprints will be discussed in this section.

PARTS OF A BLUEPRINT

Blueprints are broken down into numerous sections. Each section serves a different purpose. Understanding the purpose and information in each block of a blueprint will greatly increase your ability to use, understand, and interpret blueprints. Depending on their purpose, blueprints vary in size, format, and content. Only the title block, revision block, application block, zone numbers, and the bill of materials will be discussed in this section.

Title Block

The title block is usually located in the lower right-hand corner of all blueprints. This block contains the drawing number, the name of the part or assembly that the blueprint represents, and all information required to identify the part or assembly. The title block also includes the name and address of the government agency or organization preparing the drawing, scale, drafting record, authentication, and date the blueprint was approved (fig. 13-1).

Revision Block

The revision block, shown in figure 13-2, is in the upper right-hand corner of the print and is used for the recording of all changes (revisions) to a print. It could be quite detailed depending on the frequency of changes

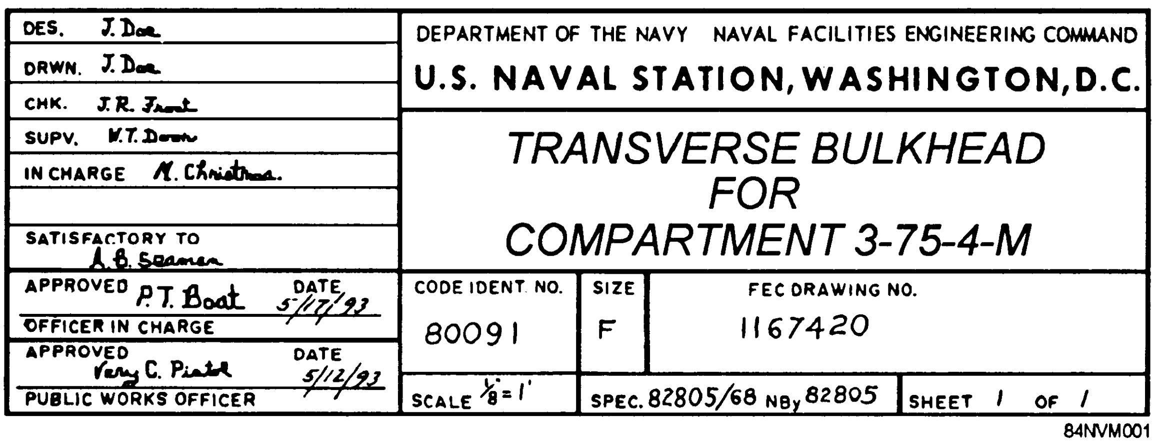


Figure 13-1.—Blueprint title block.

84NVM002		REVISIONS					
ZONE	REV.	DESCRIPTION	BY	CONTR. DATE	CONTR. APPO.	USN DATE	USN APPO.
2 VAR 1 3 3	A	1. CORRECTED ASI DWG. NO. IN GEN NOTE NO. 14 2. DELETED ALL REFERENCES TO P/L NUMBERS 3. DELETED LIST OF REFERENCES 4. ALT. REF. NO. IN GEN . NOTE NO. 5 5. ALT GEN. NOTE NO. 8	CG	12/23/ 69	888	1/9/70	[illegible]
3 VAR	B	1. ALT. ROD LENGTH & "X" DIMENSION FOR HGR. NO. S8-H1 2. HEAVIED UP LIGHT AREAS	[illegible]	1/27/ 70	888	PRC DESIGN	

Figure 13-2.—Revision block.

made to a print. All revisions are noted in this block and are dated and identified by a letter and a brief description of the revision. Other information contained in the revision block is the name of the person who made the change and when the change was made. The revision block should always be reviewed prior to beginning a job to ensure you are familiar with the latest change. The most recent revision is noted in the title block

Application Block

The application block, located near the title block, identifies directly or by reference the larger units of which the detailed part of the assembly on the drawing forms a component. On most prints used by HTs, the application block will list the class of ship and those ships in that class that are equipped with that item. But you will also use prints that are generic to a class of ship (applicable to all ships of that class). These prints usually pertain to hull structures and other associated structures. A sample of an application block is shown in figure 13-3.

Zone Numbers

Zone numbers on blueprints and machine drawings serve the same purpose as the numbers and letters printed on borders of maps to help you locate a particular point. Zone numbers on blueprints are located on the top, bottom, and side margins of the print. The draftsman uses a combination of numbers and letters along the margins to identify the zone numbers. To locate a particular point, use the following steps:

1. Locate the given zone numbers for a given item on the top, bottom, and side margins of the blueprint.

2. Follow an imaginary line from each zone number toward the opposite side.

3. The point where the two lines cross gives the exact location of the particular point and a general location of the item.

DE - 101	A.C. FDN. # 1
DE - 102	A.C. FDN. # 2
DE - 103	A.C. FDN. # 3
DE - 104	A.C. FDN. # 4
DE - 105	A.C. FDN. # 5
NEXT ASS'Y	USED ON
84NVM003 APPLICATION	

Figure 13-3.—Application block.

Bill of Material

The bill of material is a list of parts or materials required by or used on the print. It is probably the most used section on a blueprint. Not only does the bill of material list all the material used, but it also gives a description of that item, the quantity of material used or required, material weight or thickness, MILSPECs or commercial standards to which that item must conform to, and other applicable information. Figure 13-4 shows an example of a bill of material.

Each item in the drawing on a blueprint is identified with a number designation or a combination of letter and numbers. An example of an item number for a piece of pipe between two fittings would be P-3 and the fittings F-1 and F-2. In this example, the letter P means pipe, and the number 3 identifies that particular pipe. The letter F means fitting and the numbers 1 and 2 identify the particular fittings. Next, locate the item number P-3 on the bill of material. You would find out that particular piece of pipe is 2-inch, schedule 40, carbon steel pipe, conforming to an applicable MILSPEC.

It is always important that you properly locate an item on a blueprint and read the bill of material to ensure that you know what materials you will be working with. You should never substitute material listed on a blueprint without first obtaining approval from competent authority. Also, by reading the bill of material, you will be able to determine the proper welding or brazing process to join the base metals.

LINES AND SYMBOLS

To properly read blueprints, you must be familiar with the lines and symbols used on a blueprint. These lines and symbols convey important information to the HT. Lines and symbols will also keep the reader from misinterpreting information shown on the blueprint. Various types of lines are used to show different objects and their positions. Commonly used lines and symbols are shown in figure 13-5 and are listed as follows:

— Visible lines are heavy unbroken lines.

—Hidden lines are medium lines with short, evenly spaced dashes.

84NVM004

BILL OF MATERIALS

ITEM NO.	DESCRIPTION	UNIT	ASSEMBLY OR FSN NO.	QUANTITIES TROP	QUANTITIES NORTH
3 - 1	LIGHTING CIRCUIT - NAVFAC DWG. NO. 203414	EA	3016	3	3
3 - 2	POWER BUS, 100A - NAVFAC DWG. NO. 304131	EA	3047	1	1
3 - 3	RECEPTACLE CKT - NAVFAC DWG. NO. 303660	EA	3019	2	2
3 - 4	BOX, RECEPTACLE W/CLAMP FOR NONMETALLIC SHEATH WIRE	EA	5325-102-604	3	3
3 - 5	LAMP ELECTRIC, MED. BASE. INSIDE FROSTED, 200W, 120V	EA	6240-180-314	60	60
3 - 6	PLUG ATTACHMENT, 3 WIRE, 15 AMP, 125 V	EA	5935-102-309	10	10
3 - 7	PLATE : BRASS, DUPLEX RECEPTACLE	EA	3325-800-101	5	5
3 - 8	RECEPTACLE, DUPLEX, 3 WIRE, 15 AMP, 125 V	EA	5325-100-102	5	5
3 - 9	ROD, GROUND, 3/4" X 10'- 0"	EA	5306-200-180	12	12
3 - 10	WIRE, NO. 2 1/C STRANDED, HARD DRAWN, BARE	LB	6143-134-200	52	52
3 - 11	SWITCH SAFETY, 2 P, ST 30 AMP, 250 V, PLUS FUSE	EA	5930-142-401	2	2
3 - 12	CLAMP GROUND ROD	EA	5209-100-101	13	13
3 - 13	SWITCH, SAFETY, 200 AMP, 250 V, 3 P	EA	5930-201-903	1	1
3 - 14	FUSE, RENEWABLE, 200 AMP, 250V	EA	5920-100-000	6	6
3 - 15	LINK FUSE, 200 AMP, 250 V	EA	5920-100-001	6	6
	FUSE PLUG, 30 AMP, 125 V	EA	5920-100-102	12	12

Figure 13-4.—Bill of material.

—Center lines are thin lines made up of long and short dashes, alternately spaced and consistent in length.

—Dimension lines are thin lines ending with arrowheads at each end.

—Leader lines are thin lines ending with an arrowhead or a dot at one end.

— A phantom line is a medium series of one long dash and two short dashes, evenly spaced and ending with a long dash.

— A stitch line is a medium series of short dashes, evenly spaced and labeled.

—Thin solid ruled lines with freehand zig-zag indicate a break (long).

—Thick solid freehand zig-zag lines indicate a break (short).

—Thick solid lines with arrowheads indicate the direction in which a section or plane is viewed or taken.

DIMENSIONS

Dimensions on blueprints are used to indicate sizes and locations. Since items shown on a blueprint are drawn to a scale, the actual size shown on paper will be larger or smaller than the true item. Therefore, the actual dimensions are indicated by whole numbers, fractions, decimals, or angles. You will use the dimensions on prints to accurately locate, lay out, and manufacture an item to true size as shown on a blueprint. Dimensions are also used to outline shapes of objects on prints. The six major kinds of dimensions arc as follows (fig. 13-6):

- Conventional dimensions give the overall dimensions (length, width, and height) of an object.

- Base line dimensions give all the dimensions of an object and are indicated in relation to a designated base line or center line. Base line dimension is used to mark precision parts on a drawing.

- Chamfer and bevel dimensions indicate linear and angular dimensions of the edges of an object.

- Radius and arc dimensions indicate circular or rounded portions of an object.

LINE STANDARDS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
CENTER LINES		THIN LINES MADE UP OF LONG AND SHORT DASHES ALTERNATELY SPACED AND CONSISTENT IN LENGTH USED TO INDICATE SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS	
VISIBLE LINES		HEAVY UNBROKEN LINES USED TO INDICATE VISIBLE EDGES OF AN OBJECT	
HIDDEN LINES		MEDIUM LINES WITH SHORT EVENLY SPACED DASHES USED TO INDICATE CONCEALED EDGES	
EXTENSION LINES		THIN UNBROKEN LINES USED TO INDICATE EXTENT OF DIMENSIONS	
DIMENSION LINES		THIN LINES TERMINATED WITH ARROW HEADS AT EACH END USED TO INDICATE DISTANCE MEASURED	
LEADER		THIN LINE TERMINATED WITH ARROW-HEAD OR DOT AT ONE END USED TO INDICATE A PART, DIMENSION OR OTHER REFERENCE	1/4 x 20 UNC-28 THD.
BREAK (LONG)		THIN, SOLID RULED LINES WITH FREE-HAND ZIG-ZAGS USED TO REDUCE SIZE OF DRAWING REQUIRED TO DELINEATE OBJECT AND REDUCE DETAIL	
BREAK (SHORT)		THICK, SOLID FREE HAND LINES USED TO INDICATE A SHORT BREAK	
CUTTING OR VIEWING PLANE VIEWING PLANE OPTIONAL		THICK BOLD LINES WITH ARROWHEADS TO INDICATE DIRECTION IN WHICH SECTION OR PLANE IS VIEWED OR TAKEN	
CUTTING PLANE FOR COMPLEX OR OFFSET VIEWS		THICK SHORT DASHES USED TO SHOW OFFSET WITH ARROWHEADS TO SHOW DIRECTION VIEWED	

84NVM005

Figure 13-5.—Line standards.

- Drilled hole dimensions are shown on a print by a leader and a note. The leader lists drill size, the number of holes to be drilled, and the depth of the hole to be drilled. If depth is not given, the hole is drilled completely through the object.

- Tolerance dimensions represent the amount by which a dimension can vary and remain within specification. Tolerances are indicated by a plus (+) or a minus (-) symbol.

SCALE

Most blueprints are drawn to scale for the simple fact that it would be impossible to draw a full-size representation of an item on paper due to the size of many items. Large objects are reduced and smaller items enlarged to fit standard sized paper. The scale of a blueprint is indicated in the title block. It indicates the size of the drawing as compared to the actual size of the object. The scale may be shown as 1" = 2", 1"= 12", ½"= 1', and so on. It may also be indicated as full size, one-half size, one-fourth size, and so on.

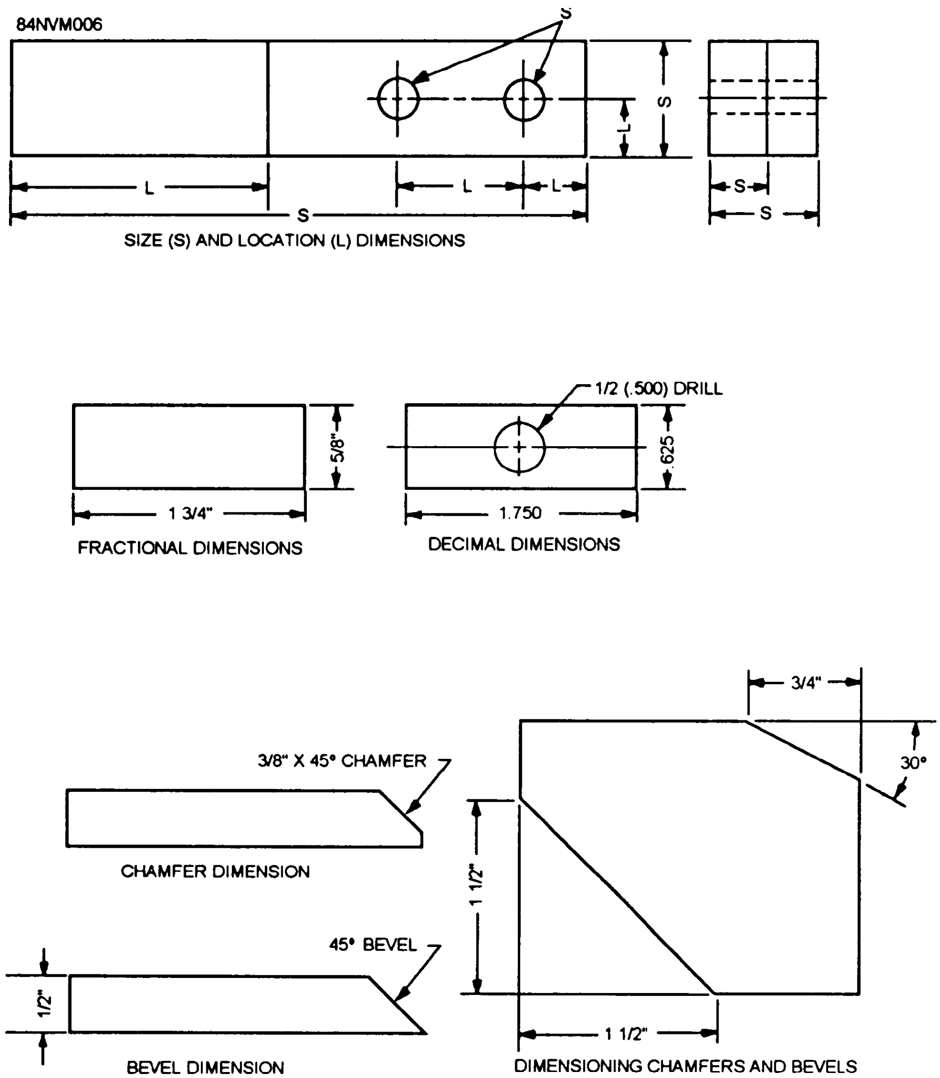


Figure 13-6.—Various dimensions that are shown on blueprints.

Remember: NEVER MEASURE A DRAWING. USE DIMENSIONS. Why? Because the print may have been reduced in size from the original drawing, or you might not take the scale of the drawing into consideration. Then too, paper stretches and shrinks as humidity changes, thus introducing perhaps the greatest source of error in actually taking a measurement by laying a rule on the print itself. Play it safe and read the dimensions on the drawing; they always remain the same.

ADDITIONAL GUIDES

Blueprints and drawings are made so that objects to be fabricated or repaired can easily be visualized by the reader. Views, detailed drawings, and assembly prints are used as guides to assist you in the fabrication and repair of structures and systems.

Views

There are numerous ways to project and draw an object, each with its own special characteristics and functions. On drawings and prints, a view is technically known as a projection. Orthographic and sectional views are the most commonly used, and will be discussed in the following paragraphs. This section will also discuss phantom, exploded, and development views.

ORTHOGRAPHIC VIEWS.—As an HT, you will be most concerned with a three-view orthographic projection, which shows all sides of an object. The sides, top, and bottom of the object are drawn in detail, but appear to be transparent, as shown in figure 13-7. Any features of an object that are hidden from view on any of the three projections are shown using hidden lines. The transparent effect of an orthographic view allows you to see exactly how the various components of an item fit together.

SECTIONAL VIEWS.—Sectional views are used to give a clearer view of the interior or hidden features of an object. These hidden features usually cannot be clearly observed in conventional outside views. Sectional views are made as if they were a cutaway part of the object along a given cutting plane. Full, half, and offset sectional views are the most commonly used on drawings. Figure 13-8 shows full- and half-sectional views. Notice the cutting plane line as shown by the letter AA. It shows where the imaginary cut has been made.

Full-Sectional View.—A full section (also known as a cross section) is shown as if the object were cut completely through along a certain plane. This type of view is usually used where hidden features vary throughout the object.

Half-Sectional View.—A half-sectional view is used when the object to be shown is symmetrical in both inside and outside details. It is assumed that the details shown in the uncut section are identical to the cutaway section. Only a quarter of the object is sectioned; the other quarter is shown as a standard view. The term *half section* means that only half of a full section is cut away. Again notice the cutting plane as shown in figure 13-8.

Offset Section.—An offset section is a section view that has the cutting plane changing directions. The cutting view plane changes direction to pass through features that are important to show. Figure 13-9 shows

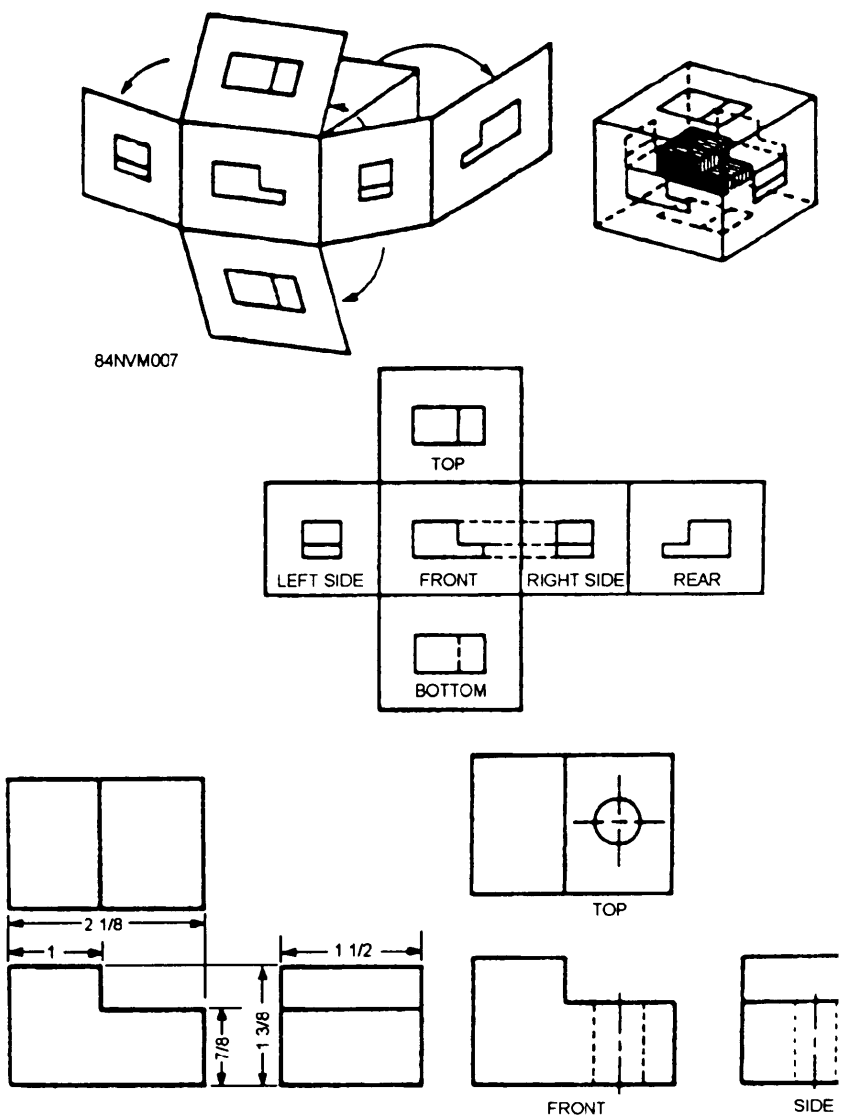


Figure 13-7.—Orthographic projections.

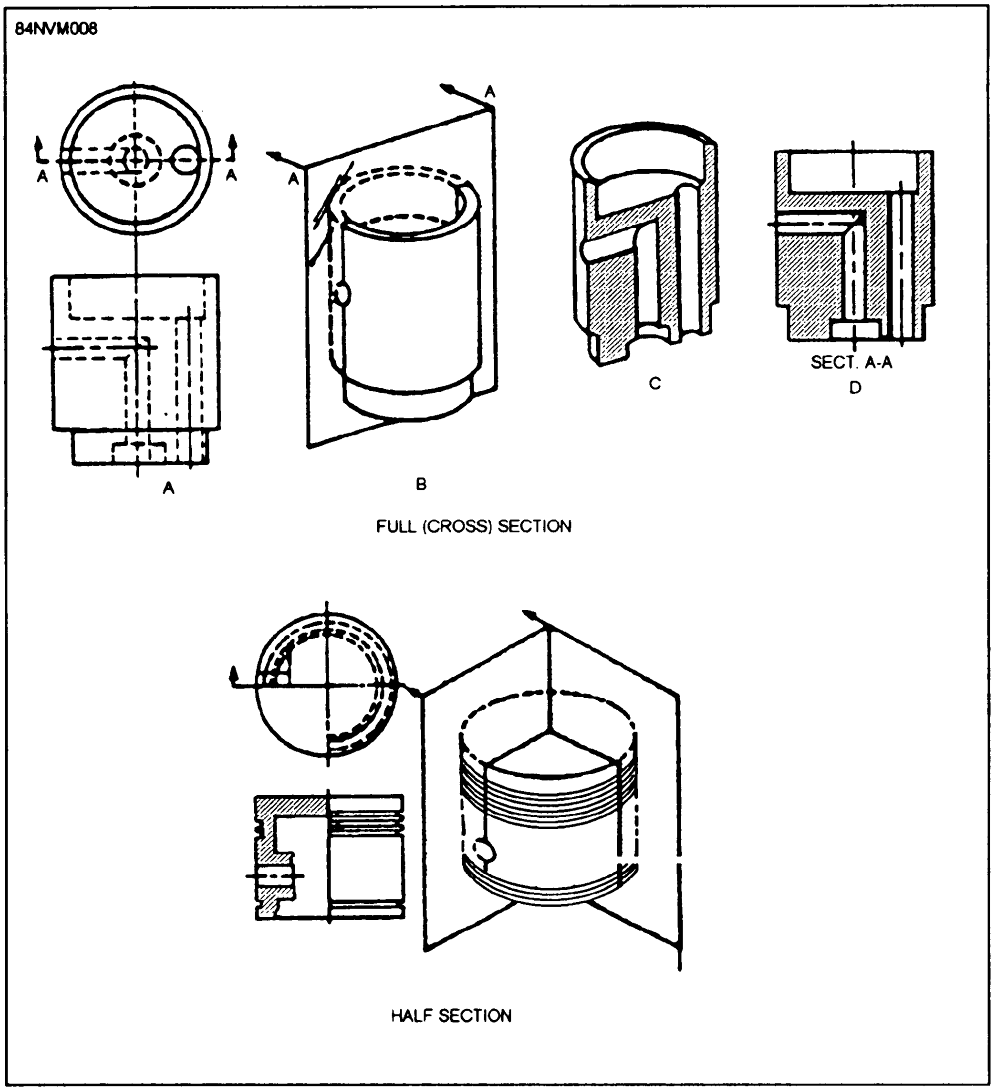


Figure 13-8.—Full- and half-sectional views.

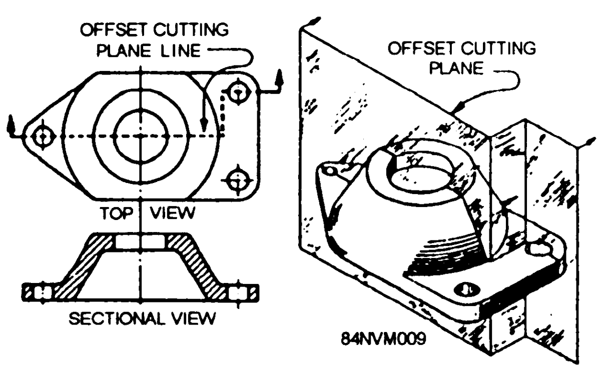


Figure 13-9.—Offset section.

an offset section view. Notice the different line used to show the cutting view.

PHANTOM VIEW.—Phantom views are used to indicate the alternate position of parts of the item drawn. It may also show repeated detail or the relative position of an absent part. Figure 13-10 shows a phantom view of a part in the alternate position. Notice the type of line (the part to the left of the figure is made up of one long line and two short dashes) used to represent the item in its original position.

EXPLODED VIEWS.—The exploded view is used to show relative location of parts; it is particularly helpful in assembling complex objects. Notice how the parts are spread out in a line to show clearly each part's relationship to the other parts, as shown in figure 13-11.

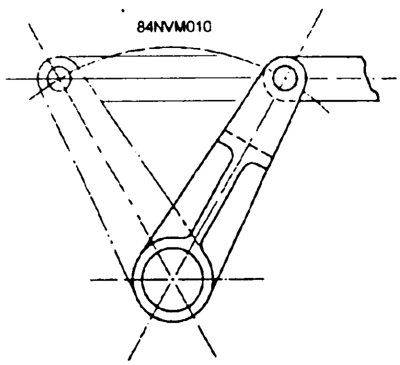


Figure 13-10.—Phantom view showing alternate position.

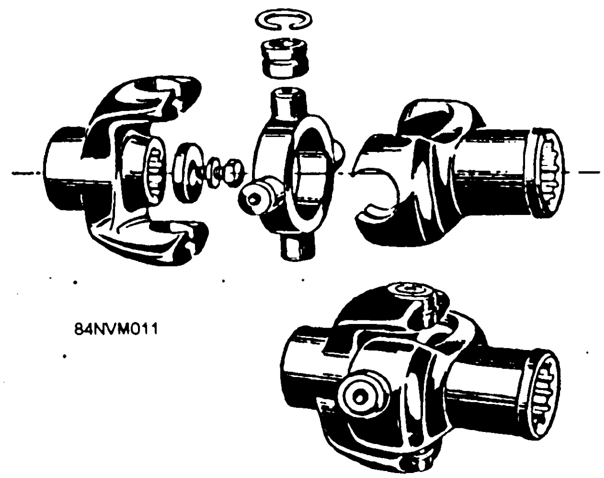


Figure 13-11.—Exploded view.

Detail Drawings and Assembly Prints

Detail drawings and assembly prints are additional guides for repairmen during the fabrication or assembly of a part.

DETAIL DRAWINGS.—Detail drawings are prints of single parts. The drawings provide an exact description of the part's shape, size, material, composition, surface finishes, tolerances, necessary shop operations, and other special requirements. Detail drawings often show where dimensions would be located on a part, as shown in figure 13-12.

ASSEMBLY PRINTS.—An assembly print (fig. 13-13) shows a unit either completely assembled or unassembled, usually without dimensions. One or more views of the assembled unit may be provided. Letters or numbers are used to identify parts on the print that correspond to various detailed drawings. Sectional views are generally used to show the assembled units. Exploded views show the exact location of each part and the sequence of assembly.

STRUCTURAL METAL SHAPES

Your work will require you to use some standard structural shapes rolled from steel and aluminum in a wide variety of cross-sectional shapes and sizes. Steel shapes are commonly used in the construction of ships' hulls, superstructures, and small crafts. Newer ships use extensive amounts of aluminum in the construction of their superstructures, and most small craft's hulls and superstructure are constructed of aluminum. This section will discuss the common shapes, sizes, types, and uses of common metal shapes and the different marking systems used to identify these structures. Angles, bars, rods, flats, and plate will also be discussed in this section.

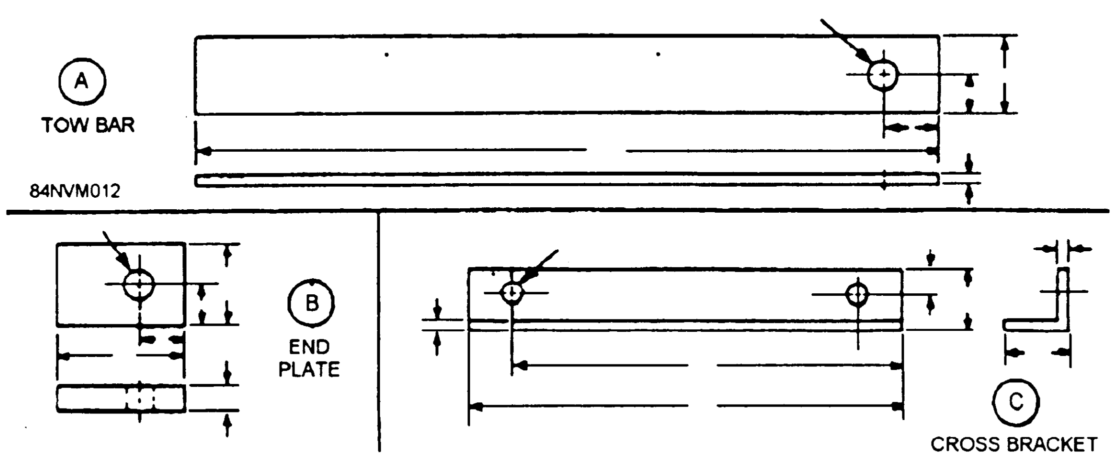


Figure 13-12.—Detail drawings.

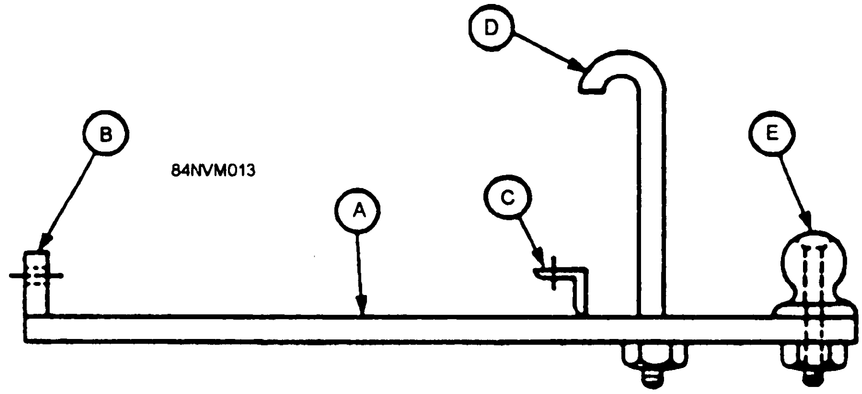


Figure 13-13.—Assembly print.

STRUCTURAL STEEL SHAPES

The HT uses standard steel shapes rolled from carbon steel. Figure 13-14 shows four structural steel shapes commonly used in the construction of ships. These are the wide-flange beam, the I-beam, the channel, and the tee-bar. These four shapes are identified by the nominal depth in inches along the web and the weight per foot of length. As an example, "12 inch WF 27" indicates a wide-flange beam section, 12 inches deep and weighing 27 pounds per foot.

Wide-Flanged Beams

The WIDE-FLANGE BEAM is a structural shape whose cross section forms the letter *H.* Wide-flange beams are the most widely used structural section. They are designed so that their flanges provide strength in a horizontal plane while the web gives strength in a vertical plane. Wide-flange beams are used as beams, columns, transverse and longitudinal framing, and in other applications where that particular shape is needed.

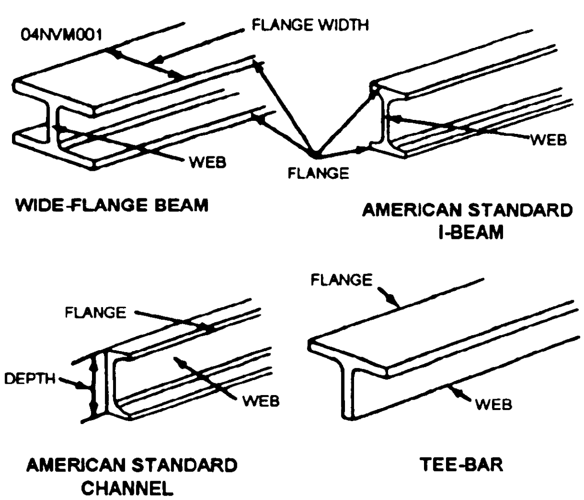


Figure 13-14.—Types of structural shapes.

I-Beams

The I-BEAM can be identified by its cross section, which is shaped like the letter I. I-beams are used less frequently than wide-flange beams because wide-flange beams have greater strength and are more adaptable than I-beams. You will find I-beams used as hoist tracks, booms, machinery foundations, and other similar applications.

Channel

The CHANNEL has a cross section similar to the letter *C.* It is especially useful in locations where a single flat face without protruding flanges on one side is required. The channel is not very efficient when used alone as a beam or column. However, you can construct effective members of channels assembled together with other structural shapes and then connected by rivets or welds. Channels are used in the construction of foundations, storage racks, tables, and other similar applications.

Tee-Bar

The TEE-BAR is similar to wide-flange beams or I-beams, but one side lacks the flange. In fact tee-bars can be manufactured from I-beams or wide-flange beams by cutting the beam down the middle or removing one of the flanges. The tee-bar offers the ideal cross section for stiffeners. The use of tee-bar stiffeners is now quite common in the construction of transverse and longitudinal frames in ships' hulls and superstructures.

OTHER STEEL SHAPES

Steel and aluminum come in numerous other shapes that are used for general structural and nonstructural usage. These shapes include angle, plates, sheets, and bars.

The designations generally used for flat steel have been established by the American Iron and Steel Institute. Flat steel is designated as bar, strip, sheet, or plate, according to the thickness, the width, and, to some extent, the rolling process by which the material was manufactured. Table 13-1 shows the designations normally used for hot rolled carbon steels. These terms are somewhat flexible, and sometimes may overlap. The terms used to designate cold rolled, flat carbon steel are very similar to those used for hot rolled, flat carbon steel, but differ in some details.

Angle

An ANGLE is a structural shape whose cross section resembles the letter L. It is also known as angle iron. Two types of angles (fig. 13-15) are in common use. The legs of these angles will be either equal or unequal. The angle is identified by the dimension and thickness of the legs, such as 6" × 4" × ½". The dimensions of the legs are found by measuring along the outside or backs of the legs. When an angle has unequal legs, the dimension of the wider leg is given first, as in the above example. The third dimension applies to the thickness of the legs, which always have equal thickness. Angles are used in general fabrication and have limited structural applications.

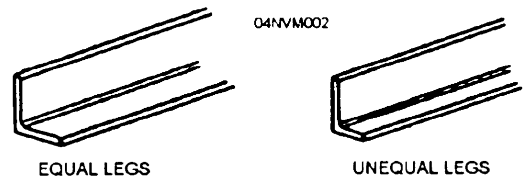


Figure 13-15.—Angles.

Plate and Sheet Metals

Metal that comes in flat rectangular pieces are known as plates and sheets. Metal is classified as a plate or sheet depending on its thickness. Generally metal l/8 inch and thicker is classified as plate. Metal less than l/8 inch thick is classified as sheet metal. Since plate and sheet are used extensively by HTs, both will be discussed in the following sections.

PLATE.—Plate is a structural shape whose cross section is in the form of a flat rectangle. Plates are generally used as connections between other structural members, or as component parts of built-up structural members. Plates are used extensively in the manufacture of ships' hulls, bulkheads, tanks, superstructures, and other similar applications. You will also form plate into numerous structural and nonstructural uses.

Plates cut to specific sizes may be obtained in widths ranging from a minimum of 6 inches to 120 inches or more. The thickness of plate will be l/8 inch or larger. The edges of these plates may be either cut by shears (sheared plates) or rolled square (universal mill plates).

Plates are frequently referred to by their width and thickness in inches, such as plate 24" × 1/2". In all cases, the length is given in feet and inches, such as 7'3". Thickness for ferrous and nonferrous plate are determined by different methods.

Steel Plate Sizes.—You will hear steel plate referred to by its nominal thickness or approximate weight per square foot for a specified thickness. Steel plate weighs about 2 l/2 pounds per square foot for each

Table 13-1.—Designations of Hot Rolled Carbon Steel According to Thickness and Weight

Width, inches	0.2500 and thicker	0.2499 to 0.2031	0.2030 to 0.1875	0.1874 to 0.0568	0.0567 to 0.0344	0.0343 to 0.0255	0.0254 to 0.0142
To 3 l/2 inclusive	bar	bar	strip	strip	strip	strip	sheet
Over 3 l/2 to 6 incl.	bar	bar	strip	strip	strip	sheet	sheet
Over 6 to 12 incl.	plate	strip	strip	strip	sheet	sheet	sheet
Over 12 to 32 incl.	plate	sheet	sheet	sheet	sheet	sheet	sheet
Over 32 to 48 incl.	plate	sheet	sheet	sheet	sheet	sheet	sheet
Over 48	plate	plate	plate	sheet	sheet	sheet	sheet

1/16 inch of thickness. Therefore, 5-pound plate is l/8 of an inch thick.

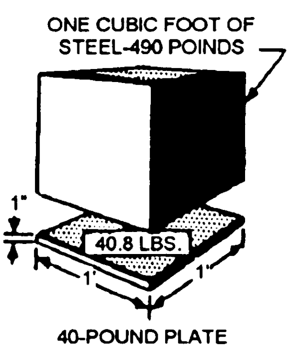
Note in figure 13-16 that 1 cubic foot of steel weighs 490 pounds. This figure divided by 12 is 40.8, which is the weight (in pounds) of a steel plate 1 foot square and 1 inch thick. In practice, the .8 is dropped and a l-inch steel plate is called 40-pound plate. Blueprints will normally list plate using the full decimal designation. The weight of plate, in a number of different thicknesses, is listed in figure 13-16.

Nonferrous Plate Sizes.—There are numerous types of nonferrous metals, such as aluminum, brass, copper, and stainless steel. Each of these metals have different weight per square foot. Therefore, nonferrous metals are simply measured by their nominal thickness, such as l/8, l/4, and l/2 inches.

SHEET METAL.—Sheet metal is very similar to plate metal. Sheet metal is used extensively in the sheet metal shop for the manufacture of lockers, bins, shelves, trim work, false bulkheads, and numerous other applications. Sheets cut to specific sizes may be obtained in widths ranging from a minimum of 6 inches to 120 inches or more. The thickness of sheets will be less than l/8 inch thick and measured by the gauge. The gauge of sheet metal is determined by a fixed standard and measured in thousands of an inch, as shown in figure 13-17. The edges of these plates may be either cut by shears (sheared plates) or rolled square (universal mill plates). Plates are frequently referred to by their width and thickness in inches, such as plate 24" X 1/2". In all cases, the length is given in feet and inches, such as 7’3".

Bars

The structural shape known as a BAR has a width of 6 inches or less and is thicker than 3/16 of an inch. The edges of bars usually are rolled square, just like the universal mill plates. The dimensions are expressed in the same manner as those for plates; for instance, bar 6" X 1/2". Bars are available in a variety of cross-sectional shapes, such as round, hexagonal, octagonal, square, and flat. Three different shapes are shown in figure 13-18. You may hear both the square and the round bars referred to as RODS or STOCK. Both squares and rounds are commonly used as bracing members for light structures. Their dimensions, in inches, apply to the side of the square or the diameter of the round.



04NVM003

STEEL PLATE

THICKNESS	NAME
2"	80-POUND
1 1/2"	60-POUND
1"	40-POUND
3/4"	30-POUND
1/2"	20-POUND
3/8"	15-POUND
1/4"	10-POUND
1/8"	5-POUND

Figure 13-16.—Weight and thickness of steel plate.

METAL CLASSIFICATION AND MARKING SYSTEMS

As an HT, you will use different types and alloys of different metals on a daily basis. An understanding of the different classification and specification systems will greatly aid you in the proper selection and use of different metals.

There are different types of classifications and specifications for different metals used in the Navy. Metal components identified on all blueprints use one of these classifications or specifications. This section will discuss the SAE/AISI classification systems, federal, ASTM, and military specification systems and aluminum classifications used today. We will also look at the continuous metal marking system.

SAE/AISI Classification Systems

The Society of Automotive Engineers (SAE) and the American Iron and Steel Institute (AISI) each have devised systems to identify and classify carbon steels and steel alloys. These systems are almost identical except that the AISI adds a letter indicating the process by which the steel was made. Both systems use a four- or five-digit number to indicate the composition of the steel.

SAE NUMBERING SYSTEM.—The SAE numbering system uses a four-digit numbering system to identify the type of steel. Infix and suffix letters may be added to the numbering system. Each number has a significance as explained in the following paragraphs. Refer to figure 13-19.

—The first and second digits of the SAE numbering system indicates the main alloying element and the approximate percentage of the alloying element in the steel. Table 13-2 shows the numbers with their corresponding alloys.

—The third and fourth digits of the SAE number indicate the percentage of carbon in the steel. Table 13-3 shows the carbon content in hundredths of 1 percent.

Gauge No.	Birmingham wire gauge (B.W.G.) or Stubs iron wire gauge, for iron wires, hot and cold rolled sheet steel	American wire gauge, or Brown & Sharpe (for nonferrous sheet and wire)	U.S. Standard gauge for sheet and plate iron and steel	Steel wire gauge, or the W & M (Washburn & Moen) for steel wire
0	.340	.3249	.3125	.3065
1	.300	.2893	.2812	.2830
2	.284	.2576	.2656	.2625
3	.259	.2294	.2500	.2437
4	.238	.2043	.2343	.2253
5	.220	.1819	.2187	.2070
6	.203	.1620	.2031	.1920
7	.180	.1443	.1876	.1770
8	.165	.1285	.1718	.1620
9	.148	.1144	.1562	.1483
10	.134	.1019	.1406	.1350
11	.120	.0907	.1250	.1205
12	.109	.0808	1093	.1055
13	.095	.0719	.0937	.0915
14	.083	.0640	.0781	.0800
15	.072	.0570	.0703	.0720
16	.065	.0508	.0625	.0625
17	.058	.0452	.0562	.0540
18	.049	.0403	.0500	.0475
19	.042	.0359	.0437	.0410
20	.035	.0319	.0375	.0348
21	.032	.0284	.0343	.0317
22	.028	.0253	.0312	.0286
23	.025	.0225	.0281	.0258
24	.022	.0201	.0250	.0230
25	.020	.0179	0218	.0204
26	.018	.0159	.0187	.0181
27	.016	.0142	.0171	.0173
28	.014	.0126	.0156	.0162
29	.013	.0112	.0140	.0150
30	.012	.0100	.0125	.0140
31	.010	.0089	.0109	.0132
32	.009	.0079	.0101	.0128
33	.008	.0071	.0093	.0118
34	.007	.0063	.0085	.0104
35	.005	.0056	.0078	.0095
36	.004	.0050	.0070	.0090

Figure 13-17.—Steel plate and sheet metal gauges and thicknesses.

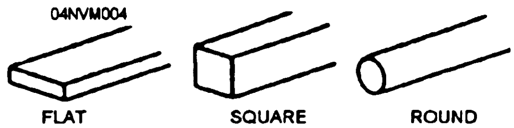


Figure 13-18.—Bars.

Table 13-2.—SAE Numbers with Corresponding Alloying Elements

Type of Steel	SAE Number
Carbon Steels	1XXX
Plain carbon	10XX
Free cutting (screw lock)	11XX
High manganese	13XX
Nickel Steels	2XXX
3.50% nickel	23XX
5.00% nickel	25XX
Nickel-Chromium Steel	3XXX
1.25% nickel, 0.60% chromium	31XX
3.50% nickel, 1.50% chromium	33XX
Molybdenum Steels (0.25% molybdenum)	4XXX
1.0% chromium	41XX
0.5% chromium, 1.8% nickel	43XX
2% nickel	46XX
3.5% nickel	48XX
Chromium Steels	5XXX
Low chrome	51XX
Medium chrome	52XX
Zhromium-Vanadium Steels	6XXX
Nickel-Chromium-Molybdenum (low amounts)	8XXX
Silicon-Manganese	92XX

Table 13-3.—SAE Specification for Plain Carbon Steel

SAE Number	Carbon range percent	SAE Number	Carbon range percent	SAE Number	Carbon range percent
1010	.08-.13	1040	.37-44	1070	.65-.75
1015	.13-.18	1045	.43-.50	1075	.70-.80
1020	.18-.23	1050	.48-.55	1080	.75-.88
1025	.22-.28	1055	.50-.60	1085	.80-.93
1030	.28-.34	1060	.55-.65	1090	.85-.98
1035	.32-.38	1065	.60-.70	1095	.90-1.03

—Infix letters are used occasionally to denote variations or modifications in the basic alloy composition. There are only two infix letters used: *B* (boron) and *L* (lead). When either of these letters are used, it indicates the addition of that element.

Example: 5040 basic composition

50B40 addition of boron

—Suffix letters are normally used when dealing with stainless steel. When used in this context, they indicate a variation in the basic chemical composition. The suffix letters used are as follows:

A, B, and C —Used to denote three types of steel differing only in carbon content

F—Denotes a free machining steel

Se—Denotes the addition of selenium

Example: 3033A .40% - .50% carbon

AISI CLASSIFICATION SYSTEM.—As previously mentioned, the AISI code system uses a letter before the number to show the process used in the making of the steel. The following letters are used:

- A—Acid

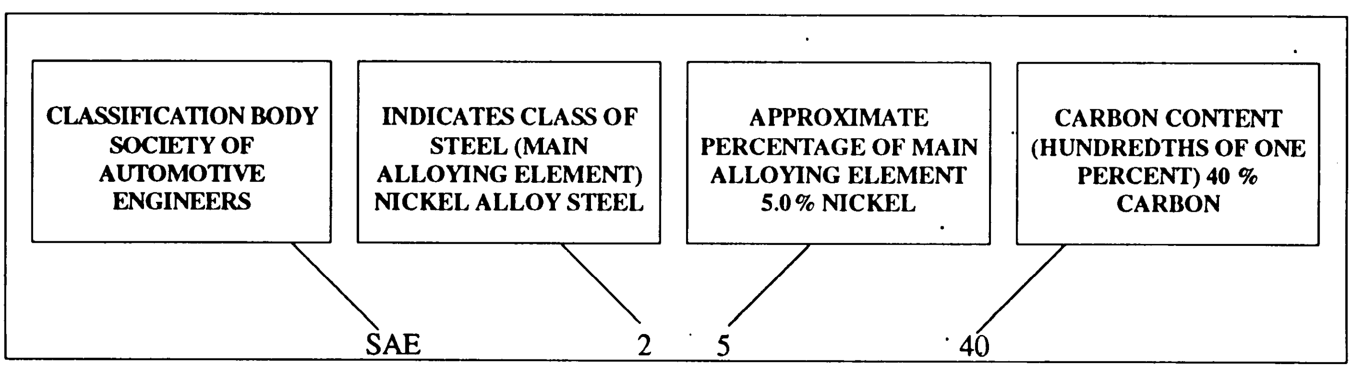


Figure 13-19.—SAE classification.

- B—Acid Bessemer, carbon steel
- C—Basic open hearth carbon steel
- CB—Either acid Bessemer or basic open hearth carbon steel at the option of the manufacture
- D—Acid open hearth carbon steel
- E—Electric furnace alloy steel

Examples of the SAE and ASIS classification code systems are as follows:

1010, 4340, 5220 = SAE steels

C1090, E4340, E3320 = AISI steels

4340 steel could be from either system.

Federal, Military, and ASTM Specification System

A knowledge of ASE/AISI identification codes is not enough to facilitate the selection of the materials used in the Navy today. The use of federal, military, and commercial specifications and the methods of cross-referencing them to other standards is becoming necessary to complete routine repairs and fabrication.

FEDERAL SPECIFICATIONS.—Federal specifications (FEDSPECs) are prepared for supplies used by several departments and offices of the federal government. As HTs, the group of materials we are most concerned with are the "QQ" (metals), and "WW" (pipe fittings, tubes, and tubing). You will find the FEDSPEC QQ used extensively in Navy sheet metal shops to identify sheet metal, especially aluminum. The FEDSPEC WW is used in the pipe shop to identify pipe fittings and pipe, but it is not as common as other material designators. To properly identify FedSpecs, you must have an understanding of the specification symbol used. The basic FEDSPEC symbol is divided into three basic parts:

- The group of materials to which the specification relates.
- The initial letter of the title materials.
- The serial number. If the serial number has been revised, the revision will be designated by a lowercase letter.

A complete FEDSPEC number would be broken down as follows for the specification QQ-A-225c:

- QQ—Refers to a metal
- A—Refers to aluminum
- 225—Is the assigned serial number
- c—Indicates the third revision to this specification

A complete list of current FEDSPEC numbers can be found in the technical library of most repair facilities.

MILITARY SPECIFICATIONS.—Military specifications (MILSPECs) are similar to FEDSPECs. MILSPECs use similar symbols for their meanings. The major difference is that MILSPECs were developed specifically for the military.

As in FEDSPECs, the symbol used to identify MILSPECs is divided into three parts. The MILSPEC, MIL-S-16216, is broken down as follows:

- MIL—Refers to military specification
- S—Identifies the material as metal plate
- 16217—Is the assigned number for HY-80

A complete list of current MILSPEC numbers can be found in the technical library of most repair facilities.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM).—The ASTM standards you will be most concerned with are those that cover ferrous and nonferrous metals. These standards, which were developed by a consensus of producers and consumers, are used widely by industry. Like federal or military specifications, the ASTM standard is a complete listing of specifications that generally include mechanical requirements, test procedures, dimensional tolerances, and chemical composition requirements. Like the MILSPEC and FEDSPEC, the symbol used to identify the ASTM specification is divided into three parts. The ASTM symbol A579-67 is broken down as follows:

- A—Identifies the general classification of the materials. "A" denotes ferrous metals, and "B" denotes nonferrous metals.
- 579—Is the assigned serial number.

- 67—Indicates the year the specification was issued or last revised.

Aluminum and Aluminum Alloy Classification

Aluminum is supplied in literally hundreds of different alloys. Making the most practical choice of aluminum to serve your needs depends largely on your knowledge and understanding of the identification and coding system. Aluminum alloys are broadly classed as castings or wrought alloys. Generally, you will not work much with aluminum castings; therefore, this section will only talk about wrought aluminum (plates, sheets, and shapes) and aluminum alloys.

NUMERICAL CLASSIFICATION SYSTEM.— A 4-digit numerical designation system is used to identify aluminum and aluminum alloys. The first digit indicates the alloy group as follows:

- 1xxx—Aluminum, 99.00% minimum purity, no alloying element
- 2xxx—Copper
- 3xxx—Manganese
- 4xxx—Silicon
- 5xxx—Magnesium
- 6xxx—Magnesium and silicon
- 7xxx—Zinc
- 8xxx—Other elements

The second digit indicates modifications of the original alloy or impurity limits. The last two digits identify the aluminum alloy or indicate the aluminum purity. Pure aluminum and aluminum alloys are classified in this manner and will be looked at further.

Pure Aluminum.—Pure aluminum is any aluminum product that is 99.00 percent aluminum and greater and classified in the 1xxx classification group. If there is a second digit after the 1, it will designate the control on impurities. These controls on individual impurities will be designated with the digits 1 through 9. If the second number is 0, it indicates natural impurity limits. The last two digits designate the minimum aluminum percentage. The following is an example of a 1xxx group aluminum metal and is broken down into its component parts:

- 1040—Is a pure aluminum. The second digit (0) indicates that there is no special control on impurities. The last two digits (40) indicate that it is 99.40 percent pure.

Aluminum Alloys.—In the 2xxx through 8xxx groups, the last two of the four digits in the designation have no special significance on the percentage of aluminum. Instead, the last two digits indicate the alloy modifications. The second digit, as in the lxxx group, indicates the control on impurities. The following is an example of a 2xxx group aluminum metal and is broken down into its component parts:

- 2117—Is an aluminum alloy with copper as the major alloying element. The second digit (1) indicates that there is some control on impurities and the last two digits (17) indicate that it is the 17th alloy of the 2xxx group.

NOTE: For complete chemical composition, specific identification numbers must be cross-referenced. These numbers can be found in most metal handbooks.

TEMPER AND HARDENING DESIGNATIONS.—In addition to the 4- digit alloy designation, a letter or letter/number combination is included as a temper/hardness designation. The temper/hardness of an aluminum alloy is one of the major factors governing strength, hardness, and ductility. As an HT, you will also need to have an understanding of the temper/hardness designation as it relates to mechanical and physical properties.

Temper Designations.—Some aluminum alloys are hardened and strengthened by cold working or strain hardening. Tempering is accomplished by cold rolling, drawing, stretching, or coining. Other aluminum alloys are heat treatable and their properties can be improved by thermal treatment methods. The following temper designations denote the condition of aluminum alloys and the method used to obtain that condition.

- F—As fabricated
- Q—Annealed and recrystallized (wrought only)

- H—Strained hardened (wrought only)

  H1—Strain hardened only

  H2—Strain hardened, then partially annealed

  H3—Strain hardened, then stabilized

- W—Solution heat treated—unstable temper

- T—Treated to produce stable tempers

  T2—Annealed (cast only)

  T3—Solution heat treated, then cold worked

  T4—Solution heat treated and naturally aged at room temperature to a substantially stable temper

  T5—Artificially aged

  T6—Solution heat treated, then artificially aged

  T7—Solution heat treated then stabilized to control growth and distortion

  T8—Solution heat treated, cold worked, then artificially aged

  T9—Solution heat treated, artificially aged, then cold worked

It is important that you be aware of these conditions as a metal worker. When you weld, heat, roll, or bend aluminum, you will change the temper of aluminum. In certain applications, you may have to use special precautions or post treatments to prevent changing the characteristics of the aluminum.

Hardness Designations.—In many cases, a second digit may appear to the right of the temper designation. This digit indicates the degree of hardening. The numbers 2 through 9 are used to express this hardness. Hardness is obtained by heat treatment, aging, or the cold working of aluminum. The following is a list of the numbers and their meaning:

- 2—1/4 hard

- 4—1/2 hard

- 6—3/4 hard

- 8—Full hard

- 9—Is sometimes used to express extra hard

As with temper, it is important that you are aware of hardness conditions as a metal worker, especially in welding applications. When you weld, heat, roll, or bend aluminum, you will change the hardness of aluminum. In certain applications, you may have to use special precautions or post treatments to prevent changing the characteristics of the aluminum. In some applications, you may not be able to use a repaired aluminum structure for a specific amount of time while the aluminum age hardens.

The following are two examples of a complete aluminum classification broken down into its component parts:

- 2218-T72—-Aluminum/copper alloy with special control over impurities, alloy #18 in the aluminum/copper group, solution heat treated (T7), then stabilized to 1/4 hard (2).

- 1060-H18—-99.60% pure aluminum with no special control over impurities, strain hardened (Hl) to full hard (8).

Material Cross-Referencing

Due to the numerous specification and classification systems used and the availability of specified material from blueprints, you will be required to cross-reference metal from one specification to another.

Continuous Identification Marking System

The continuous identification marking system is used to identify different metal shapes and forms. The marking is printed on the metal with heavy ink or paint in constantly recurring symbols at intervals of no more than 3 feet throughout the length of the material. The manufacturer is required to make these markings on the material before delivery. The marking system consists of the following information (refer to fig. 13-20):

- The name or trademark of the producer who performs the final processing before marking.

- The commercial designation or the material, such as the ASTM, AISI, ASE, or FED/MIL specification.

- Physical condition and quality designation that shows temper or other physical condition approved by a nationally recognized technical

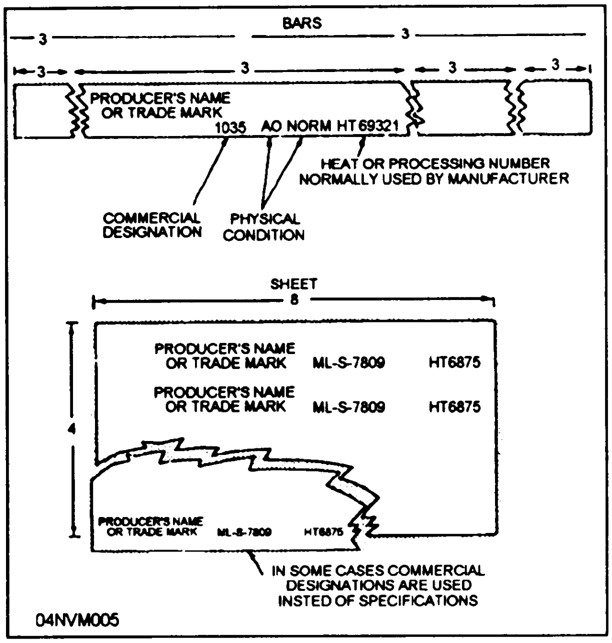


Figure 13-20.—Examples of continuous identification marking.

society or industrial association. Some of the designations used are as follows:

CR—Cold rolled

HR—Hot rolled

HT—Heat treated

AQ—Aircraft quality

1/4H—Quarter hard

HTQ—High tensile quality

- Specification data, such as the revision letter of the specification number, type, grade, class of material or manufacturer's specification data, such as heat number.

Small metal shapes, such as small tubing, coils of wire, and bar stock, cannot be marked readily by this method. On these items, the material may be tagged. Whenever a piece of material is removed from the original piece, you should mark the piece if the marking label is incomplete or destroyed. This will prevent the piece from being mistaken for another type of material or from being used where it shouldn't be used.

SHIPFITTER SHOP EQUIPMENT

Shipfitter shops, whether ashore are afloat, are equipped with some of the largest, most powerful, and dangerous equipment found in R-l division. All structural shops, regardless of the type of ship or shore facility you will be assigned to, have some or all of the equipment discussed in this chapter. It is important that you have a general understanding and knowledge of how to use these different types of equipment. It is not the intent of this training manual to make you an expert on the use and operation of the different machines. You should, however, be able to identify the types of machinery, the general operation, and safety precautions associated with this equipment.

The machinery found in most structural shops can be classified into two basic categories: cutting machines and forming machines.

CUTTING MACHINERY

This section will take a look at machinery associated with cutting metal plate and shapes. You have already studied some of the equipment associated with cutting plate, such as the oxyacetylene torch, mechanical hacksaw, and band saws that are found in some of the smaller shops in the fleet. This section will include such machinery as the shear, universal ironworker, Pullmax, and plasma arc machine.

Drop Shear

The drop shear enables the HT to produce quality work in minimum time. The drop shear is used to trim metal and make straight cuts with square sides. Metal, such as mild steel, black iron, copper, aluminum, and stainless steel, can be cut on the drop shear.

You have already been introduced to the squaring shear in chapter 12 of this text. The drop shear is very similar to the squaring shear but the drop shear is designed to cut thick plates. Most drop shears on ships and at shore facilities are designed to cut plate from l/8 to l/2 inch thick. Metal thinner than l/8 inch should be cut on a squaring shear in the sheet metal shop since the drop shear would just bend the sheet metal around the knives. Drop shears at some shipyards are designed to cut plate 1 inch and thicker.

SHEAR SAFETY.—As with any job or equipment, safety should be your primary concern. The drop shear is a very dangerous piece of equipment to operate due to the force required to cut thick metal. As you can imagine, it requires a lot of shearing force to cut thick plate. To compound this danger, the shearing force is accomplished in one stroke of the machine. Once you have tripped the release lever, the shearing action is nonstoppable until the machine has made one complete revolution. If you accidently trip the release lever, whatever is beneath the knives will be cut, including fingers.

The following is a list of some of the more common safety precautions:

—Become familiar with the type of drop shear installed in your shop. Qualify on its use and operation under qualified supervision prior to operating the shear.

—Determine the capacity of the machine being used from the manufacturer's technical manual and NEVER exceed its maximum capacity. Capacities for most machines are given in metal thickness, and length, and, unless otherwise noted, are given for mild steel not alloy steels. As metal hardness increases, machine capacity decreases.

—Never place any part of your body under the knives or dogs (holddowns) of the shear.

—Never place hands or fingers between the metal plate and the bed.

—Ensure that the metal plate is under a holddown dog.

—Never, never have your foot on the trip lever or pedal while loading or adjusting plate on the shear. Numerous accidents have occurred because of the shear being accidentally tripped.

—Never cut pipe, bar stock, round stock, flat bar less than 2 inches in width or other similar metal shapes. If you attempt to shear these types of metal shapes, you will damage the cutting knives and risk injury due the met al flying out from the holddown dogs, since the dogs are designed for flat plate.

SHEAR NOMENCLATURE.—As with any piece of equipment, you should have an understanding of the major parts of the equipment and their function. Figure 13-2 1 illustrates some of the parts common to all drop shears. These parts arc listed as follows:

- The finger guard is located on the front of the machine and is designed to prevent your fingers from king cut.

- Holddowns (dogs) are located behind the linger guard and arc designed to automatically operate when the release lever is tripped. These dogs clamp the plate in place with

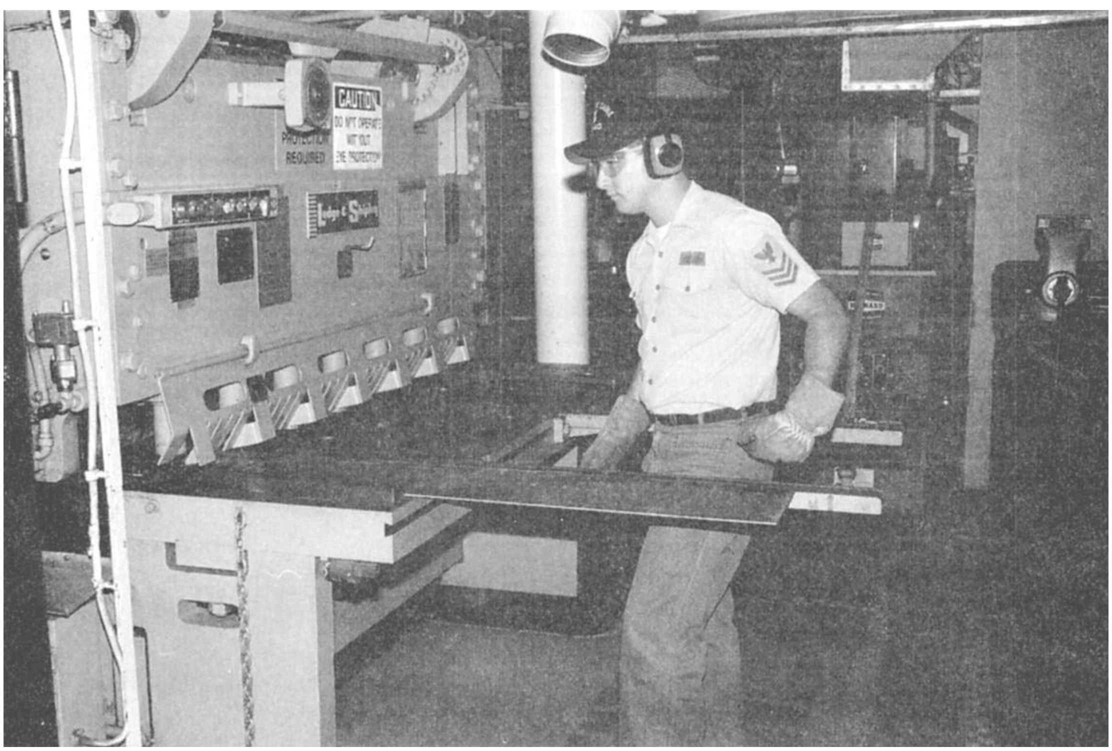


Figure 13-21.—Common drop shear.

several tons of pressure to prevent movement of the plate during the shearing action.

- The back gauge (not shown) is at the back of the machine and provides a stop for the exact measurements for shearing more than one piece of plate. The back gauge is usually set from an adjustment wheel on the front of the machine.

- The bed is the flat part of the shear that provides a surface and support for the metal to be sheared.

- The flywheel is on the left side of the machine. It is part of the pulley system that sets the machine in motion. Some machines use a hydraulic system and cylinder in place of the flywheel/pulley system.

- A set of upper and lower cutting knives provide the shearing action.

- The control panel is a station from which the shear is operated. The control panel has a stop/start button, a control lever for the dogs so that they can engage manually, and a control lever for the shearing action. The control lever for the shearing action usually has three positions: OFF, JOG, and ONCE. In the JOG position, the machine will cut repeatedly as long as the trip lever is depressed. In the ONCE position, the shear will only make one cutting revolution when the trip lever is depressed.

- The final item is the trip device that sets the machine in motion. This lever is usually foot operated and is of the foot pedal type or the bar type (which runs the length of the machine).

OPERATION OF THE DROP SHEAR.— Operation of the drop shear is a relatively simple operation provided you follow all manufacturers' directions and safety precautions. The following is a list of procedures to follow when setting and loading the machine for operation.

1. Determine that the plate to be sheared does not exceed the capacity of the machine.

2. Adjust the back gauge for the proper cutoff length.

3. Start the machine and cycle it through one complete revolution to check the machine for proper operation and binding.

4. Stop the machine and place the plate flat on the bed and snug against the back gauge. Ensure the metal is under a holddown.

5. Start the machine and engage the holddowns manually, if desired, or check the holddown lever to ensure that it is in the proper mode. For inexperienced operators, the shear lever should always be in the ONCE position.

6. Depress the trip lever and shear the plate. If the dogs were not previously set, they will automatically engage when the trip lever is depressed.

KNIFE SETTING AND CLEARANCE.—After repeated use of the shear, the knives will begin to wear. You will begin to notice that the sheared plate will have rough edges and burrs left on the edge. A worn blade will decrease machine efficiency and will require additional work to remove the burrs from the edge. You should also inspect the knives periodically for indentations, cracks, dullness, and other signs of wear that could cause inefficient operation.

Setting The Knives.—If the knives show signs of wear but do not need replacement, you may simply rotate the knives to a new cutting edge. Each knife has four cutting edges that enable the knives to be rotated until each edge has been used. When rotating the knives, rotate the upper and lower blades together so that you have two new cutting edges exposed. The following is a general description of how to rotate or replace the knives:

NOTE: Always refer to the manufacturer's technical manual for the particular machine installed in your shop for the correct procedure for blade setting.

- Block the ram in the up position while removing the upper knife.

- Remove the knives from the scats. The knives will have shims installed between the knife and the blade, so ensure that you save the shims and mark the location of each shim for reinstallation.

- Rotate or install new knives, as required.

- Tighten the knife by holding it firmly against the seat. Pry the upper knife with a wooden lever placed at the center of the blade and tighten the center bolt. Continue prying and tighten from the center to the right bolts and from the center to the left bolts until the knife is secure.

- Repeat the above step for the lower knife.

Knife Clearance.—After the knives has been installed, you must set the proper clearance (fig. 13-22) between the upper and lower knives. This is the most important adjustment on most drop shears. Unlike a pair of regular handheld shears that have the blades scraping next to each other during the cutting stroke, the knives on the drop shear have a clearance between the two knives to prevent binding during the shearing stroke. If the knives are set too close, the shear will bind and cause damage to the machine. If the blades are set too far apart, the plate will be sheared with rough edges and burrs. If the knives have excessive clearance, thin plate may even be bent between the knife edges, causing binding. The following procedure should be used to set knife clearance:

1. Select the proper knife clearance for the metal type and thickness being sheared. (Always refer to the manufacturer's technical manual when selecting knife clearance.) Most drop shears in shipfitter shops are adjusted with a side clearance of 0.010 inch at the edge dogs and 0.008 inch in the center, which is satisfactory for general shearing requirements.

2. Rotate the flywheel by hand until the knives cross the first holddown and the clearance of 0.010 inch is reached using a feeler gauge.

3. Slowly lower the ram until the knives cross at the last holddown, adjusting to 0.010 inch at each holddown.

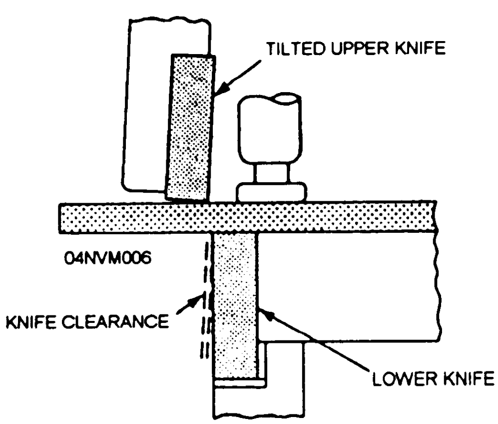


Figure 13-22.—Drop shear knife clearance.

4. Tighten the remaining bolts that hold the knife in place.

5. Lower the ram again and recheck the knife clearances. Make additional adjustments if you do not get a reading of 0.010 inch at the first and last holddowns and 0.008 inch in the center. As a rule of thumb, the center measurement should be 0.002 inch less than the end measurements to allow for flexing of the knives during shearing.

Universal Ironworker

The universal ironworker performs many of the basic machine operations in the shipfitter shop. It is best used for performing identical operations on many pieces of standard metal stock. The universal ironworker is capable of several operations, including punching, stock cutting, notching, and coping.

There are two basic types of ironworkers used in the Navy: the old mechanical driven type, as shown in figure 13-23, and the newer hydraulic version, as shown in figure 13-24. In this section, we will discuss safety associated with the universal ironworker and the punching, stock cutting, and coping evolutions.

UNIVERSAL IRONWORKER SAFETY.—As with the shear, safety should be of great concern. The ironworker is a very dangerous piece of equipment to operate due to the force required to work thick metal. A special safety concern for the ironworker is the operation of several different stations from one foot pedal or trip lever. The following is a list of some of the more common safety precautions:

—Become familiar with the type of ironworker installed in your shop. Prior to operating the machine, qualify on its use and operation under qualified supervision.

—Determine the capacity of the machine being used from the manufacturer's technical manual and never exceed its maximum capacity. Capacities for most machines are given in metal thickness, length, and, unless otherwise noted, are given for mild steel not alloy steels. As metal hardness increases, machine capacity decreases.

—Stay alert! Never insert hands between tooling for any reason, keep them out of strippers and holddowns.

—Properly align and tighten all tooling. Check clearance before proceeding.

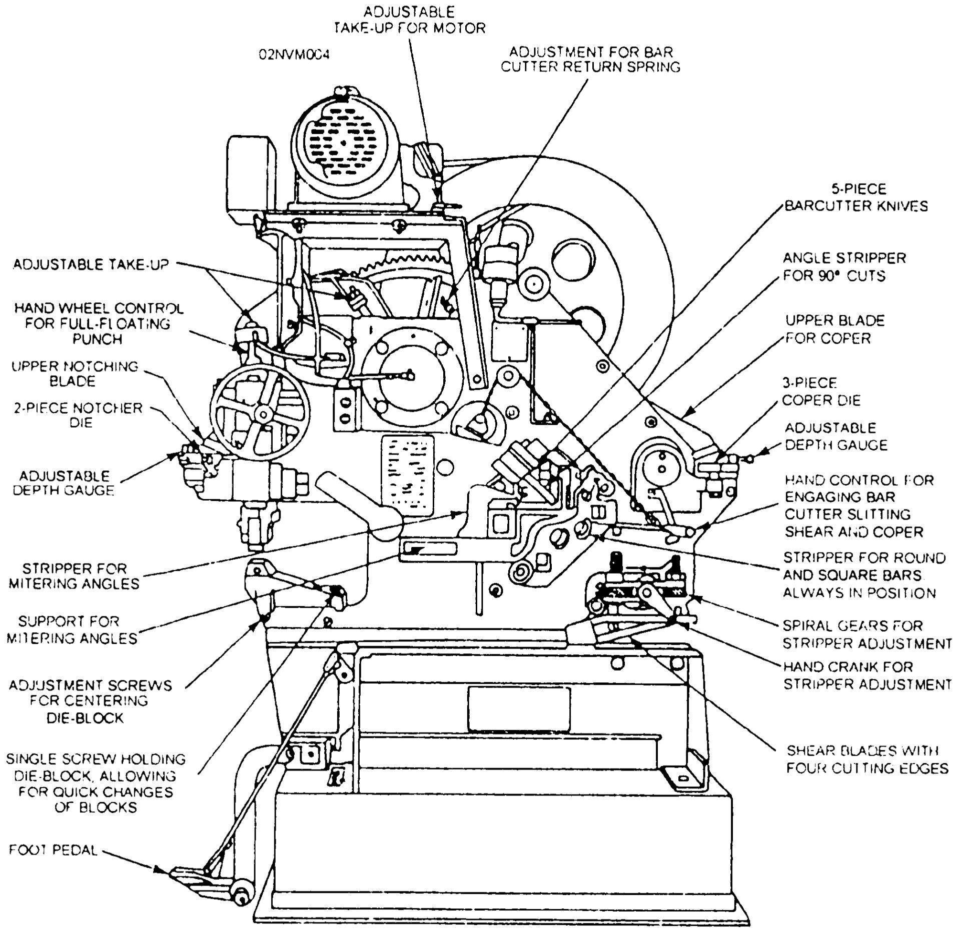


Figure 13-23.—Universal ironworker.

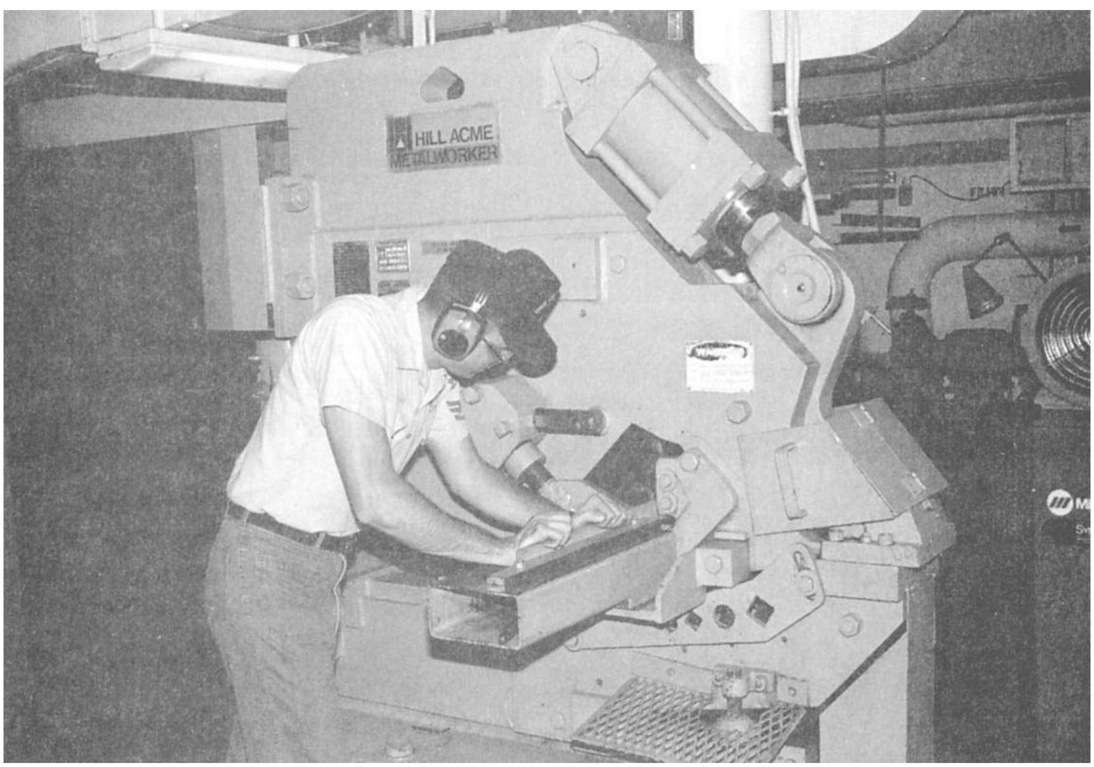


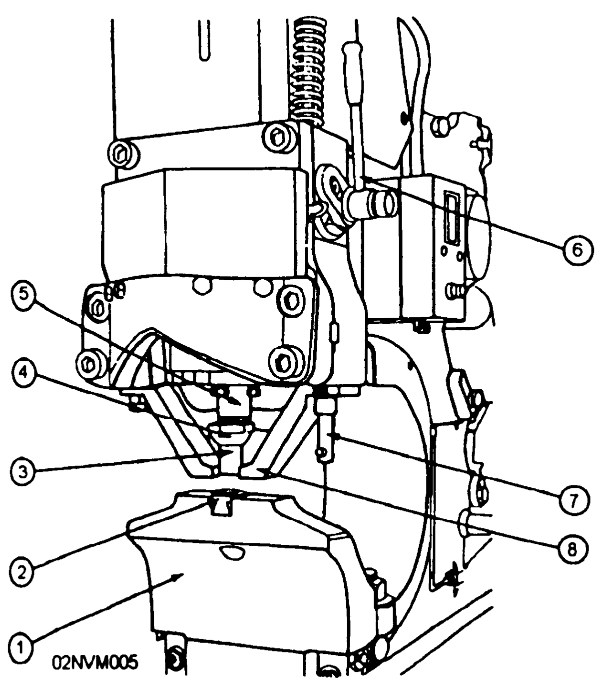
Figure 13-24.—Hydraulically operated universal ironworker.

—Make no modifications that will speed up or continually cycle machine.

PUNCHING OPERATIONS.—The punch end of the universal ironworker punches rounds, squares, and oblongs. The deep punch throat allows punching to the center of wide plates. The standard universal die block permits punching a full range of angles, beams, and channels.

Punch Head.—The main part of the punching device is a punch head. In the older machines, the punch head is referred to as a full-floating head since the dieblock is adjustable to allow the alignment of the die to the punch. In the newer machines, the dieblock is stationary while the die is adjusted for alignment with the punch. The major components of the punch end are as follows (fig. 13-25).

Punch and Die Selection.—On the punch end, the punch to die selection is the utmost importance. Select the proper size and shape of the punch and die according to the type and thickness of material to be punched. Refer to the manufacturer's manual for standard tooling sizes. You should keep the following points in mind when selecting punches and dies.



1. Dieblock
2. Die
3. Punch
4. Coupling Nut
5. Punch Holder
6. Hand Lever
7. Stripper ACS Lever
8. Stripper

Figure 13-25.—Punch floating head.

—Select the appropriate die, depending on the punch-to-die clearance. Figure 13-26 shows the punch-to-die clearance. The punch-to-die clearance is the distance between the outer circumference of the punch and the inner circumference of the die, when the punch sits in the die.

—The punch diameter must be the same thickness or greater than the plate thickness being punched.

—The punch-to-die clearance for mild steel with a thickness of l/4 inch through 5/8 inch should be l/32 inch.

—The punch-to-die clearance for 3/4-inch mild steel should be l/16 inch.

—For metal less than l/4 inch, the recommended punch-to-die clearance is l/10 of the thickness of the material.

—The punch-to-die ratio should never be less than 0.010 inch due to working clearances necessary in the punch head.

Operating Procedure.—To operate the punch, refer to figure 13-25 and proceed according to the following precautions and steps:

- Install the punch and die and check the alignment and adjust as necessary. Ensure that the punch passes through the die without striking the shoulders of the die.
- Cycle the machine through one complete revolution checking the machine for binding or misalignment.
- Place the workpiece under the punch and "spot" the punch to the workpiece. This may be accomplished by using the hand lever in the older mechanical machines or by the jog button on the hydraulic machines.

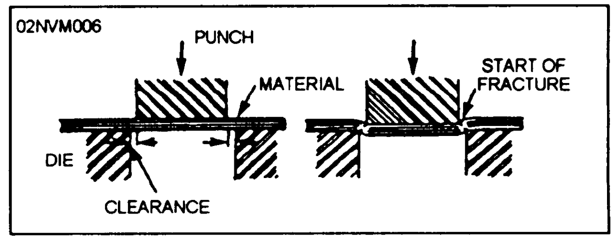


Figure 13-26.—Punch-to-die clearance.

- Step on the foot pedal and hold the pressure until the punch has penetrated the workpiece.

STOCK CUTTING OPERATIONS.—The bar cutter of the universal ironworker cuts and miters angles and shears flat, round, and square stock (fig. 13-27). Special knives can be added to the ironworker to shear beams, channels, tees, and other structural shapes. Most stock cutting operations are performed in the center of the machine with special cutting knives, as shown in figure 13-28, or at one end, as shown in figure 13-29.

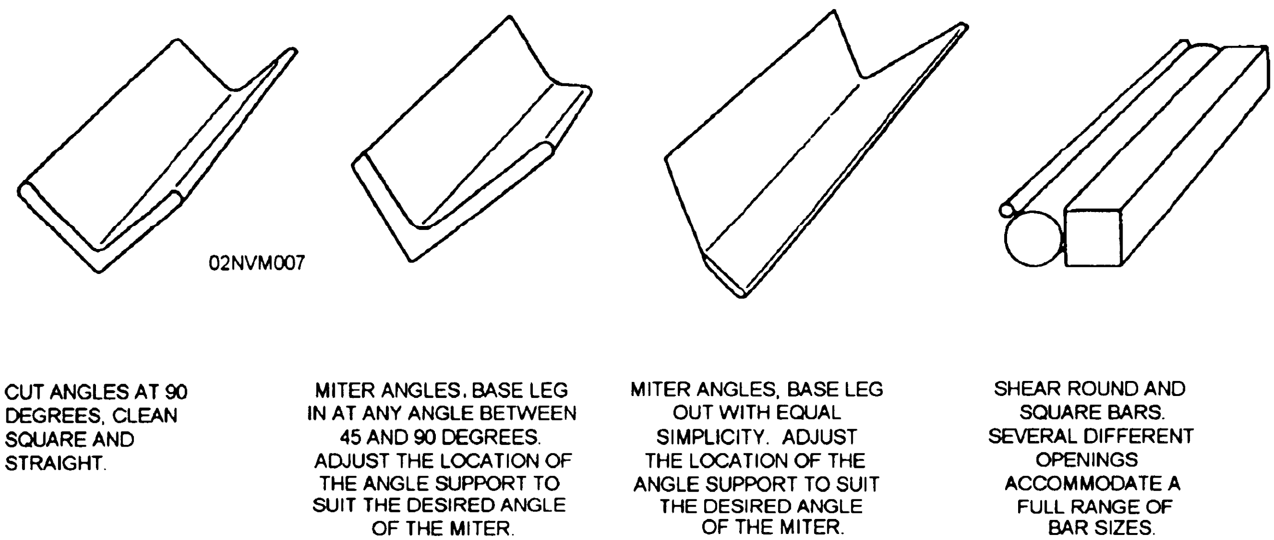
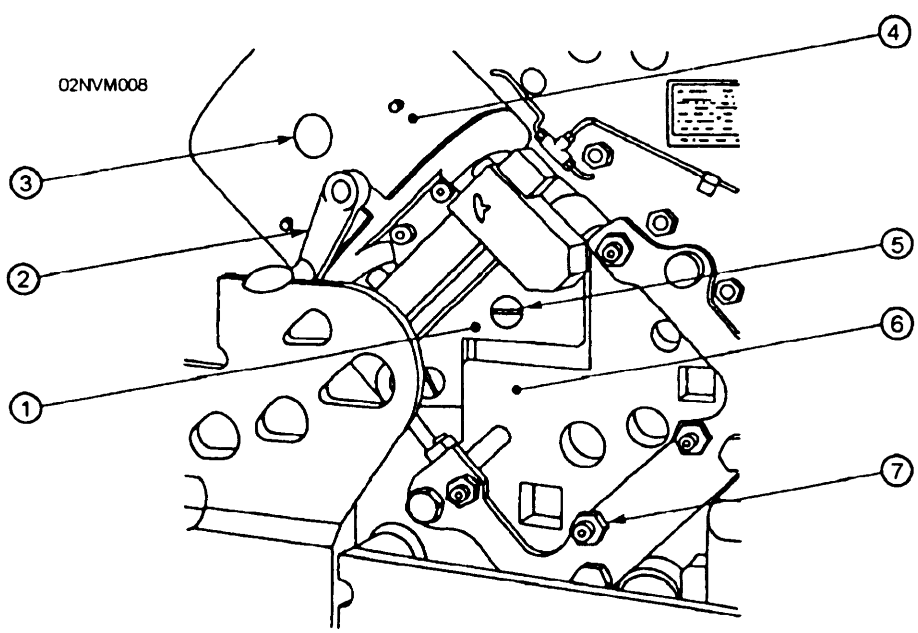
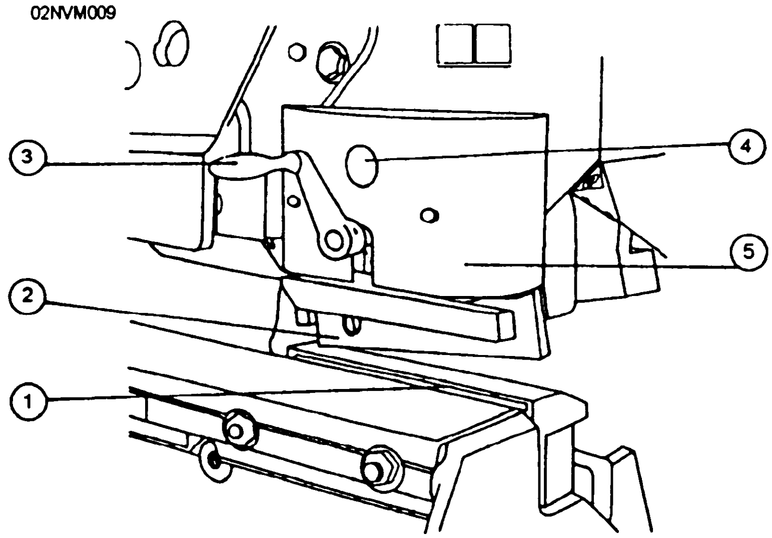


Figure 13-27.—Typical bar cutting work.



1. Plunger Knife
2. Holddown Crank
3. Grease Fitting
4. Plunger
5. Plunger Knife Contact Screw
6. Stationary Knife
7. Stationary Knife Locking Nuts

Figure 13-28.—Universal ironworker bar cutter.



1. Stationary Blade
2. Shear Blades
3. Holddown Adjusting Crank
4. Grease Fitting
5. Holddown

Figure 13-29.—Universal ironworker shear end.

Knife Clearances.—There are two sets of knife clearances for the stock cutting stations. For the bar cutter station (fig. 13-28), the proper knife clearance is 0.006 inch. The shearing station has a clearance of 0.002 inch to 0.003 inch. If shimming is required to maintain clearances, always shim the stationary knife, never the plunger (moveable) knife.

Operating Procedure.—To operate the bar cutting stations, proceed according to the following precautions and steps:

1 .Check the alignment and clearances of the cutting knives and adjust as necessary. Ensure that the knives are firmly fastened since they have a tendency to work loose during use.

2. Cycle the machine through one complete revolution to check the machine for binding or misalignment.

3. Place the workpiece between the cutting knives and adjust the holddowns to support the material being cut and prevent kickup.

4. Step on the foot pedal and hold the pressure until the knives have cut the workpiece.

COPING AND NOTCHING OPERATIONS.—Coping and notching operations are performed at individual stations on some machines and at the same station on other machines. Regardless of the physical arrangement of the machine, a punch and die are used to perform the cutting action. The notcher makes angle cuts of 90 degrees to permit the bending of angle shapes. The coper makes partial rectangularcuts into metal stock. On some machines the coper punch is also designed for notching. Figure 13-30 shows some of the typical notching and coping work and figures 13-31 and 13-32 show the notching and coping stations.

Knife Clearances.—There are two sets of knife clearances for the notching and coping stations if they are separate stations. If the stations are combined, there will only be one set of clearances. For the coping station (fig. 13-32) the proper knife clearance is l/16 inch. The notching station (fig. 13-31) has a clearance of l/64 inch. If shimming is required to maintain clearances, always shim the stationary knife, never the plunger (moveable) knife. On combined stations, the knife clearance is l/l6 inch.

Operating Procedure.—To operate the notching and coping stations, proceed according to the following precautions and steps:

1. Check the alignment and clearances of the cutting knives and adjust as necessary. Ensure that the

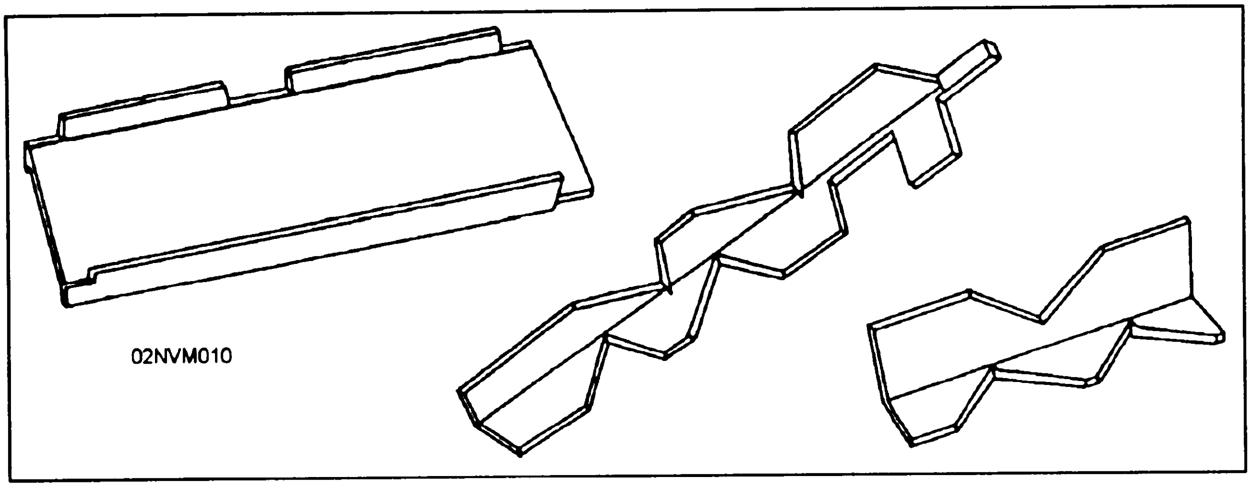
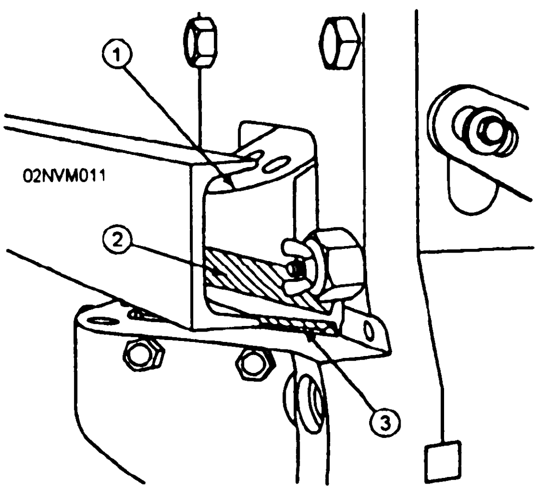
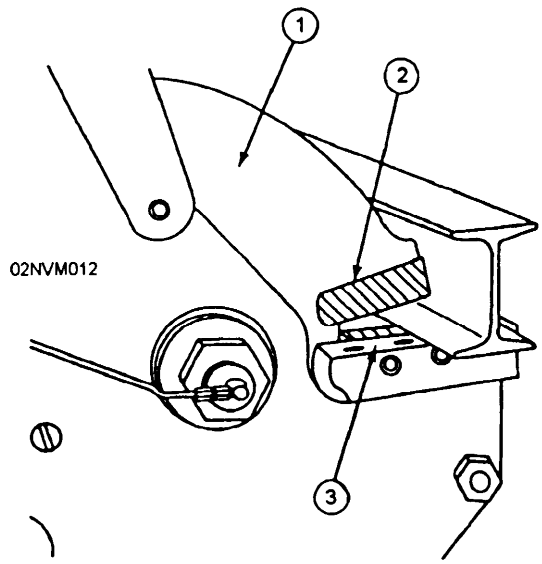


Figure 13-30.—Typical notcher and coper work.



1. Punch Holder
2. Notcher Puncher
3. Die Holder

Figure 13-31.—Universal ironworker notcher punch.



1. Punch Holder
2. Coper Punch
3. Die Holder

Figure 13-32.—Universal ironworker coper punch.

knives are firmly fastened since they have a tendency to work loose during use.

2. Cycle the machine through one complete revolution, checking the machine for binding or misalignment.

3. Place the workpiece between the cutting knives and adjust the holddowns, if installed, to support the material being cut and to prevent kickback.

4. Ensure that the material to be cut is supported on two sides of the die to prevent kickup and rolling during the cutting evolution.

5. Step on the foot pedal and hold the pressure until the knives have cut the workpiece.

Pullmax

The Pullmax machine is one of the most important timesaving machines in the shipfitter shop. It is also one of the most underutilized machines in the shipfitter shop. It is capable of shearing, nibbling, slot-cutting, beading, edge-bending, dishing, and numerous other operations depending on setup and tooling. The Pullmax is being included in this section on cutting metals since that is its primary function in the shipfitter shop. For the purpose of this training manual, we will only discuss the shearing capabilities of the machine. If you want to become more familiar with the capabilities of this machine, you should study the operator's manual and practice on the machine in your shop, if it has one installed.

PULLMAX SAFETY.—The Pullmax is a relatively simple machine to operate and does not present any special safety requirements. However, you need to ensure that the tooling is installed correctly. The machine cuts using a reciprocating action that causes abnormal vibration in the workpiece. Therefore, do not operate the machine for extended periods of time without taking a break from machine operations. You can seriously damage your hands and arms by exposing them to continuous vibration.

GENERAL SPECIFICATIONS.—Most shipfitter shops are equipped with machines capable of cutting plate up to 3/8 inch thick, as shown in figure 13-33. As in all machines, the thickness capacity is given for mild steel. If using alloy steel, the thickness capacity will be reduced. The cutting and shaping action is provided by tools mounted in tool holders at the front of the machine. The machine has two speeds of operation: slow and fast.

When the motor is running at slow speed, the cutting tool makes 500 to 1,000 strokes per minute. Slow speed is used to cut heavy gauge metal.

When the motor is running at high speed, the cutting tool makes 1,000 to 2,000 strokes per minute. High speed is used to cut thin gauge metal.

PULLMAX OPERATIONS.—The Pullmax has the capacity to perform many specific operations depending on the tools (blades) installed in the machine. Figures 13-35 and 13-36 show two of several different tools made for the Pullmax. We will be discussing the tools used for shearing (cutting) (fig. 13-34).

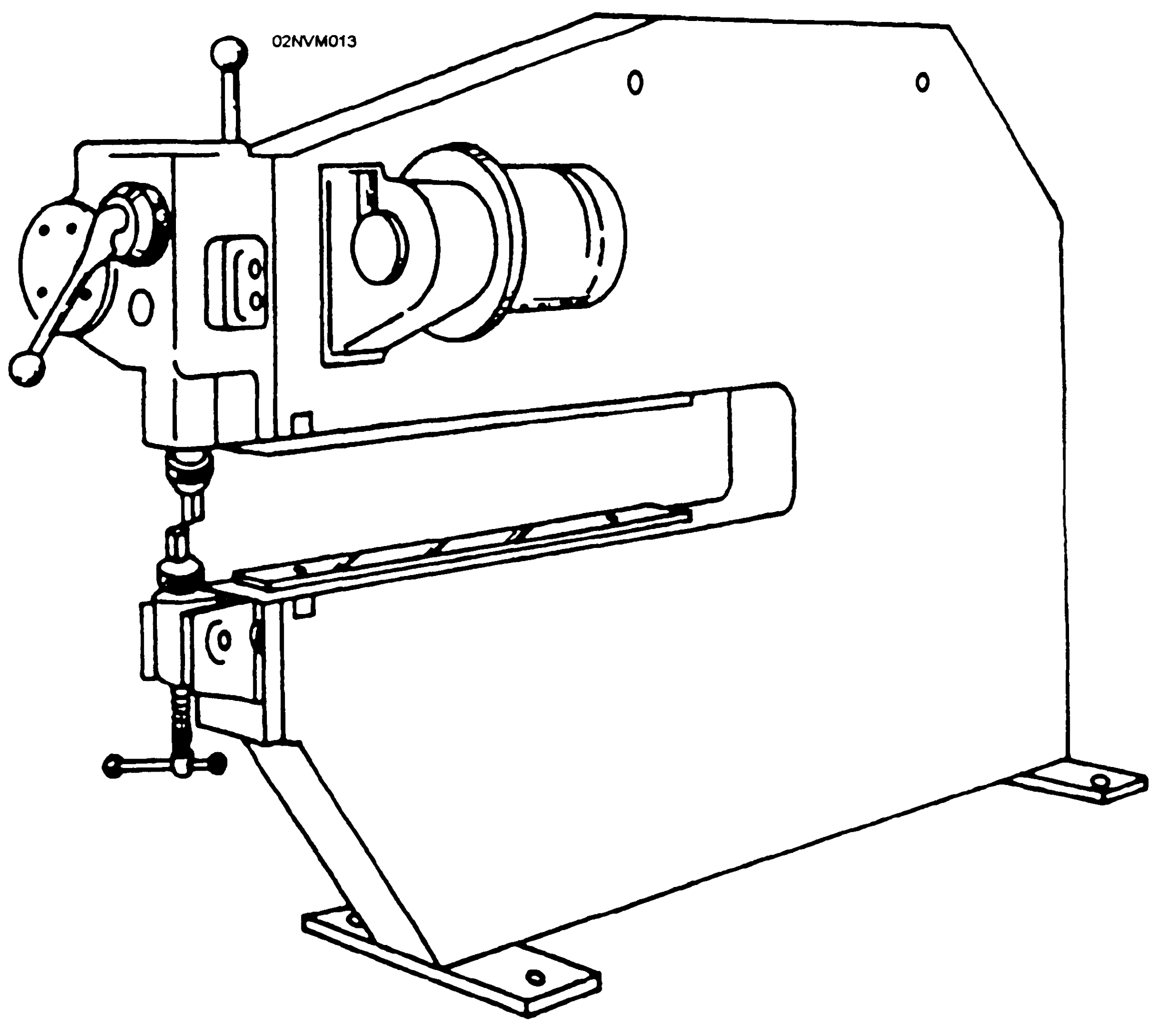


Figure 13-33.—Universal Pullmax machine.

Tooling Setup.—Select the proper tooling for the task assigned. For cutting straight and circular lines, use shearing tools, as shown in figure 13-36. Shearing tools may be used for cutting a freehand pattern or for contouring the inside or outside perimeter of a project. Tooling setup steps are as follows:

1. Select the proper tooling and install them in the proper tool holder. Hand tighten the tightening nut. Figure 13-36 shows the proper positioning of the tools.

2. Lower the upper tool into the cutting position by using the lever on the front of the machine, as shown in figure 13-36.

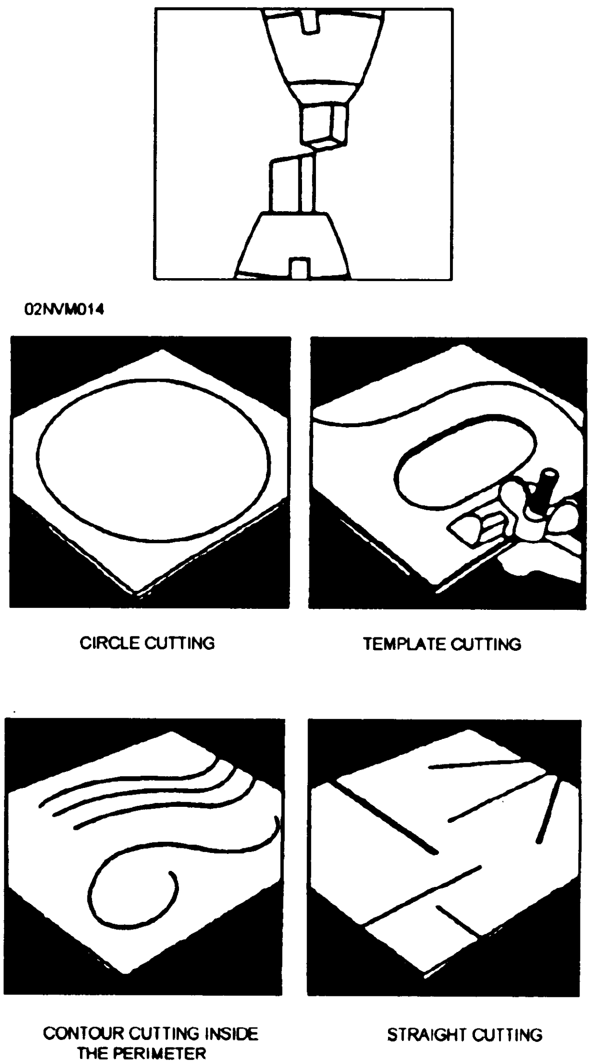


Figure 13-34.—Shearing tools.

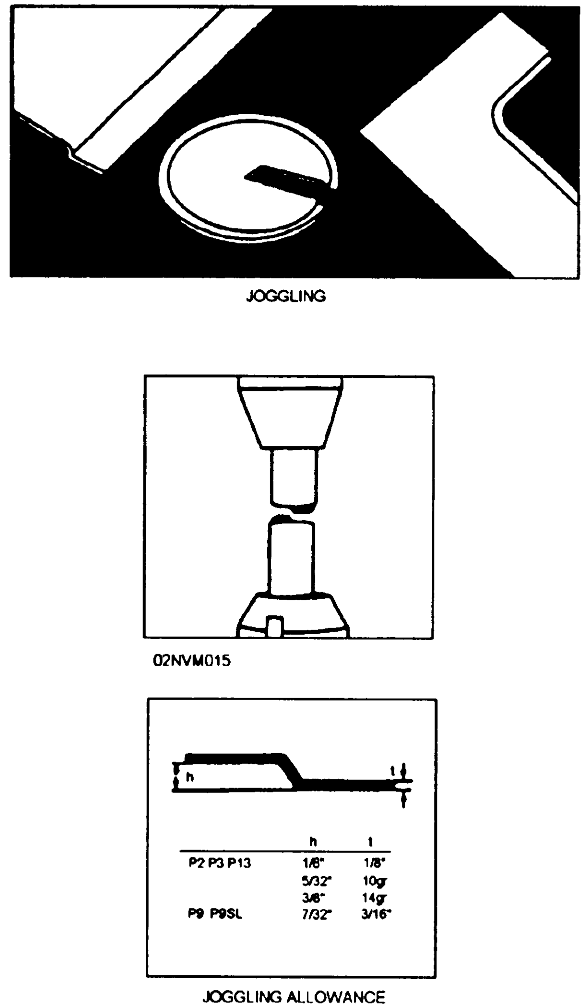


Figure 13-35.—Joggling tools.

3. With the tools in the cutting position, check the clearance between the upper and lower tooling. Use a piece of white paper as a background to check for side clearance. Look from one side directly at the white paper background. You should have a clearance of 0.002 to 0.003 inch. An improper clearance adjustment will result in a poor quality cut or damage to the machine.

4. Adjust the tool for side clearance by turning the side adjustment screw located on the left-hand side of the toolholder, as shown in figure 13-36. Turning the adjustment screw clockwise will close the clearance; while turning it counterclockwise will open the clearance between the tools.

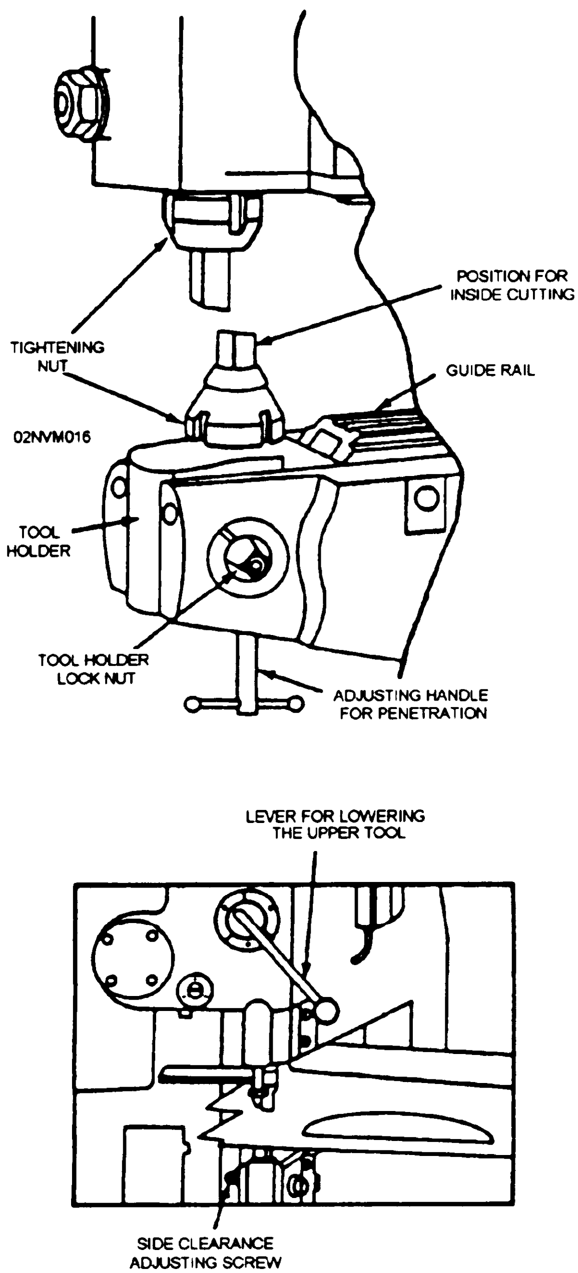


Figure 13-36.—Pullmax universal machine, upper and lower cutting tools.

5. When the adjustment is correct, tighten the toolholder locknut opposite the adjusting screw.

6. Make adjustments for proper penetration with the tools in the cutting position. Use the adjusting handle at the bottom of the toolholder to adjust the lower tool so that it will only penetrate 1/3 of the thickness being cut.

7. Cycle the machine, checking the machine for binding or misalignment.

8. Make a test cut on a sample of the metal being cut.

Stroke and Speed Control.—The stroke and speed of the upper tool is important if a smooth cut is to be obtained. We have already discussed speed control earlier. You should remember that high speed is used to cut thin metal and slow speed is used to cut thicker gauge metal Stroke control is obtained by using the same lever that lowers the upper tool into the cutting position. When the lever is engaged to the left, you will get a short stroke. A short stroke is used to cut thin metal. When the lever is engaged to the right, you will get a long stroke, which is used to cut thin metal.

Plasma Arc Machine

Plasma arc cutting is a high-speed, high-quality metal cutting process that greatly reduces cutting and edge preparation costs. Plasma arc cutting is similar to tungsten inert gas welding because it uses the same basic circuit and shielding gas. The plasma arc cutting torch greatly reduces cutting time and replaces slower machinery previously used to accomplish the same task. The cutting process uses extremely high temperatures, high-velocity ions, and a constricted arc between a tungsten electrode and the piece to be cut. This section will describe the procedures for using a typical thermal arc cutting system with water cooling at 300 amperes.

PLASMA ARC CUTTING SAFETY.—Plasma arc cutting requires the same personal protection equipment that is required for arc welding. Plasma arc cutting produces toxic gases from the cutting process. It also produces hot sparks and sound levels above 105 decibels. It uses higher temperatures than arc welding. You should never use solvents and degreasers of the halogen family near the cutting operation, because light from the arc can break these down into toxic components. The halogen family includes any of the nonmetallic elements, such as fluorine, chlorine, iodine, bromine, and astatine.

PLASMA ARC EQUIPMENT.—The equipment used for plasma arc cutting is similar to a gas tungsten arc welding (GTAW) unit. The plasma arc cutting unit has four basic components: the control panel, torch, torch leads, and gas supply. Figure 13-37 shows a typical setup for the control panel and torch.

Control Panel and Power Source.—The control panel is the operating station for the machine. It controls the power supply to the torch. The power supply is a 200-volt, open-circuit, dc power source with a drooping volt/ampere characteristic. It also provides a pilot power supply of less than 200 volts, dc, open circuit for the operation of the pilot arc to start the arc cutting process. A typical control panel will have a gas flowmeter, ammeter, fuse panel, gas mixing control panel, and amperage setting dial.

Plasma Arc Torch.—The torch body is composed of a handle, a ceramic cup, and a tungsten electrode. The handle is similar to a GTAW torch and serves as an attachment base for the ceramic cup and as an electrode holder. The ceramic cup concentrates and columnates the energy of the arc stream created inside the torch. The electrode provides the electrical current required to produce the ionized plasma gas. The electrode should be replaced if it becomes eroded or out-of-round. Resharpen the electrode when the eroded part in the center becomes l/8 inch in diameter. Keep the following points in mind when sharpening electrodes:

- Sharpen the electrode with a 0.218-inch diameter, flat in the center, and a 60-degree included angle.
- The electrode must be concentric with the electrode outside diameter.
- A scribe line on the electrode body indicates the limit to which the electrode can be resharpened.

Torch Leads.—The plasma arc machine has four different color-coded torch leads and connections to supply plasma gas and cooling water to the torch. The four color-coded connections are as follows:

- Green for the negative water-cooled lead
- Red for the positive water-cooled lead
- Black for the plasma gas
- Yellow for the shield gas

CAUTION: Purge the gas hoses prior to use to remove any moisture that may have entered the torch or leads during storage, shipment, or setup.

Gas Mixture.—Gas mixtures for plasma arc cutting serves similar functions as those used for GTAW welding. A mixture of argon (AR) and hydrogen (H)

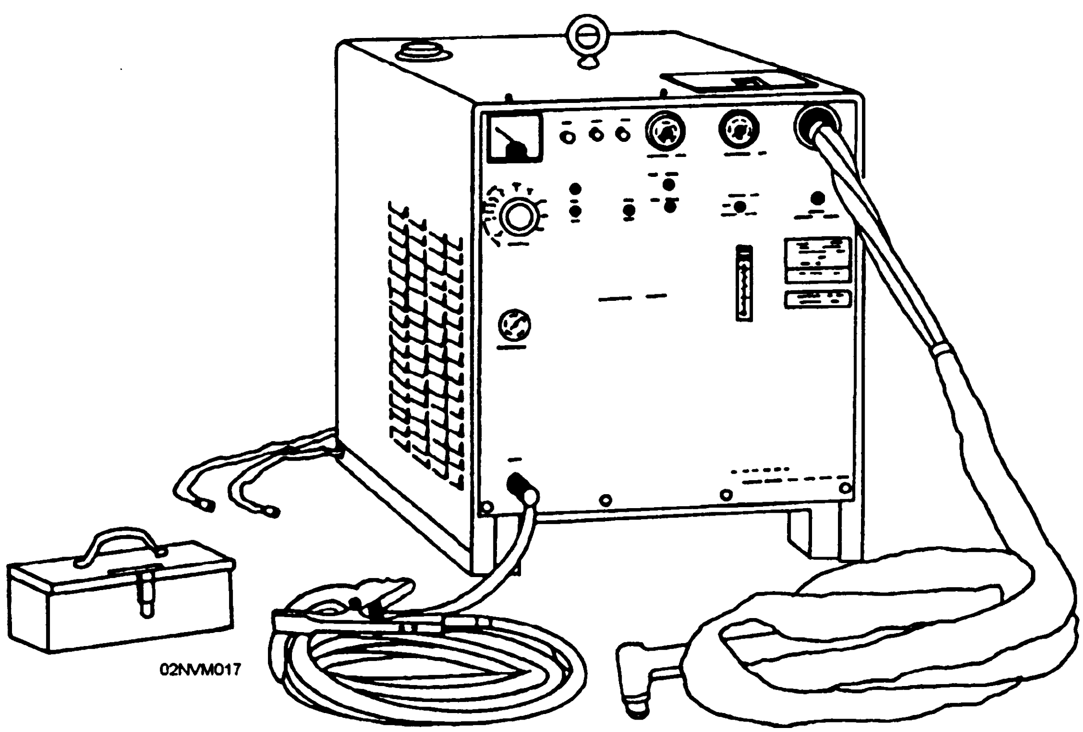


Figure 13-37.—Plasma arc cutting equipment.

gases are used for the plasma gas in cutting aluminum, and nitrogen(N) is used for other metals. The shielding gas used is carbon dioxide (CO_2). Table 13-4 shows the gas mixtures for automatic and manual cutting process.

PLASMA ARC CUTTING PROCESS.—The plasma arc cutting process employs extremely high temperatures, high-velocity ions, and a constricted arc between a tungsten electrode and the piece to be cut. This concentrated and columnated energy is produced by the electrode heating the plasma gas in the torch body to produce high-temperature ionized gas. This ionized gas is forced out of the torch through the ceramic cup, which concentrates and colmunates the energy. As the ionized gas strikes the plate, the metal is melted and the jet-like action of the arc removes the molten metal mechanically. The inert gas atmosphere prevents oxidation of the kerf wall.

Table 13-4.—Gas Mixtures for Plasma Arc Cutting Machines

Plasma Gas AR/H_2	40 psi	(Aluminum)
Plasma Gas N_2	20 - 40 psi	(All others)
Secondary Gas CO_2	40 psi	

FORMING MACHINERY

This section will take a look at machinery associated with forming metal plate and shapes, such as the sliproll forming machine, the brake press, and the Hossfeld Bender.

Sliproll Forming Machine

Sheet metal can be formed into curves over pipe or a mandrel, but steel plate requires machinery capable of providing considerably more pressure in the forming process. You have already been introduced to the sliproll forming machine in the chapter 12. The powered sliproll machine (fig. 13-38) used in the shipfitter shop operates on the same principle as the hand-powered sliproll used in the sheet metal shop. The powered sliproll machines found in the shipfitter shop are capable of rolling plate up to l/2 inch in thickness. Since steel plate is stiffer than sheet metal, you must take greater care when feeding the plate into the machine to ensure accurate rolling of the plate. Figure 13-39 shows some of the common problems associated with rolling plate.

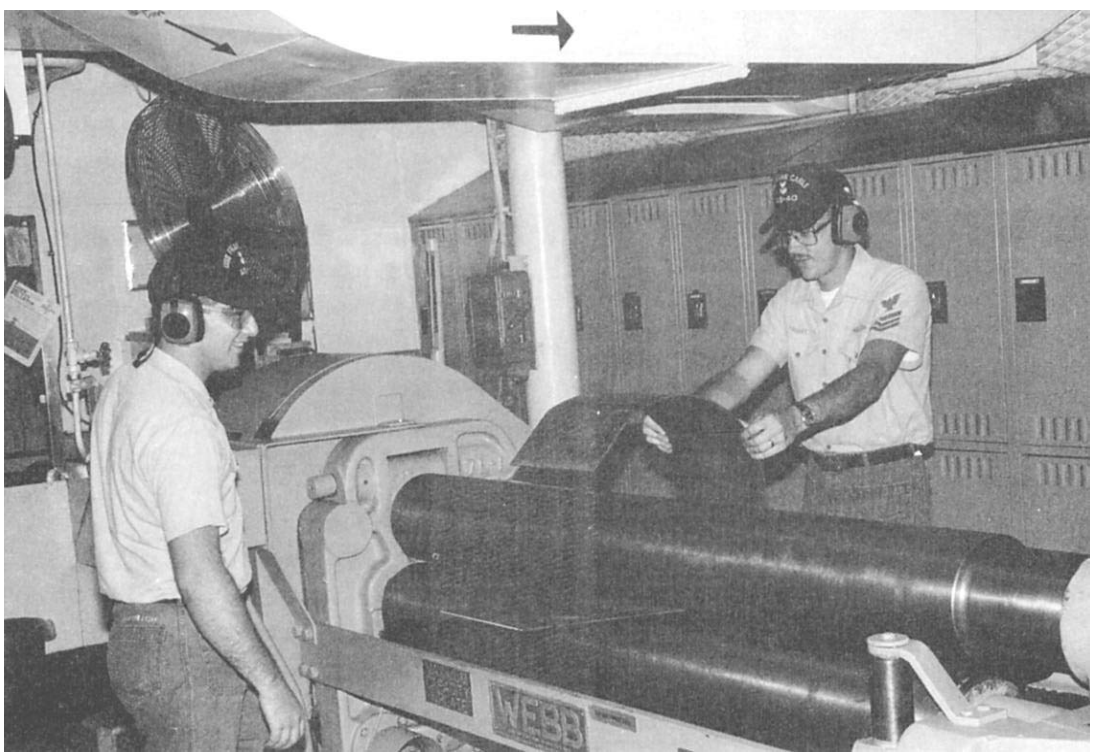


Figure 13-38.—Sliproll forming machine.

Press Brake

The power press brake is a large hydraulically driven machine that bends metal to desired angles using punches and dies. Most press brakes are rated at 300 tons of hydraulic bending pressure. They are capable of bending steel plate between l/8 to l/2 inch thick by 8 feet long to a 90-degree bend. These machines are generally used to bend plate steel to various degrees up to 90 degrees. Press brakes may also be used to bend cone and cylindrically shaped objects by making several smaller bends close together to roll the plate. In this section, we will look at the safety precautions,

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TROUBLE SHOOTING CHART

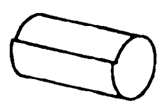
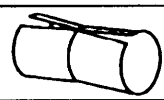
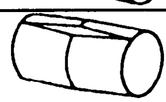
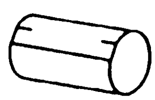
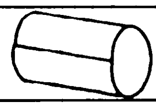
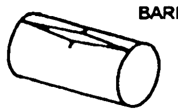
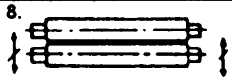
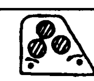
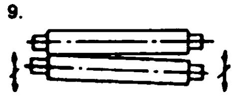
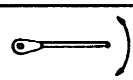
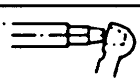
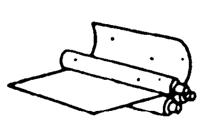
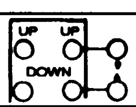
EXAMPLE	CAUSE	CORRECTION
1.  CYLINDER WILL NOT LINE UP SPIRALLING	A. SHEET DID NOT ENTER ROLLS STRAIGHT B. LOWER ROLLS NOT LEVEL C. SHEET IS NOT SQUARE	A. CHANGE ANGLE OF ENTRY B. CHECK WITH GAUGE, ALINE WITH CLUTCH, COUPLING, RATCHET WRENCH OR HAND WHEEL C. USE SQUARE SHEETS
2.  HOUR-GLASSING	LIGHT MATERIAL TOO TIGHT SETTING ON PINCH ROLL	CHANGE SETTING OF PINCH ROLL
3.  BARRELLING	OVERLOAD	CHECK CAPACITY CHART
4.  FLAT SPOT	EDGE NOT PREFORMED	PREFORM ON BACK SIDE OF MACHINE THEN ENTER PREFORM EDGE IN FRONT SIDE PREFORM ON PRESS BRAKE PRIOR TO ROLLING
5.  CYLINDER IS NOT CONCEN-TRIC	ROLLS MAY BE BENT	CHECK WITH INDICATOR, STRAIGHTEN
6.  BARRELLING AT JOINT ONLY LEADING OR TAILING EDGES BODY OF CYLINDER TRUE	OVERLOAD OR PINCH ROLLS SET TOO TIGHT	CHANGE SETTING ON PINCH ROLL
7.  ALL ROLLS NOT ROTATING	DRIVE CLUTCH SLIPPING	ADJUST CLUTCH
8.  ROLLS LOCKED IN POSITION	ROLLS JAMMED	MANUALLY ROTATE CONNECTING SHAFT  TO LOWER
9.  ONE END OF LOWER ROLL WILL NOT MOVE	A. CHECK SHEAR PIN IN RAISING SCREW HEAD B. CHECK WORM GEAR C. CHECK COUPLING & CLUTCH ON CONNECTING SHAFT	REPLACE
10.  RATCHET WRENCH FAILS TO LOWER ROLL	NEW MACHINE NOT BROKEN IN	TURN ON MAIN DRIVE AND WHILE THE ROLLS ARE TURNING USE RATCHET WRENCH
11.  TOP ROLL WILL NOT ENTER TAIL HINGE	PULL ROD OUT OF ADJUSTMENT	TO RAISE TOP ROLL TIGHTEN PULL ROD TO LOWER TOP ROLL LOOSEN PULL ROD
12.  MARRING MARRING DOES NOT EFFECT THE ROLLING OPERATION	A. MARRING OF ROLLS MAY TAKE PLACE ON NEW MACHINE UNTIL THE ROLLS WORK HARDEN B. MARRING MAY BE CAUSED BY FRAME CUT EDGES ON PLATE SLIPPING DRIVE CLUTCH C. SEE FIGURE 7. D. METAL BUILD UP ON ROLL SURFACES	A. AFTER ROLLING FIRST FEW SHEETS THE ROLLS WILL BECOME WORK HARDENED AND MARRING SHOULD CEASE B. FLAME CUT EDGES SHOULD BE GROUND C. TIGHTEN CLUTCH D. GRIND OR EMERY OFF
13.  LOWER ROLLS TRAVEL IN WRONG DIRECTION THAN INDICATED ON CONTROL PANEL	WIRED WRONG	REVERSE TWO POWER LEADS

Figure 13-39.—Sliproll forming machine troubleshooting chart.

setup, and operation of a typical brake press. Figure 13-40 shows a typical brake press.

BRAKE PRESS SAFETY.—The brake press is capable of operating at hydraulic pressures of up to 300 tons. Due to these high pressures and the machine operating capacity, there are several important safety precautions you should follow. They are as follows:

—Become familiar with the type of brake press installed in your shop. Qualify on its use and operation under qualified supervision prior to operating the brake press.

—Determine the capacity of the machine being used from the manufacturer's technical manual and NEVER exceed its maximum capacity. Capacities for most machines are given in metal thickness, length, and, unless otherwise noted, are given for mild steel not alloy steels.

—Never place any part of your body under the dies and punches of the press brake.

—Never place hands or fingers between the metal plate and the die.

—Never, never have your foot on the trip lever or foot pedal while loading or adjusting plate on the brake.

—Never attempt to bend pipe, bar stock, round stock, flat bar less than 2 inches in width, or other similar metal shapes. If you attempt to bend these types of metal shapes, you will damage the dies and risk injury.

BRAKE PRESS SETUP.—When you set up the brake press, there are three important setup adjustments to make. You must select the proper set of dies, bending pressure, and machine stroke. We will look at the requirements for each of these adjustments.

Die Selection.—The brake press is capable of using different dies to perform several different functions. The top half of the die is called the punch and the lower half is called the die. The "V" die is the most common punch and die combination used in the shipfitter shop. These dies allow plate to be bent at various angles. When selecting the opening for the "V" die, it should equal eight times the thickness of plate being bent. You will find a single "V" die with four openings in most shipfitter shops for bending l/8-, l/4-, 3/8-, and

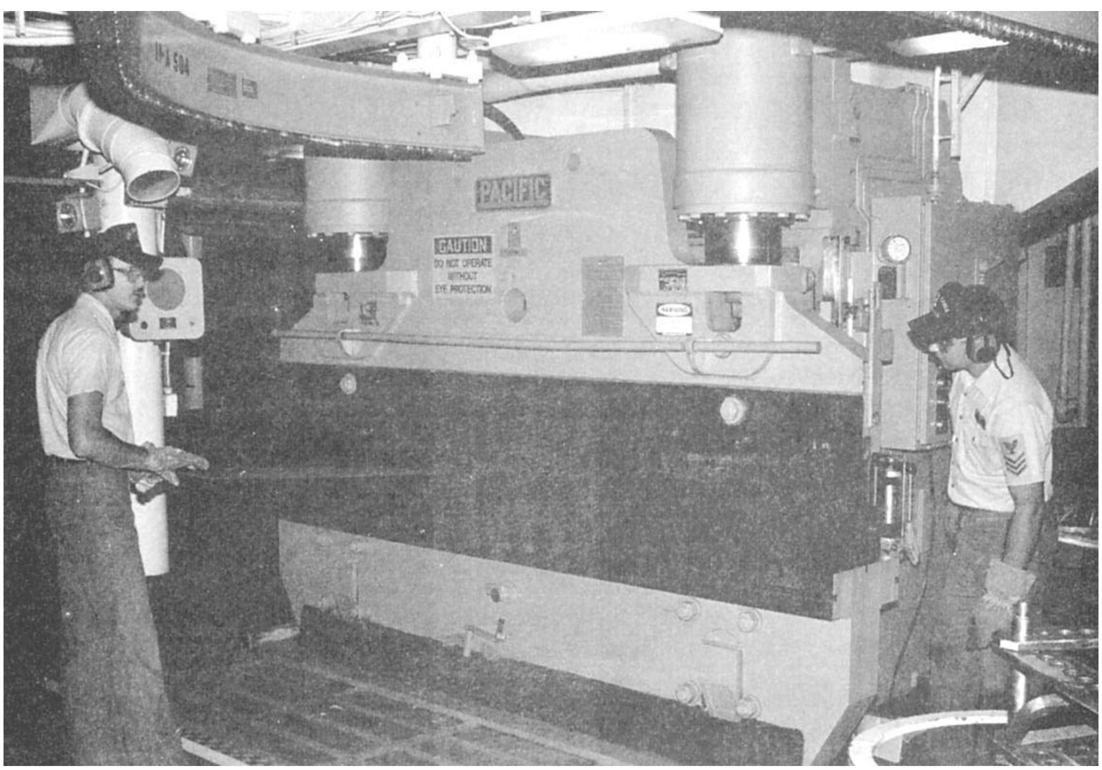


Figure 13-40.—Brake press.

l/2-inch plate (fig. 13-41). This die is simply rotated to the correct opening for the task at hand.

Bending Pressure.—Bending pressures on brake presses are set to the correct pressure to allow for the proper bending of the desired material to be bent. Too low of a pressure setting will cause incomplete bending of the plate. If the bending pressure is set too high, the metal may be forced too far into the dies, causing marring of the surface and overbending of the plate. Due to the number of different machines in use, we will not cover the actual setting of hydraulic pressure. You should refer to the owner's technical manual for proper bending pressure and pressure adjustment.

Stroke Setting.—Stroke setting is how far the ram will travel in one cycle of the ram. You will choose the type of stroke to use depending on the job at hand and the experience of the operator. The machine in your shop may have stroke selector switches with different labels but will perform the same basic functions. The four choices of the stroke are as follows:

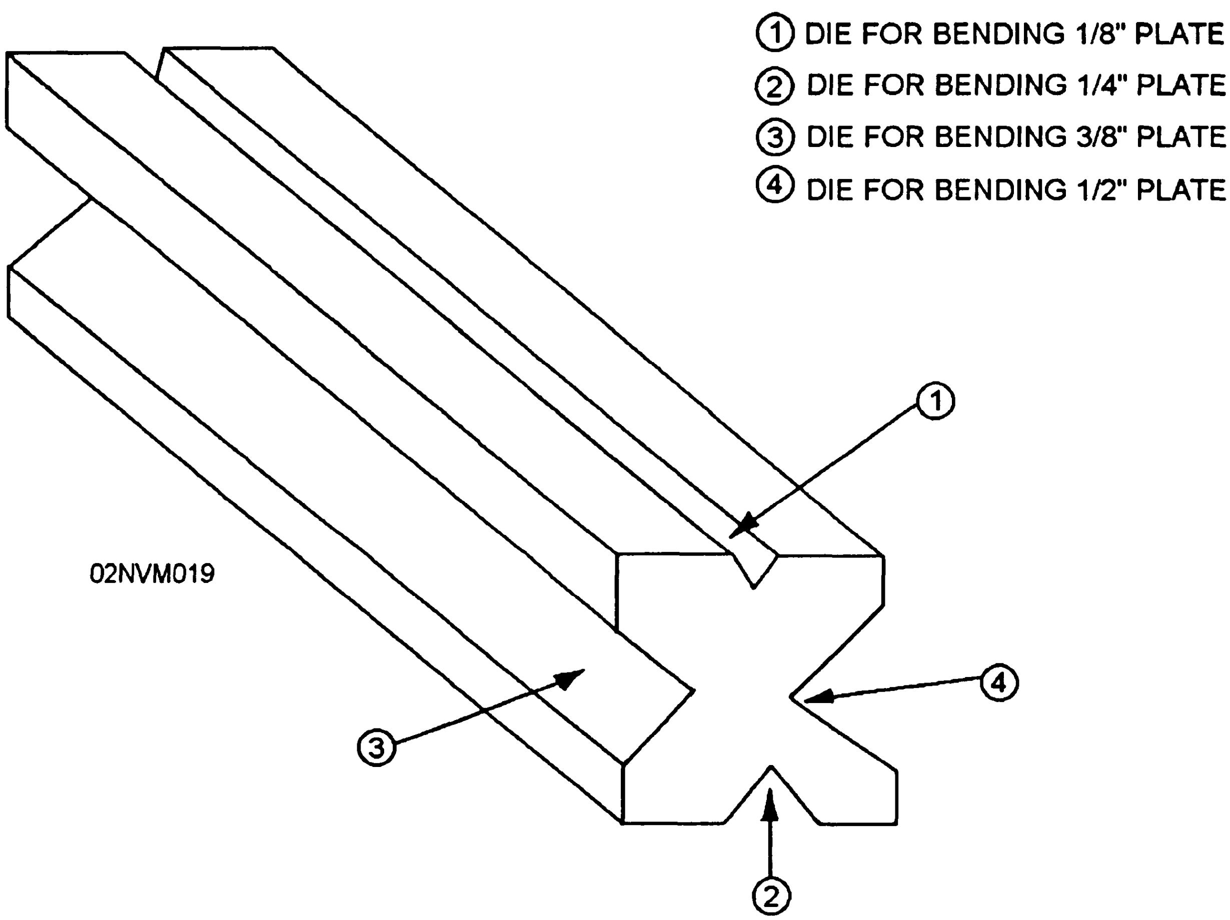


Figure 13-41.—Typical "V" die.

- CONTINUOUS—The press will run continuously until the stop button is pushed.

- INCH—The ram may be inched by use of any selected button or foot switch and will stop whenever the button is released, regardless of the stroke position.

- LONG—The operator holds the run button or foot switch until the ram reaches the bottom of the stroke. When the run button or foot switch is released, the ram automatically returns to the top of the stroke and stops.

- SHORT—A single momentary operation of buttons or foot switches will cause the ram to go through one complete cycle.

The total travel of the ram is controlled by the setting limit switches. Limit switches are installed to provide an accurate range of travel for the ram so that the same bend may be made time after time without resetting the machine. There are several types of limit switches used depending on the type of machine. Some machines use set screws, depth gauges, pressure switches, micrometer adjustments, or a combination of several different types. The use of a depth gauge and micrometer are the most accurate, since you can make adjustments in one-thousandths of an inch.

PRESS BRAKE OPERATIONS.—After setting up and making all necessary adjustments to the machine, you are ready to make bends with the press brake. The following is a list of the procedures to follow when operating the press brake:

- Select and position the proper dies.

- Check the ram to ensure that the ram is parallel to the bed. Make adjustments, if necessary. Some presses are capable of working with the ram tilted so that you can bend items, like funnels, where you would want a tighter bend in the throat than at the edge. For most work, you will want the ram parallel to the bed.

- Set the depth of the ram stroke and check the setting on a scrap piece of metal.

- Load the plate in the machine. Work in the center of the press, where possible. If it is necessary to make heavy bends at one end of the machine, place a dummy load at the opposite end of the machine.

- Ensure that the plate is aligned for proper location of bend. Place hands under the plate. Be sure the head and upper body are clear from the plate. Do not lean over the work while bending the plate.

- Engage the ram by activating the foot switch or hand buttons.

Hossfeld Bender

The Hossfeld Bender is used to bend radii and angles on a wide variety of shapes including small rods, piping, tubing, flat stock, and angle iron. The Hossfeld Bender is available in two models. Model No. 1 is a manually operated machine. Model No. 2 is a larger hydraulically operated machine. Due to the numerous attachments and arrangement of these attachments on the frame of the bender, we will only discuss the components of the machine, die selection, and the capacity of the machine. To properly set up the machine, refer to the manufacturer's technical manual.

HOSSFELD BENDER COMPONENTS.—The Hossfeld Bender consists of two frames, a stop gauge, and a center pin. The component parts of the Hossfeld Bender are shown in figure 13-42 and are as follows:

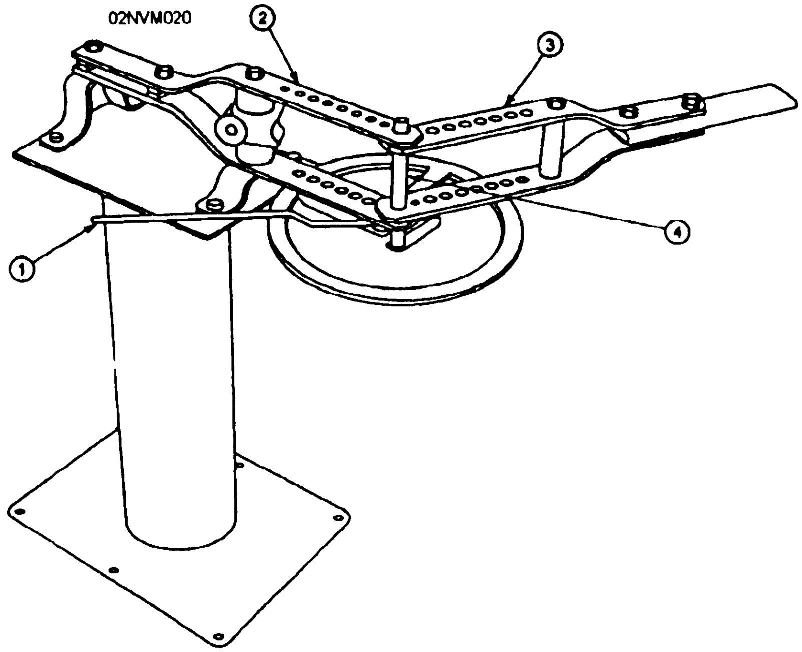
- MAIN FRAME—Stationary frame to which dies are attached. Each hole in the frame is labeled for proper die installation.

- SWINGING FRAME—Movable frame to which dies are attached. Each hole in the swinginig frame is labeled for proper die installation.

- ADJUSTABLE STOP GAUGE—Used as a guide for stopping the swinging frame when producing quantities of identical parts.

- CENTER PIN—Joins the main frame to the swinging frame. Used to mount dies.

DIE SELECTION.—Die selection is the most important consideration when setting up the Hossfeld Bender for use. You must follow the manufacturer's



1. Adjustable Stop Gauge
2. Main Frame
3. Swinging Frame
4. Center Pin

Figure 13-42.—Hossfeld Bender.

technical manual when setting the proper dies for the task at hand. Each die will be labeled with a number/letter combination to identify its use. An example of a die is 13B4, which is a grooved pipe bending die 2 inches in diameter. The dies are mounted on the frames at predetermined holes by pins. As with the dies, the holes in the frame and pins are also labeled so that you will position the dies in the correct position. Figure 13-43 shows the standard parts and dies used with the Hossfeld Bender.

Hossfeld Bender Capacities.—The Hossfeld Bender is used to bend pipe or tubing up to 2 inches in diameter, flat stock up to l/2 by 4 l/2 inches, 1 l/4-inch round or square stock, and 2-inch by 2-inch by 3/l6-inch angle iron.

FABRICATION

The fabrication of new items in the shop or on the job site will be your primary concern as a shipfitter. You will often work off of blueprints to manufacture parts to specifications. At other times, you will be manufacturing parts from preexisting parts and will be required to make targets or templates to work from. For you to function effectively in the shop, you need to have an understanding of the use of templates, targets, and erection aids, and the procedure used to figure bend allowances.

LIFTING TEMPLATES

A good deal of the plate work can be done by using lifting templates instead of actually developing patterns. Templates for plate work are commonly made from cardboard, heavy rosin paper, or template wood. Cardboard or paper are normally used for small parts and wood for larger sections. However, rosin paper can be used to make a lift template of a plate that has practically no curvature. Clear white pine in varying lengths, widths, and thicknesses is normally used as template wood. This material is soft and can be easily cut with a jackknife.

To lift a template, you need to get the size and shape of the piece, along with the size and location of all rivet holes or other special features, directly from the frames, stringers, plates, and other structures and around the repair area. To obtain the template, temporarily attach the template material to the particular piece that the template is to be lifted from. Then transfer an outline of the piece to the template material. You will normally

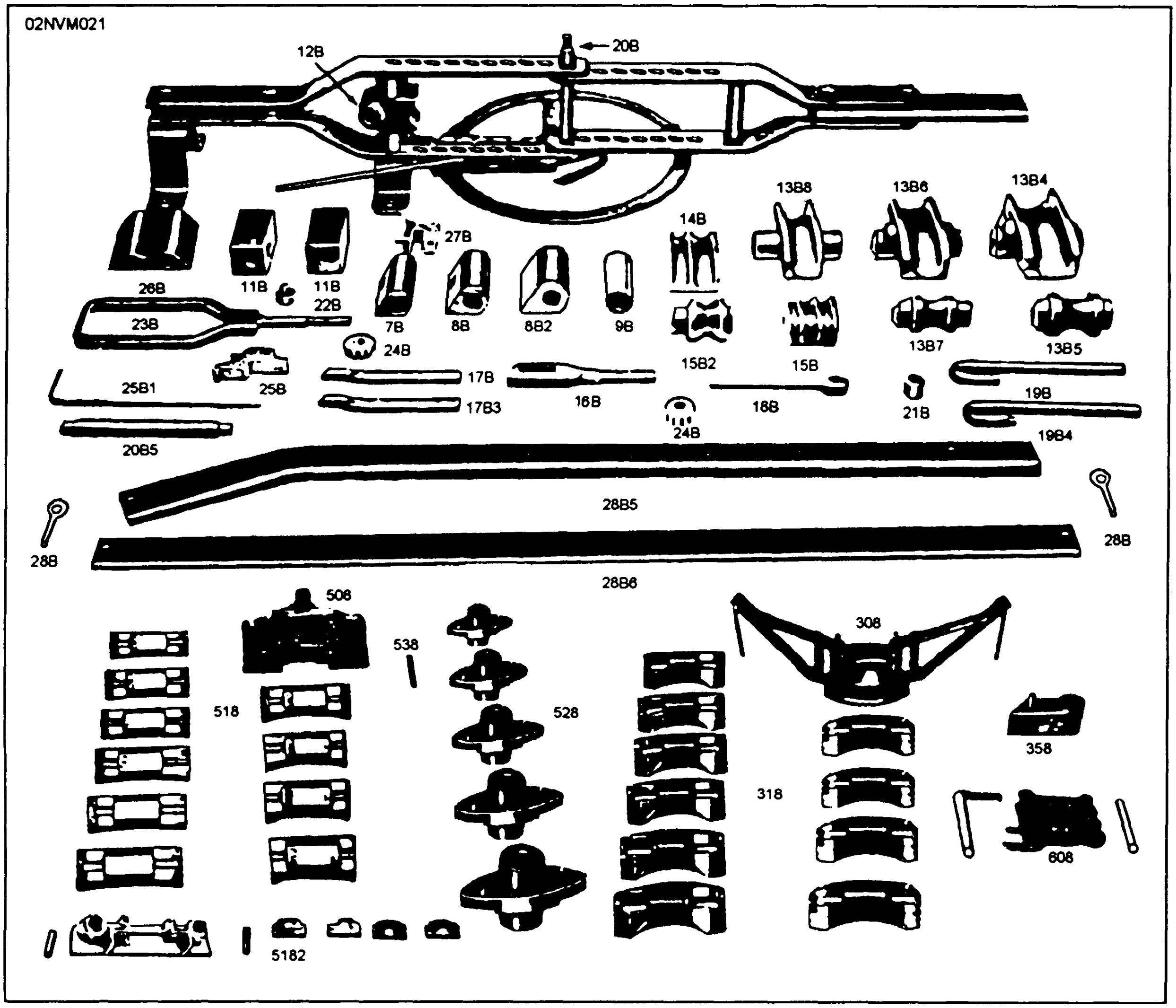


Figure 13-43.—Standard parts and dies.

have to cut and trim the template until you get the proper fit. Figure 13-44 demonstrates some of the more common uses for templates.

If the piece has a marked curvature, you will also need to make a SET (or gauge) to use as a guide while you roll the new part to the correct shape.

SET

A set is merely a narrow bar or strip of soft iron bent to the required curvature. The set is made of material that is the same thickness as the plate to be used. If the curvature is complex, more than one set will be required. Once the lift template and necessary sets are made, the new plate can be laid out. A lift template and set for a shell plate are shown in figure 13-45.

TARGETS

As a shipfitter, you will need to build targets from time to time when you manufacture numerous identical items or make repairs to structures that have numerous attachments that must be removed. You may also build a target to maintain certain dimensions or tolerances. Targets will be discussed in greater detail in the chapter on pipefitting and repair (chapter 16) but has similar applications to the shipfitter as well.

ERECTION AIDS

You will find the erection aids, shown in figure 13-46, to be very useful in fitting plate to the curvature of structures where it is not feasible to use the power bending machines. Erection aids are also used to align

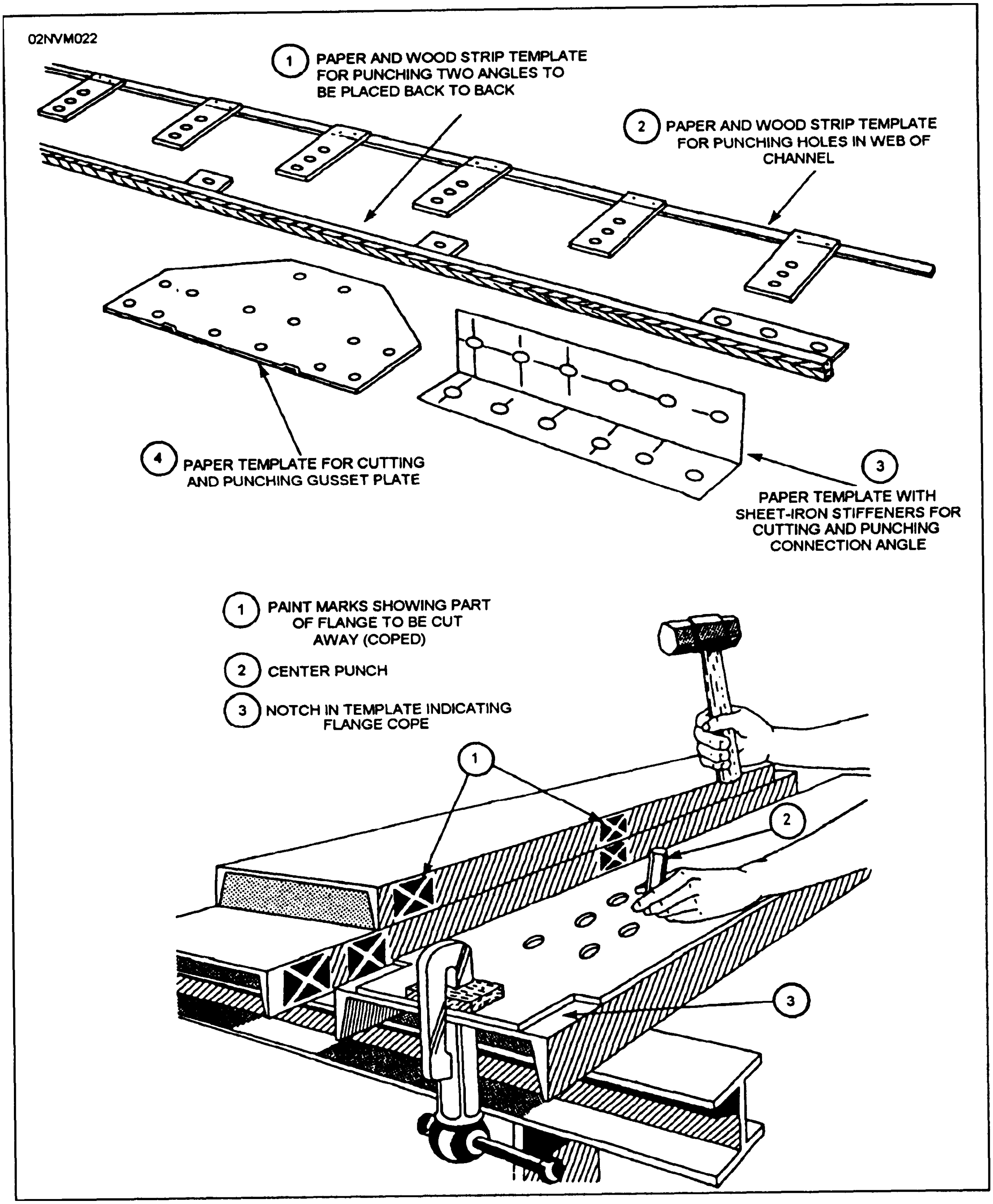


Figure 13-44.—Types of templates and their use.

and hold plate and structure in place while being joined. They are usually tack welded in place while being used. You should always install the erection aids so that they may be readily removed by striking the dog or clip with a hammer. Never fully weld an erection aid in place unless absolutely necessary. Figure 13-46 shows the correct way to use some of these aids.

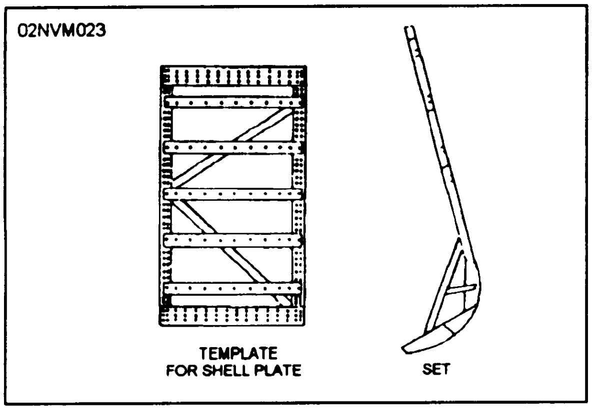


Figure 13-45.—Lifting template and set for shell plate.

BEND ALLOWANCE

Regardless of the method used to bend plate, you must always consider the thickness of the plate and provide an adequate bend allowance. The thicker the metal, the more important the calculation of the bend allowance. When working with thin sheet, you can estimate (or sometimes even disregard) the thickness of the material. If the thickness of the material in heavy plate is not considered, it will cause serious errors in specified dimensions, perhaps even a complete lack of fit between component parts.

When bending metal to exact dimensions, you must know the amount of material required to form the bend.

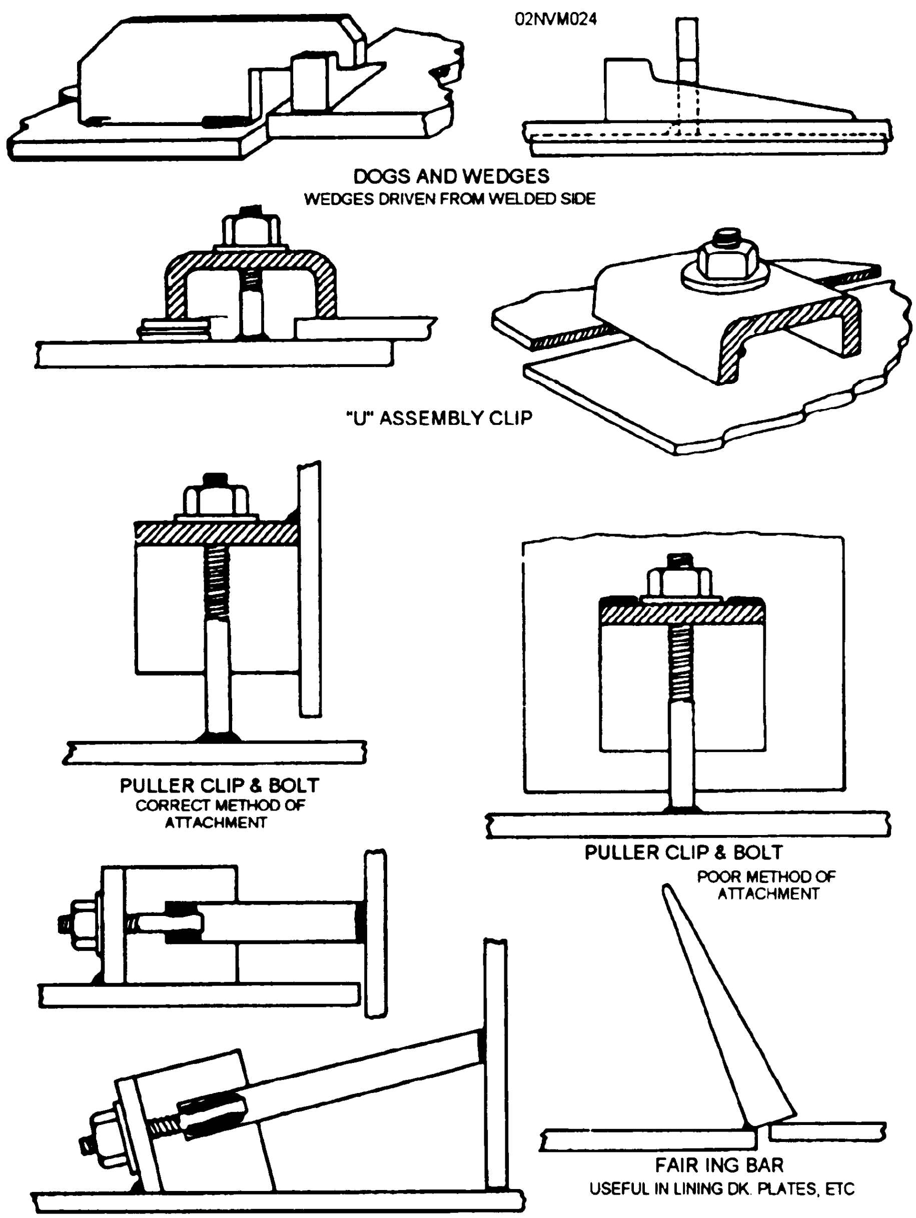


Figure 13-46.—Erection aids.

The amount of material required is known as the bend allowance.

In bending, the metal is compressed on the inside of the bend, and stretched on the outside of the bend. Halfway between these two surfaces or extremes is a space that neither shrinks nor stretches but retains the same length. This is known as the neutral axis. Figure 13-47 shows the neutral axis of a bend. The bend allowance is computed along this neutral axis.

Bend Allowance Terms

To understand the calculation and discussion of bend allowance, you need to be thoroughly familiar with the definitions used to calculate bend allowance. As you study the definitions, refer to figure 13-48 and locate each part described. Some parts are not shown in the figure but are described in the text. This section may be difficult to understand. You may need to go over it with a more experienced HT. The definitions are as follows:

LEG—The longer part of a formed angle.

FLANGE—The shorter part of a formed angle. If both parts are the same length, each is known as a leg.

MOLD LINE (ML)—The line formed by extending the outside surfaces of the leg and flange so that they intersect.

BEND TANGENT LINE (BL)—The line at which the metal starts to bend.

BEND ALLOWANCE (BA)—The amount of material consumed in making the bend.

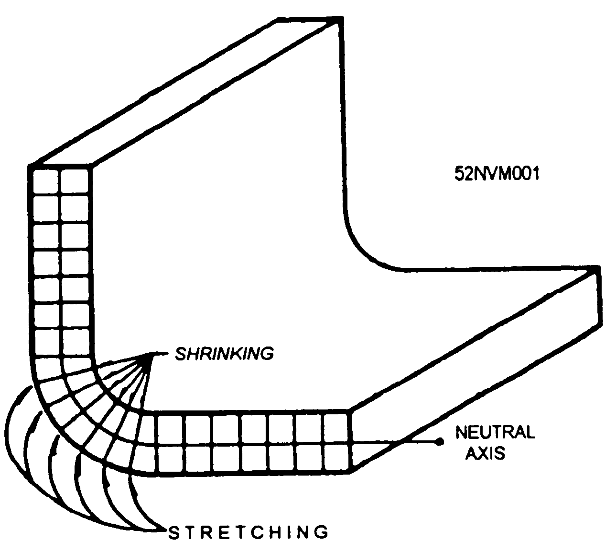


Figure 13-47.—Neutral axis.

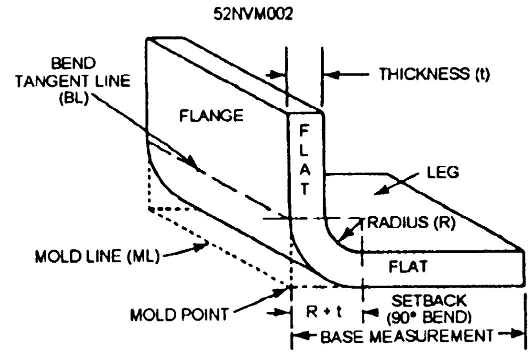


Figure 13-48.—Bend allowance terms.

RADIUS (R)—The radius of the bend. It is always measured from the inside of the bend unless otherwise stated.

SETBACK (SB)—The amount that the two mold line dimensions overlap when they are bent around the formed part. In a 90-degree bend, SB = R + t (radius of the bend plus thickness of the metal).

BEND LINE (also called brake or sight line)—The layout line on the metal being formed which is set even with the nose of the brake and serves as a guide in bending the work. (Before forming a bend, you must decide which end of the material can be most conveniently inserted in the brake.) The bend line is then measured and marked off with a soft pencil. Measure from the bend tangent line closest to the end that is to be placed under the brake. This measurement should be equal to the radius of the bend. The metal is then inserted in the brake so that the nose of the brake will fall directly over the bend line.

FLAT PORTION OR FLAT—The flat portion or flat of a plate is that portion that is not included in the bend. It is equal to the base measurements minus the setback.

BASE MEASUREMENT (or mold line measurement)—The base measurement is the outside dimensions of a formed plate. Base measurement will either be given on the blueprint or drawing, or it may be obtained from the original part.

CLOSED ANGLE—An angle that is less than 90° when measured between legs, or more than 90° when the amount of bend is measured.

OPEN ANGLE—An angle that is more than 90° when measured between legs, or less than 90° when the amount of bend is measured.

Computing Bend Allowance

To compute bend allowance, you must know two primary facts: the radius of the bend and the degree of angle in the bend. Usually, this information can be found on your blueprints or drawings.

As you study the following examples, refer to figure 13-49 to help you understand where and how the mathematical figures are obtained. Remember, bend allowance is measured from the inside of the bend but is computed along the neutral axis of the material being used. Therefore, when calculating bend allowance, add the bend radius to one-half of the thickness of the metal. This will determine the radius of the neutral axis.

Bend allowance is the product of the radius of the neutral axis of the bend which is multiplied by the size

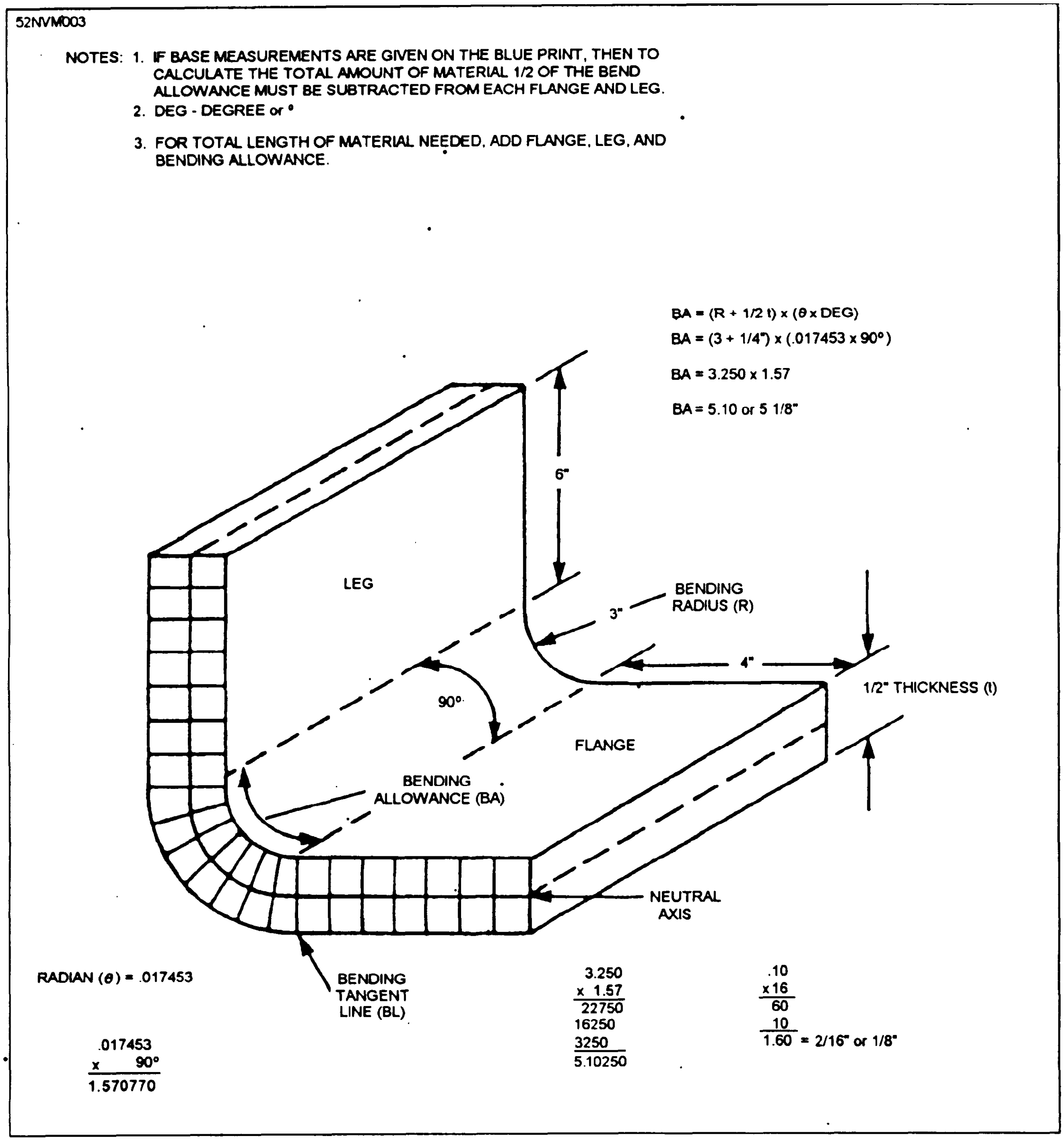


Figure 13-49.—Calculating bend allowance.

of the bend in radians. The radian relates the length of the arc generated to the size of the angle. For the purpose of computing bend allowance, the number of radians per degree of bend is 0.017453. Thus, the formula for bend allowance is:

$$ba = r \times R$$

Where:

ba = bend allowance

r= radius of the neutral axis of the bend

θ = size of the angle of the bend in radians

EXAMPLE 1 (fig. 13-49)—What is the bend allowance for a 90-degree bend with a 3-inch radius which is to be made in plate that is l/2 inch thick?

$r = 3.00 + 0.250 = 3.250$ inches.

(Remember you must add one-half the thickness of the plate to be bent to the radius of the bend.)

$8 = 0.017453 \times 90 = 1.57$ radians

Therefore:

$ba = 3.250 \times 1.57 = 5.10$ inches

EXAMPLE 2 (fig. 13-50)—What is the bend allowance for a 180-degree bend which is to be made in a length of l/2-inch stock?

$r = 1.0 + 0.250 = 1.25$ inches

$8 = 0.017453 \times 180 = 3.14$ radians

Therefore:

$ba = 1.25 \times 3.14 = 3.925$ inches

REPAIRS AND FABRICATION

Much of your work will consist of repairs and alterations made to the existing ship's structures. Repairs are different from alterations in that the design of the ship’s structure is not changed by repairs.

For example, if you remove a deteriorated section of a watertight bulkhead and install a new section, it is

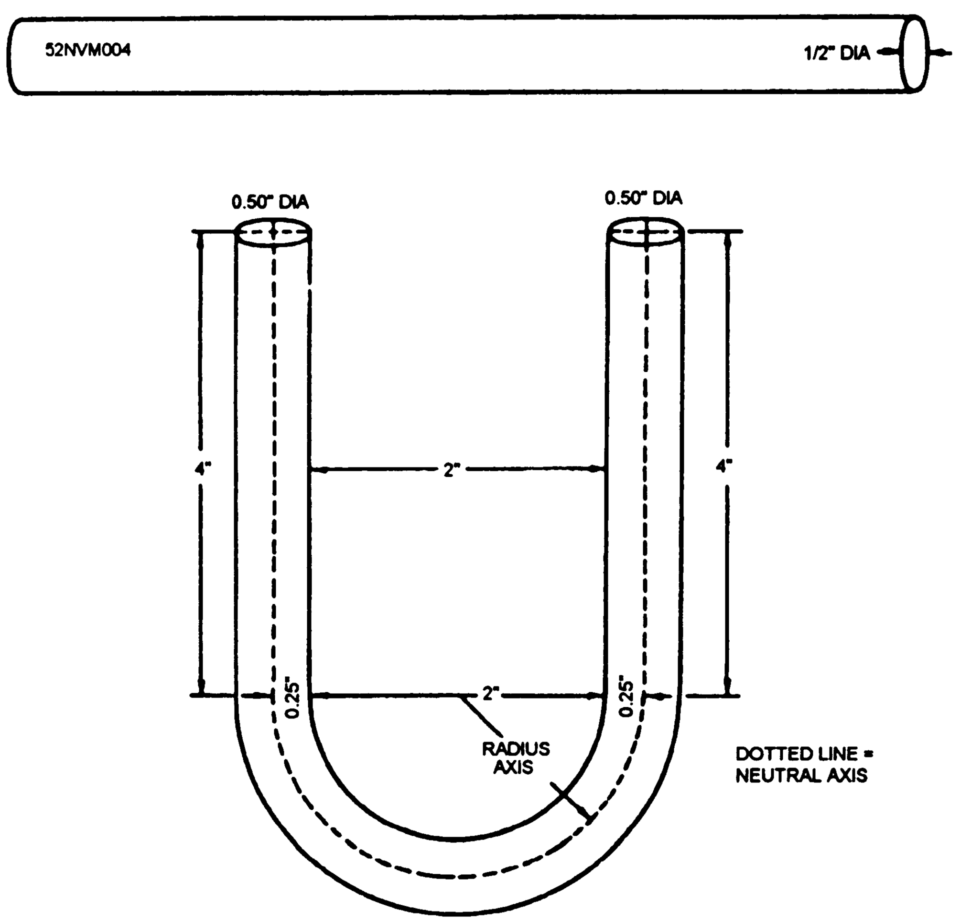


Figure 13-50.—Computing the overall length of a U-bolt.

considered a repair. However, if you cut a hole in a watertight bulkhead and install a watertight door that modifies the ship's structure, it is an alteration. All repairs and alterations must be performed according to the appropriate specifications and authorizations.

Some of the problems encountered when making repairs and alterations, such as avoiding notches in plate, cutting holes in plate, stopping cracks in plate, correcting distortion and other problems associated with plate, are discussed in the following paragraphs.

AVOIDING NOTCHES IN PLATE

When repairs and alterations are being made, you must take care to avoid introducing notches (geometrical discontinuities) in the ship's structure. These points of stress concentration form the starting points for fractures. Serious notches are often caused by striking arcs on plating adjacent to a weld or by leaving rough burned edges on the structure. Corners of doublers, insert plates, chips, and pads must lx rounded to eliminate the notch effect. Discontinuities, such as slag inclusions, incomplete fusion, and undercut in a weld, can also become the starting point for fractures. You must be careful in your workmanship and inspections to prevent the introduction of such notches into the structure.

HOLE REPAIRS

You will be called upon to make repairs to all types of holes in ship and submarine structures as well as equipment. A major source of hole repair is the repair of stripped out bolt holes in accesses and covers exposed to the weather. Generally, a hole must be 2 l/2 inches or less in diameter. Holes greater than 2 l/2 inches must be replaced with a patch. We will look at partial penetration holes and full penetration holes, as shown in figure 13-5 1.

Partial Penetration Holes

Partial penetration holes are those holes that do not extend through the base material more than three-fourths of the thickness of the plate, as shown in figure 13-51. Before welding up the hole, it must be opened up to a minimum of l/2 inch and a maximum of 2 l/2 inches at the bottom. The sides are tapered with a 20-degree minimum bevel to prevent slag entrapment and allow for rod manipulation. The hole is welded up using a filler metal compatible to the base material and the weld procedure being used.

Full Penetration Holes

Full penetration holes are those holes that extend through the base material, as shown in figure 13-51. Before welding up the hole, it must be opened up to a minimum of l/2 inch and a maximum of 2 l/2 inches at the bottom. The sides are tapered with a 20-degree minimum bevel to prevent slag entrapment and allow for rod manipulation.

The hole may be welded using a backing strap or left open. If a backing strap is used, it may be permanent or removable depending on the fabrication requirements. If a permanent backing strap is used, it must be of the same material as the base metal. If the removable backing strap is used, remove it by mechanical means such as a cutting torch or grinder. Most welders use a brass or copper backing strap clamped in place during the welding process. Since the brass backing strap will not fuse with the welding material, it will normally fall off with a light tap of a hammer. After the backing strap is removed the hole must be back gouged to 1/3T (where T equals material thickness) or 3/8 inch depth, whichever is less, and the back gouge is welded up. The reason for backgouging the repair is to remove impurities that are drawn into the weld metal from the brass plate. The hole is welded up using a filler metal compatible to the base material and the weld procedure being used.

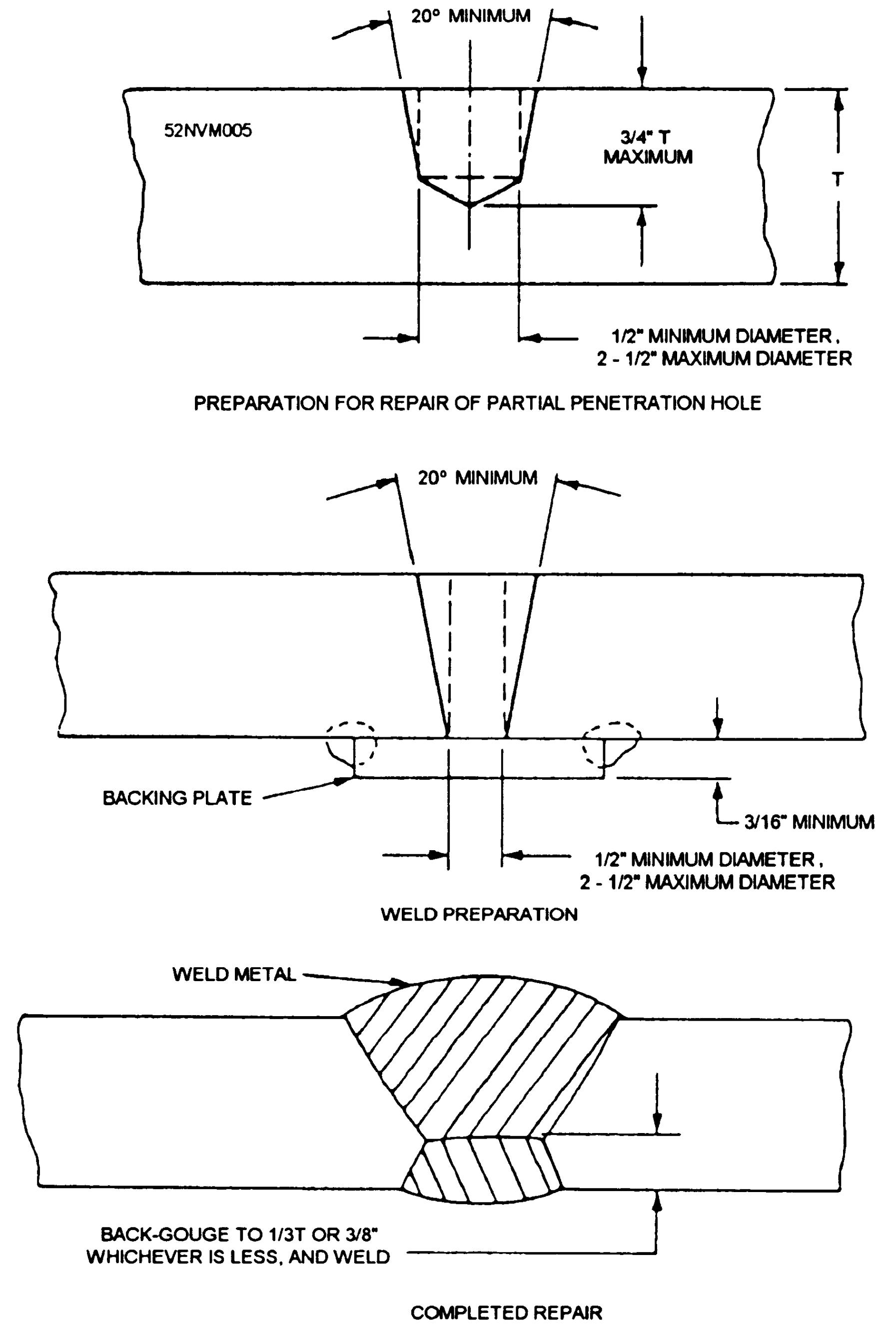
MAKING CLOSURES WITH PLATE PATCHES

Sometimes it is necessary to cut temporary holes in shell plating, bulkheads, and decks to remove and install machinery. You will have to measure, cut, and prepare the patch for insertion. All work must carefully be done so no unnecessary damage occurs. We will look at cutting new access holes and cutting access holes involving previously made holes.

Cutting New Access Holes

Cutting new access holes involves making cuts where no previously made cut existed. Before you make an access cut you must determine the location and configuration of the access cut. Figures 13-52 and 13-53 demonstrate some of the requirements for determining access cuts and weld preparations.

DETERMINING LOCATION.—Before making an access cut, you should consult the ship's plans for the



NOTES:

1. MULTIPLE PASSES SHALL BE USED WHEN MAKING REPAIR WELDS. REPAIR OF ORIGINAL HOLE DIAMETERS OVER 2-1/2 INCHES REQUIRES REPLACEMENT BY A 6-INCH OR 4T (WHICHEVER IS LARGER) MINIMUM DIAMETER PATCH ACCORDING TO MILSTD-1688, FABRICATION, WELDING, AND INSPECTION OF HY-80/100, SUBMARINE APPLICATIONS.
2. THIS FIGURE IS NOT DRAWN TO SCALE.

Figure 13-51.—Weld repair of partial and full penetration holes.

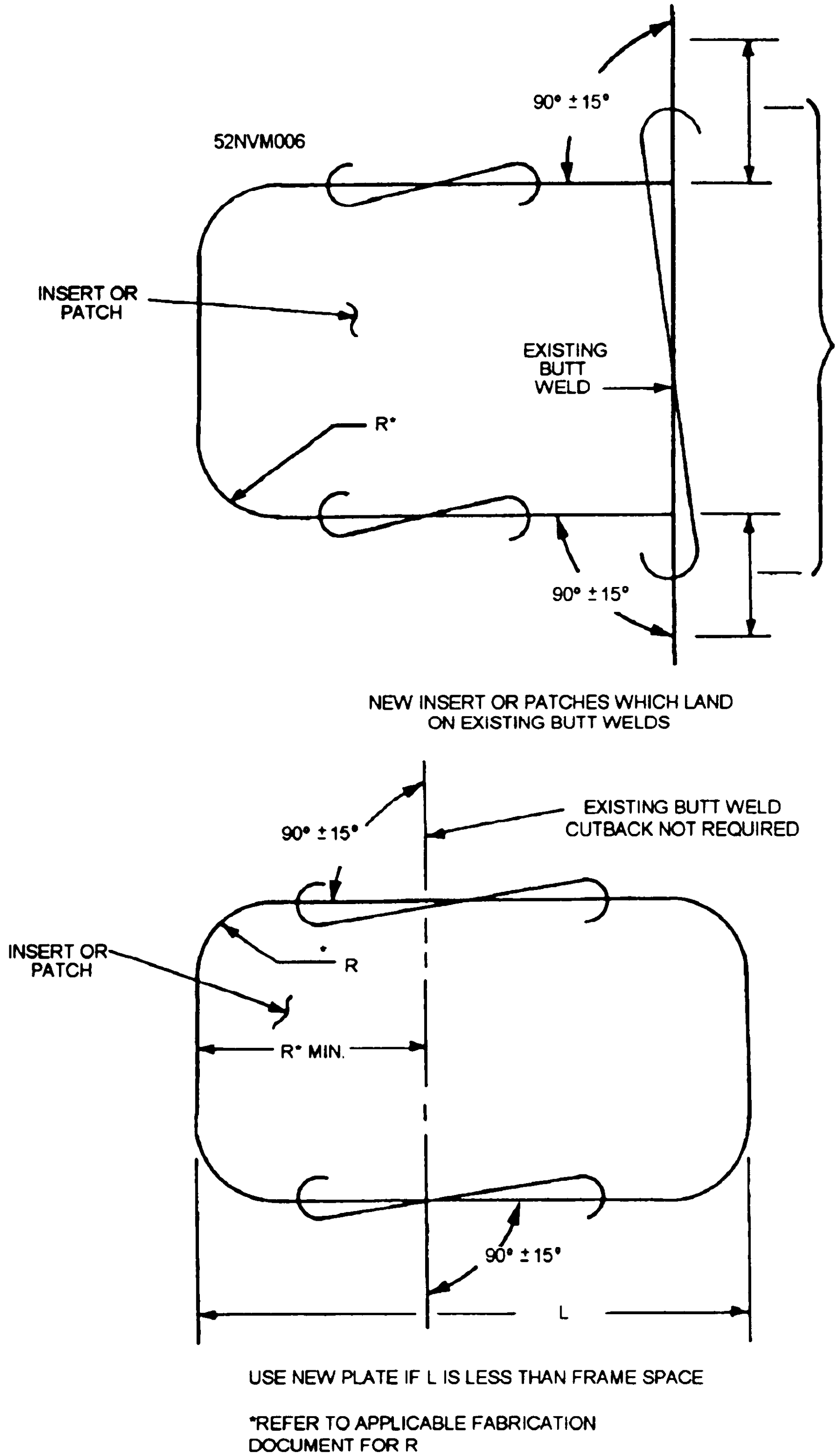


Figure 13-52.—New inserts or patches crossing existing butt welds.

location of access holes that may have been included in the ship's original construction. If the ship's plans include access areas for the removal of equipment, use these areas for your cut. If no access location is shown, use the following guidelines in determining a suitable area for a cut:

- Do not cut holes in the sheer stringer, keel, or bilge strakes unless necessary.

- Avoid cuts that will require rewelding closer than 6 inches from a riveted joint.

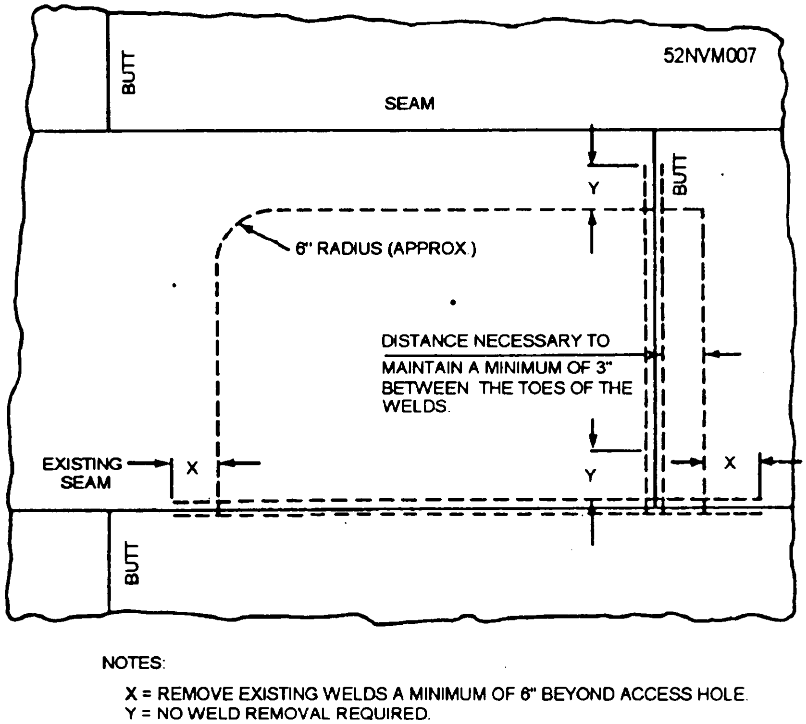


Figure 13-53.—Access holes intersecting existing welds.

- Cut no more than two holes in any tank.
- Cut holes to the minimum size necessary.
- Locate the edges of openings along existing butts or seams whenever practical.
- Locate holes between principle ship framing or bulkheads, cutting at least 3 inches from any of these members.

CUTTING THE ACCESS HOLE.—After you determine the location of the access hole, you are ready to make the cut. As a general rule, follow the requirements of the fabrication document, such as blueprints, technical manuals, or other approved documents, for laying out and cutting the access hole. If no fabrication document exists, use the following guidelines:

- Cut all comers except those involving existing butts or seams to a radius of 6 inches. The 6-inch radius in the comers is designed to eliminate stress associated with a 90-degree comer cut.
- Where corners involve butts or seams, remove the existing weld for a minimum distance of 6 inches beyond the existing butt or seam, as shown in figure 13-53.
- Maintain a minimum of 3 inches between the toes of two welds, as shown in figure 13-53.
- If crossing an existing butt weld, ensure that the new cut crosses the existing butt weld at a 90-degree angle.
- Cutouts involving riveted seams, or cuts closer than 6 inches to riveted seams, require the removal and replacement of the rivets for a distance of 6 inches from the weld area.

The first step in laying out the access cut is to remove all paint and rust from the cutting area. This will make the layout easier and the cutting process faster and cleaner. Using soap stone, lay out the new access cut, installing radii in the corners. You should then use a center punch to punch the outline of the cut. It is well worth the time to punch the outline to prevent having to lay out the outline again if it becomes erased accidentally. Install lifting padeyes if the patch is large in size or difficult to handle and tie it off before making the cut. The final step is to cut the access hole using a cutting torch or other method.

REINSTALLATION OF THE PATCH.—After the equipment has been removed and new equipment has been reinstalled, you will be required to reinstall the patch. If the removed plate is still usable, it should be reinstalled. If the plate cannot be reused, cut a new closure plate using the old plate as a guide. Determine the weld joint design to be used and bevel the patch and the bulkhead or hull to the required angle. Install the patch in place and check clearance as required by the weld joint design from MIL-STD-22.

WELDING IN CLOSURE PATCHES.—Welding of closure patches should be done by certified welders and inspected by NDT personnel. Welding is usually done using the block welding sequences to reduce weld metal cracking. You would usually weld the straight edges of the plate first and comers last to allow the comers to expand and reduce stress. If you are using a butt joint design, you must backgouge the root to remove impurities introduced during the welding process. This is usually accomplished after the first side is completely welded or enough weld metal has been deposited to allow for backgouging.

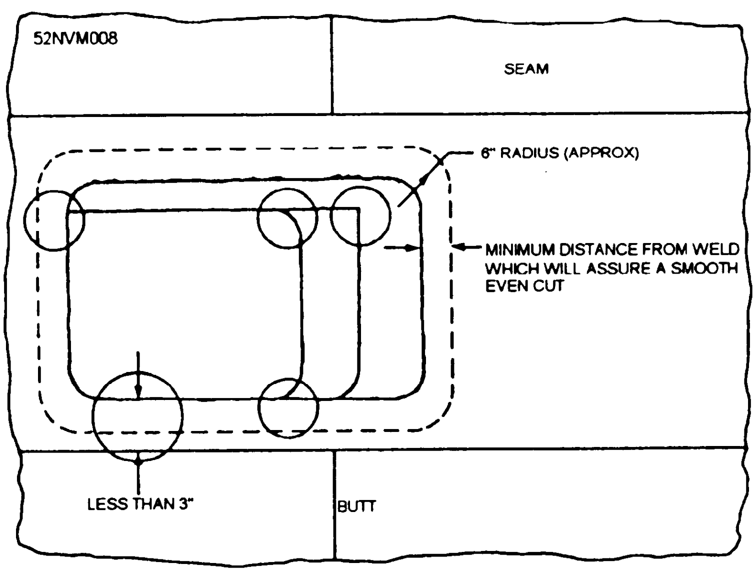
Cutting Access Holes Involving Previously Made Joints

When cutting access holes involving previously made cuts, cut in the center of the existing weld. If this is impractical or the access hole is required to be larger, follow the steps required for new access holes. If you must make the access cut larger or where more than two multiple cuts and replacements have been made, remove and replace the patch. Figure 13-54 shows patch removal involving more than two existing cuts and some of the typical mistakes made while making access cuts.

INSTALLING WATERTIGHT DOORS, HATCHES, AND SCUTTLES

As a shipfitter, you will replace numerous watertight fixtures in your career. This is a relatively easy process that involves no special skills. However, fixtures can be installed incorrectly if special precautions are not followed. When installing watertight closures, you should keep the following suggestions in mind:

- Ensure the watertight door has been properly maintained before cutting out the door. Some major problems with watertight fixtures are simply a lack of PMS and fixtures may not need to be replaced.
- Check the door and frame for warping. Sometimes the door is warped but the frame is straight. If the door is warped, replace the door. If the frame is warped, it must be cut out and replaced.



NOTES:

1. CIRCLED AREAS ARE EXAMPLES OF TYPICAL VIOLATIONS OF REQUIREMENTS.
2. REMOVE PATCH AREA BY FLAME CUTTING ALONG DASH LINE.

Figure 13-54.—Patch removal involving more than two existing multiple cuts.

If the frame is warped, it must be cut out and replaced.

- If removing the frame for a watertight door, do not cut the bulkhead. Watertight doors are welded in place using a lap joint. Only the weld metal should be removed.

- Weld repair any gouges or nicks in the bulkhead plating before reinstalling the door.

- When fitting the new frame and door in place, do not force the frame to the bulkhead. Instead, straighten the bulkhead. If the door is forced to the bulkhead, you will warp the frame.

- When welding in the new watertight fixture, ensure that the door is dogged tightly to the frame to prevent warping the door during welding.

- Perform a chalk test on the knife edge to the seal after the watertight door is installed according to the PMS card to ensure that the door was not warped during installation.

STOPPING CRACKS IN PLATE

In an emergency, you may stop a crack by drilling a hole that is 1/2T (where T is equal to the thickness of the plate) or 3/8 inch in diameter, whichever is the largest, and welding an overlay, as shown in figure 13-55, to arrest the crack. Drill the hole in the end of the crack, making sure that none of the crack extends beyond the drilled hole. An overlay of one layer is applied in the form of a trapezoid. This overlay is not to be any closer than one-half inch to the hole. No welding should be done on the crack nor within l/2 inch of the hole. The long dimension should be about 15 inches, with the deposit tapering away from the drilled hole to 10 inches at its 3 inch width. This will require ten to twelve passes. If possible, an overlay should be applied on both sides of the plate. A MIL-309 or 310-15/16 stainless steel 3/16-inch electrode is recommended. Care should be taken to fill craters and minimize arc strikes to prevent stress concentrations. After this temporary overlay has been accomplished, actual repair of cracks may be accomplished according to the requirements of the applicable fabrication document.

CORRECTING DISTORTION

Distortion (buckling or twisting) of structural steel members is caused by uneven expansion and contraction of the metal during welding. Distortion can be corrected by flame shrinkage (also known as flame straightening). Flame shrinkage is accomplished by directing a flame from a gas torch on an area where excess metal has accumulated as a result of earlier welding. The metal is displaced in the desired direction and the distortion is corrected or reduced. The operator of the torch must be able to recognize the areas of excess metal and determine the necessary amount of heat to apply.

Figure 13-56 shows how flame shrinkage is used to control expansion and contraction. In view A, the flame is directed toward a spot that is centrally located on a distorted steel plate. The spot heats up quickly and must expand. The cooler plate surrounding the distorted area prevents the spot from expanding along the plane of the plate, as shown in view B. This, in turn, will cause it to expand abnormally through its thickness, as shown in view C. Up to this point, the plate has actually thickened where the heat is applied. Upon cooling, the plate will contract uniformly in all directions, as shown in view D. When flame shrinkage is applied carefully, it will give a planned shrinkage that is useful for correcting distortion that was caused by previous heating and cooling cycles.

A high temperature is not required for flame shrinkage; however, a large torch tip should be used. The effectiveness of this process depends on your ability to rapidly change the temperature of the plate to a high degree at a given spot. A large torch will help to attain the required rapid temperature change. When a long piece of metal, such as the flange of a beam, needs to be flame shrunk, one of two methods should be used. You should either (1) move the torch progressively along the length, or (2) heat the metal at selected spots and then let it cool. You should make intermediate checks of the effect of the flame on the correction of the distortion as you go through this process.

Distortion Problems

Figure 13-57 shows a panel that has buckled due to welding stiffeners to it. There is an excess of metal between the stiffeners. If you apply the necessary heat in the proper areas, and allow it to contract upon cooling, you provide the shrinkage needed to straighten the panel. If the panel is under restraint (as is the case with many weldments), too much heating could cause

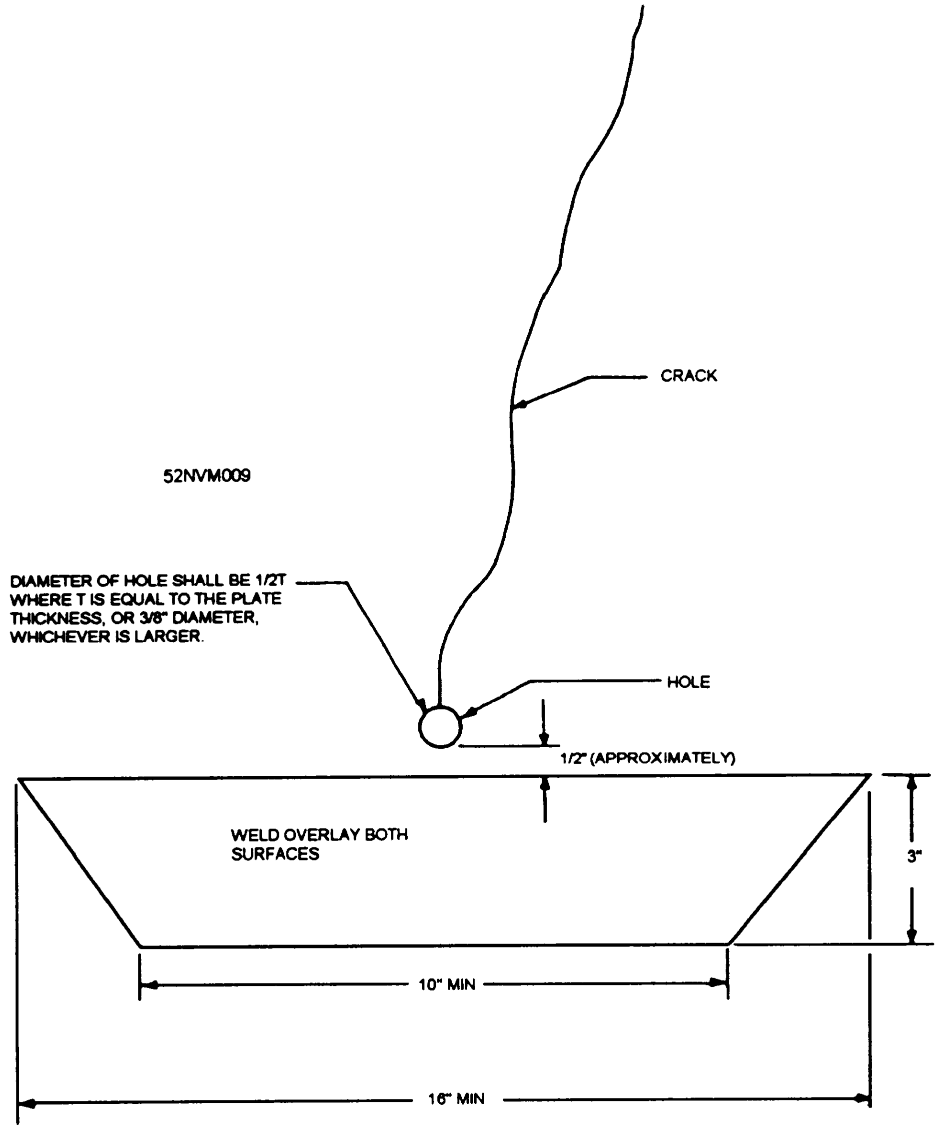


Figure 13-55.—Ductile metal overlay to arrest cracks in surface ship hull structure.

the development of locked-in stresses. When you use the flame shrinkage process, be sure you proceed cautiously, periodically allowing cooling to take place, and checking on the degree of distortion (buckling) removed.

A beam with a cover plate welded to it (fig. 13-58) is very likely to bend in the direction of the cover plate because the welding is not balanced about the neutral axis. Essentially, the act of welding on the cover plate produces shrinkage that shortens the length of the flange to which it is welded, as shown in view B of figure 13-58. You should then use flame shrinkage to shorten the other flange to the same length, thus straightening the beam as shown in view C of figure 13-58.

Flame shrinkage can also be used to give a beam a desired amount of curvature. Figure 13-59 shows a rolled beam with a cover plate welded to the lower flange. The bend resulting from the welding on the cover plate has not produced enough curvature and it is decided to use flame shrinkage to get the desired amount. How is this to be done?

If the cover plate alone is heated and shrunk, it will pull against the lower beam flange and you will get a considerable amount of locked-in tensile stress. Should the beam at some later time be accidentally overloaded, the yield point of the cover plate might be exceeded. This will cause stretching and some of the curvature will be lost. It would be desirable to minimize the tension stress developed in the cover plate by flame shrinkage so that a larger amount of the strength may be used to

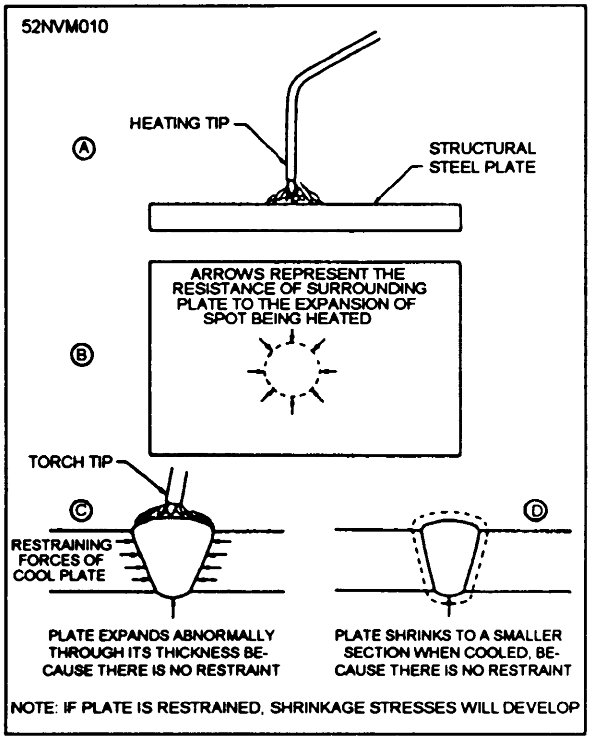
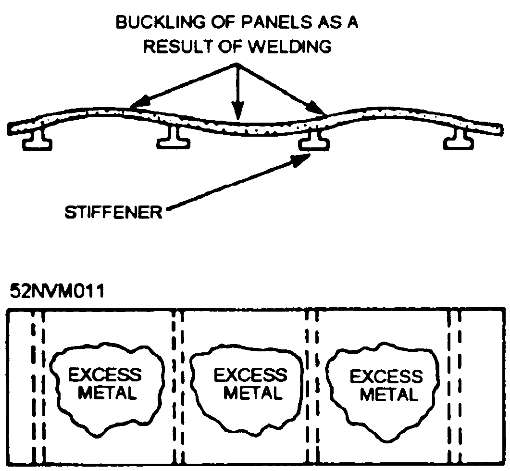


Figure 13-56.—Flame shrinkage used to correct distortion.



NOTE: HEAT IS APPLIED TO AREAS OF EXCESS METAL

Figure 13-57.—Flame shrinkage used to control distortion of panels with welded stiffeners.

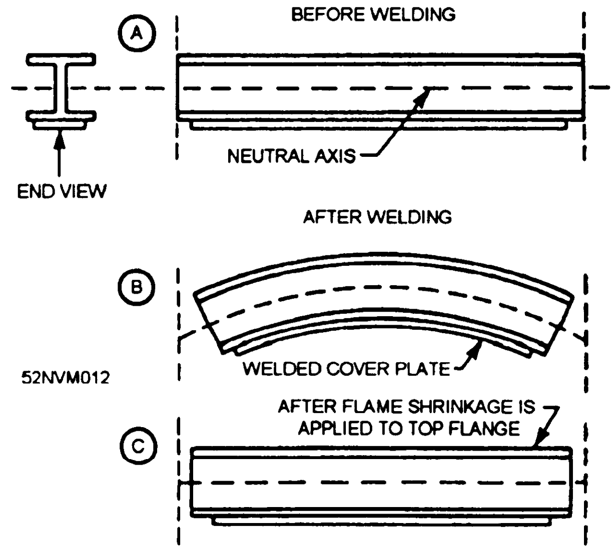


Figure 13-58.—Flame shrinkage used to straighten beam with a welded cover plate.

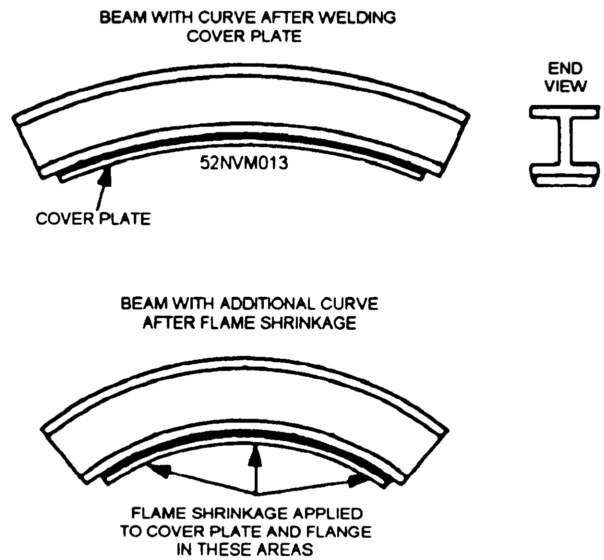


Figure 13-59.—Developing a curve in a beam.

resist the load and maintain the curvature. You can accomplish this by flame shrinking the beam flange along with the cover plate.

Figure 13-60 illustrates the technique of using flame shrinkage to develop curves in a beam or girder (with or without a cover plate) in such a way that little or no locked-in stress is developed. The rolled beam is straight at the start. A wedge-shaped area is marked off on the web and lower flange with soapstone. The wedged area is then heated to a dull red, using one or more torches. When the wedged area is a dull red, remove the heat and allow the area to cool. The curvature produced should then be noted. Then mark off other areas and repeat the process until you get the desired curvature.

This type of flame shrinkage produces the same results as if the entire beam had been heated red hot and bent to shape. There will be little or no locked-in stress

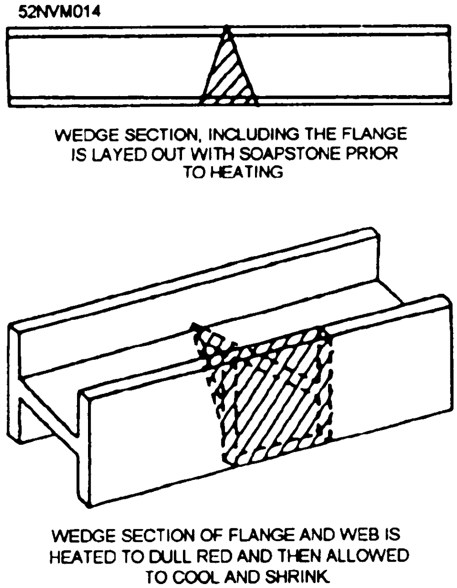


Figure 13-60.—Developing a curve without locked-in stresses.

and no danger of snapping the curve out later by accidental overload.

Water Spray Equipment

The water spray torch shown in figure 13-61 may be used to reduce cooling time. The torch consists of a nozzle, a "Y" fitting, a control valve, and a l/4-inch rubber hose. The air hose is connected to the ship's service compressed air and the rubber hose is run to a pail of water. When you open the control valve, the rush of air past the orifice in the "Y" fitting draws some water into the air stream, creating an atomized spray. When the spray strikes the hot plate, it turns into steam and absorbs a substantial amount of heat. One pound of water will absorb 142 Btu while vaporizing into steam. Because of the heat requirements for vaporization, the cooling is rapid, even with the use of only a small amount of water. Since all of the sprayed water is vaporized, the work will remain dry.

FABRICATION EXAMPLES

The variety of fabrication problems that arises on board ship is almost endless. The examples in this chapter are not to be considered as a complete listing of jobs you may have to perform.

The following basic considerations apply to most fabrication jobs:

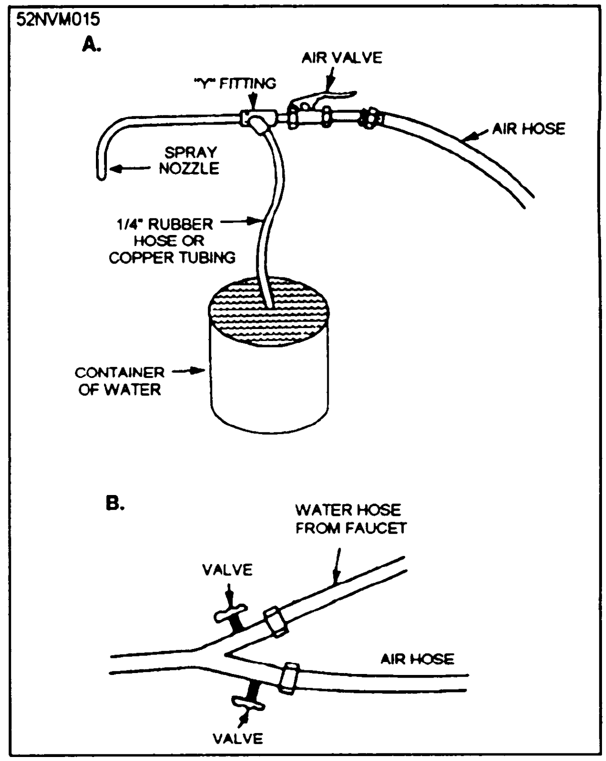


Figure 13-61.—Water spray torch used for reducing cooling time.

—Select the correct material for the job. Selecting materials for the fabricating plate structures is essentially a design problem, requiring a thorough knowledge of the properties of materials. The materials for most shipboard fabrication jobs are specified in the job order or on the blueprints. You must ALWAYS consult these sources of information before the material is selected. However, you should know enough about the properties of materials to be able to make an intelligent selection when this responsibility is left up to you.

—In making a repair or replacement, substitution of one material for another requires a knowledge of the service conditions that the piece must withstand. Low-carbon steel has an ultimate tensile strength of 60,000 psi and cast iron has an ultimate tensile strength of 20,000 psi. When you substitute low-carbon steel for cast iron, the cross-sectional area of the steel need only be one-third that of the cast iron if tensile strength is the ONLY consideration. In many cases, rigidity will be the controlling factor. When it is necessary to maintain the same rigidity, a low-carbon steel piece would have to be four-fifths the thickness of the cast-iron piece. When substituting another material for the one specified, you will have to find this type of information concerning the relationship between the two materials.

—Make full use of all available shapes, pieces, or subassemblies. For example, you can make many structures from standard rolled shapes and formed plate, joined together by welding. You can save both time and money by using available shapes.

Fabricating a Lever

The lever shown in figure 13-62 is made up of hubs and a formed box section. The hubs are cut from high-pressure tubing. The center box portion of the lever is formed from

l/4-inch rolled steel plate. Each half of the section is then bent to form a U-channel of the proper size and shape. The component parts are then assembled and joined by welding.

Fabricating a Bracket

The swinging knee bracket shown in figure 13-63 can be fabricated in several different ways just by using various structural shapes. By changing the design slightly, you can use a channel bar, an H-beam, or an I-beam just as well as the angle bar shown in the illustration. The cast bracket shown at the top of figure 13-63 weighed 570 pounds; the fabricated bracket made to serve the same purpose weighed only 317 pounds and cost 40 percent less than the cast bracket. As you can see, the parts were cut from various standard shapes and then welded together.

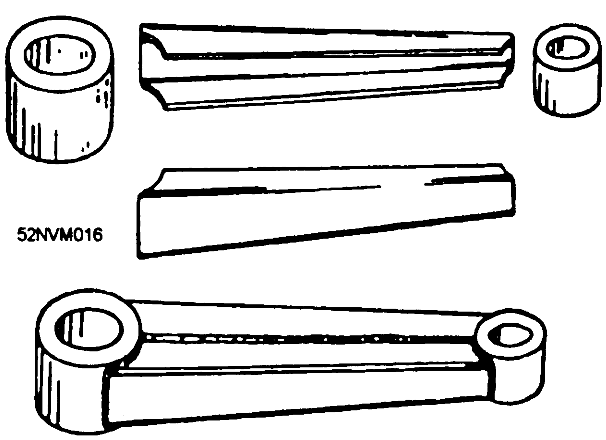


Figure 13-62.—Lever fabricated from high-pressure tubing and rolled steel plate.

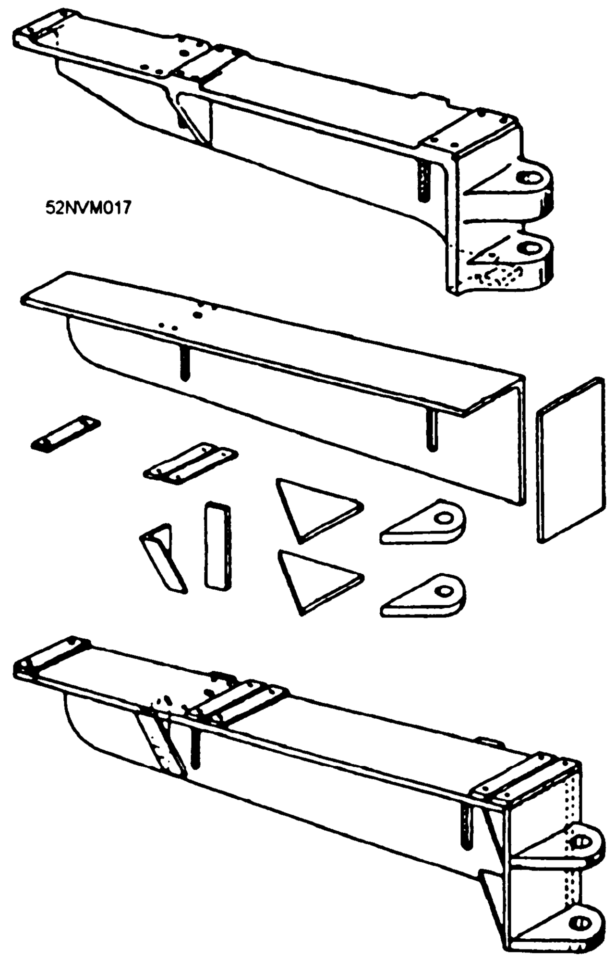


Figure 13-63.—Cast swing knee bracket (top) and fabricated swinging knee bracket.

Fabricating a Clevis

The clevis shown in figure 13-64 is another example of an item that can be made both lighter and cheaper by fabrication rather than by casting. Also note that the rough casting (top view) must be considerable thicker than the fabricated clevis. Although some of the excess metal would have to be machined off the rough casting, the casting would still have to be thicker than a fabricated clevis to serve the same purpose.

Fabricating Foundations and Supports

Bases, foundations, and supports are required for numerous pieces of equipment and machinery aboard ship. Figure 13-65 shows various bases and supporting members fabricated from standard shapes.

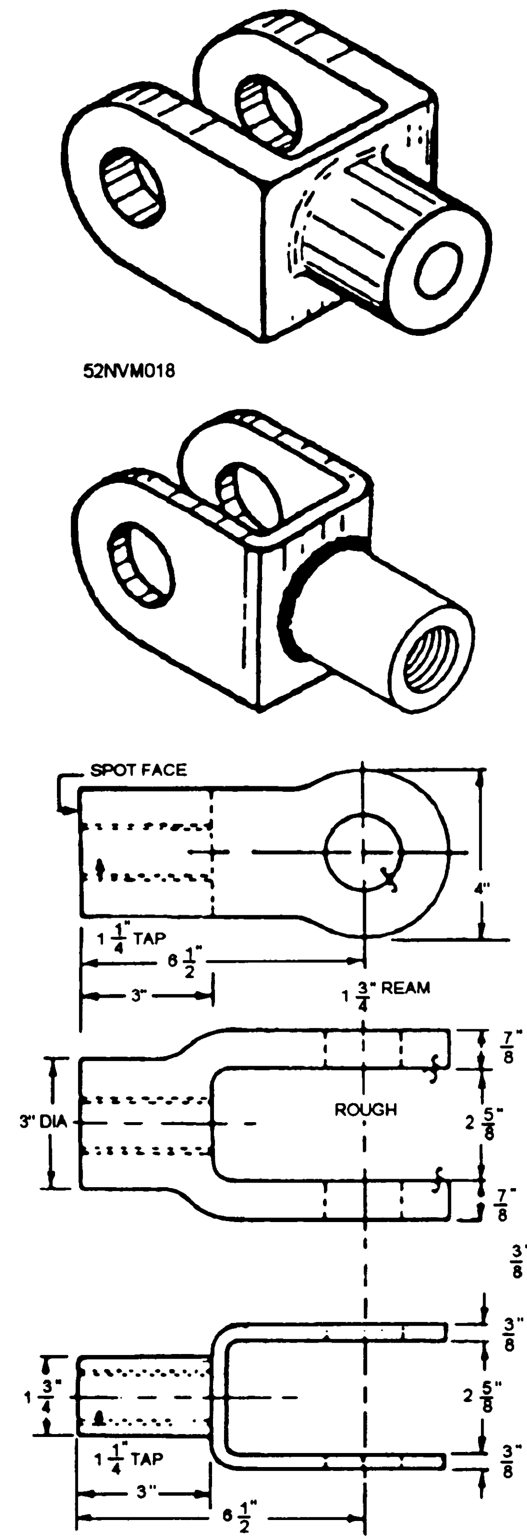


Figure 13-64.—Cast clevis (top) and fabricated clevis.

Fabricating Hinges

Hinges of many types and sizes can be drawn from stock. Once in awhile, you will find that you need an odd size or shape that is not available. You could forge the hinges, but it is usually quicker and cheaper to fabricate them in a manner shown in figure 13-66. The leaf is cut from a heavy gauge sheet metal. The eye is cut from either pipe or tubing. Small, lightweight hinges can be made from sheet metal, with the eye or sleeve being formed in much the same way that a wired edge is turned.

Fabricating a Padeye

Padeyes are installed aboard ships in areas where lifting of heavy items are required. Most ships, especially submarines, have detailed drawings that list the type and location of all permanently installed padeyes. Sometimes, you may have to fabricate padeyes in a particular size or shape, depending on the specific application and weight requirements. You should always manufacture padeyes according to blueprints or ship's drawings. If no blueprints exist for your ship, use a standard blueprint for padeyes before attempting to manufacture and install padeyes of any type. All padeyes subjected to any load, or where the safety of personnel might be endangered, must be tested before being put into service.

Fabricating a Scupper Drain

The scupper drain (fig. 13-67) may be made by rolling steel plate to a half round shape of the required diameter or by cutting a piece of pipe lengthwise in half. The half round pipe or rolled steel plate is then welded to a flat piece of plate that is slightly shorter and slightly wider than the drain. The flat plate is then bolted to clips that are welded to the shell of the ship. The scupper discharges water into the pipe just above the flat plate.

Fabricating a Boom Cradle

Another job sometimes needed on board ship is the fabrication of a boom cradle (fig. 13-68) to support a boom when it is not in use. A boom cradle can be made from a piece of plate of suitable thickness. Lay out the required dimensions on the plate. Use a cutting torch to cut a semicircular opening in the top of the plate to accommodate the boom. After the cradle has been cut out and ground smooth, it is ready to be welded to the deck.

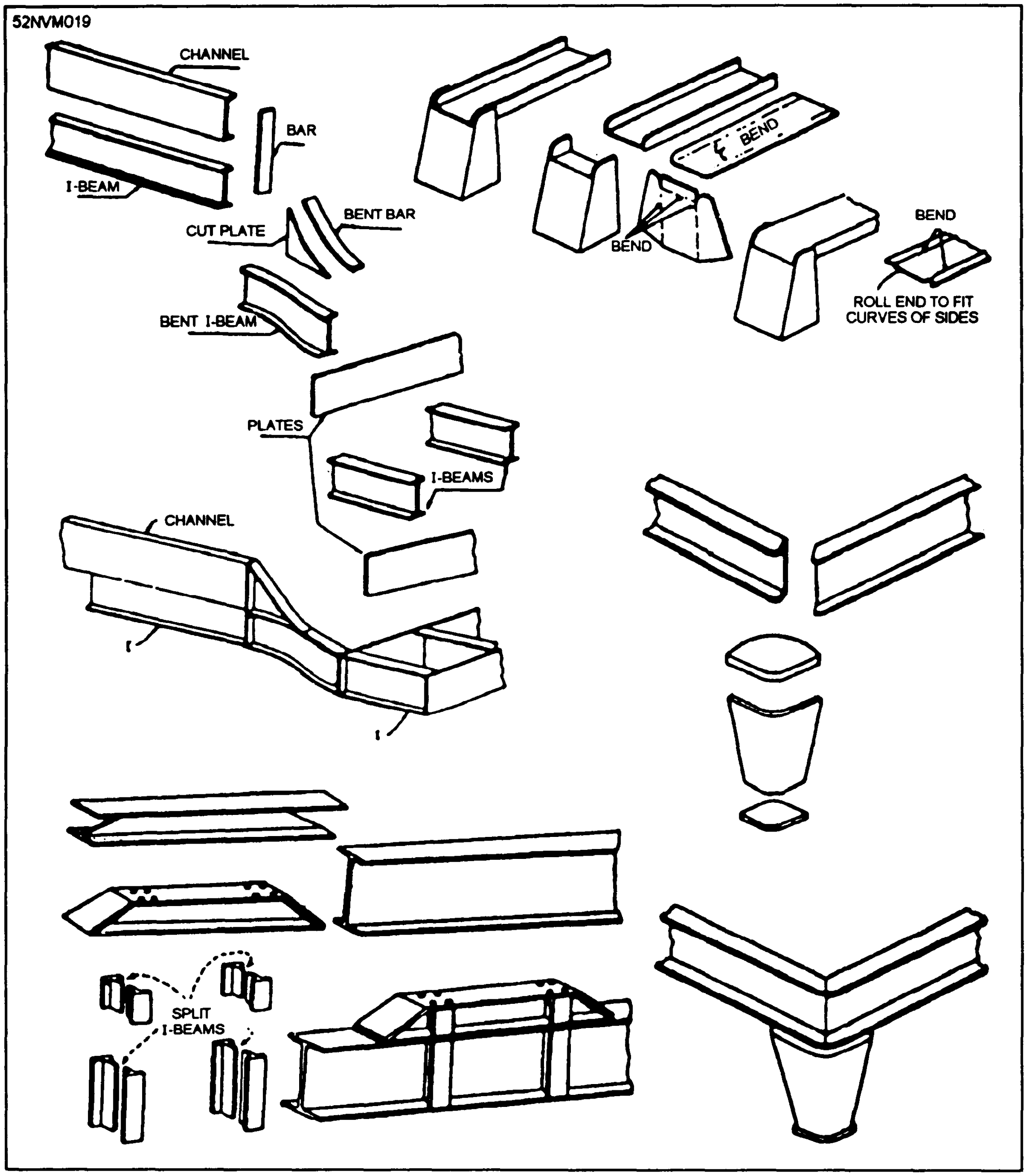


Figure 13-65.—Fabricated bases, foundations, and supports.

Fabricating Tanks

From time to time you may need to fabricate quench tanks, rinse tanks, or storage tanks. The material used in these tanks will vary from sheet metal to heavy plate, depending upon the use of the tank The shape and size of these tanks will depend upon the purpose of the tank, the space available for its installation, and its volume. Most of these tanks will either be rectangular or cylindrical in shape. Some of the larger tanks you might manufacture may require the installation of internal or external gussets, partitions, or stiffeners to support the tank walls.

To build a tank to blueprint specifications, you need to know how to convert fractions to decimals and figure the volume of squares, rectangles, and cylinders. Information on these mathematical computations can be found in chapter 14 of this manual and in *Mathematics,* Volume 1, NAVPERS 10069-D1.

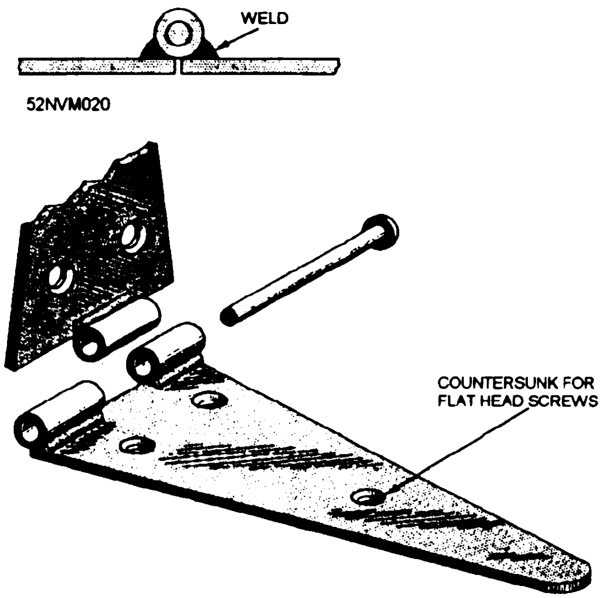


Figure 13-66.—Fabricated flat leaf hinge.

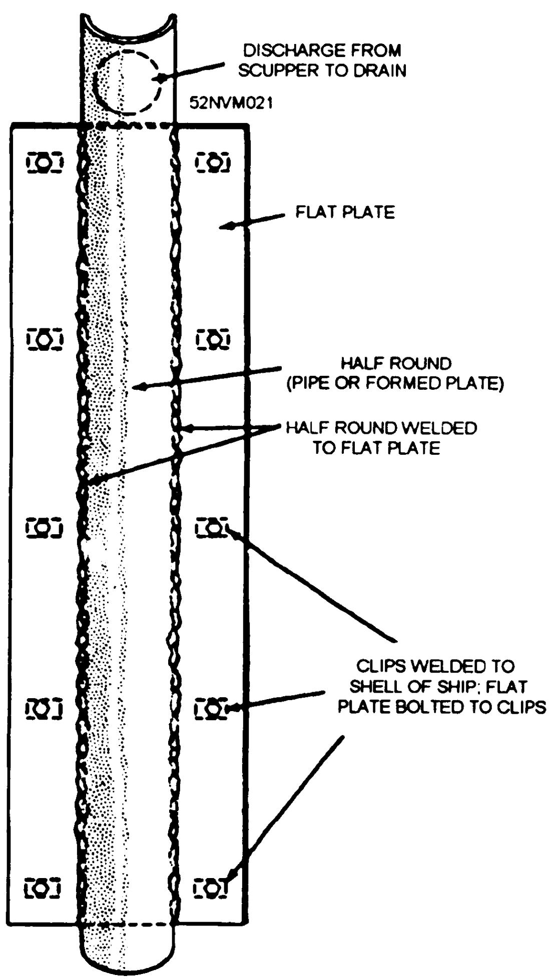


Figure 13-67.—Fabricated scupper drain.

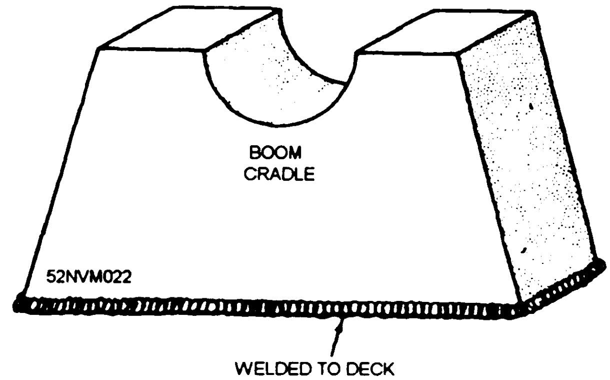


Figure 13-68.—Fabricated boom cradle.

SUMMARY

You may be assigned to a ship where the HT will work primarily in one area of the rating. You also may be assigned to a smaller ship where you will work in just about every one of the areas. Whatever ship you are assigned to, the information in this chapter will be helpful to you. It is quite common for the HT to either repair or replace items that have been damaged or that have deteriorated. The fabrication of new foundations, brackets, supports, padeyes, and other such items will almost be a daily job. Other personnel who have more experience will help you get your experience.

CHAPTER 14

SHOP MATHEMATICS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Identify the fundamentals of the four branches of mathematics, and describe how they are related to the Hull Technician rating.*
- *Describe the method of geometric construction.*
- *Describe the methods of construction for several plane figures.*
- *Determine the areas and volumes of geometric shapes and figures.*
- *Describe the metric system, and convert the English system to the metric system.*

INTRODUCTION

Mathematics is as important a tool for you to use as a Hull Technician as are manual skills and good tools. It is a universal language that lets you understand measurements and values written in any language. HTs are constantly working with measurements and calculating weights and quantities of materials. HTs develop geometric outlines. This chapter is not a complete text in ship mathematics. Instead, it is a review of the basic mathematical knowledge you will need as a Hull Technician.

Tables of weights, measures, and equivalents are useful references when you are solving mathematical problems. This chapter contains a number of tables that you will use frequently.

If you desire further study of mathematics, you should request the following manuals through your educational services office:

Mathematics, Volume 1, NAVEDTRA 10069-D1

Mathematics, Volume 2-A, NAVEDTRA 10062-B

Mathematics, Volume 2-B, NAVEDTRA 10063

Mathematics, Volume 3, NAVEDTRA 10073-A1

FUNDAMENTALS OF MATHEMATICS

The basics of mathematics remain the same no matter what the field. Mathematics is divided into several different branches. You will be concerned with arithmetic, algebra, geometry, and trigonometry.

Arithmetic deals with the manipulation of numbers, using addition, subtraction, multiplication, and division.

Algebra uses letters and symbols in place of numbers and values. These letters and symbols construct equations that follow established mathematic rules.

Geometry investigates the relationships, properties, and measurements of solids, plane surfaces, lines, angles, graphs, and other geometric characteristics.

Trigonometry investigates the properties of triangles and of trigonometric functions and their applications.

COMMON FRACTIONS

Common fractions are often used in sheet metal layout, woodworking, piping repairs, and structural repairs. Most of your measuring devices, such as the shrink rule, are divided into common fractional increments.

The common fraction is a simple method of expressing the division of a whole number or object. Fractions show one or more parts divided into any number of equal parts. Examples are dividing 1 inch into four equal parts or dividing a line into four equal parts. These equal parts are expressed as increments of one—fourth. You know that four increments equal the whole number or object. You can write any part less than the whole as a common fraction, such as l/4 or 3/4.

The common fraction contains two parts—the denominator and the numerator. The denominator shows how many equal parts the whole divides into. The numerator shows the number of equal parts being considered.

Example: $\dfrac{5 \text{ (Numerator)}}{8 \text{ (Denominator)}}$

DECIMAL FRACTION

A decimal fraction is a fraction whose denominator is 10 or some multiple of 10, such as 100, 1,000, or 10,000. *Decimal fractions differ from common fractions in that the denominators are not written but are expressed by place value.* Figure 14-1, views A and B, shows a place value chart. As we proceed from left to right in place value, the value of each place is one-tenth the value of the preceding place. Notice in views A and B that the units place is the center of the system and that the place values proceed to the right or left by powers of ten. Ten on the left is replaced by tenths on the right, hundreds by hundredths, thousands by thousandths, and so on. Notice that each decimal fraction begins with a period. This period is called a decimal point. To call attention to the decimal point, we usually begin the decimal fraction with a zero.

Examples of decimal fractions, their equivalent common fractions, and how you read them are as follows:

$$0.3 = \frac{3}{10} = \text{three tenths}$$

$$0.07 = \frac{7}{100} = \text{seven hundredths}$$

$$0.023 = \frac{23}{1000} = \text{twenty–three thousandths}$$

$$0.1276 = \frac{1276}{10000} = \begin{array}{l}\text{one thousand two hundred}\\ \text{seventy–six ten–thousandths}\end{array}$$

A mixed decimal is an integer and a decimal fraction combined. We use a decimal point to separate the integer portion from the decimal fraction portion.

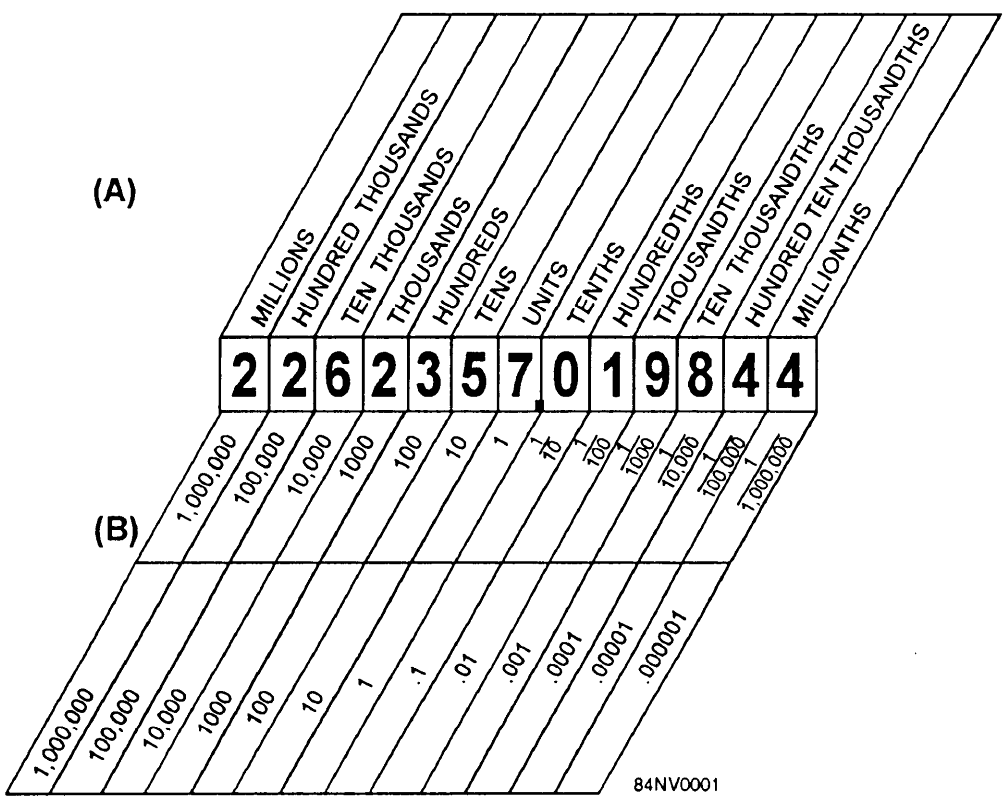


Figure 14-1.—Place value chart.

The following are examples of mixed decimals, their equivalent mixed numbers, and how they are read:

$160.32 = 160\frac{32}{100} =$ one hundred sixty and thirty–two hundredths

$21.005 = 21\frac{5}{1000} =$ twenty–one and five thousandths

A decimal is any number written with a decimal point, which includes decimal fractions and mixed decimals. For the rest of the manual, we will refer to decimal fractions and mixed decimals as decimals.

Equivalent Decimals

From our study of fractions, it should be clear that

$$\frac{5}{10} = \frac{50}{100} = \frac{500}{1000}$$

Writing the same values as decimals would be equivalent to

0.5 = 0.50 = 0.500

In other words, the value of a decimal is not changed by attaching zeros to the right of any decimal point after the last digit.

Converting Fractions to Decimals

One way to convert a fraction to a decimal is to divide the numerator by the denominator. To obtain our answer, we will attach as many zeros after the understood decimal point in the numerator as needed, since we have determined this will not change the value of our numerator.

Example: Convert 3/5 to a decimal.

Solution:

```
   0.6
5)3.0
  0
  30
  30
   0
```

So the answer is 3/5 = 0.6. Notice that the decimal point in the quotient was placed directly above the decimal point of the number we are dividing into.

Example: Convert -7/32 to a decimal

Solution:

```
    -0.21875
32)(-)7.00000
      0
      70
      64
       60
       32
       280
       256
        240
        224
         160
         160
           0
```

Therefore, -7/32 = -0.21875.

Example: Convert 51/8 to a decimal.

Solution:

```
  6.375
8)51.000
  48
   30
   24
    60
    56
     40
     40
      0
```

Hence, 51/8 = 6.375.

The answers in the examples just covered were all considered terminating decimals since each quotient terminated or ended. A repeating decimal will have a repeating pattern and never terminate.

Example: Convert l/3 to a decimal.

Solution:

```
  0.333...
3)1.000
   9
   10
    9
    10
     9
     1
```

As you can see, there is a repeating pattern of 3. We will represent the repeating digits with a bar over the repeating pattern. Therefore, l/3 = $0.\overline{3}$.

Example: Convert -25/11 to a decimal.

Solution:

$$\begin{array}{r} -2.2727\ldots \\ 11\overline{)(-)25.0000} \\ \underline{22} \\ 30 \\ \underline{22} \\ 80 \\ \underline{77} \\ 30 \\ \underline{22} \\ 80 \\ \underline{77} \\ 3 \end{array}$$

Hence, -25/11 =2.$\overline{27}$.

You may find it of interest to know that if the denominator of a common fraction reduced to lowest terms is made up of prime factors of just 2s or just 5s or both, the fraction can be converted to an exact or terminating decimal.

Another way to convert a fraction to a decimal is to express the fraction as an equivalent fraction whose denominator is a multiple of 10, such as 10, 100, 1000. Then, change the fraction to adecimal. You will always get a terminating decimal with this method.

Example: Convert 3/4 to a decimal.

Solution:

$$\frac{3}{4}=\frac{3\times 25}{4\times 25}=\frac{75}{100}=0.75$$

Example: Convert -47/200 to a decimal.

Solution:

$$\frac{-47}{200}=\frac{-47\times 5}{200\times 5}=\frac{-235}{1000}=-0.235$$

Example: Convert -11/8 to a decimal.

Solution:

$$\frac{-11}{8}=\frac{-11\times 125}{8\times 125}=\frac{-1375}{1000}-1\frac{375}{1000}=-1.375$$

Example: Convert 102/25 to a decimal.

Solution:

$$\frac{102}{25}=\frac{102\times 4}{25\times 4}=\frac{408}{100}=4\frac{8}{100}=4.08$$

In the two previous examples, the fractions could have been expressed as mixed numbers and then converted to decimals. To convert a mixed number to a decimal, leave the integer portion as it is and convert the fractional portion to a decimal.

Example: Convert -15 2/5 to a decimal.

Solution:

$$-15\frac{2}{5}=\left[15+\left(\frac{2\times 2}{5\times 2}\right)\right]=-15\frac{4}{10}=-15.4$$

Example: Convert 2 5/16 to a decimal.

Solution:

$$2\frac{5}{16}=2+\left(\frac{5\times 625}{10\times 1000}\right)=2+\left(\frac{3125}{10000}\right)=2.3125$$

Example: Convert 3 5/6 to a decimal.

Solution: Since the denominator 6 is not made up of just 2s or just 5s or both, we will have to divide 6 into 5 to obtain a repeating decimal and then add 3 to our answer.

$$\begin{array}{r} 0.83333\ldots \\ 6\overline{)5.0000} \\ \underline{4\,8} \\ 20 \\ \underline{18} \\ 20 \\ \underline{18} \\ 20 \\ \underline{18} \\ 2 \end{array}$$

Therefore, 3 5/6 = 3.$\overline{83}$.

Example: Convert -61 13/15 to a decimal.

Solution:

$$\begin{array}{r} 0.8666\ldots \\ 15\overline{)13.0000} \\ \underline{12\,0} \\ 1\,00 \\ \underline{90} \\ 100 \\ \underline{90} \\ 100 \\ \underline{90} \\ 100 \\ \underline{90} \\ 10 \end{array}$$

Therefore, -61 13/15 = -61.$\overline{86}$.

We could also convert a fraction to a decimal to a particular decimal place.

Example: Convert 25/16 to a decimal to the nearest tenth.

Solution:

$$\frac{25}{16}=\frac{25\times 625}{16\times 625}=\frac{15625}{10000}=1.5625$$

So, 25/16 = 1.6 to the nearest tenth.

Example: Convert -72 5/11 to a decimal to the nearest hundredth.

Solution: In this case, you would divide 5 by 11 to one place past the desired place value of hundredths and then round.

$$\begin{array}{r}0.454\\11\overline{)5.000}\\\underline{4\,4}\\60\\\underline{55}\\50\\\underline{44}\\6\end{array}$$

So, -72 5/11 = -72.45 to the nearest hundredth.

Converting Terminating Decimals to Fractions

To convert a terminating decimal to a fraction, count the number of digits to the right of the decimal point. Move the decimal point that many places to the right, and write the answer you get over a denominator beginning with 1 followed by as many zeros as places moved to the right. Reduce to lowest terms, if possible.

Example: Convert 0.77 to a fraction.

Solution: The number of digits to the right of the decimal point is 2. Therefore, we will move the decimal point 2 places to the right and place 77 over 100. So

$$0.77 = \frac{77}{100}$$

Example: Convert -0.045 to a fraction and reduce to lowest terms.

Solution:

$$-0.045 = \frac{-45}{1000}$$

$$= \frac{-9}{200}$$

When converting mixed decimals to fractions, you will usually find it is easier to keep the integer portion as an integer and change the decimal fraction to a common fraction.

Example: Convert 12.625 to a fraction and reduce to lowest terms.

Solution:

$$12.625 = 12\,\frac{625}{1000}$$

$$= 12\,\frac{5}{8}$$

Example: Convert -200.4 to a fraction and reduce to lowest terms.

Solution:

$$-200.4 = -200\,\frac{4}{10}$$

$$= -200\,\frac{2}{5}$$

Converting Repeating Decimals to Fractions

Converting a repeating decimal to a fraction is a little more confusing than the conversions we have previously performed. A repeating decimal can be converted to a fraction by the following steps:

1. Form an equation letting n equal the repeating decimal.
2. Multiply both sides of the equation by a multiple of 10 in order to shift a set of the repeating pattern.
3. Subtract the original equation from the new equation (in step 2).
4. Solve for n and reduce to lowest terms.

Example: Convert $0.\overline{2}$ to a fraction.

Solution: First, let n equal the repeating decimal, or

$n = 0.222...$

Second, multiply both sides of the equation by 10 since there is only one digit in the repeating pattern. Hence,

$10n = 2.222...$

Third, subtract the original equation from the new equation. That is,

$$\begin{array}{r}10n = 2.222...\\ -\quad n = 0.222...\\ \hline 9n = 2.000...\end{array}$$

Fourth, solve for n.

$9n = 2$

$$\frac{9n}{9} = \frac{2}{9}$$

$$n = \frac{2}{9}$$

Therefore, $0.\overline{2} = 2/9$.

Example: Convert $5.\overline{63}$ to a fraction and reduce to lowest terms.

Solution: Let

$n = 5.636363...$

Multiply both sides by 100, since there are two repeating digits.

$100n = 563.636363...$

Subtract the original equation from the new equation.

$$\begin{array}{r} 100n = 563.636363... \\ -\quad n = \quad 5.636363... \\ \hline 99n = 558 \end{array}$$

Solve for n and reduce to lowest terms.

$$99n = 558$$

$$\frac{99n}{99} = \frac{558}{99}$$

$$n = \frac{558}{99} = \frac{62}{11} \text{ or } 5\,\frac{7}{11}$$

Hence, $5.\overline{63} = 57/11$.

For the previous problem we could have kept the integer portion as an integer and converted the repeating decimal to a fraction.

Example: Convert $-38.\overline{054}$ to a fraction and reduce to lowest terms.

Solution: We will retain -38 and work with .

$$\begin{array}{r} 1000n = 54.054054... \\ -\quad n = \quad 0.054054... \\ \hline 999n = 54 \end{array}$$

$$n = \frac{54}{999} = \frac{2}{37}$$

Therefore, $-38.\overline{054} = -38\ 2/37$.

Example: Convert $-12.\overline{637}$ to a fraction.

Solution:

$$\begin{array}{r} 100n = 63.73737... \\ -\quad n = \quad 0.63737... \\ \hline 99n = 63.1 \end{array}$$

$$n = \frac{63.1}{99} = \frac{631}{990}$$

Hence, $-12.\overline{637} = -12\ 631/990$.

PERCENTAGE

Percentage is the expression of numbers in hundredths. The percent sign (%) is used to show percentage. Three terms apply to percentage problems—*base, rate*, and *percentage.* The base is the number upon which a percent is calculated. The rate is the amount of the percent. The percentage is the result of the calculations made with the base and rate. For example, 2% of $125.00 equals $2.50. The rate is 2%. The base is $125.00. The percentage is $2.50.

Percentage is calculated as a decimal fraction. Therefore, the rate must be a decimal fraction. For example, 2% and 25% are equal to 2/100 and 25/100, respectively. Convert these to 0.02 and 0.25, respectively. Write a rate of 100% as 1.00, 225% as 2.25, and so on.

RATIO AND PROPORTION

You can use ratio and proportion to solve problems quickly and reduce the chances of error.

Ratio

A ratio is a method of comparing two numbers or values in fractional form. For example, a fast frigate has a top speed of 30 knots and a cargo ship has a top speed of 15 knots. You can easily compare their speeds. This comparison can be written as 30:15 and 30/15. This makes the fractional form easier to calculate. To simplify the comparison, you reduce the fraction 30/15 to its simplest form of 2/l. Now, you can use this fraction form of a comparison very easily when calculating.

Comparison by a ratio is limited to quantities of the same kind. To express the ratio between 6 feet and 3 yards, both quantities must be in like terms. The proper forms of this ratio would be either 2 yards:3 yards or 6 feet:9 feet. Mathematically, like terms cancel each other. The yards or feet would cancel each other and the resulting ratio would read 2:3 or 6:9.

Proportion

Closely related to the study of ratio is the subject of proportion. The term *proportion* is defined as a relation of equality. A proportion is nothing more than an equation of two ratios that are equal to each other. Proportion can be written in three different ways, as shown in the following examples:

Example 1: 15:20::3:4

Example 2: 15:20 = 3:4

Example 3: $\frac{15}{20} = \frac{3}{4}$

As shown in the examples, a proportion is nothing more than an equation of common fractions. The value of proportion is that if any three of the terms are given, the fourth or unknown term can be found. This is done by solving a simple problem of common fractions.

GEOMETRIC CONSTRUCTION

Patterns are geometric shapes that conform to a draftsman's plan (blueprint) and contain allowances for draft, shrinkage, and machine finish. To construct a pattern, you must solve graphics problems of geometric construction. Graphics problems can be solved by trial and error or by measuring with a scale. However, neither method is accurate; therefore, they cannot be used in patternmaking. Because of its accuracy, only the geometric method of construction should be used in patternmaking. No other method is acceptable.

NOTE: You will need specific tools to USC during geometric construction. Sonic of these tools include a pencil divider, a 12-inch scale, a flexible straightedge, a 30- to 60-degree triangle, and a T-square.

As you read about geometric construction, the discussion will contain some geometric terms that you should know. These terms arc defined as follows:

Angle—A figure formed by two lines converging on a common point .

Apex—The highest point of a triangle.

Arc—A portion of a circle or curve.

Bisect—To divide into two equal parts.

Circumference—The distance around a circle, ellipse, or closed curve.

Curve—Any geometric line or shape that is not straight, contains no angles, and does not form a closed figure.

Diameter—The distance from a point on the circumference of a circle, through the center, to the opposite point on a circle.

Hypotenuse—The side of a right triangle that is opposite the right angle.

Intersect—To meet and cross at a point or series of points. Two lines intersect at one point. Two plants intersect at a series of adjacent points (which is the definition of a line).

Parallel—Maintaining an equal distance at all points on two or more lines or plants.

Perpendicular—Right angles (90°) to a line or plane.

Plane—A two—dimensional geometric figure.

Point—The intersection of two lines. A point has no dimensions.

Polygon—Any closed figure having three or more sides.

Radius—The distance from the center of a circle to the circumferece of that circle (one-half of the diameter).

Tangent—A curved or straight lint that touches but does not cross another curved or straight line at a point other than its ends.

Vertex—The point of intersection of two lines forming an angle.

BISECTING A LINE

As you read this section, refer to figure 14-2. You arc going to learn how to bisect a line by using the following steps:

1. USC your dividers and adjust them with a spread that is visually greater than one-half the length of the line.
2. Insert one point of the dividers at one end of the line (point A, view A) and draw an arc. Be careful not to change the adjustment on the dividers.
3. Insert one point at the other end of the line (point B, view B) and draw an arc from that end intersecting the first arc.
4. Draw a straight line connecting the two intersection points of the arcs to bisect the line (view C).

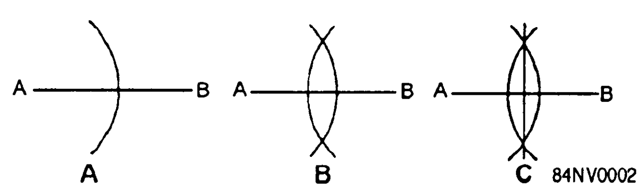


Figure 14-2.—Bisecting a line.

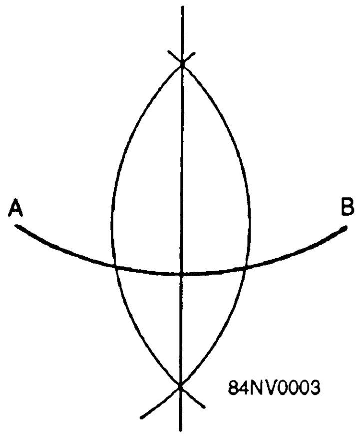


Figure 14-3.—Bisecting an arc.

BISECTING AN ARC

To bisect an arc, you should follow the same steps as those given for bisecting a line. Use the ends of the arc (points A and B in fig. 14-3) as centers for the arcs that intersect.

BISECTING AN ANGLE

Look at figure 14-4 as you read about bisecting an angle. Use the following steps to bisect an angle:

1. Use the vertex of the angle as the center for one point of the dividers. Draw arcs cutting the legs of the angle (view A).
2. Use the intersections of the arcs and the legs as centers to draw arcs that intersect each other inside the angle (view B).
3. Connect the intersection point of these last two arcs with the vertex of the angle to bisect the angle (view C).

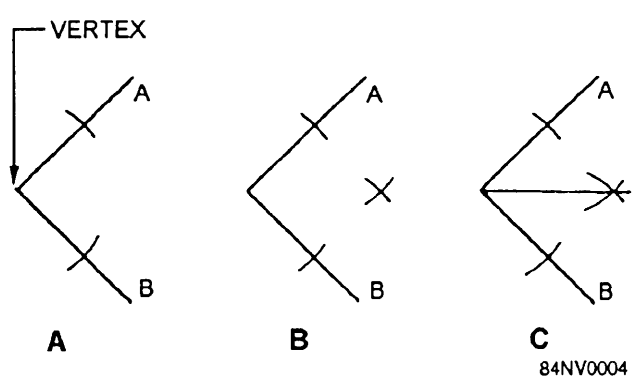


Figure 14-4.—Bisecting an angle.

COPYING OR TRANSFERRING AN ANGLE

A simple geometrical method can be used to copy or transfer an angle. Figure 14-5 shows you how to do this. To use this method, use the following steps to copy angle AOB onto base line B´O´:

1. Insert one point of the dividers at point 0 (view A). Adjust the other leg to intersect line A´O´ at a distance that is convenient to work with.
2. Draw an arc that intersects both legs of the angle (view A).
3. Look at view B. Without changing the adjustment on the dividers, place the point on point O´ and draw an arc intersecting the base line.
4. Look at view C. Use the dividers to measure between the legs of the angle where the arc cuts the legs. Transfer this measurement to line O´B´ by placing one point of the dividers at the intersection of line O´B´ and the transferred arc. Draw a short arc that intersects the transferred are (view C).
5. Connect the intersection point of the two arcs to point O´ to draw leg A´O´ and form A´O´B´ (view D).

DIVIDING A LINE INTO FIVE EQUAL PARTS

You may wonder, why not just measure and divide into the required number of parts? This is not a very

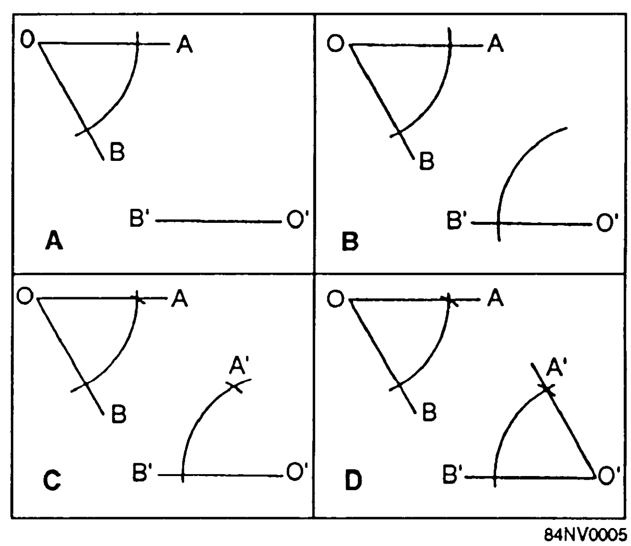


Figure 14-5.—Copying an angle.

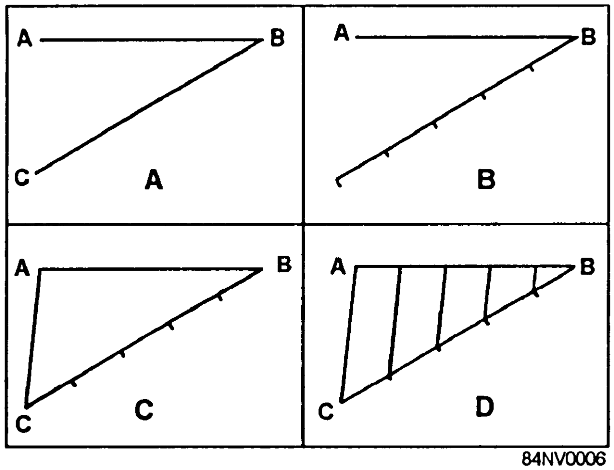


Figure 14-6.—Dividing a line geometrically.

accurate way to divide a line. A more accurate division can be made by using dividers. You may divide a line into any number of equal parts by using the following procedure (fig. 14-6):

1. Draw a line at an angle from one end of line AB (view A).
2. On this line mark off five equal points with dividers (view B).
3. Draw a line from the last point at the widest part of the angle (point C in view C) to the end of the original line (point A). This line is shown as AC in view C.
4. From each of the other marked-off points, draw lines parallel with line AC (view D).

DRAWING A CIRCLE OR AN ARC THROUGH THREE GIVEN POINTS

The steps used in drawing a circle through three given points are given in the following list and are

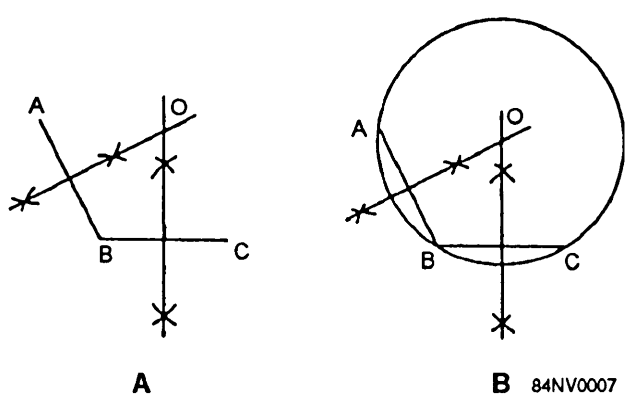


Figure 14-7.—Drawing a circle through three given points.

shown in figure 14-7, which you should refer to as you read this section.

1. Draw lines between points A, B, and C, and bisect these lines (view A).
2. The point where the bisecting lines intersect each other (point D) is the center of the circle. Place one point of the dividers at this point and the other point at one of the other three lettered points.
3. Draw the circle as shown in view B. The circle will now pass through all three lettered points.

DRAWING A PERPENDICULAR FROM THE END OF A LINE

Figure 14-8 shows the steps you will follow to draw a perpendicular from the end of a line.

1. Pick any point, such as C, above base line AY.
2. With the dividers set at a radius of CA, place the point at point C. Draw an arc so the arc intersects line AY at point B. It must extend an equal distance on the other side of A.
3. Draw a line intersecting the arc through points B and C. Label this point D.
4. Then, draw line DA perpendicular to line AY.

DRAWING A PERPENDICULAR TO A GIVEN LINE FROM A GIVEN POINT

At times, you will need to draw a perpendicular to a given line from a given point. The steps for drawing

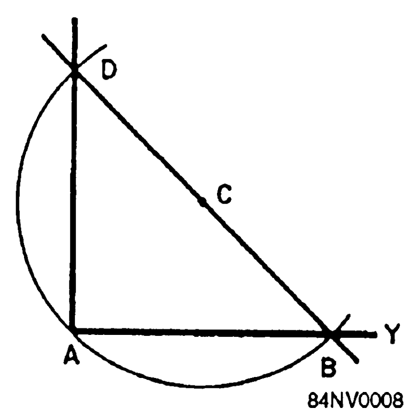


Figure 14-8.—Drawing a perpendicular from the end of the line.

a perpendicular to a given line from a given point are shown in figure 14-9.

1. From point A above line XY, pick any two points on line XY, such as C and B. Points C and B can either be on opposite sides of A or both on the same side of A.
2. With B as a center, and with a radius of BA, draw short arcs above and below line XY.
3. With C as a center, and a radius of CA, draw short arcs intersecting the arcs drawn in step 2.
4. Draw line DA through the intersecting arcs. Line DA is perpendicular to line XY.

BLENDING ARCS AND TANGENTS

Laying out circles or arcs, and straight lines tangent to them, is difficult. It is difficult because there is an element of optical illusion involved. Drawing a straight line to a curved one is easier than drawing a curved line to a straight one. Because of this, major circles or arcs are drawn first on layouts.

Even when you draw a straight line to a curve, an optical illusion may make it difficult for you to blend the curve and the line perfectly. This section discusses a few simple methods that should help you to blend lines and arcs.

The Draftsman's Method of Drawing a Tangent to a Circle at a Given Point

The draftsman's method of drawing a tangent to a circle is described in the following steps. It is shown in figure 14-10, and you should refer to this figure as you read this section. You will need your triangle and straightedge to draw a tangent to a circle.

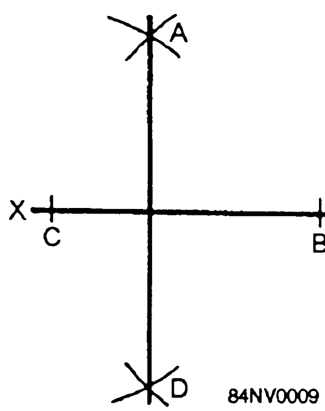


Figure 14-9.—Drawing a perpendicular to a given line from a given point.

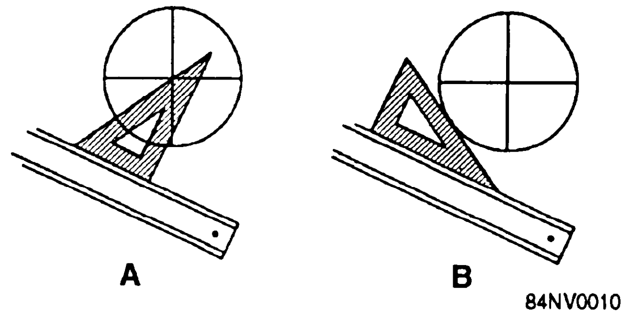


Figure 14-10.—Drawing a tangent to a circle at a given point.

1. Place a triangle against a straightedge, as shown in view A. The hypotenuse of the triangle should pass through the center of the circle and the point where the line is to be tangent to the circle.
2. Hold the straightedge firmly in place, and turn the triangle over.
3. Move the triangle until the hypotenuse passes through the point of tangency, and then draw the tangent, as shown in view B.

Drawing an Arc to a Line

You may find that when you draw an arc that ends in a straight line, you have a tendency to overdraw the arc (fig. 14-11). Use the following procedure and the steps shown in figure 14-12 to avoid this.

1. Use any given radius as the distance to set your dividers.
2. Set one point of the dividers at point A and strike tangent points at B and C (view A).
3. Without changing the dividers, place one point at B and strike an arc at D.

Figure 14-11.—Errors in drawing a line to the end of an arc.

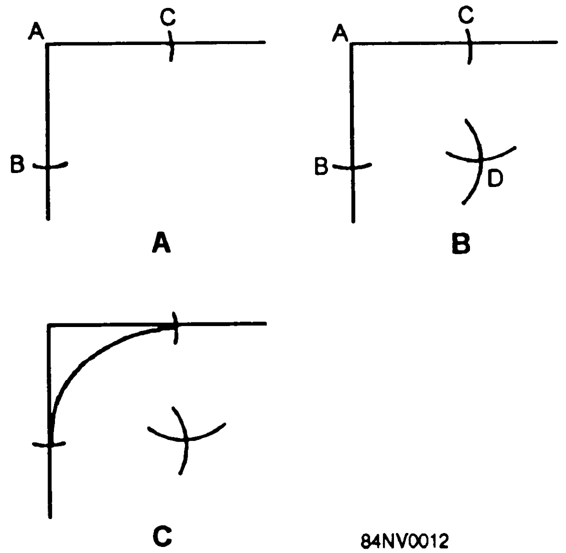


Figure 14-12.—Precaution to avoid overdrawing an arc that ends in a straight line.

4. Next, place the point at C and strike another arc intersecting the arc at D (view B).
5. Place one divider point where these two arcs intersect and strike an arc to the points of tangency (view C).

Drawing Arcs Tangent to Two Lines (Fillets and Rounds)

Small arcs tangent to two lines forming an inside comer are fillets. They must often be drawn after the straight lines have been drawn. Small arcs tangent to two lines forming an outside comer are rounds.

Use the following steps to draw a fillet or round when two lines form a right angle. Remember, look at figure 14-13 as you read these steps.

1. Adjust the dividers to the required radius.
2. Place one point of the dividers at the comer of the angle, and draw a short arc intersecting each straight line (view A). Intersection points of the arcs and the lines are the point of tangency.

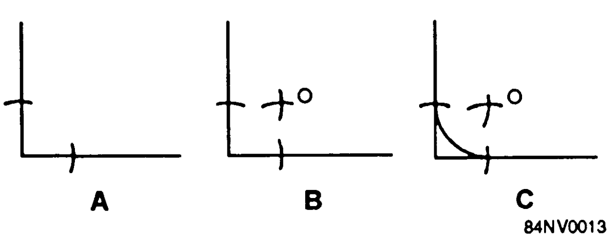


Figure 14-13.—Drawing a fillet or round to a right angle.

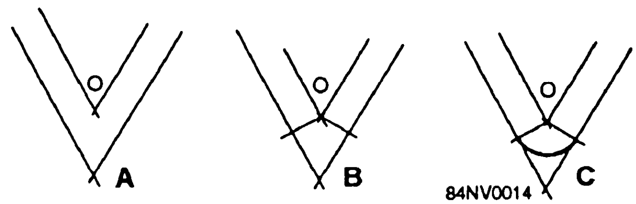


Figure 14-14.—Drawing a fillet or round to two lines that do not form a right angle.

3. Use the intersection points as alternate centers for the point of the dividers. Draw intersecting arcs inside the angle (view B).
4. Use this point of intersection (O) as the center for the point when you draw the fillet, as shown in view C.

Use the following steps to draw a fillet or round when the lines form an angle that is not a right angle. Look at figure 14-14 as you read these steps.

1. Draw lines inside the angle that are parallel to the first two lines. Draw them a distance of a given radius from the first two lines (view A). The intersection of these parallel lines will be the center of the fillet's arc.
2. Find the exact points of tangency, as shown in view B.
3. Now draw the fillet, using the intersection of the inside lines (point 0) as the center of the circle. Start at one point of tangency and stop when the arc touches the other point of tangency (view C).

Drawing Large Arcs Tangent to Smaller Arcs

Any of the methods of drawing fillets apply in laying out large circles or arcs tangent to other arcs. The trial-and-error method is shown in figure 14-15. In this figure, the arc of a large circle is tangent to two small circles or arcs. Points T and T´ are estimated as the points of tangency. Use them to find the intersecting arcs at point O. Point 0 is used as the center in drawing the arc from T to T´.

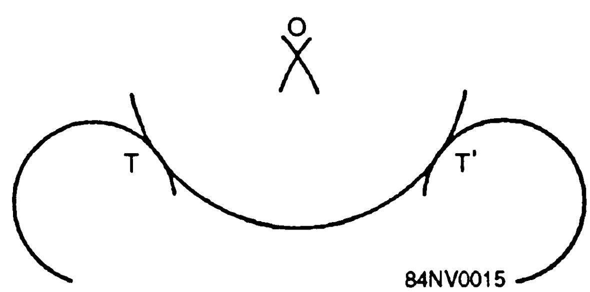


Figure 14-15.—Trial-and-error method of drawing a large arc tangent to two smaller arcs.

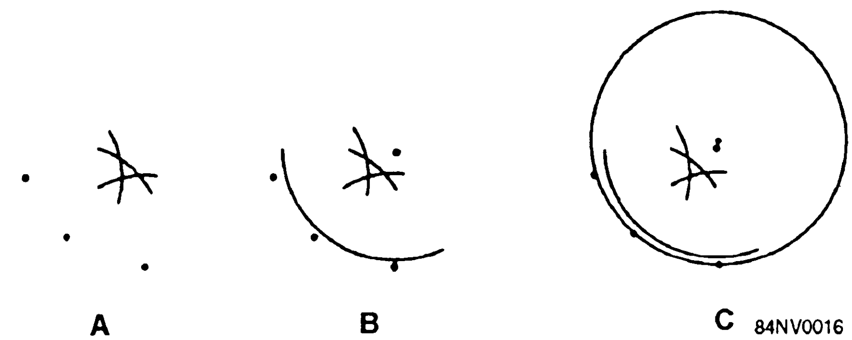


Figure 14-16.—Trial-and-error method of finding the center of a circle that passes through three given points.

The trial-and-error method also can be used in drawing a circle through three given points. In figure 14-16, view A, arcs with an equal radius have been drawn from each of the three points. You can see that they fail to have a common point of intersection and are, therefore, not at the proper center.

If the arcs from the two outer points intersect below the center point arc (view B), you know that the radius of the circle is larger. If the two outer points intersect above the center point arc, then the radius of the circle is smaller.

From this trial you can judge where the center will probably fall. Select a point (O) to use as the center in drawing your first trial arc. If this trial arc fails to pass through the three points perfectly (view B), move the center, as shown in view C.

This time you can judge the position of the center so accurately that the circle may be drawn through the points (view C).

Drawing a Reverse or Ogee Curve Tangent to Two Lines

The following steps tell you how to draw a reverse or ogee curve. Refer to figure 14-17 as you read this section.

1. Erect a perpendicular at point A and drop one at point B (view A).
2. Connect points A and B with a line (view B).
3. Assume a point (C) on this line through which the curve will pass. This point may be the midpoint of the line if equal arcs are desired.
4. Bisect AC and CB, as shown in view C. The intersection of these lines with the perpendiculars from points A and B are the centers of the required arcs. Complete the curve, as shown in view D.

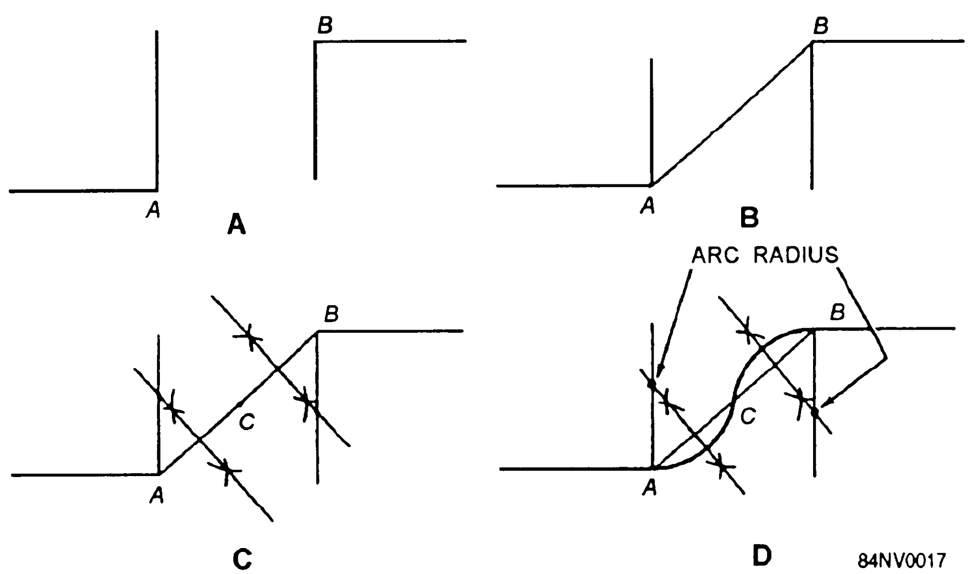


Figure 14-17.—Reverse or ogee curve.

DRAWING PLANE FIGURES

A plane has only two dimensions. Your layout is a plane. This section gives methods of construction for several plane figures.

DRAWING TRIANGLES WITH GIVEN LENGTH SIDES

Figure 14-18 shows the steps in drawing a triangle with given lengths for its sides. The lengths for the sides are shown in view A.

1. Draw one side of the triangle in the desired position as the base line (view B).
2. Adjust the dividers to the length of a second side. Using one end of the base line as a center for the point of the dividers, draw an arc (view B).
3. Adjust the dividers to the length of the third side. From the other end of the base line, draw another arc that intersects the first arc (view B).
4. Draw lines from the intersection point of these arcs to the ends of the base line. They are for the sides of the triangle (view C).

DRAWING EQUILATERAL, ISOSCELES, AND RIGHT TRIANGLES

An equilateral triangle has three equal sides. To draw this type of triangle, first draw one side as the base line. Then, use the length of that side as the radius to draw intersecting arcs from each end of the base line (fig. 14-19, view A).

An isosceles triangle has two equal sides. To draw an isosceles triangle, first draw the base. Then, draw intersecting arcs from each end of the base line. Use the length of one of the equal sides as the radius (fig. 14-19, view B).

A right triangle has a 90-degree angle. You can draw a right triangle by using the method for bisecting a line (refer to fig. 14-2). Draw a perpendicular from the end of a line (refer to fig. 14-8), or draw a perpendicular to a given line from a given point (refer to fig. 14-9).

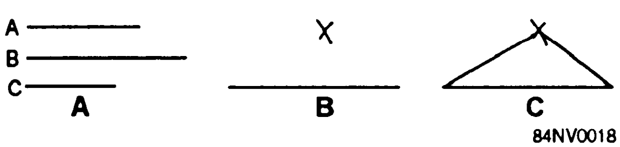


Figure 14-18.—Drawing a triangle with three given sides.

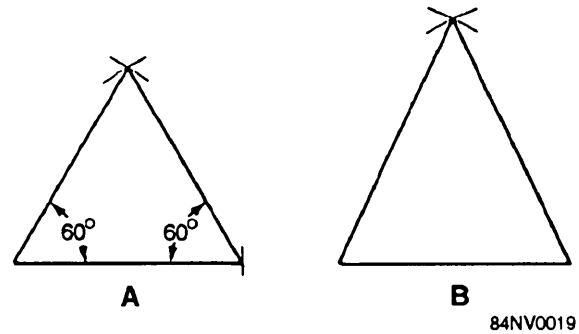


Figure 14-19.—Drawing triangular plane figures. A. An equilateral triangle. B. An isosceles triangle.

CONSTRUCTING A REGULAR PENTAGON WITHIN A CIRCLE

Look at figure 14-20. Here, you can see how to draw a pentagon. Refer to figure 14-20 as you read the following section.

1. Draw the diameter of the circle, shown as line AOB (view A).
2. Bisect radius OB of the circle (view B).
3. With D as a center and a radius equal to DC, strike arc CE (view C).
4. With C as a center, strike arc FG passing through point E (view D).
5. Distance CF or CG is equal to the length of one side of the pentagon. Mark off the other sides with the dividers (view E).

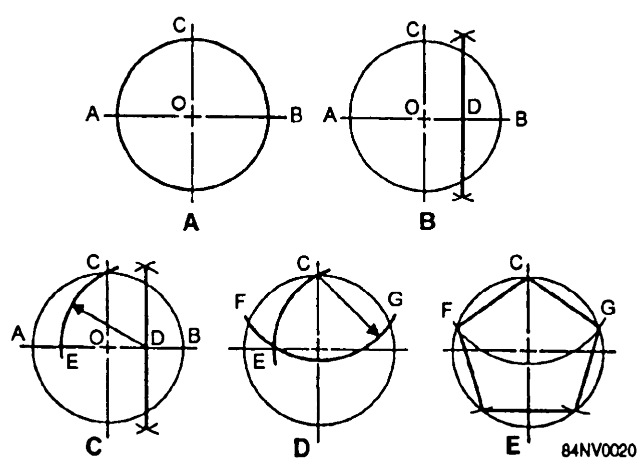


Figure 14-20.—Drawing a regular pentagon in a circle.

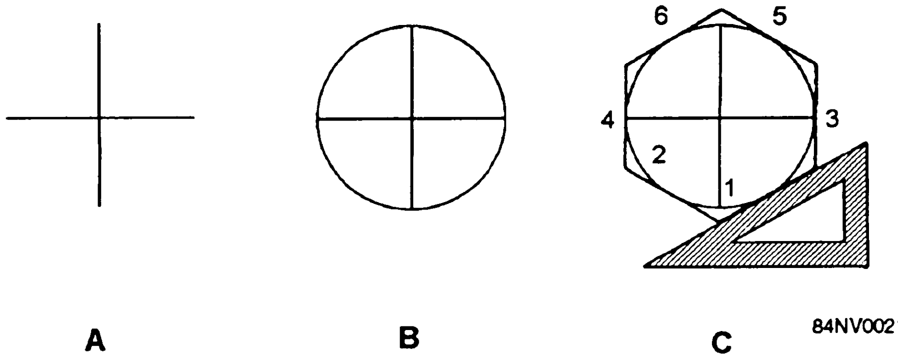


Figure 14-21.—Drawing a regular hexagon when the distance across flats is given.

DRAWING A REGULAR HEXAGON

Bolt heads and nuts are hexagonal forms (six sided) and are common figures in mechanical drawings. You can draw a regular hexagon if you are given the distance between opposite sides of a hexagon. The opposite sides are the *short distance* or *distance across the flats.* To draw the hexagon, use the following steps. Refer to figure 14-21 as you read this section.

1. Draw a horizontal line and a vertical line. Draw each as long as a given distance. They intersect at right angles to each other (view A).
2. With these lines as diameters and their intersection as the center for the point of the dividers, draw a circle as shown in view B.
3. Using the 30- to 60-degree triangle resting on a T-square or straightedge base, draw lines tangent to the circle in the order shown in view C.

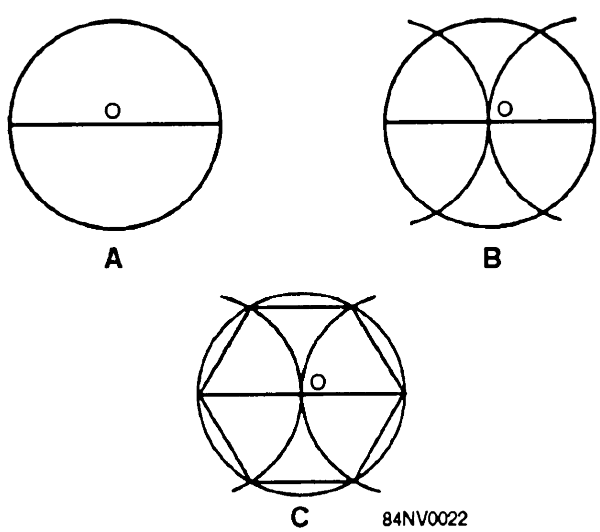


Figure 14-22.—Drawing a regular hexagon when the distance across corners is given.

If you are given the distance between opposite comers of a hexagon, called the *distance across comers* or the long *diameter,* use the method shown in figure 14-22.

1. Draw a circle with the long diameter as the circle diameter (view A).
2. Using the same radius as you used to draw the circle, draw arcs with the ends of the diameter as centers (view B).
3. Draw lines from the points where the arcs intersect the circle to those where the diameter touches the circle (view C).

DRAWING A REGULAR OCTAGON (AN EIGHT-SIDED FIGURE)

As you read this section, refer to figure 14-23. If you are given the distance between opposite sides of an octagon, you can use the following method to draw a regular octagon.

1. Use the given distance as the side dimension in drawing a square (view A).
2. Draw the diagonals of the square.
3. Adjust the dividers to a radius equal to one-half the length of a diagonal.

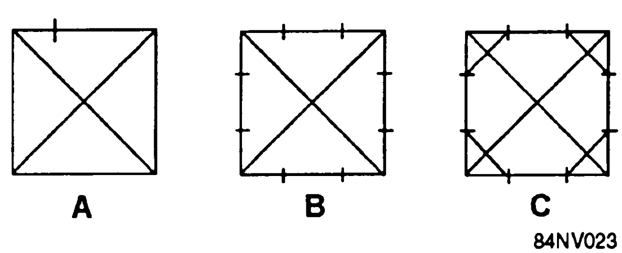


Figure 14-23.—Drawing a regular octagon when the distance between sides is given.

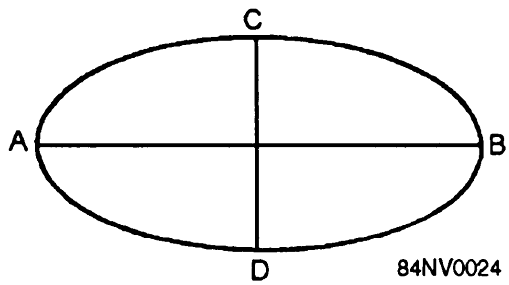


Figure 14-24.—An ellipse with major axis AB and minor axis CD.

4. Place the point of the dividers on each comer and draw arcs intersecting the sides of the square (view B).
5. Draw lines connecting the intersecting points and form a regular octagon (view C).

DRAWING AN ELLIPSE

The ellipse is a difficult figure to draw. There are several ways you can use to draw it. Normally, you are given the length of the major and minor axes of the ellipse (fig. 14-24).

Using a Compass to Draw an Ellipse

As you read this section, refer to figure 14-25. An ellipse that is not accurate but gives a good visual effect may be drawn, using a compass, as follows:

1. Draw the major and minor axes.
2. Draw a line connecting one end of the major axis and one end of the minor axis (view A).
3. Using a radius equal to half the major axis and with C as the center, lay off OE on OB (view B).
4. Using a radius equal to EB, lay off CF on CB (view C).
5. Bisect line FB as shown in view D. Extend the bisecting line to intersect AB at X and CD at Y.
6. Using a radius equal to XB, lay off AX´. Using a radius equal to DY, lay off CY´ (view D).
7. Using radii XB and X´A, draw the arcs, as shown in view E.
8. Using radii YC and Y´D, draw the side arcs, as shown in view F.

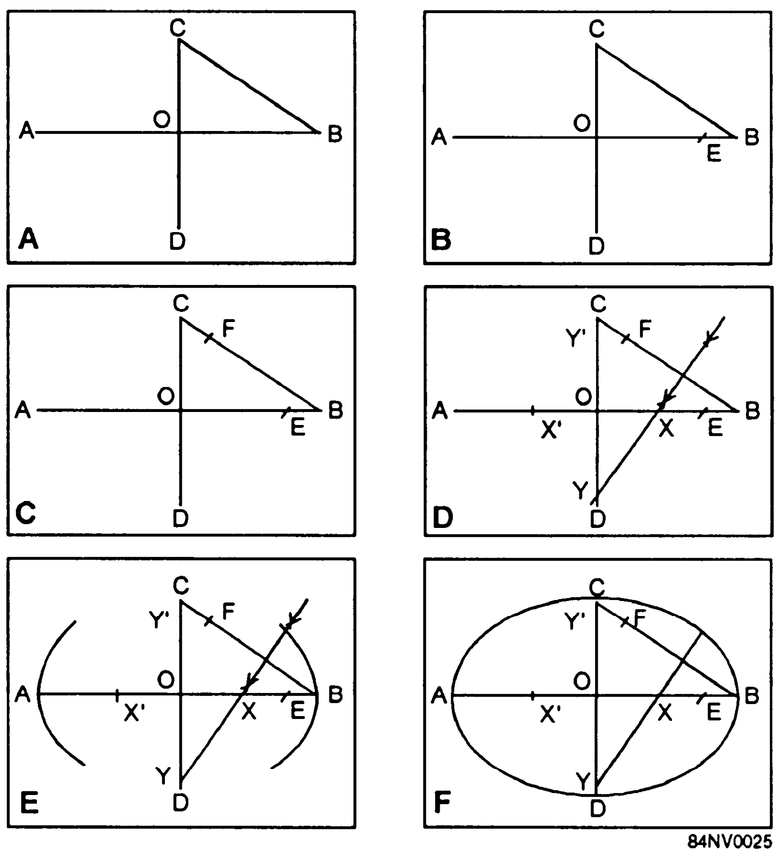


Figure 14-25.—Drawing an ellipse.

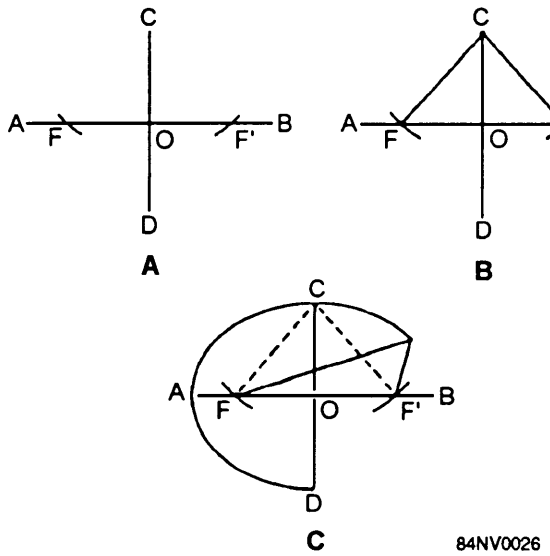


Figure 14-26.—Drawing an ellipse using a pin and string.

Pin-and-String Method

The easiest method of drawing a large ellipse is the pin-and-string method. To use this method, refer to figure 14-26 and use the following steps:

1. Draw the major and minor axes.
2. Set the dividers to one-half the length of the major axis. Using one end of the minor axis as a center, draw arcs intersecting the major axis. Points F and F´ are the foci of the ellipse (view 4 .
3. Drive pins at the foci and at one end of the minor axis. Tie a cord around the three pins, as shown in view B.
4. Remove the pin at the end of the minor axis, and place a pencil or pen inside the loop. Keep the string taut and draw the line of the ellipse.

Trammel Method

An ellipse may also be drawn by the trammel method. You will need your straightedge. On the straight edge of a strip of material, mark half the distance of the major axis, AO (fig. 14-27, view A). Then, mark half the distance of the minor axis, CO. Draw the major and minor axes on the drawing sheet. Move the straightedge, keeping point A on the minor axis and point C on the major axis. Using point 0 as the guide, draw the ellipse as shown in view B.

Concentric-Circle Method

The concentriccircle method of drawing an ellipse is the most accurate of the methods discussed in this section. However, you must be able to handle your instruments accurately. As you read this section, refer to figure 14-28.

1. Draw the major and minor axes.
2. With the intersection as a center, draw a circle that has the major axis as a diameter. Then, draw another circle with the minor axis as the diameter (view A).
3. Draw several radii from the center to the arc of the larger circle (view B).
4. Wherever these lines cut the smaller circle, draw short horizontal lines outward from the arc of that circle.
5. Wherever the radii touch the larger circle, draw short vertical lines to intersect the short horizontal lines (view C). The points where these short horizontal and vertical lines intersect define the ellipse.
6. Use the French curve and draw the ellipse from these plotted points (view D). The French curve

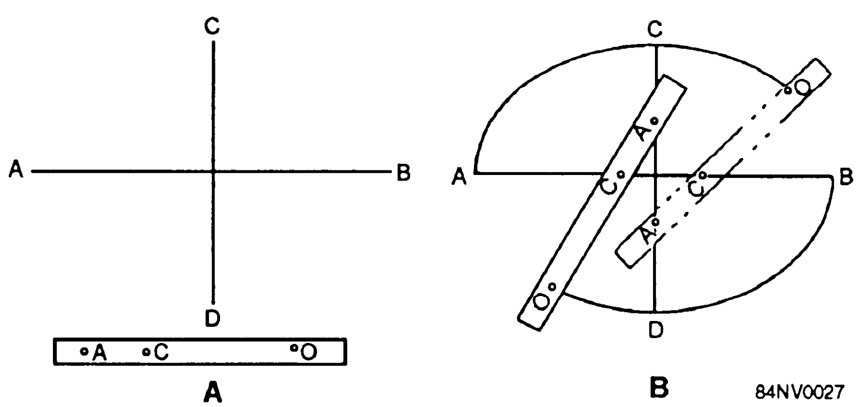


Figure 14-27.—Drawing an ellipse using the trammel method.

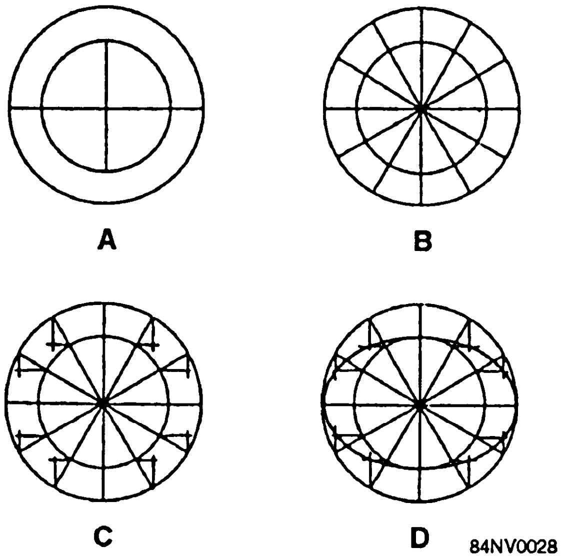


Figure 14-28.—Drawing an ellipse using the two-circle method.

is an instrument used to draw smooth irregular curves.

DRAWING SPIRALS AND INVOLUTES

A spiral or involute is a constantly changing curve that winds, coils, or circles around a center point. For a practical example, the main spring in your watch is a spiral. This section gives methods of construction for common spirals.

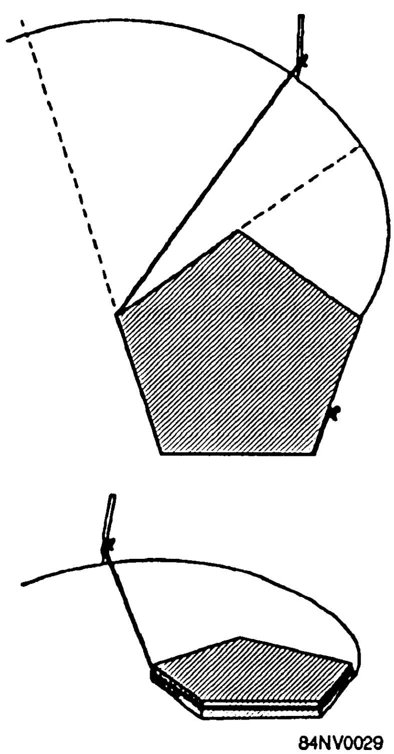


Figure 14-29.—Drawing the involute of a pentagon using pin and string.

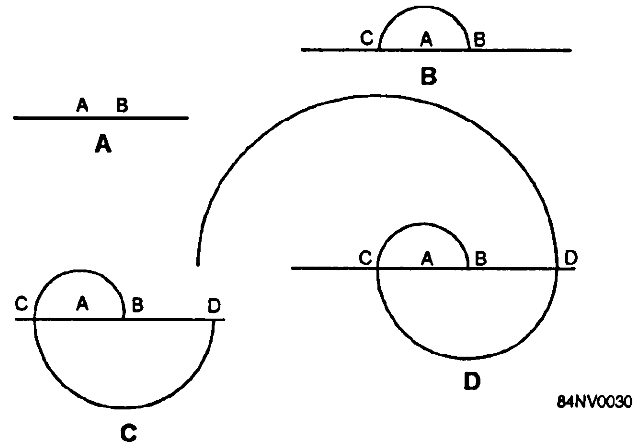


Figure 14-30.—Drawing the involute of a line.

An involute is the curve that might be traced by a point on a cord that is being unwound from a line, a triangle, a square, or other geometric figure. Figure 14-29 shows the pin-and-string method of drawing the involute of a pentagon.

Drawing the Involute of a Line

Look at figure 1430. To draw the involute of a line, extend line AB (view A). Using length AB as a radius and A as a center, draw a semicircle (view B). Then, using BC as the radius and B as the center, draw a second semicircle, continuing the curve as shown in view C. Then, with CD as the radius and C as the center, draw the next arc as shown in view D. Proceed until the curve is the desired size.

Drawing the Involute of a Triangle

As you draw the involute of a triangle, refer to figure 14-3 1. Extend the sides of the triangle (view A).

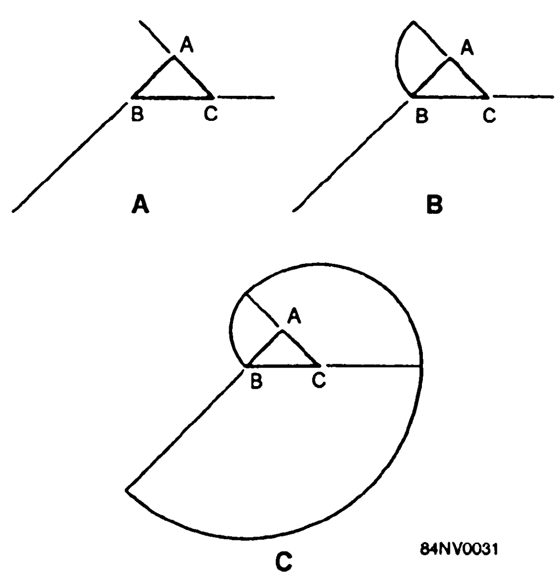


Figure 14-31.—Drawing the involute of a triangle.

Use one side of AB as a radius and A as the center. Draw an arc from B to the extension of side AC, as shown in view B. Next, measure a radius the length of AC plus its extension. With C as the center, draw an arc to the extension of side BC. With BC plus its extension as the radius and B as the center, draw an arc to the extension of side AB, as shown in view C. Continue in this manner until the figure is the desired size.

Drawing the Involute of a Circle

Consider the circle as a polygon with many sides. Divide the circumference of the circle into several equal segments (fig. 14-32, view A). Then, draw tangents from each segment (view B). With the cord of a segment as a radius, draw an arc from one segment to intersect the tangent of the next segment, as shown in view B. With the intersection point on this tangent to the point of tangency as a radius, draw an arc to intersect the next tangent (view C). Continue until the figure is the required size.

Drawing a Spiral of Archimedes

The spiral is generated by a point moving around a fixed point, its distance increasing uniformly with the angle. To draw a spiral that makes one turn in a given circle, divide the circle into several equal segments (fig. 14-33, view A). Then, divide the radius of a circle into the same number of parts, and number them from the center outward (view A). Using the center of the circle as a center, draw an arc from each of the numbered segments that intersect the corresponding numbered divisions on the radius (view B). These intersections are the points of the curve (view C).

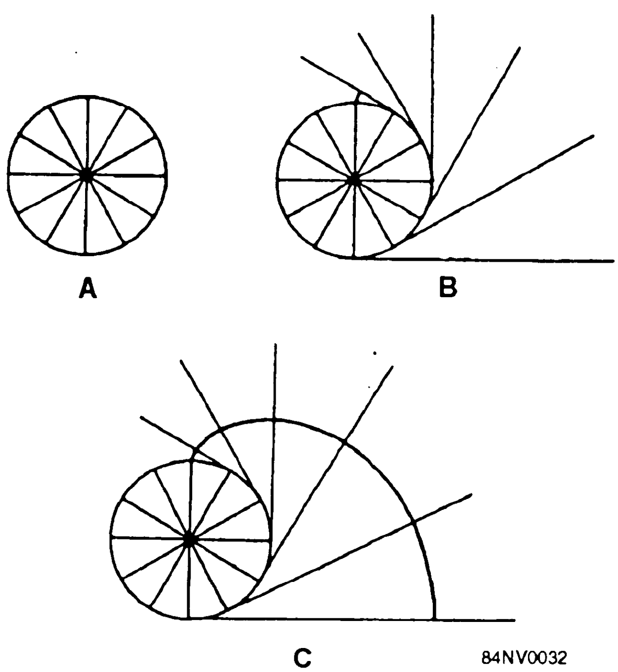


Figure 14-32.—Drawing the involute of a circle.

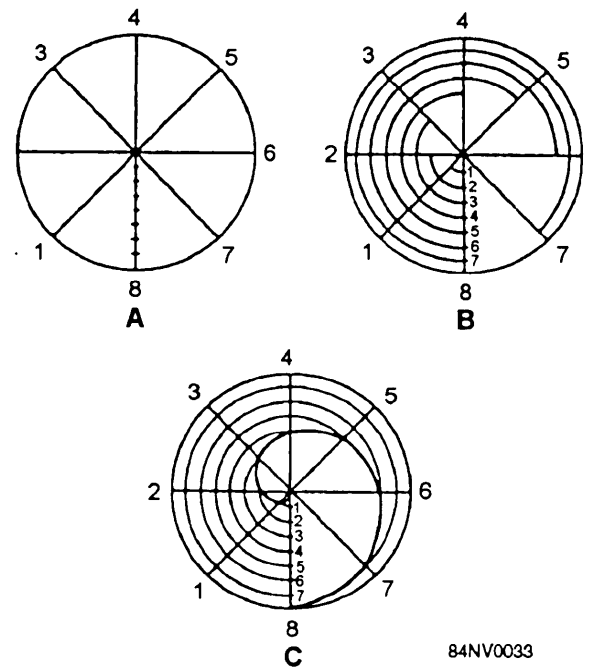


Figure 14-33.—Drawing the spiral of Archimedes.

Drawing the Helix

Consider the helix (fig. 14-34), a curve that is generated by a point moving uniformly along a straight line that revolves around an axis. If the line moves parallel to the axis, it will generate a cylindrical helix. If it moves at an angle to the. axis, it will generate a conical helix. The lead of a helix is the distance along the axis to which the point advances in one revolution.

To draw a helix, draw two views of the cylinder, as shown in view A. Divide the lead into an equal number of parts. Divide the circle into the same number of parts (view B). The intersection of the lines from these points (view C) are the points of a cylindrical helix.

AREAS AND VOLUMES

You must be able to calculate the amount of material needed to manufacture or repair many different items used throughout the Navy. You must also be able to determine the weight of the finished product to calculate the approximate weight of an object. To do this, you must have a knowledge of geometry and be able to determine areas and volumes of geometric shapes and figures.

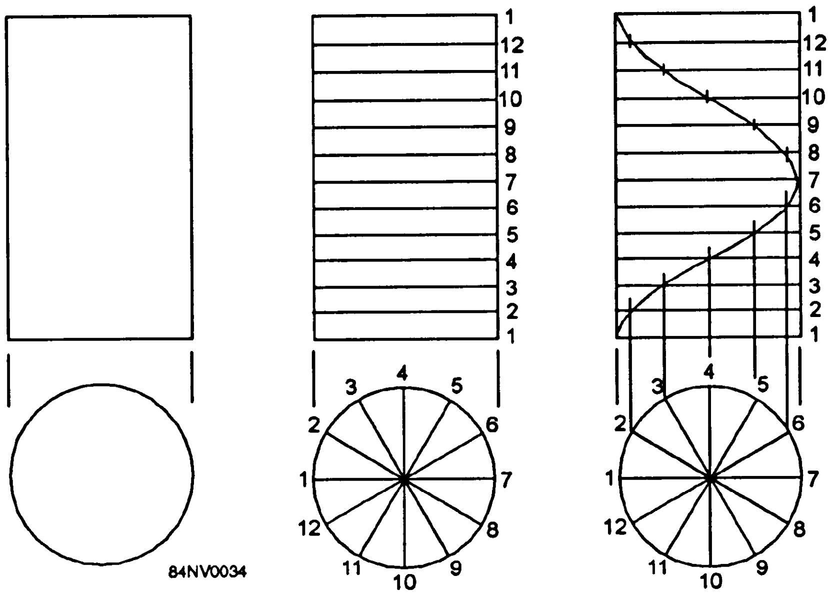


Figure 14-34.—Drawing a helix.

Area is the extent of a surface bounded by two dimensions, such as length and width. The unit of measure showing area is the square, such as square inches, square feet, and square yards.

Volume is the extent of an object bounded by three dimensions, such as length, width, and height. The unit of measure showing volume is the cube, such as cubic inches or cubic feet.

To find the area (A) of the rectangle shown in figure 14-35, you must multiply the length (L) by the width (W) or A = LW. Since L = 8 inches and W = 5 inches, A = 8 x 5 = 40 square inches.

To find the volume (V) of the cube shown in figure 14-36, you must multiply length (L) times width (W) times height (H), or V = LWH. Since L = 8 inches, W = 5 inches, and H = 7 inches, V = 8 × 5 × 7=280 cubic inches.

Many of the geometric figures you will be concerned with are shown in figure 14-37. With each figure is the formula and some examples of problems for calculating area and volume for that particular figure.

When values are enclosed in parentheses ( ), brackets [ ], or braces { }, they are grouped. Some equations contain a group within a group. An example of this is the formula for finding the area of a trapezium where

A = 1/2[a(e + d) + bd + ce].

In this formula you have parentheses and brackets. Parentheses can be enclosed in braces, and braces can

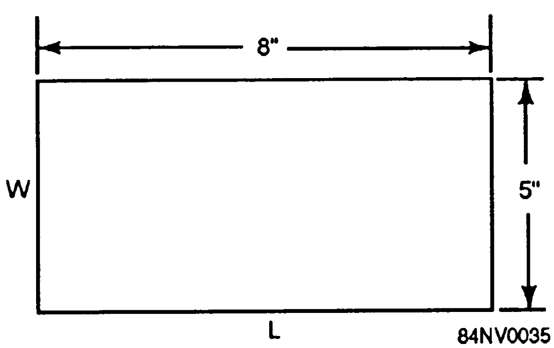


Figure 14-35.—Two-dimensional view.

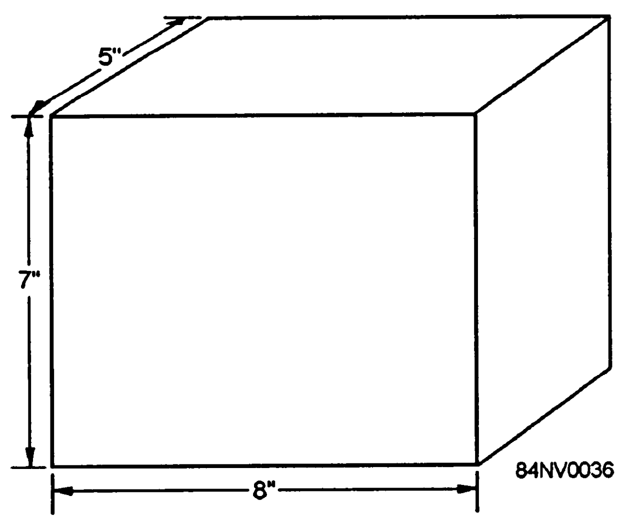
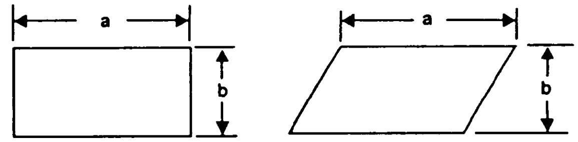


Figure 14-36.—Three-dimensional view.

Rectangle and Parallelogram

Area = ab



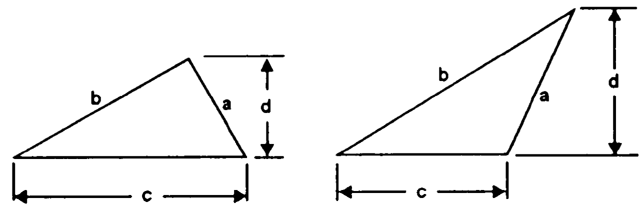
Triangle

Area = ½ cd.

Example: d = 5"

c = 6"

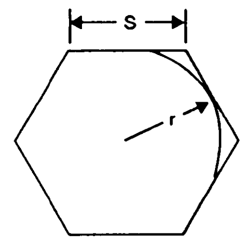
Then, ½ × 5" × 6" = 15 sq. in.



Regular Polygons

n = Number of sides, s = Length of one side, r = Inside radius

Area = ½ nsr



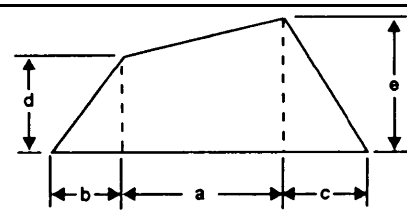
Number of Sides	Area
5	1.72047 s^2 = 3.63273 r^2
6	2.59809 s^2 = 3.46408 r^2
7	3.63395 s^2 = 3.37099 r^2
8	4.82847 s^2 = 3.31368 r^2
9	6.18181 s^2 = 3.27574 r^2
10	7.69416 s^2 = 3.24922 r^2
11	9.36570 s^2 = 3.22987 r^2
12	11.19616 s^2 = 3.21539 r^2

Trapezium

Area = ½ [a (e + d) + bd + ce]

Example: a = 10", b = 3", c = 5", d = 6", e = 8"

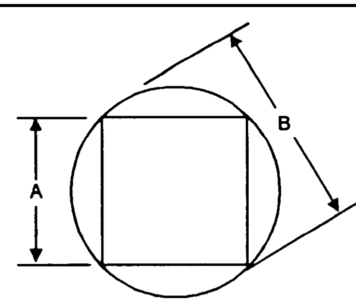
Area = ½ [10 (8 + 6) + (3 × 6) + (5 × 8)] = 99 sq. in.



Square

The diagonal of a square = A X 1.414

The side of a square inscribed in a given circle is B X 0.707.



84NV0037

Figure 14-37.—Areas and volumes for calculating weights of castings.

be enclosed in brackets. The reverse is not true. The values enclosed by parentheses must be calculated before the values within brackets. As an example, find the area of a trapezium using the formula and values shown in figure 14-37.

A= 1/2[a(e + d) + bd + ce]

A= 1/2[10(8 + 6) + 3 x 6 + 5 × 8]

A= 1/2[10(14) + 18 + 40]

A= 1/2[140+18 + 40]

Circle

θ (the Greek letter Theta) = angle included between radii

π (pi) = 3.1416, D = Diameter, R = Radius, C = Chord.

h = Height of Arc, L = Length of Arc.

Circumference $= \pi D = 2\pi R = 2\sqrt{\pi \times \text{Area}}$

Diameter $= 2R =$ Circumference $\div \pi = 2\sqrt{\dfrac{\text{Area}}{\pi}}$

Radius $= \frac{1}{2}D =$ Circumference $\div 2\pi = \sqrt{\dfrac{\text{Area}}{\pi}}$

Radius $= \dfrac{\left(\frac{C}{2}\right)^2 + h^2}{2h}$

Area $= \frac{1}{4}\pi D^2 = 0.7854\ D^2 = \pi R^2$

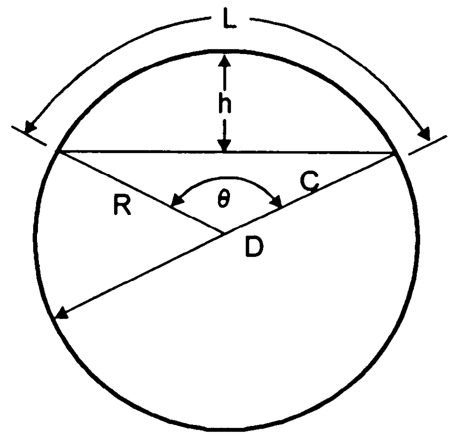
Chord $= 2\sqrt{h\ (D - h)} = 2R \times \text{sine}\ \frac{1}{2}\theta$

Height of Arc, $h = R - \sqrt{R^2 - \left(\frac{C}{2}\right)^2}$

Length of Arc, $L = \dfrac{\theta}{360} \times 2\pi R = 0.0174533\,R\theta$

$\frac{1}{2}\theta$ (in degrees) $= 28.6479\dfrac{L}{R}$

Sine $\frac{1}{2}\ \theta = \dfrac{C}{2} \div R$



Sector of a Circle

Area $= \frac{1}{2}$ LR

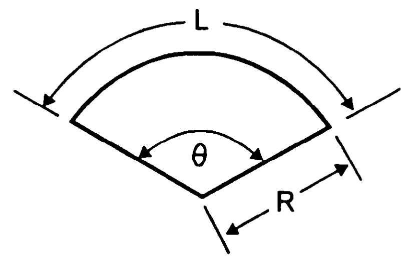
Example: L = 10.472", R = 5"

Area $= \dfrac{10.472}{2} \times 5 = 26.180$ sq. in.

or Area $= \pi R^2 \times \dfrac{\theta}{360} = 0.0087266\,R^2\theta$

Example: R = 5", $\theta = 120°$

Area $= 3.1416 \times 5^2 \times \dfrac{120}{360} = 26.180$ sq. in.



Segment of a Circle

Area $= \pi R^2 \times \dfrac{\theta}{360} - \dfrac{C\ (R - h)}{2}$

Example: R = 5", θ = 120°, C = 8.66", h = 2.5"

Area $= 3.1416 \times 5^2 \times \dfrac{120}{360} - \dfrac{8.66\ (5 - 2.5)}{2} = 15.355$ sq. in.

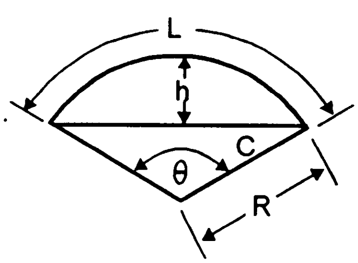
Length of arc L = $0.0174533\,R\theta$

Area $= \frac{1}{2}\left[LR - C(R - h)\right]$

Example: R = 5", C = 8.66", h =- 2.5", $\theta = 120°$

L = 0.0174533 X 5 X 120 = 10.472"

Area $= \frac{1}{2}\left[(10.472 \times 5) - 8.66\,(5 - 2.5)\right] = 15.355$ sq. in.



84NV0038

Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

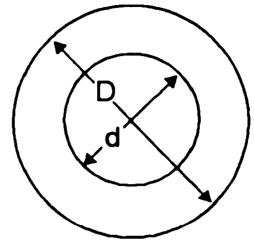
A = 1/2[198]

A= [99]

After substituting numerical values for the letter symbols, add *e* + *d*, since they are enclosed within parentheses. There are no symbols between a and the first parenthesis. This means that a must be multiplied by the sum of *e* + *d*, which results in a product of 140. Next multiply *bd* and *ce*. This results in products of 18 and 40. When these products are added to 140, you

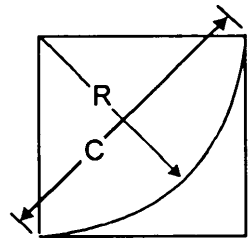
Circular Ring

Area = $0.7854 (D^2 - d^2)$. or $0.7854 (D - d) (D + d)$
Example: $D = 10''$, $d = 3''$
Area = $0.7854 (10^2 - 3^2) = 71.4714$ sq. in.



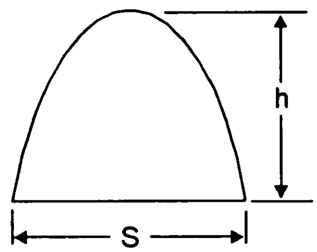
Spandrel

Area = $0.2146 R^2 = 0.1073 C^2$
Example: $R = 3$
Area = $0.2146 \times 3^2 = 1.9314$



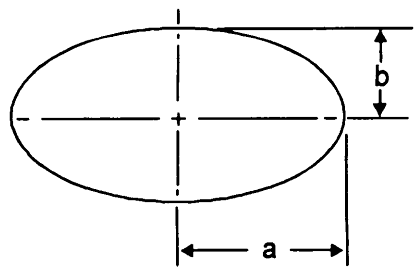
Parabolic Segment

Area = $\frac{2}{3}sh$
Example: $s = 3$, $h = 4$
Area = $\frac{2}{3} \times 3 \times 4 = 8$



Ellipse

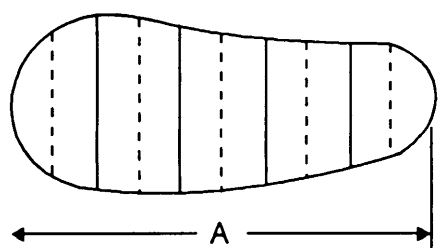
Area = $\pi ab = 3.1416\ ab$
Example: $a = 3$, $b = 4$
Area = $3.1416 \times 3 \times 4 = 37.6992$



Irregular Figures

Area may be found as follows:
Divide the figure into equal spaces as shown by the lines in the figure.

(1) Add lengths of dotted lines.
(2) Divide sum by number of spaces.
(3) Multiply result by A.



84NV0039

Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

have a value of 198. This value is now multiplied by 1/2, resulting in a product of 99. Since all values are in inches, the area is 99 square inches.

PRINCIPLES OF SURFACE DEVELOPMENT

A surface has two dimensions—length and width. It is bounded by lines that are either straight or curved.

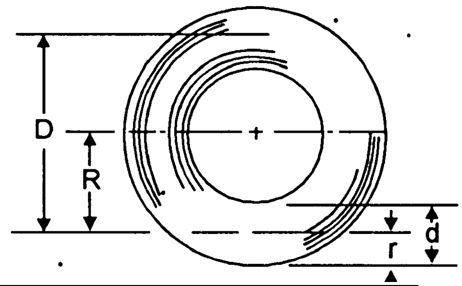
Ring of Circular Cross Section

Area of surface $= 4\pi^2 Rr = 39.4784\ Rr$

Area of surface $= \pi^2 Dd = 9.8696\ Dd$

Volume $= 2\pi^2 Rr^2 = 19.7392\ Rr^2$

Volume $= \frac{1}{4}\pi^2 Dd^2 = 2.4674\ Dd^2$

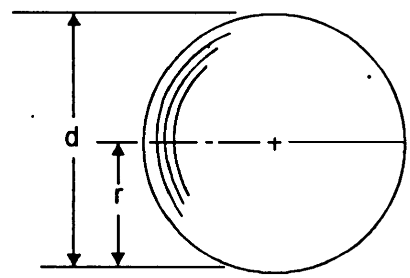


Sphere

Surface $= 4\pi r^2 = 12.5664\ r^2 = \pi d^2$

Volume $= \frac{4}{3}\pi r^3 = 4.1888\ r^3$

Volume $= \frac{1}{6}\pi d^3 = 0.5236\ d^3$



Segment of a Sphere

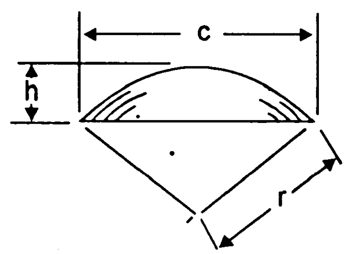
Spherical surface $= 2\pi rh = \frac{1}{4}(c^2 + 4h^2) = 0.7854\ (c^2 + 4h^2)$

Total surface $= \frac{1}{4}\pi(c^2 + 8rh) = 0.7854\ (c^2 + 8rh)$

Volume $= \frac{1}{3}\pi h^2 (3r - h) = 1.0472\ h^2\ (3r - h)$

or

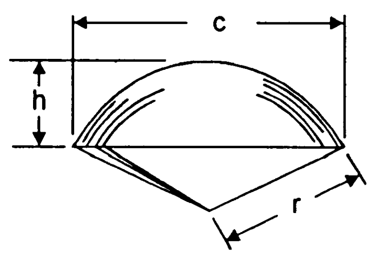
Volume $= \frac{1}{24}\pi h\ (3c^2 + 4h^2) = 0.1309\ h\ (3c^2 + 4h^2)$



Sector of a Sphere

Total surface $= \frac{1}{2}\pi r\ (4h + c) = 1.5708\ r\ (4h + c)$

Volume $= \frac{2}{3}\pi r^2 h = 2.0944\ r^2 h$



Cylinder

Cylindrical surface $= \pi dh = 2\pi rh = 6.2832\ rh$

Total surface $= 2\pi r\ (r + h) = 6.2832\ r\ (r + h)$

Volume $= \pi r^2 h = \frac{1}{4}\pi d^2 h = 0.7854\ d^2 h$

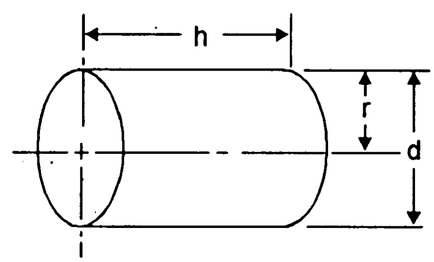


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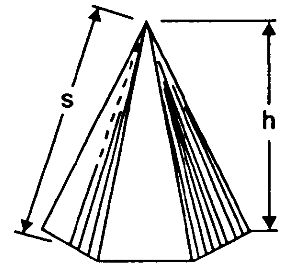
Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

The surface itself may be plane or flat. It could be plane-curved, such as the peripheral surface of a cylinder; warped, like the surface of a screw thread; or double-curved, like the surface of a sphere. A plane-curved surface can be unrolled and laid out flat. This is called developing the surface, A warped surface or double-curved surface can only be developed approximately.

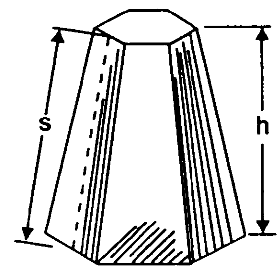
Pyramid

A = Area of base
P = Perimeter of base
Lateral area = $\frac{1}{2}$ Ps
Volume = $\frac{1}{3}$Ah



Frustum of a Pyramid

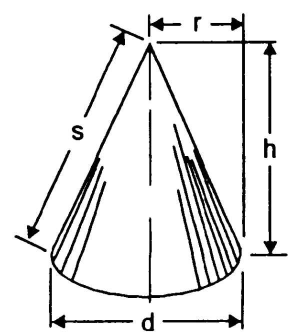
A = Area of base
a = Area of top
m = Area of midsection
P = Perimeter of base
p = Perimeter of top
Lateral area = $\frac{1}{2}s\,(P + p)$
Volume = $\frac{1}{3}h\,(a + A + \sqrt{aA})$
Volume = $\frac{1}{6}h\,(A + a + 4m)$



Cone

Conical area + $\pi rs = \pi r\sqrt{r^2 + h^2}$

Volume $= \frac{1}{3}\pi r^2 h = 1.0472\ r^2 h = 0.2618\ d^2 h$



Frustum of a Cone

A = Area of base
a = Area of top
m = Arca of midsection
$R = D \div 2;\ r = d \div 2$
Arca of conical surfacc $= \frac{1}{2}\pi s\,(D + d) = 1.5708\,s\,(D + d)$
Volume $= \frac{1}{3}h\,(R^2 + Rr + r^2) = 1.0472\,h\,(R^2 + Rr + Rr + r^2)$
Volume $= \frac{1}{12}h\,(D^2 + Dd + d^2) = 0.2618\,h\,(D^2 + Dd + d^2)$
Volume $= \frac{1}{3}h\,(a + A + \sqrt{aA}) = \frac{1}{6}h\,(a + A + 4m)$

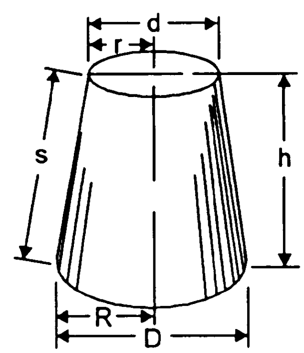


Figure 14-37.—Areas and volumes for calculating weights of castings—Continued.

In figure 14-38, several three-dimensional figures are shown. Try to form a mental picture of how these figures would look if they were unfolded or unrolled and laid out in a flat plane. The polyhedrons, of course, would be merely a system of connected squares, triangles, or other polygons. A cylinder with parallel ends would unroll into a parallelogram. A cone would unroll into a section of a circle. However, warped surfaces cannot lie flat. Double-curved surfaces present a similar problem.

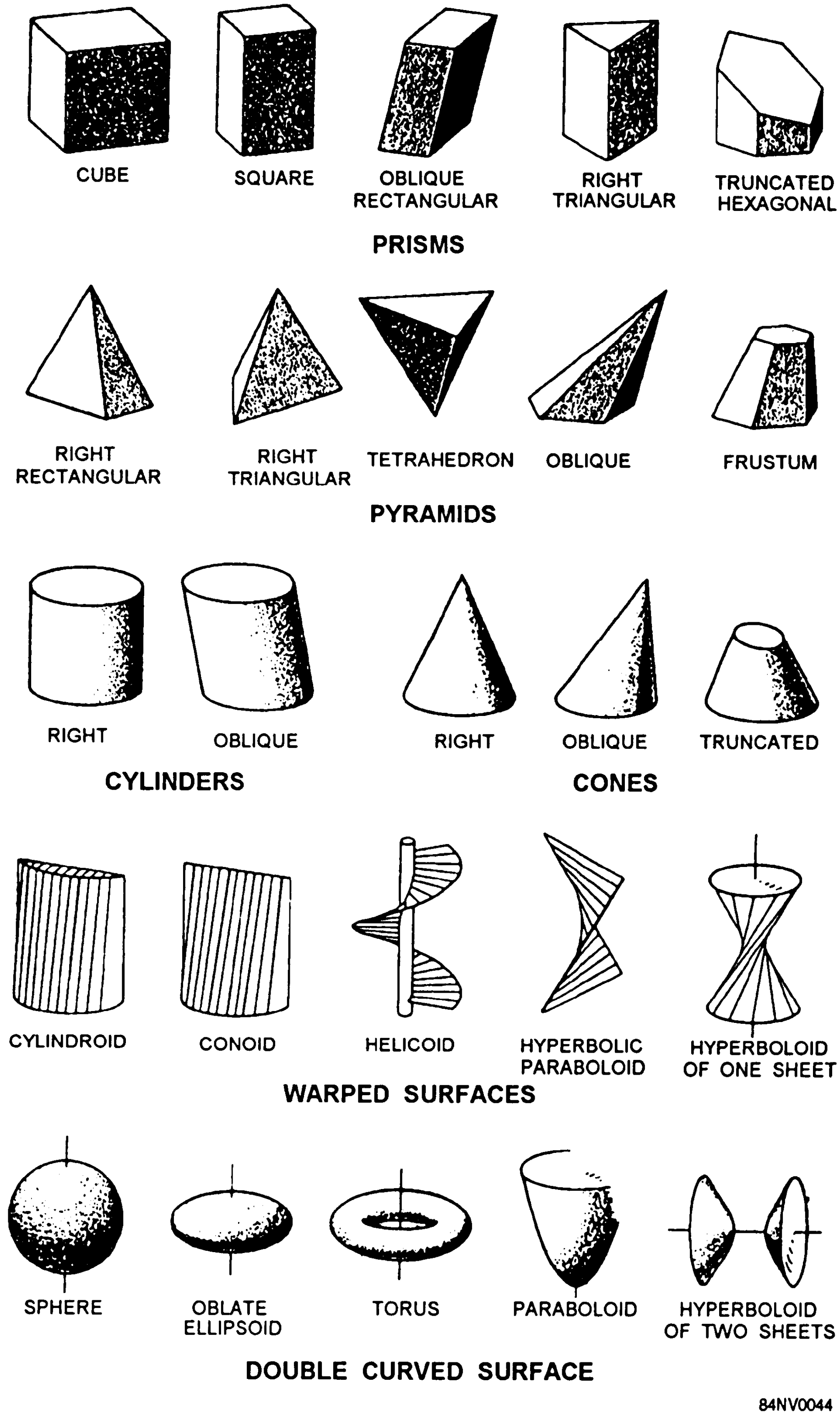


Figure 14-38.—Three-dimensional shapes.

The three principal methods of developing the surface of three-dimensional objects are parallel development, radial development, and triangulation. Parallel development is for surfaces such as prisms or

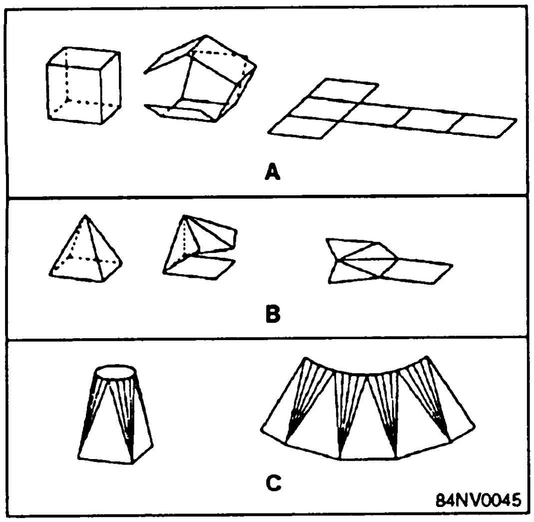


Figure 14-39.—Surface development. A. Parallel development. B. Radial development. C. Development by triangulation.

cylinders (fig. 14-39, view A). Radial development is for surfaces such as cones and pyramids (view B). Triangulation is for surfaces that do not lend themselves to either of the other two methods (view C).

Double-curved surfaces, such as a sphere, may be developed approximately by the same methods as those used for map projecting. A sphere can be cut into horizontal sections or zones that may be considered and developed as frustrums of cones (fig. 14-40, view A).

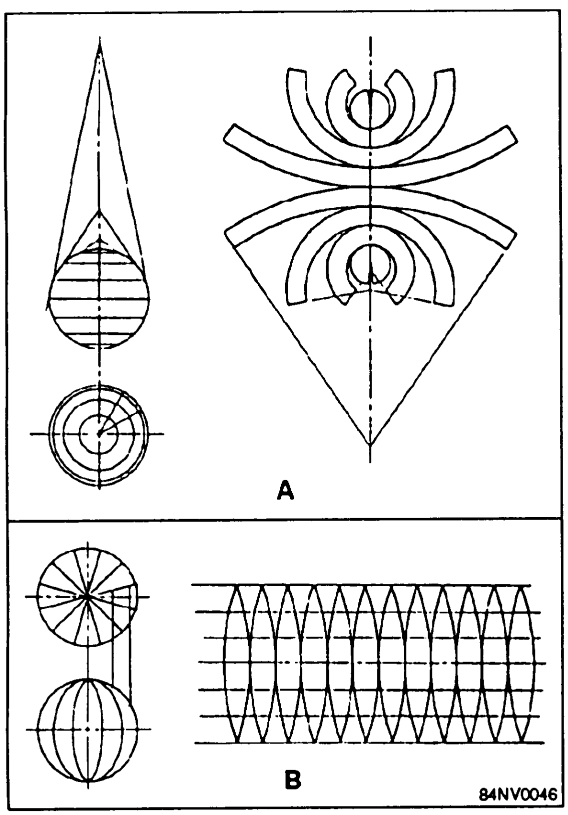


Figure 14-40.—Development of double-curved surfaces.

A sphere also can be cut into equal meridian sections called lunes, and these developed as if they were sections of cylinders (view B).

PARALLEL DEVELOPMENT

The surfaces of prisms and cylinders are parallel elements or elements that can be treated as parallel elements. Figure 14-41 shows the steps in developing a rectangular prism. You should refer to it as you read the following section.

1. To determine the length of all the edges of the prism, draw the front and top views in orthographic projection (view A).
2. Draw the development to one side of the front view so dimensions of vertical elements on that view can be projected to the development (view B).
3. Transfer the dimensions of other elements from the top view (view C). Mark all bend lines with crosses near their ends to distinguish them from outlines.
4. To check the drawing, measure the edges that are to join (view D). Such edges must correspond exactly.

Figure 14-42 shows the following steps in the development of a truncated hexagonal prism:

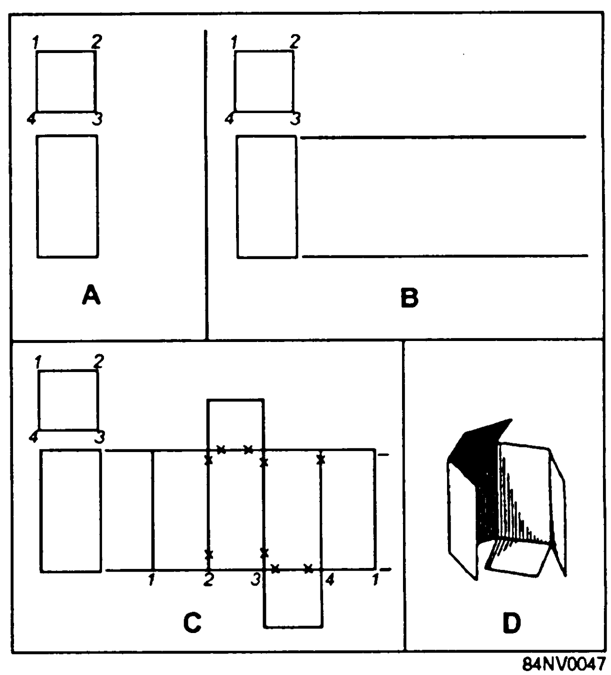


Figure 14-41.—Parallel development of a rectangular plane.

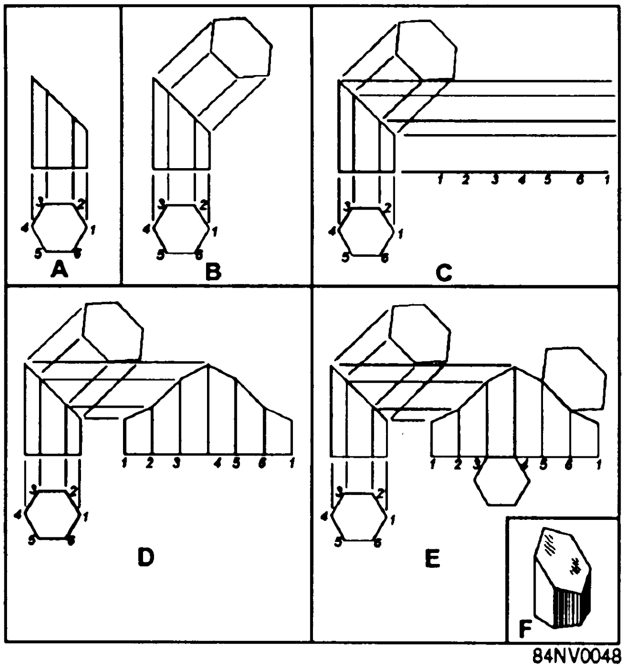


Figure 14-42.—Development of a truncated hexagonal prism.

1. Draw a front view and a bottom view of the prism in orthographic projection (view A).
2. Draw an auxiliary view (view B) since the true shape of the slanting plane and the length of the lines of its edges are not shown in these views. Note that drawing the entire prism in the auxiliary view is not necessary. Only the dimensions of the plane surface are required.
3. Project the lines of the front view horizontally as the first step in constructing the development (view C).
4. Number the points of intersection of planes on the bottom view. Mark off line segments of the same length on the base line of the development.
5. Erect vertical lines from these numbered points to intersect the lines projected from the front view of the prism (view D). These intersections mark the comers of the prism.
6. Connect the intersection points with straight lines.
7. Draw the bottom of the prism attached to one of the sides at the base line. Draw the slanting plane at the top of the prism (view E).
8. Check all edge measurements to be joined, as shown in the pictorial drawing (view F), to be sure they will coincide exactly.

The truncated cylinder is a prism with an infinite number of sides. The number of sides must be limited when developing a cylinder. However, the greater the number of sides, the more accurate the development. The following steps for the development of a truncated cylinder are shown in figure 14-43.

1. To develop one-half of a two-piece elbow, first draw a front and bottom view of that piece in orthographic projection (view A). Since the elbow does not require an end piece, you do not need to draw an auxiliary view showing the true shape of the ellipse formed by the cutting plane at the top of the cylinder.
2. Divide half the circumference of the circle into several equal parts. The parts should be small enough so a straight line drawn between division points will approximate the length of the arc. Project lines from these points to the front view (view B). The resulting parallel lines on the front view are called elements.

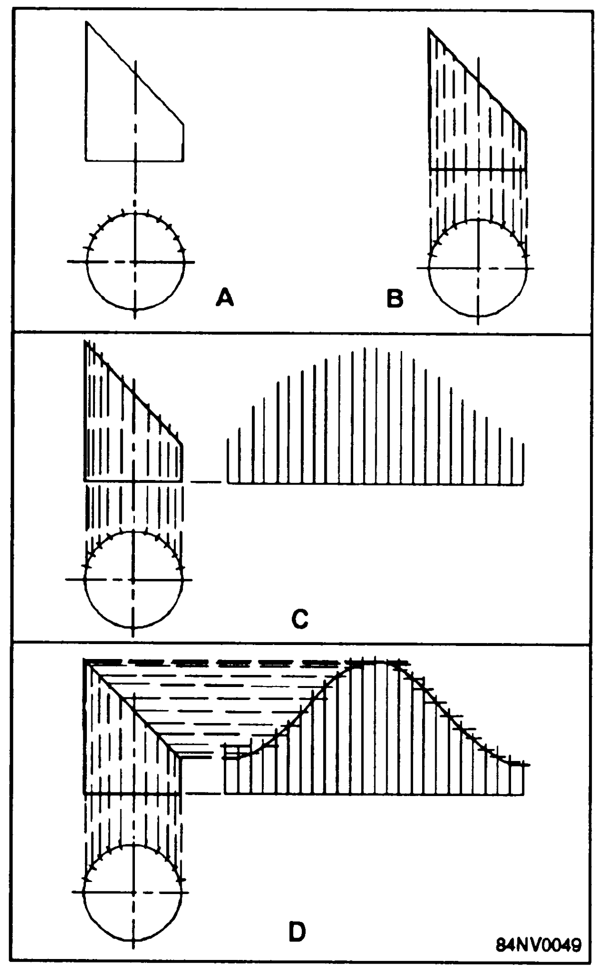


Figure 14-43.—Development of a truncated cylinder.

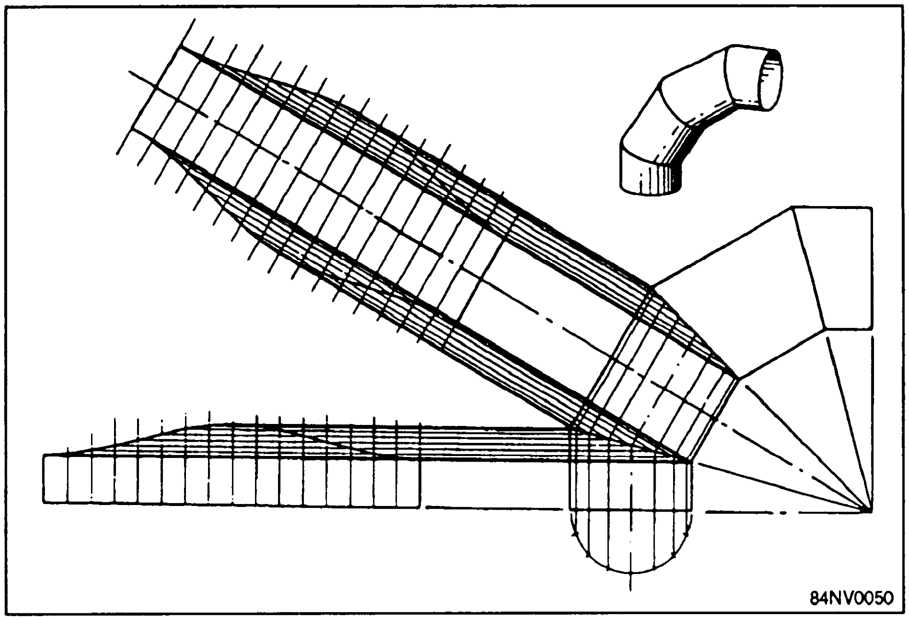


Figure 14-44.—Development for a four-piece elbow.

3. Lay off the base line, called the stretch-out line, of the development. The length of this line can be calculated as π times the diameter of the cylinder ($3.14 \times D$).
4. Divide the stretch-out line into twice the number of equal parts as the number on the half circle of the orthographic view (view C).
5. Erect perpendiculars at each point, as shown in view C.
6. Using a T-square, project the lengths of the elements on the front view to the development (view D).
7. Using a French curve, join the resulting points of intersection in a smooth curve.

When the two pieces of the elbow are the same, you only need to make one drawing.

When a four-piece elbow is to be drawn, follow the same steps to produce as many developments as may be required. The orthographic view may be drawn of the whole elbow and the developments drawn beside each separate piece, as shown in figure 14-44. Here, only one end and one middle development are drawn. The other two pieces are the same as these.

You must determine the exact points of intersection when two pieces, such as two cylinders or a cylinder and a prism, intersect. This is so you can make developments, for the pieces, that will fit together without gaps or unnecessary overlaps. These intersections are determined by carefully drawing the elements intersecting on orthographic views and then projecting or transferring these intersection points to the developments. The following steps in making developments for a T-joint are shown in figure 14-45.

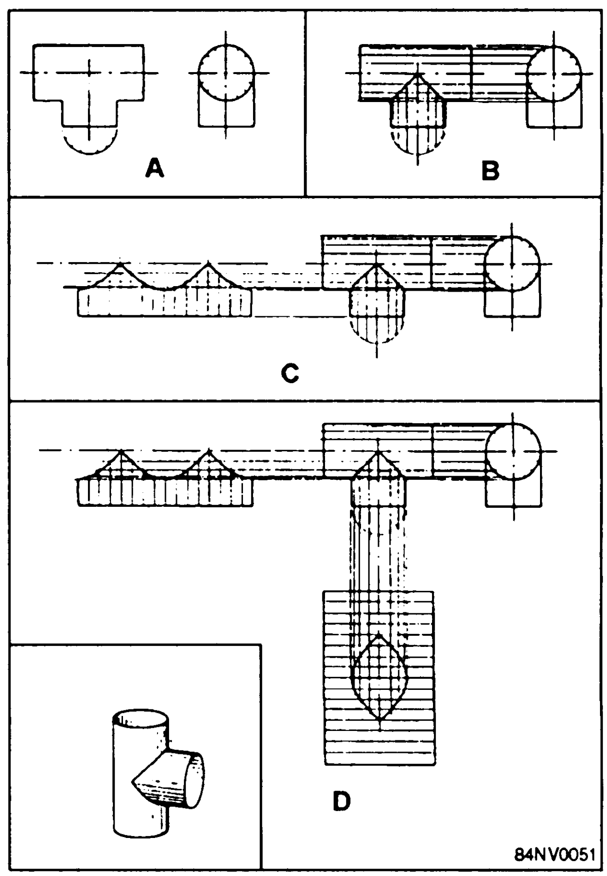


Figure 14-45.—Development of a T-joint with two cylindrical pipes of unequal diameters.

You should refer to this figure as you read the following section. The T-joint consists of two cylinders with equal diameters that intersect at right angles.

1. Draw a front view and a side view of the T-joint. A bottom view representing the open end of the other cylinder might also be drawn. Since this cylinder is perfectly round, a semicircle may be drawn attached to the front view. The division points for the elements can be located on it (view A).
2. Draw equally spaced divisions to locate the elements. Project these divisions to both cylinders. The points where the elements of one cylinder intersect those of the other define the intersection of the two cylinders (view B).
3. Draw the surface of the projecting pipe at one side of the orthographic view so the length of each element can be projected from the front view (view C).
4. Draw the surface of the cross pipe below the front view. Project lines down from the branch pipe to locate the opening for it (view D).

When making the T-joint of two cylindrical pipes of unequal diameter, the procedure differs slightly. Refer to figure 14-46 as you read the following section.

1. Draw the orthographic views.
2. Divide the smaller diameter branch pipe into equal parts. Draw the elements on this pipe in both views (view A). The length of each element is shown in the side view.
3. Project lines from the upper end of each element in the side view to the front view (view B). The intersections of these lines with the vertical lines drawn on the branch pipe define the intersection of the two pipes.
4. Draw the line of intersection on the front view.
5. Draw the surface of the branch pipe to the left, continuing the projection lines to locate the element ends (view C).
6. Draw the surface of the larger diameter main pipe beneath the front view. Project lines down from the branch pipe to locate the opening for it (view D).

Figure 14-47 shows the following steps in drawing a round pipe joint made up of two cylindrical pipes of unequal diameters that intersect at an angle other than 90°.

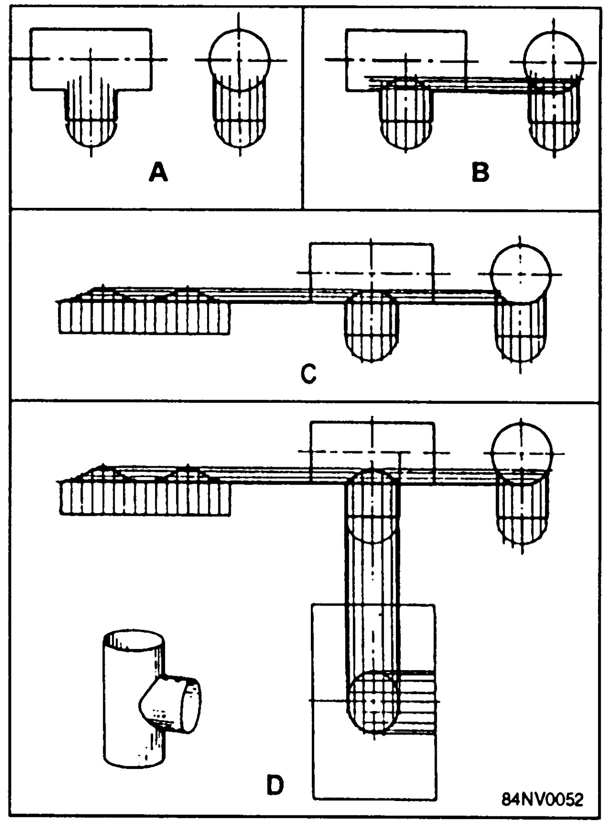


Figure 14-46.—Development of a T-joint with two cylindrical pipes of unequal diameters.

1. Draw the front and top orthographic views (view A). The ellipse formed by the top of the branch pipe may be omitted at this point and drawn later.
2. Draw the elements on the branch pipe in both views (view B).
3. Project lines down from the left end of each element in the top view to the corresponding element in the front view. Draw the line of intersection (view C).
4. Draw the ellipse formed by the end of the branch pipe in the top view. Do this by projecting lines up from the upper end of each element in the front view to the corresponding element in the top view (view D).
5. Draw the pattern of the branch pipe to the right and perpendicular to the pipe the same as in the front view (view E).
6. Draw the pattern for the main pipe to the left, with lines projecting from the intersection of the two pipes on the orthographic view to locate the opening for the branch pipe (view F).

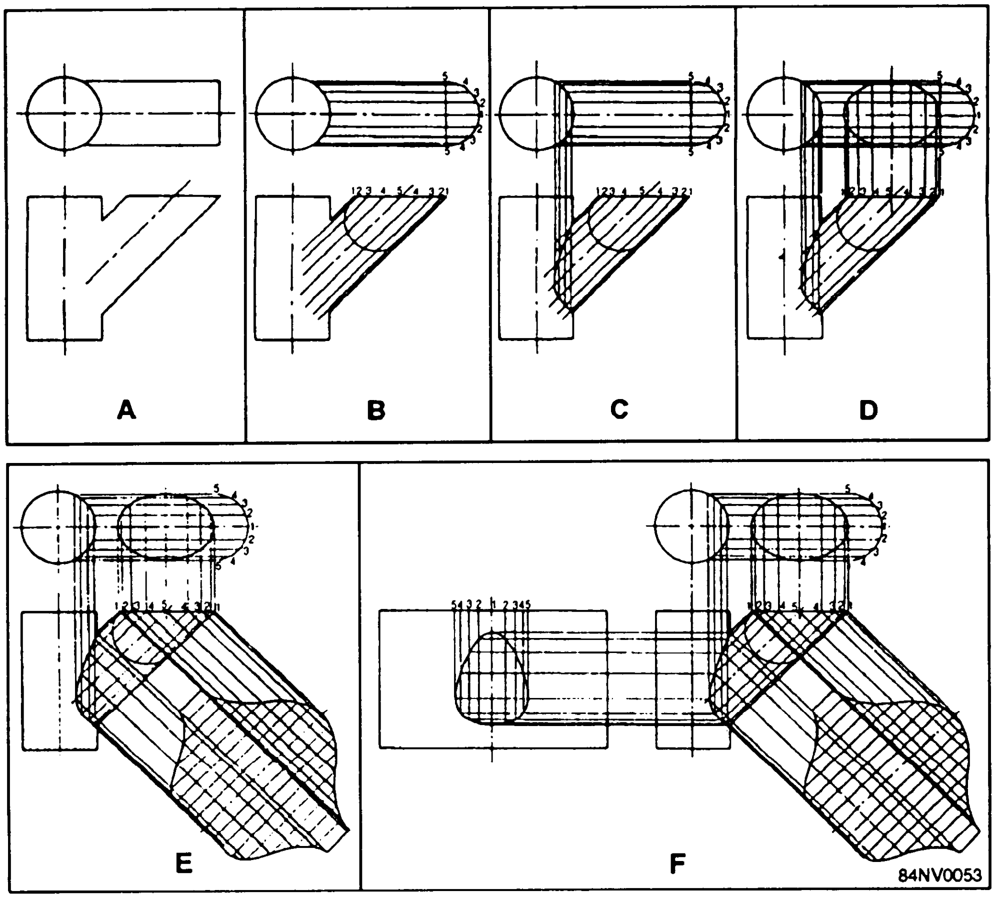


Figure 14-47.—Development of a round pipe joint made of two cylindrical pipes of unequal diameters, intersecting at an angle of other than 90°.

When a pipe joint consists of a rectangular pipe intersecting a round pipe at an angle other than 90°, the procedure is similar. This procedure is shown in figure 14-48 and is described in the following steps:

1. Draw the orthographic views, as shown in view A. Divide the upper surface of the rectangular pipe in the top view by equally spaced elements.
2. Project the points of intersection of these lines with the circle down to the upper and lower surfaces of the branch pipe in the front view (view B).
3. Develop the surface of the rectangular pipe perpendicular to it in the front view (view C).
4. Draw the surface of the round pipe with the opening for the rectangular pipe to the side of the front view (view D).

RADIAL DEVELOPMENT

The sides of a pyramid and the elements of a cone meet at a point called the vertex or apex. These same lines meet at a point in the development of a pyramid or cone and radiate from this point. Therefore, the method of developing pyramids or cones is radial development (fig. 14-49).

Follow the same general procedures in radial development as those used in parallel development. The only major exception is that since the slanting lines of pyramids and cones do not always appear in their true lengths on the orthographic views (fig. 14-49, view A), other procedures must be followed to determine these true lengths.

To find the true lengths of these edges, rotate the pyramid so some of the edges appear in their true lengths (view B). In this case, the lines that appear as horizontal lines in the top view are shown in outline and in their true length in the front view. In other words, when a line appears as horizontal or as a point in the top view, the corresponding line in the front view is its true length. Conversely, when a line appears as horizontal in the front view, the corresponding line in the top view is its true length.

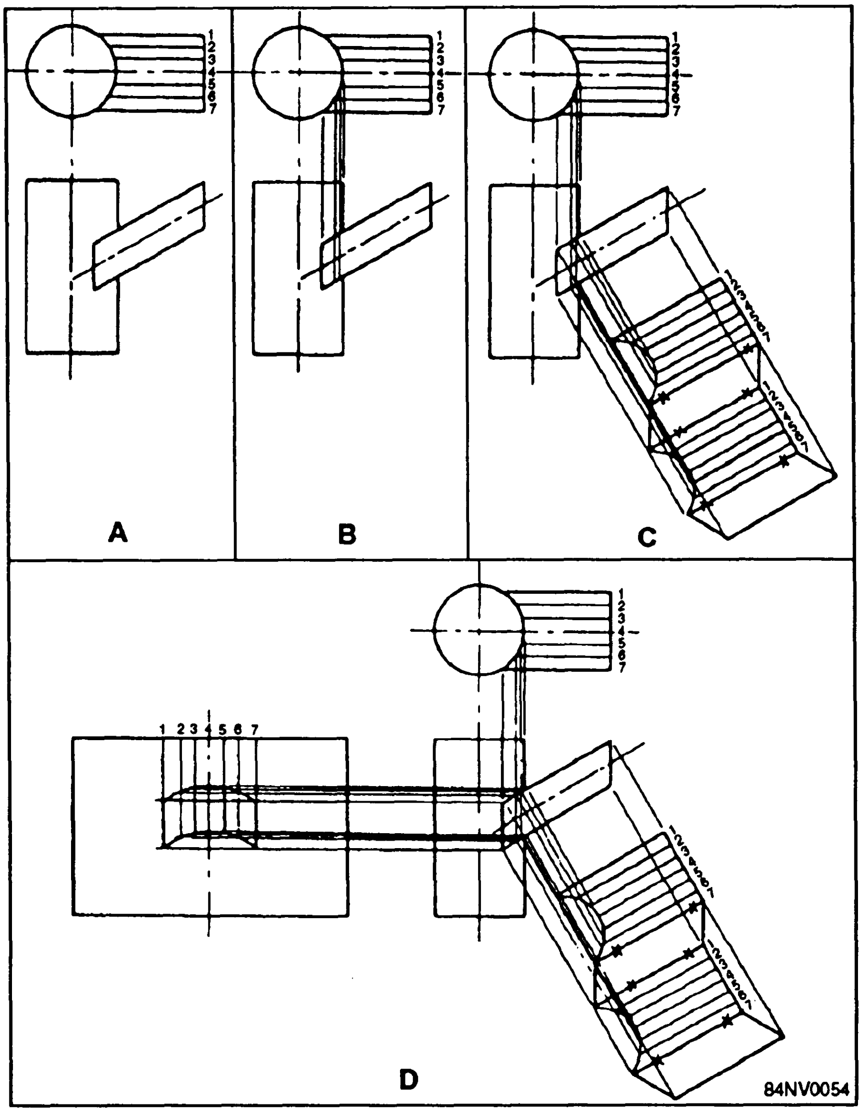


Figure 14-48.—Development of a pipe joint in which a rectangular pipe intersects a round pipe at an angle other than 90°.

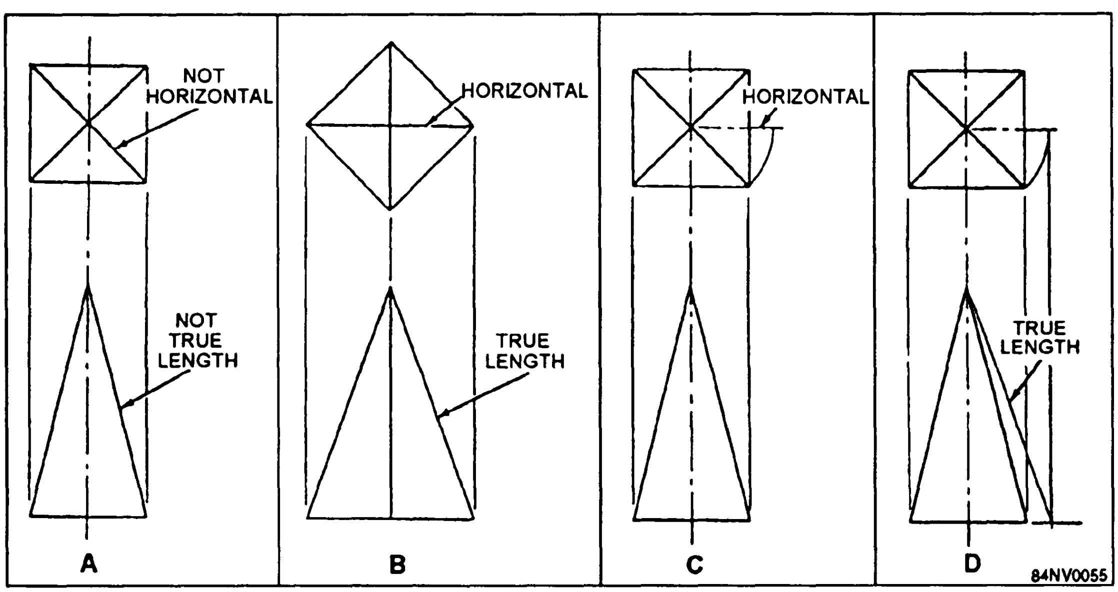


Figure 14-49.—Methods of finding the true length of a line in a radial development.

Instead of rotating the whole pyramid, simply rotate the line of the edge itself into the horizontal on a conventional orthographic view. For example, in view C, the line of an edge from apex to base, as it appears in the top view, is used as the radius for an arc to the horizontal The point of intersection of the arc with the horizontal is projected to the front view. A true-length line for that edge is drawn (view D).

The following steps for developing a truncated pyramid are shown in figure 14-50. This is a transition piece for connecting a large square pipe with a smaller one. Normally, the square ends would end in square collars, which also would be developed.

1. Draw the orthographic views, completing the lines of the sides to the apex (view A).
2. Rotate the line of one edge in the top view to the horizontal and project it to the front view (view W
3. Draw an arc with a radius equal to the length of this true-length line, plus its extension to the apex of the pyramid. Draw a second arc defining the upper limit of the true-length line (view C).
4. Step off lengths along these arcs equal to the sides of the pyramid (view D).
5. Connect these points with the vertex, as shown in view D.

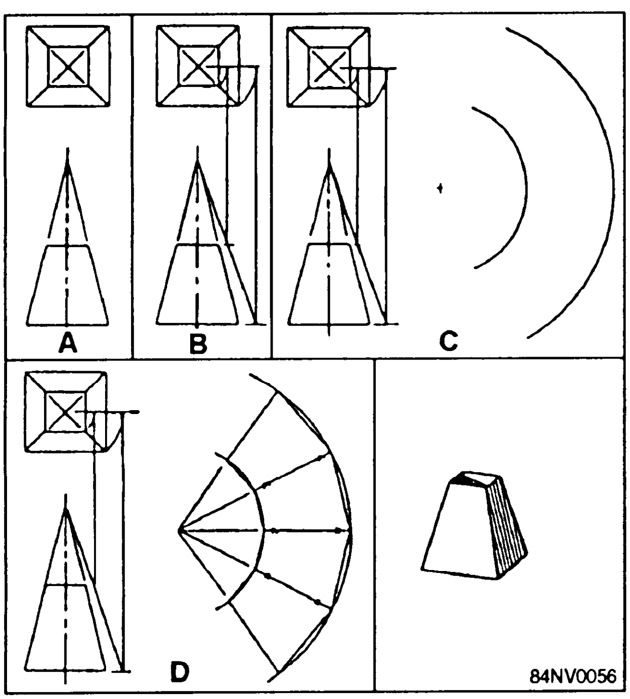


Figure 14-50.—Development of a truncated pyramid.

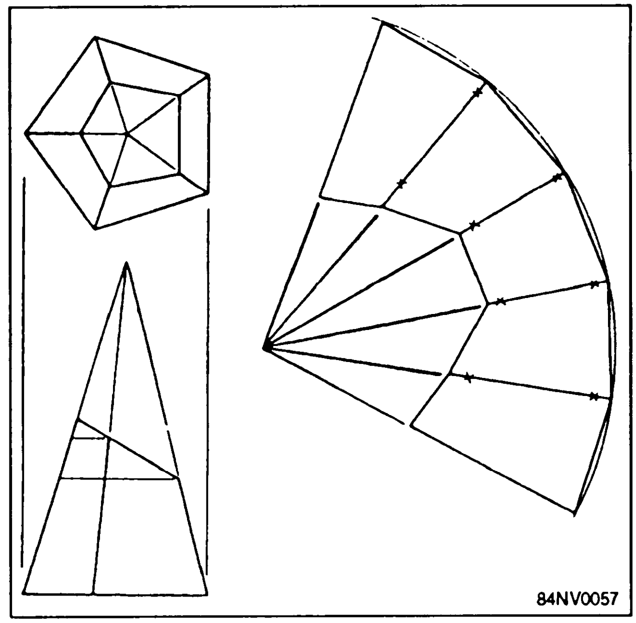


Figure 14-51.—Development of a truncated pentagonal pyramid with the upper corners cut by a slanting plane.

To develop a truncated pentagonal pyramid, like that shown in figure 14-51, follow the same general steps. However, since one lateral edge appears in its true length in the front view, the limits of the other edges can be projected onto the line of this edge to determine the true lengths. Measure the length of each edge. Transfer this measurement to the development.

Figure 14-52 shows the following steps in the development of an offset transition piece. It is offset

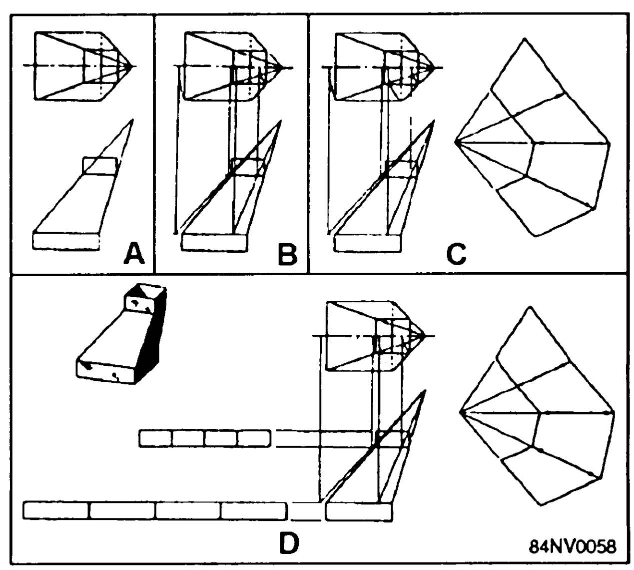


Figure 14-52.—Development of an offset transition piece.

because the center of one end is not in line with the center of the other end. The three parts consist of an upper and a lower section that are truncated rectangular prisms. The third section is a truncated oblique pyramid.

1. Draw the orthographic views, extending the lines of the sides of the pyramid to its apex in both views (view A).
2. Rotate the lines of the sides to the horizontal in the top view. Project the points located on the front view and draw the true-length lines (view W
3. At one side of the views, develop the surface of the oblique square pyramid. Construct one triangle at a time, and take the length of the three sides of each triangle from the views (view C). Draw the upper edges to complete the drawing.
4. Draw the surface patterns of the upper and lower prisms (view D).

The development of a cone is similar to the development of a pyramid. Consider it a pyramid with an infinite number of sides. In actual practice, of course, the number of sides are drawn on the orthographic views and projected to the development. The steps in developing a truncated right cone are shown in figure 14-53.

The truncated right cone has a center line that is perpendicular to its base. The elements on a right cone are all the same length. The true length of these elements is shown by those that fall to the extreme right and left in a front view. These elements are horizontal lines in a top view. A slanting plane cuts the cone in figure 14-53. The end points of the elements between the two outside elements must project to one of the outside lines to determine their true lengths.

To develop a truncated right cone, use the following steps:

1. Draw the orthographic views. Include either a side view (view A) or an auxiliary view of the ellipse formed by the slanting plane. Note that the center of the ellipse must be determined since it does not fall on the center line of the cone. This center point is projected to the side view and defines the length of the minor axis of the ellipse. The length of the major axis is defined by the length of the slanting line in the front view.

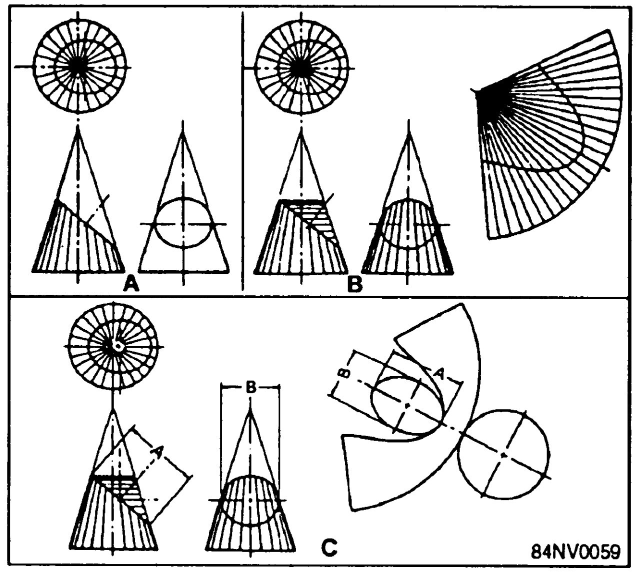


Figure 14-53.—Development of a truncated right cone.

2. Develop the surface pattern of the cone using the length from the apex to the base as a radius for drawing the arc. Step off on this line the equally spaced division of the base. Then, measure each element individually and transfer this measurement to the development. The ends of each of these elements define the curve of the upper edge of the peripheral surface (view B).
3. Draw the base surface circle and the top surface ellipse attached to the peripheral surface (view C).

TRIANGULATION DEVELOPMENT

Triangulation is slower and more difficult than parallel line or radial development, but it is more practical for many types of figures. It is the only method with which the development of warped surfaces may be approximated. In development of triangulation, the piece is divided into a series of triangles, as in radial development. However, there is no one single apex for the triangles. The problem becomes one of finding the true lengths of the varying oblique lines. This is usually done by drawing a true-length diagram.

Figure 14-54 shows the following steps in the triangulation of a warped transition piece joining a large square pipe and a smaller round pipe:

1. Draw the top and front orthographic views (view A).
2. Divide the circle in the top view into several equal spaces and connect the division points with the comers of the square (view B).
3. Transfer the division points to the front view and draw the elements. Some of the triangles curve slightly, but they can be considered flat.
4. Now the true length of each of these elements may be found. Draw a right triangle with a base equal to the length of an element on the top view. Draw it with an altitude equal to the altitude of the corresponding element on the front view. The hypotenuse of the triangle is the true length of the element. In view C, the true-length diagram consists of only three right triangles. Since the piece is symmetrical, several elements are the same length.
5. Draw the surface pattern by constructing one triangle at a time.

Figure 14-55 shows the following steps in developing a rectangular transition piece that is not a true pyramid because the extended lateral edges would not meet at a common vertex. The best way to develop

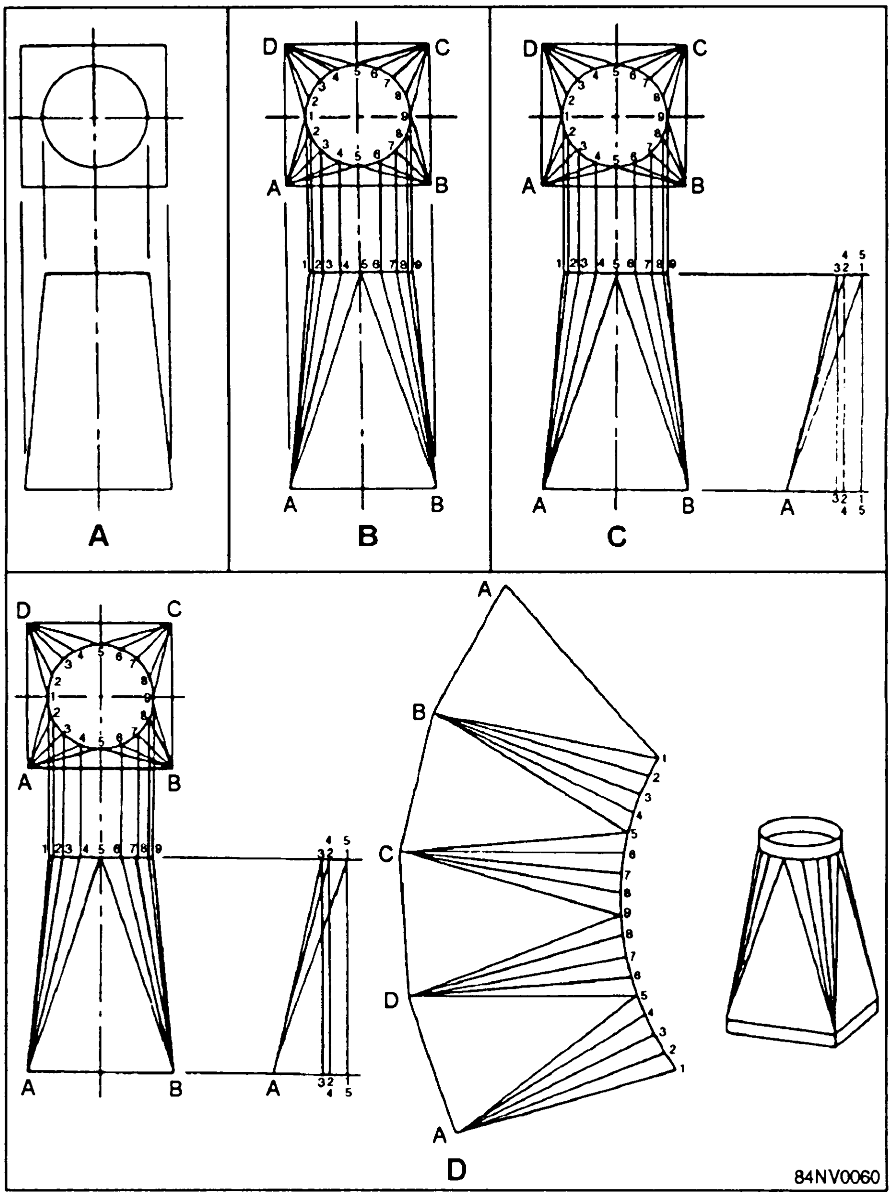


Figure 14-54.—Development by triangulation of a transition piece.

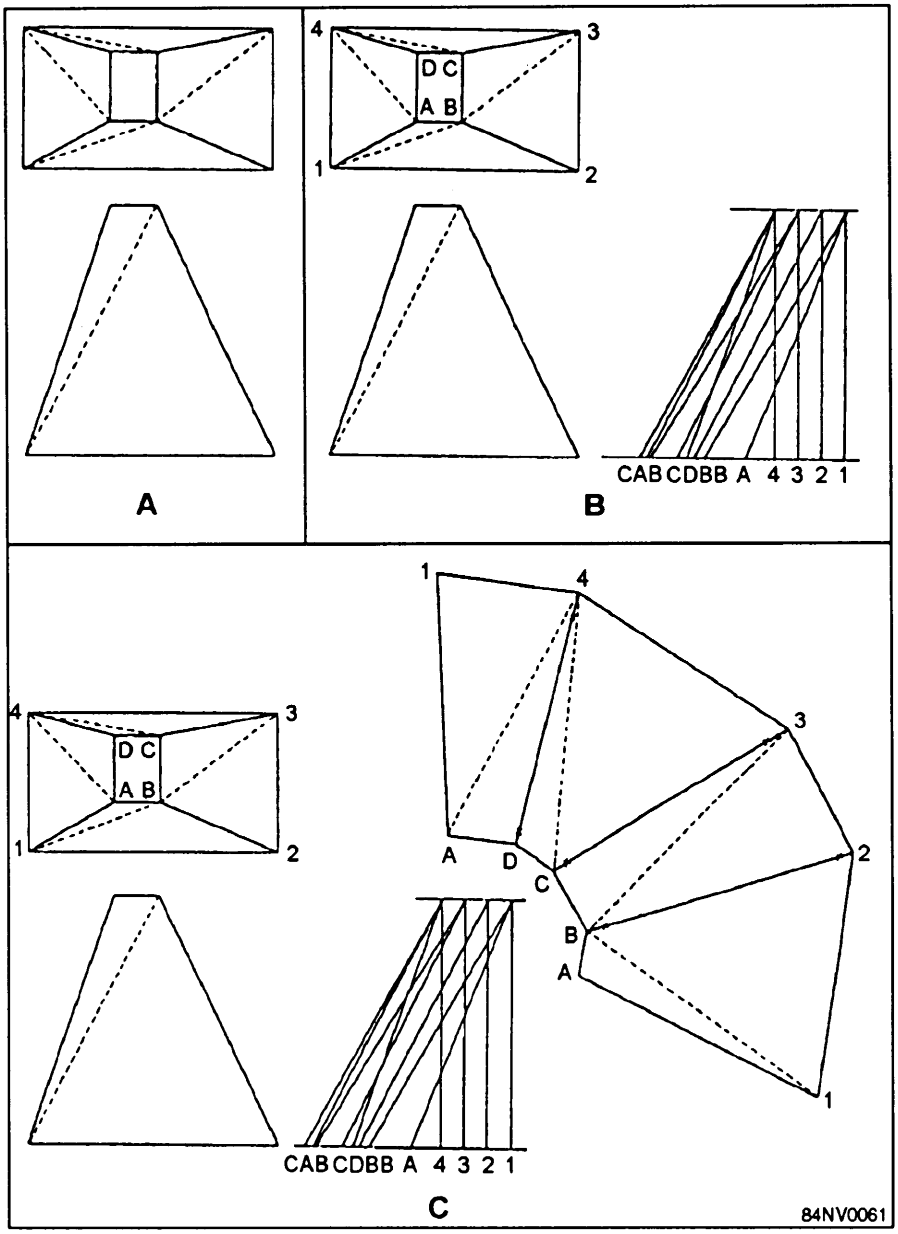


Figure 14-55.—Development of a rectangular transition piece, which is not a true pyramid.

this is by drawing diagonals that split the sides into two triangles. These diagonals are usually drawn as dotted lines to separate them from other elements. Then, the true length of each element is found, and the surface pattern developed by constructing each triangle in turn. To find the true-length lines, draw a true-length diagram.

1. Draw the orthographic views with the bend lines and the diagonals (view A).
2. Draw a true-length diagram of these elements (view B).
3. Draw the surface pattern by constructing one triangle at a time (view C).

The fitting in figure 14-56 has a warped surface. Its base is round and its top is oblong. The following method for development consists of dividing the surface into quadrilaterals of about the same size. A quadrilateral is a plane figure having four sides and four angles. A diagonal is then drawn across each of these to produce two triangles. When the true lengths of these elements have been found, the surface pattern may be drawn triangle by triangle.

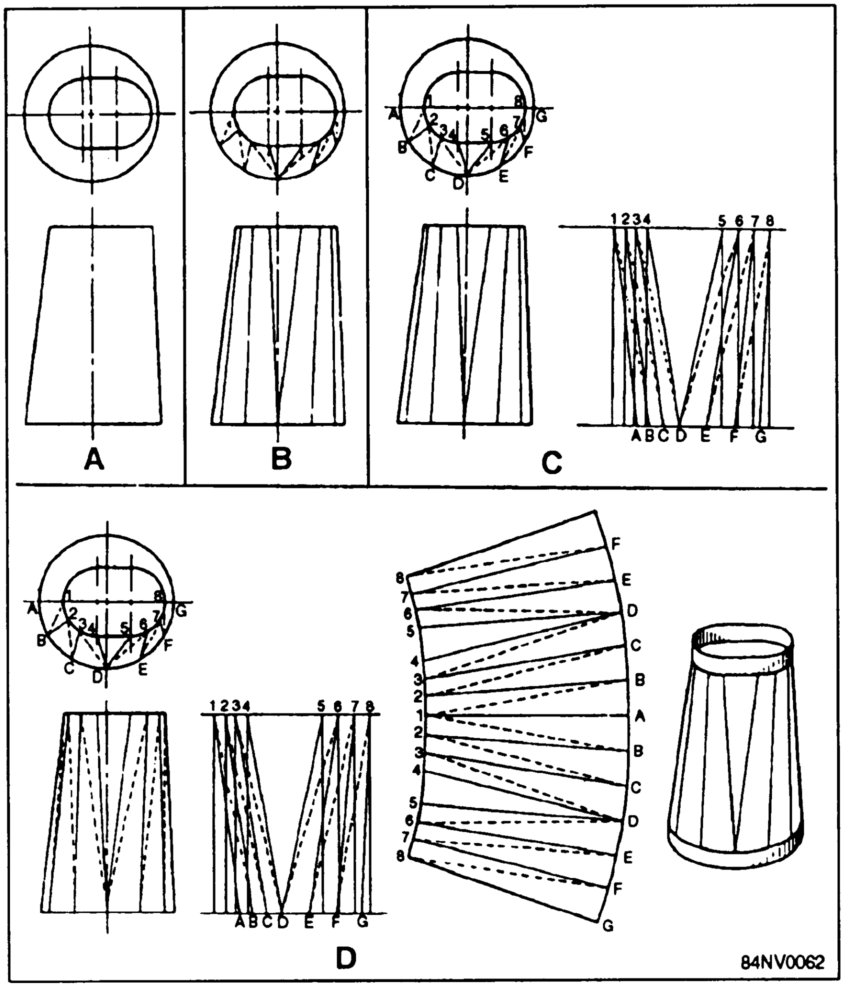


Figure 14-56.—Development of a warped transition piece.

1. Draw the top and front orthographic view (view A).
2. Divide the circle of the base into several equal spaces. Divide the arcs at the ends of the oblong into half as many spaces. Since the transition piece is symmetrical on a central axis, this may be done on only half of the top view. Connect these division points (view B). Use dotted lines for the diagonals to differentiate them.
3. Project the division points to the front view and draw the elements there.
4. Draw the true-length diagram for the elements (view C).
5. Draw an approximation of the surface pattern of the warped surface by constructing one triangle after another (view D).

METRIC SYSTEM

The metric system is an extremely accurate universal system of weights and measures. It is based on a unit called a meter.

NOTE: 1 meter was originally 1/10,000,000 the distance from the earth's equator to its pole. It is a system based on units of ten, making it a very uncomplicated system with which to work. A meter is 39.37 inches long or slightly longer than a yard.

Adding prefixes to the name of the primary unit of measure, such as micrometer or millimeter, form the names of metric denominations

Table 14-1 explains the metric system by showing nomenclature and giving the English measure equivalents.

Tables 14-1, 14-2, 14-3, 14-4, 14-5, and 14-6 are given as a quick reference when solving math-related problems.

The gram, which is the primary unit of weights, is the weight of one cubic centimeter of pure distilled water at a temperature of 39.2° F., the kilogram is the weight of 1 liter of water; the ton is the weight of 1 cubic meter of water. The gram is used in weighing gold, jewels, and small quantities of things. The kilogram, commonly called kilo for brevity, is used by grocers; the ton is used for weighing heavy articles.

Measures of Pressure

1 pound per square inch	=	144 pounds per square foot 0.068 atmosphere 2.042 inches of mercury at 62° F. 27.7 inches of water at 62° F. 2.31 feet of water at 62° F.
1 atmosphere	=	30 inches of mercury at 62° F. 14.7 pounds per square inch 2116.3 pounds per square foot 33.95 feet of water at 62° F.
1 foot of water at 62° F.	=	62.355 pounds per square foot 0.433 pound per square inch
1 inch of mercury at 62° F.	=	1.132 foot of water 13.58 inches of water 0.491 pound per square inch

Metric and English Conversion Table

Measures of Length

1 millimeter	=	0.03937 inch
1 centimeter	=	0.3937 inch
1 meter	=	39.37 inches 3.2808 feet 1.0936 yards
1 kilometer	=	0.6214 mile
1 inch	=	25.4 millimeters 2.54 centimeters
1 foot	=	304.8 millimeters 0.3048 meter
1 yard	=	0.9144 meter
1 mile	=	1.609 kilometer

Square Measure—Measures of Surface

1 square millimeter	=	0.00155 square inch
1 square centimeter	=	0.155 square inch
1 square meter	=	10.764 square feet 1.196 square yard
1 are	=	0.0247 acre 1076.4 square feet
1 hectare	=	2.471 acres 107,640 square feet
1 square kilometer	=	0.3861 square mile 247.1 acres
1 square inch	=	6.542 square centimeters 654.2 square millimeters
1 square foot	=	0.0929 square meter 9.290 square centimeters
1 square yard	=	0.836 square meter
1 acre	=	0.4047 hectare 40.47 acres
1 square mile	=	2.5899 square kilometers

Cubic Measure—Measures of Volume and Capacity

1 cubic centimeter	=	0.061 cubic inch
1 cubic decimeter	=	61.023 cubic inches 0.0353 cubic foot

Micro, a millionth	=	$\frac{1}{1,000,000}$
Milli, a thousandth	=	$\frac{1}{1000}$
Centi, a hundredth	=	$\frac{1}{100}$
Deci, a tenth	=	$\frac{1}{10}$
Deca, ten	=	10
Hecto, one hundred	=	100
Kilo, one hundred	=	1000
Myria, ten thousand	=	10,000
Mega, one million	=	1,000,000

Principal Units of Metric System

The meter for lengths

The square meter for surfaces

The cubic meter for large volumes

The liter for small volumes

The gram for weights

Measures of Length

10 millimeters (mm.)	= 1 centimeter (cm.)
10 centimeters	= 1 decimeter (dm.)
10 decimeters	= 1 meter (m.)
10 meters	= 1 decameter (Dm.)
10 decameters	= 1 hectometer (Hm.)
10 hectometers	= 1 kilometer (Km.)
10 kilometers	= 1 myriameter

A meter is used in ordinary measurements; the centimeter or millimeter in calculating very small distances; and the kilometer for long distances.

Square Measure—Measures of Surface

100 square millimeters ($mm.^2$)	= 1 square centimeter ($cm.^2$)
100 square centimeters	= 1 square decimeter ($dm.^2$)
100 square decimeters	= 1 square meter ($m.^2$)
100 centiares, or square meters	= 1 are (a.)
100 ares	= 1 hectare (ha.)

The square meter is used for ordinary surfaces; the are, a square, each of whose sides is 10 meters, is the unit of land measure.

Cubic Measure—Measures of Volume

1000 cubic millimeters ($mm.^3$)	= 1 cubic centimeter ($cm.^3$ or cc.)
1000 cubic centimeters	= 1 cubic decimeter ($dm.^3$)
1000 cubic decimeters	= 1 cubic meter ($m.^3$)

The term stere is used to designate the cubic meter in measuring wood and timber. A tenth of a stere is a decistere, and ten steres and a decastere.

Liquid and Dry Measures—Measures of Capacity

10 milliliters (ml.)	= 1 centiliter (cl.)
10 centiliters	= 1 deciliter (dl.)
10 deciliters	= 1 liter (l.)
10 liters	= 1 decaliter (Dl.)
10 decaliters	= 1 hectoliter (Hl.)
10 hectoliters	= 1 kiloliter (Kl.)

The liter, which is a cube each of whose edges is $\frac{1}{10}$ of a meter in length, is the principal unit of measures of capacity. The hectoliter is the unit that is used in measuring large quantities of grain, fruits, roots, and liquids.

Measures of Weight

10 milligrams (mg.)	= 1 centigram (cg.)
10 centigrams	= 1 decigram (dg.)
10 decigrams	= 1 gram (g.)
10 grams	= 1 decagram (Dg.)
10 decagrams	= 1 hectogram (Hg.)
10 hectograms	= 1 kilogram (Kg.)
1000 kilograms	= 1 (metric) ton (T.)

$$\text{1 cubic meter} = \begin{cases} \text{35.314 cubic feet} \\ \text{1.308 cubic yards} \\ \text{264.2 U.S. gallons} \end{cases}$$

$$\text{1 liter} = \begin{cases} \text{1 cubic decimeter} \\ \text{61.023 cubic inches} \\ \text{0.0353 cubic foot} \\ \text{1.0567 U.S. quarts} \\ \text{0.2642 U.S. gallons} \\ \text{2.202 lbs. of water at 62° F.} \end{cases}$$

1 cubic inch = 16.383 cubic centimeters

1 cubic foot = { 0.02832 cubic meter; 28.317 cubic decimeters; 28.317 liters }

1 cubic yard = 0.7645 cubic meter

1 gallon U.S. = 3.785 liters

1 gallon British = 4.543 liters

Measures of Weight

1 gram = { 0.03216 ounce troy; 0.03527 ounce avoirdupois; 15.432 grains }

1 kilogram = { 2.2046 pounds aviordupois; 35.274 ounces avoirdupois }

1 metric ton = { 0.9843 ton of 2,240 pounds; 19.68 hundredweight; 2204.6 pounds; 1.1023 tons of 2,000 pounds }

1 grain = 0.0648 gram

1 ounce troy = 31.103 grams

1 ounce avoirdupois = 28.35 grams

1 pound = { 0.4536 kilogram; 453.6 grams }

1 ton of 2240 pounds = { 1.016 metric tons; 1016 kilograms }

Inches and Equivalents in Millimeters

Inches	MM	Inches	MM	Inches	MM
1/64	.397	45/64	17.859	26	660.4
1/32	.794	23/32	18.256	27	685.8
3/64	1.191	47/64	18.653	28	711.2
1/16	1.588	3/4	19.050	29	637.6
5/64	1.984	49/64	19.447	30	762.0
3/32	2.381	25/32	19.844	31	787.4
7/64	2.778	51/64	20.241	32	812.8
1/8	3.175	13/16	20.638	33	838.2
9/64	3.572	53/64	21.034	34	863.6
5/32	3.969	27/32	21.431	35	889.0
11/64	4.366	55/64	21.828	36	914.4
3/16	4.763	7/8	22.225	37	939.8
13/64	5.159	57/64	22.622	38	965.2
7/32	5.556	29/32	23.019	39	990.6
15/64	5.953	59/64	23.416	40	1016.0
1/4	6.350	15/16	23.813	41	1041.4
17/64	6.747	61/64	24.209	42	1066.8
9/32	7.144	31/32	24.606	43	1092.2
19/64	7.540	63/64	25.003	44	1117.6
5/16	7.938	1	25.400	45	1143.0
21/64	8.334	2	50.8	46	1168.4
11/32	8.731	3	76.2	47	1193.8
23/64	9.128	4	101.6	48	1219.2
3/8	9.525	5	127.0	49	1244.6
25/64	9.922	6	152.4	50	1270.0
13/32	10.319	7	177.8	51	1295.4
27/64	10.716	8	203.2	52	1320.8
7/16	11.113	9	228.6	53	1346.2
29/64	11.509	10	254.0	54	1371.6
15/32	11.906	11	279.4	55	1397.0
31/64	12.303	12	304.8	56	1422.4
1/2	12.700	13	330.2	57	1447.8
33/64	13.097	14	355.6	58	1473.2
17/32	13.494	15	381.0	59	1498.6
35/64	13.891	16	406.4	60	1524.0
9/16	14.288	17	431.8	61	1549.4
37/64	14.684	18	457.2	62	1574.8
19/32	15.081	19	482.6	63	1600.2
39/64	15.478	20	508.0	64	1625.6
5/8	15.875	21	533.4	65	1651.0
41/64	16.272	22	558.8	66	1676.4
21/32	16.669	23	584.2	67	1701.8
43/64	17.066	24	609.6	68	1727.2
11/16	17.463	25	635.0	69	1752.6

Table 14-1.—Metric System and English Conversion—Continued

Inches and Equivalents in Millimeters—*Continued*

Inches	MM	Inches	MM	Inches	MM
70	1778.0	114	2895.6	158	4013.2
71	1803.4	115	2921.0	159	4038.6
72	1828.8	116	2946.4	160	4064.0
73	1854.2	117	2971.8	161	4089.4
74	1879.6	118	2997.2	162	4114.8
75	1905.0	119	3022.6	163	4140.2
76	1930.4	120	3048.0	164	4165.6
77	1955.8	121	3073.4	165	4191.0
78	1981.2	122	3098.8	166	4216.4
79	2006.6	123	3124.2	167	4241.8
80	2032.0	124	3149.6	168	4267.2
81	2057.4	125	3175.0	169	4292.6
82	2082.8	126	3200.4	170	4318.0
83	2108.2	127	3225.8	171	4343.4
84	2133.6	128	3251.2	172	4368.8
85	2159.0	129	3276.6	173	4394.2
86	2184.4	130	3302.0	174	4419.2
87	2209.8	131	3327.4	175	4445.0
88	2235.2	132	3352.8	176	4470.4
89	2260.6	133	3378.2	177	4495.8
90	2286.0	134	3403.6	178	4521.2
91	2311.4	135	3429.0	179	4546.6
92	2336.8	136	3454.4	180	4572.0
93	2362.2	137	3479.8	181	4597.4
94	2387.6	138	3505.2	182	4622.8
95	2413.0	139	3530.6	183	4648.2
96	2438.4	140	3556.0	184	4673.6
97	2463.8	141	3581.4	185	4699.0
98	2489.2	142	3606.8	186	4724.4
99	2514.6	143	3632.2	187	4749.8
100	2540.0	144	3657.6	188	4775.2
101	2565.4	145	3683.0	189	4800.6
102	2590.8	146	3708.4	190	4826.0
103	2616.2	147	3733.8	191	4851.4
104	2641.6	148	3759.2	192	4876.8
105	2667.0	149	3784.6	193	4902.2
106	2692.4	150	3810.0	194	4927.6
107	2717.8	151	3835.4	195	4953.0
108	2743.2	152	3860.8	196	4978.4
109	2768.6	153	3886.2	197	5003.8
110	2794.0	154	3911.6	198	5029.2
111	2819.4	155	3937.0	199	5054.6
112	2844.8	156	3962.4	200	5080.0
113	2870.2	157	3987.8		

Millimeters and Equivalents in Inches

MM	Inches	MM	Inches	MM	Inches
1/100	.0004	45/100	.0177	89/100	.0350
2/100	.0008	46/100	.0181	90/100	.0354
3/100	.0012	47/100	.0185	91/100	.0358
4/100	.0016	48/100	.0189	92/100	.0362
5/100	.0020	49/100	.0193	93/100	.0366
6/100	.0024	50/100	.0197	94/100	.0370
7/100	.0028	51/100	.0201	95/100	.0374
8/100	.0031	52/100	.0205	96/100	.0378
9/100	.0035	53/100	.0209	97/100	.0382
10/100	.0039	54/100	.0213	98/100	.0386
11/100	.0043	55/100	.0217	99/100	.0390
12/100	.0047	56/100	.0221	1	.0394
13/100	.0051	57/100	.0224	2	.0787
14/100	.0055	58/100	.0228	3	.1181
15/100	.0059	59/100	.0232	4	.1575
16/100	.0063	60/100	.0236	5	.1969
17/100	.0067	61/100	.0240	6	.2362
18/100	.0071	62/100	.0244	7	.2756
19/100	.0075	63/100	.0248	8	.3150
20/100	.0079	64/100	.0252	9	.3543
21/100	.0083	65/100	.0256	10	.3937
22/100	.0087	66/100	.0260	11	.4331
23/100	.0091	67/100	.0264	12	.4724
24/100	.0094	68/100	.0268	13	.5118
25/100	.0098	69/100	.0272	14	.5512
26/100	.0102	70/100	.0276	15	.5906
27/100	.0106	71/100	.0280	16	.6299
28/100	.0110	72/100	.0284	17	.6693
29/100	.0114	73/100	.0287	18	.7087
30/100	.0118	74/100	.0291	19	.7480
31/100	.0122	75/100	.0295	20	.7874
32/100	.0126	76/100	.0299	21	.8268
33/100	.0130	77/100	.0303	22	.8661
34/100	.0134	78/100	.0307	23	.9055
35/100	.0138	79/100	.0311	24	.9449
36/100	.0142	80/100	.0315	25	.9843
37/100	.0146	81/100	.0319	26	1.0236
38/100	.0150	82/100	.0323	27	1.0630
39/100	.0154	83/100	.0327	28	1.1024
40/100	.0158	84/100	.0331	29	1.1417
41/100	.0161	85/100	.0335	30	1.1811
42/100	.0165	86/100	.0339	31	1.2205
43/100	.0169	87/100	.0343	32	1.2598
44/100	.0173	88/100	.0347	33	1.2992

Table 14-1.—Metric System and English Conversion-Continued

Millimeters and Equivalents in Inches—*Continued*

MM	Inches	MM	Inches	MM	Inches
34	1.3386	78	3.0709	122	4.8031
35	1.3780	79	3.1102	123	4.8425
36	1.4173	80	3.1496	124	4.8819
37	1.4567	81	3.1890	125	4.9213
38	1.4961	82	3.2283	126	4.9606
39	1.5354	83	3.2677	127	5.0000
40	1.5748	84	3.3071	128	5.0394
41	1.6142	85	3.3465	129	5.0787
42	1.6535	86	3.3858	130	5.1181
43	1.6929	87	3.4252	131	5.1575
44	1.7323	88	3.4646	132	5.1968
45	1.7717	89	3.5039	133	5.2362
46	1.8110	90	3.5433	134	5.2756
47	1.8504	91	3.5827	135	5.3150
48	1.8898	92	3.6220	136	5.3543
49	1.9291	93	3.6614	137	5.3937
50	1.9685	94	3.7008	138	5.4331
51	2.0079	95	3.7402	139	5.4724
52	2.0472	96	3.7795	140	5.5118
53	2.0866	97	3.8189	141	5.5512
54	2.1260	98	3.8583	142	5.5905
55	2.1654	99	3.8976	143	5.6299
56	2.2047	100	3.9370	144	5.6693
57	2.2441	101	3.9764	145	5.7087
58	2.2835	102	4.0157	146	5.7480
59	2.3228	103	4.0551	147	5.7874
60	2.3622	104	4.0945	148	5.8268
61	2.4016	105	4.1339	149	5.8661
62	2.4409	106	4.1732	150	5.9055
63	2.4803	107	4.2126	151	5.9449
64	2.5197	108	4.2520	152	5.9842
65	2.5591	109	4.2913	153	6.0236
66	2.5984	110	4.3307	154	6.0630
67	2.6378	111	4.3701	155	6.1024
68	2.6772	112	4.4094	156	6.1417
69	2.7165	113	4.4488	157	6.1811
70	2.7559	114	4.4882	158	6.2205
71	2.7953	115	4.5276	159	6.2598
72	2.8346	116	4.5669	160	6.2992
73	2.8740	117	4.6063	161	6.3386
74	2.9134	118	4.6457	162	6.3779
75	2.9528	119	4.6850	163	6.4173
76	2.9921	120	4.7244	164	6.4567
77	3.0315	121	4.7638	165	6.4961

Millimeters and Equivalents in Inches—*Concluded*

MM	Inches	MM	Inches	MM	Inches
166	6.5354	211	8.3071	256	10.079
167	6.5748	212	8.3464	257	10.118
168	6.6142	213	8.3858	258	10.157
169	6.6535	214	8.4252	259	10.197
170	6.6929	215	8.4646	260	10.236
171	6.7323	216	8.5039	261	10.276
172	6.7716	217	8.5433	262	10.315
173	6.8110	218	8.5827	263	10.354
174	6.8504	219	8.6220	264	10.394
175	6.8898	220	8.6614	265	10.433
176	6.9291	221	8.7008	266	10.472
177	6.9685	222	8.7401	267	10.512
178	7.0079	223	8.7795	268	10.551
179	7.0472	224	8.8189	269	10.591
180	7.0866	225	8.8583	270	10.630
181	7.1260	226	8.8976	271	10.669
182	7.1653	227	8.9370	272	10.709
183	7.2047	228	8.9764	273	10.748
184	7.2441	229	9.0157	274	10.787
185	7.2835	230	9.0551	275	10.827
186	7.3228	231	9.0945	276	10.866
187	7.3622	232	9.1338	277	10.905
188	7.4016	233	9.1732	278	10.945
189	7.4409	234	9.2126	279	10.984
190	7.4803	235	9.2520	280	11.024
191	7.5197	236	9.2913	281	11.063
192	7.5590	237	9.3307	282	11.102
193	7.5984	238	9.3701	283	11.142
194	7.6378	239	9.4094	284	11.181
195	7.6772	240	9.4488	285	11.220
196	7.7165	241	9.4882	286	11.260
197	7.7559	242	9.5275	287	11.299
198	7.7953	243	9.5669	288	11.339
199	7.8346	244	9.6063	289	11.378
200	7.8740	245	9.6457	290	11.417
201	7.9134	246	9.6850	291	11.457
202	7.9527	247	9.7244	292	11.496
203	7.9921	248	9.7638	293	11.535
204	8.0315	249	9.8031	294	11.575
205	8.0709	250	9.8425	295	11.614
206	8.1102	251	9.8819	296	11.654
207	8.1496	252	9.9212	297	11.693
208	8.1890	253	9.9606	298	11.732
209	8.2283	254	10.000	299	11.772
210	8.2677	255	10.039		

Table 14-1.—Metric System and English Conversion—Continued

Useful Factors, English Measures

Inches	×	0.08333	= feet
"	×	0.02778	= yards
"	×	0.00001578	= miles
Square inches	×	0.00695	= square feet
" "	×	0.0007716	= square yards
Cubic inches	×	0.00058	= cubic feet
" "	×	0.0000214	= cubic yards
" "	×	0.004329	= U.S. gallons
Feet	×	0.3334	= yards
"	×	0.00019	= miles
Square feet	×	144.0	= square inches
" "	×	0.1112	= square yards
Cubic feet	×	1,728	= cubic inches
" "	×	0.03704	= cubic yards
" "	×	7.48	= U.S. gallons
Yards	×	36	= inches
"	×	3	= feet
"	×	0.0005681	= miles
Square yards	×	1,296	= square inches
" "	×	9	= square feet
Cubic yards	×	46,656	= cubic inches
" "	×	27	= cubic feet
Miles	×	63,360	= inches
"	×	5,280	= feet
"	×	1,760	= yards
Avoirdupois ounces .	×	0.0625	= pounds
" " .	×	0.00003125	= tons
" pounds .	×	16	= ounces
" " .	×	.001	= hundredweight
" " .	×	.0005	= tons
" " .	×	27.681	= cubic inches of water at 39° F
" tons	×	32,000	= ounces
" "	×	2,000	= pounds
Watts	×	0.00134	= horse power
Horse power	×	746	= watts

Weight of round iron per foot = square of diameter in quarter inches + 6.

Weight of flat iron per foot = width × thickness × 10/3.

Weight of flat plates per square foot = 5 pounds for each 1/8 inch thickness.

Useful Factors, Metric Measures

Millimeters × 0.03937	= inches
Millimeters + 25.4	= inches
Centimeters × 0.3937	= inches
Centimeters + 2.54	= inches
Meters × 39.37	= inches
Meters × 3.281	= feet
Meters × 1.094	= yards
Kilometers × 0.621	= miles
Kilometers + 1.6093	= miles
Kilometers × 3280.7	= feet
Square millimeters × 0.0155	= square inches
Square millimeters + 645.1	= square inches
Square centimeters × 0.155	= square inches
Square centimeters + 6.451	= square inches
Square meters × 10.764	= square feet
Square kilometers × 247.1	= acres
Hectares × 2.471	= acres
Cubic centimeters + 16.385	= cubic inches
Cubic centimeters + 3.69	= fluid drachms, U.S. Pharmacopoeia
Cubic centimeters + 29.57	= fluid ounce U.S. Pharmacopoeia
Cubic meters × 35.315	= cubic feet
Cubic meters × 1.038	= cubic yards
Cubic meters × 264.2	= gallons, United States
Liters × 61.022	= cubic inches
Liters × 33.84	= fluid ounces
Liters × 0.2642	= gallons, United States
Liters + 3.78	= gallons, United States
Liters + 28.316	= cubic feet
Hectoliters × 3.531	= cubic feet
Hectoliters × 2.84	= bushels, United States
Hectoliters × 0.131	= cubic yards
Hectoliters × 26.42	= gallons, United States
Grams × 15.432	= grains
Grams (water) + 29.57	= fluid ounces
Grams + 28.35	= ounces, avoirdupois
Kilograms × 2.2046	= pounds
Kilograms × 35.3	= ounces, avoirdupois
Kilograms + 1102.3	= tons, 2000 pounds

Table 14-2.—Mathematics Symbols

SYMBOL	NAME OR MEANING	SYMBOL	NAME OR MEANING
$+$	Addition or positive value	$\sqrt{\ }$	Square root symbol
$-$	Subtraction or negative value	$\sqrt[n]{\ }$	Radical symbol. Letter n represents a number indicating which root is to be taken.
$\pm$	Positive or negative value		
$\cdot$	Multiplication dot (Centered; not to be mistaken for decimal point.)	i or j	Imaginary unit; operator j for electronics; represents $\sqrt{-1}$.
$\times$	Multiplication symbol	∞	Infinity symbol
( )	Parentheses	...	Ellipses. Used in series of numbers in which successive numbers are predictable by their conformance to a pattern; meaning is approximated by "etc."
[ ]	Brackets Grouping symbols		
{ }	Braces		
%	Percent		
$+$	Division symbol	$\log_a N$	Logarithm of N to the base a.
:	Ratio symbol	log N	Logarithm of N to the base 10. (understood)
: :	Proportion symbol	ln N	Natural or Napierian logarithm of N. Base of the natural or Napierian logarithm system.
$=$	Equality symbol		
$\neq$	"Not equal" symbol	$\lvert X \rvert$	Absolute value of X.
$<$	Less than	π	Pi. The ratio of the circumference of any circle to its diameter. Approximate numerical value is 22/7.
$\leq$	Less than or equal to		
$>$	Greater than		
$\geq$	Greater than or equal to		Therefore
$\propto$	"Varies directly as" or "is proportional to" (Not to be mistaken for Greek alpha (α).)	$\angle$ or $\measuredangle$	Angle

Table 14-3.—Table of Decimal Equivalents of Fractions of an Inch

1/64	0.0156	17/64	0.2656	33/64	0.5156	49/64	0.7656
1/32	.0313	9/32	.2813	17/32	.5313	25/32	.7813
3/64	.0469	19/64	.2969	35/64	.5469	51/64	.7969
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
5/64	.0781	21/64	.3281	37/64	.5781	53/64	.8281
3/32	.0938	11/32	.3438	19/32	.5938	27/32	.8438
7/64	.1094	23/64	.3594	39/64	.6094	55/64	.8594
1/8	.125	3/8	.375	5/8	.625	7/8	.875
9/64	.1406	25/64	.3906	41/64	.6406	57/64	.8906
5/32	.1563	13/32	.4063	21/32	.6563	29/32	.9063
11/64	.1719	27/64	.4219	43/64	.6719	59/64	.9219
3/16	.1875	7/16	.4375	11/16	.6875	15/16	.9375
13/64	.2031	29/64	.4531	45/64	.7031	61/64	.9531
7/32	.2188	15/32	.4688	23/32	.7188	31/32	.9688
15/64	.2344	31/64	.4844	47/64	.7344	63/64	.9844
1/4	.25	1/2	.5	3/4	.75	1	1.0

Table 14-4.—Weights and Measures

Distance

12 inches	= 1 foot (ft)
3 feet	= 1 yard (yd)
5-1/2 yards	= 1 rod (rd)
16-1/2 feet	= 1 rod
1,760 yards	= 1 statute mile (mi)
5,280 feet	= 1 statute mile

Additional measures of length occasionally used

1000 mils = 1 inch; 3 inches = 1 palm; 4 inches = 1 hand

9 inches = 1 span; 2-1/2 feet = 1 military space

5-1/2 yards or 16-1/2 feet = 1 rod; 2 yards = 1 fathom; a cable length = 120 fathoms = 720 feet;

1 inch = 0.0001157 cable length = 0.013889 fathom = 0.111111 span.

Old Land or Surveyors' Measure*

7.92 inches = 1 link (l.)

100 links, or 66 feet, or 4 rods = 1 chain (ch.)

10 chains or 220 yards = 1 furlong

8 furlongs or 80 chains = 1 mile (mi.)

*Sometimes called Gunter's Chain.

Nautical Measure

6080.26 feet or 1.15156 statute miles = 1 nautical mile or knot†

3 nautical miles = 1 league

60 nautical miles, or 69.169 statute miles = 1 degree at the equator

360 degrees = circumference of the earth at the equator

†The value varies according to different measures of the earth's diameter.

Square Measures–Measures of Surface

144 square inches (sq. in.) = 1 square foot (sq. ft.)

9 square feet = 1 square yard (sq. yd.)

$\left.\begin{array}{c}30\frac{1}{4} \text{ square yards} \\ \text{or} \\ 272\frac{1}{4} \text{ square feet}\end{array}\right\}$ = 1 square rod (sq. rd.)

160 square rods or 43,560 square feet	= 1 acre (A.)
640 acres	= 1 square mile (sq. mi.)

Surveyors' Measure

16 square rods	= 1 square chain (sq. ch.)
10 square chains	= 1 acre (A.)
640 acres	= 1 square mile (sq. mi.)
1 square mile	= 1 section (sec.)
36 sections	= 1 township (tp.)

Solid or Cubic Measure–Measures of Volume

1728 cubic inches (cu. in.) = 1 cubic foot (cu. ft.)

27 cubic feet = 1 cubic yard (cu. yd.)

The following measures are also used for wood and masonry.

1 cord of wood = a pile, 4 × 4 × 8 feet = 128 cubic feet

1 perch of masonry = $16\frac{1}{2} \times 1\frac{1}{2} \times 1$ foot = $24\frac{3}{4}$ cubic feet

Shipping Measure

Register Ton—For register tonnage or for measuring entire internal capacity of a ship or vessel:

100 cubic feet = 1 register ton

Shipping Ton—For the mreasurement of cargo.

40 cubic feet = 1 United States shipping ton = 32.143 U.S. bushels

42 cubic feet = 1 British shipping ton = 32.719 imperial bushels.

Carpenter's Rule—To find the weight a vessel will carry, multiply the length of keel by the breadth at main beam by the depth of the hold in feet and divide by 95 (the cubic feet allowed for a ton). The result will be the tonnage.

Dry Measure

2 cups = 1 pint (pt)

2 pints = 1 quart (qt)

4 quarts = 1 gallon (gal)

8 quarts = 1 peck (pk)

4 pecks = 1 bushel (bu)

Counting Units

12 units	= 1 dozen (doz)
12 dozen	= 1 gross
144 units	= 1 gross
24 sheets	= 1 quire
480 sheets	= 1 ream

Equivalents

1 cubic foot of water weighs 62.5 pounds (approx) = 1,000 ounces

1 gallon of water weighs 8-1/3 pounds (approx)

1 cubic foot = 7.48 gallons

1 inch = 2.54 centimeters

1 foot = 30.4801 centimeters

1 meter = 39.37 inches

1 liter = 1.05668 quarts (liquid) = 0.90808 quart (dry)

1 nautical mile = 6,080 feet (approx)

1 fathom = 6 feet

1 shot of chain = 15 fathoms

Liquid Measure

3 teaspoons (tsp) = 1 tablespoon (tbsp)

16 tablespoons = 1 cup

2 cups = 1 pint

16 fluid ounces (oz) = 1 pint

4 gills (gi.) = 1 pint (pt.)

2 pints = 1 quart (qt.)

4 quarts = 1 gallon (gal.) U.S. 231 cubic inches; British 277.274 cubic inches

1 cubic foot = 7.48 U.S. gallons

Table 14-4.—Weights and Measures—Continued

Old Liquid Measure

$31\frac{1}{2}$ gallons	= 1 barrel (bbl.)
42 gallons	= 1 tierce
2 barrels or 63 gallons	= 1 hogshead (hhd.)
84 gallons or 2 tierces	= 1 puncheon
2 hogsheads or 4 barrels or 126 gallons	= 1 pipe or butt
2 pipes or 3 puncheons	= 1 tun

Apothecaries' Fluid Measure

60 minims = 1 fluid drachm; 8 drachms = 1 fluid ounce

1 U.S. fluid ounce = 8 drachms = 1.805 cubic inch = $\frac{1}{128}$ U.S. gallon. The fluid ounce in Great Britain is 1.732 cubic inches.

Measures of Weight

Avoirdupois or Commercial Weight

16 drachms or 437.5 grains	= 1 ounce (oz.)
16 ounces or 7000 grains	= 1 pound (lb.)
2000 pounds	= 1 net or short ton
2240 pounds	= 1 gross or long ton
2204.6 pounds	= 1 metric ton

Measures of weight occasionally used in collecting duties on foreign goods at U.S. custom houses and in freighting coal are:

1 hundredweight = 4 quarters = 112 pounds (1 gross or long ton = 20 hundredweight); 1 quarter = 28 pounds; 1 stone = 14 pounds; 1 quintal = 100 pounds.

Troy Weight*

24 grains	= 1 pennyweight (pwt.)
20 pennyweights	= 1 ounce (oz.)
12 ounces or 5760 grains	= 1 pound (lb.)

A carat of the jewelers, for precious stones = 3.2 grains in the United States. The International carat = 3.168 grains or 200 milligrams. In avoirdupois, apothecaries' and troy weights, the grain is the same, 1 pound troy = 0.82286 pound avoirdupois.

*Used for weighing gold, silver, jewels, etc.

Apothecaries' Weight†

20 grains (gr.)	= 1 scruple (℈)
3 scruples	= 1 drachm (ʒ)
8 drachms	= 1 ounce (℥)
12 ounces	= 1 pound troy (lb.)

†This table is used in compounding medicines and prescriptions.

Measures of Time

one millionth of a second	= 1 microsecond (µsec.)
one thousandth of a second	= 1 millisecond (msec.)
1/3600 hour	= 1 second (sec.)
60 seconds (sec.)	= 1 minute (min.)
60 minutes	= 1 hour (hr.)
24 hours	= 1 day (da.)
7 days	= 1 week (wk.)
365 days	= 1 solar year (yr.)
366 days	= 1 leap-year (every four years)
100 years	= 1 century

By the Gregorian calendar every year in which the number is divisible by 4 is a leap year except that the centesimal years (each 100 years: 1800, 1900, 2000, etc.) are leap-years only when the number of the year is divisible by 400.

Water Conversion Factors

U.S. gallons	×	8.33	=	pounds
U.S. gallons	×	0.13368	=	cubic feet
U.S. gallons	×	231	=	cubic inches
U.S. gallons	×	0.83	=	English gallons
U.S. gallons	×	3.78	=	liters
English gallons (Imperial)	×	10	=	pounds
English gallons (Imperial)	×	0.16	=	cubic feet
English gallons (Imperial)	×	277.274	=	cubic inches
English gallons (Imperial)	×	1.2	=	U.S. gallons
English gallons (Imperial)	×	4.537	=	liters
Cubic inches of water (39.1°)	×	0.036024	=	pounds
Cubic inches of water (39.1°)	×	0.004329	=	U.S. gallons
Cubic inches of water (39.1°)	×	0.003607	=	English gallons
Cubic inches of water (39.1°)	×	0.576348	=	ounces
Cubic feet (of water) (39.1°)	×	62.425	=	pounds
Cubic feet (of water) (39.1°)	×	7.48	=	U.S. gallons
Cubic feet (of water) (39.1°)	×	6.232	=	English gallons
Cubic feet (of water) (39.1°)	×	0.028	=	tons
Pounds of water	×	27.72	=	cubic inches
Pounds of water	×	0.01602	=	cubic feet
Pounds of water	×	0.12	=	U.S. gallons
Pounds of water	×	0.10	=	English gallons

Table 14-4.—Weights and Measures—Continued

Miscellaneous Tables

Numbers		Circular and Angular Measures	
12 units	= 1 dozen	60 seconds (″)	= 1 minute (′)
12 dozen	= 1 gross	60 minutes	= 1 degree (°)
12 gross	= 1 great gross	90 degrees	= 1 quadrant
20 units	= 1 score	360 degrees	= 1 circumference

Table 14-5.—Rectangular Capacities

RECTANGULAR TANKS
Capacity in U.S. Gallons Per Foot of Depth

Widths, Feet	Length of Tank—in Feet						
	2	2 1/2	3	3 1/2	4	4 1/2	5
2	29.92	37.40	44.88	52.36	59.84	67.32	74.81
2 1/2	—	46.75	56.10	65.45	74.81	84.16	93.51
3	—	—	67.32	78.55	89.77	101.0	112.2
3 1/2	—	—	—	91.64	104.7	117.8	130.9
4	—	—	—	—	119.7	134.6	149.6
4 1/2	—	—	—	—	—	151.5	168.3
5	—	—	—	—	—	—	187.0
	5 1/2	6	6 1/2	7	7 1/2	8	8 1/2
2	82.29	89.77	97.25	104.7	112.2	119.7	127.2
2 1/2	102.9	112.2	121.6	130.9	140.3	149.6	159.0
3	123.4	134.6	145.9	157.1	168.3	179.5	190.8
3 1/2	144.0	157.1	170.2	183.3	196.4	209.5	222.5
4	164.6	179.5	194.5	209.5	224.4	239.4	254.3
4 1/2	185.1	202.0	218.8	235.6	252.5	269.3	286.1
5	205.7	224.4	243.1	261.8	280.5	299.2	317.9
5 1/2	226.3	246.9	267.4	288.0	308.6	329.1	349.7
6	—	269.3	291.7	314.2	336.6	359.1	381.5
6 1/2	—	—	316.1	340.2	364.7	389.0	413.3
7	—	—	—	366.5	392.7	418.9	445.1
7 1/2	—	—	—	—	420.8	448.8	476.9
8	—	—	—	—	—	478.8	508.7
8 1/2	—	—	—	—	—	—	540.5
	9	9 1/2	10	10 1/2	11	11 1/2	12
2	134.6	142.1	149.6	157.1	164.6	172.1	179.5
2 1/2	168.3	177.7	187.0	196.4	205.7	215.1	224.4
3	202.0	213.2	224.4	235.6	246.9	258.1	269.3
3 1/2	235.6	248.7	261.8	274.9	288.0	301.1	314.2
4	269.3	284.3	299.2	314.2	329.1	344.1	359.1
4 1/2	303.0	319.3	336.6	353.5	370.3	387.1	403.9
5	336.6	355.3	374.0	392.7	411.4	430.1	448.8
5 1/2	370.3	390.9	411.4	432.0	452.6	473.1	493.7
6	403.9	426.4	448.8	471.3	493.7	516.2	538.6
6 1/2	437.6	461.9	486.2	510.5	534.9	559.2	583.5
7	471.3	497.5	523.6	549.8	576.0	602.2	628.4
7 1/2	504.9	533.0	561.0	589.1	617.1	645.2	673.2
8	538.6	568.5	598.4	628.4	658.3	688.2	718.1
8 1/2	572.3	604.1	635.8	667.6	699.4	731.2	763.0
9	605.9	639.6	673.2	706.9	740.6	774.2	807.9
9 1/2	—	675.1	710.6	746.2	781.7	817.2	852.3
10	—	—	748.1	785.5	822.9	860.3	897.7
10 1/2	—	—	—	824.7	864.0	903.3	942.5
11	—	—	—	—	905.1	946.3	987.4
11 1/2	—	—	—	—	—	989.3	1032
12	—	—	—	—	—	—	1077

U.S. Gallon of water weighs 8.34523 pounds avoirdupois at 4° C.

Table 14-6.—Circular Capacities

Diam., Ft.	In	Gallons	Diam., Ft.	In	Gallons	Diam., Ft.	In	Gallons
1		5.875	3	6	71.97	5	11	205.7
1	1	6.895	3	7	75.44	6		211.5
1	2	7.997	3	8	78.99	6	3	229.5
1	3	9.180	3	9	82.62	6	6	248.2
1	4	10.44	3	10	86.33	6	9	267.7
1	5	11.79	3	11	90.13	7		287.9
1	6	13.22	4		94.00	7	3	308.8
1	7	14.73	4	1	97.96	7	6	330.5
1	8	16.32	4	2	102.0	7	9	352.0
1	9	17.99	4	3	106.1	8		376.0
1	10	19.75	4	4	110.3	8	3	399.9
1	11	21.58	4	5	114.6	8	6	424.5
2		23.50	4	6	119.0	8	9	449.8
2	1	25.50	4	7	123.4	9		475.9
2	2	27.58	4	8	127.9	9	3	502.7
2	3	29.74	4	9	132.6	9	6	530.2
2	4	31.99	4	10	137.3	9	9	558.5
2	5	34.31	4	11	142.0	10		587.5
2	6	36.72	5		146.9	10	3	617.3
2	7	39.21	5	1	151.8	10	6	647.7
2	8	41.78	5	2	156.8	10	9	679.0
2	9	44.43	5	3	161.9	11		710.9
2	10	47.16	5	4	167.1	11	3	743.6
3	11	49.98	5	5	172.4	11	6	777.0
3		52.88	5	6	177.7	11	9	811.1
3	1	55.86	5	7	183.2	12		846.0
3	2	58.92	5	8	188.7	12	3	881.6
3	3	62.06	5	9	194.2	12	6	918.0
3	4	65.28	5	10	199.9	12	9	955.1
3	5	68.58						

U.S. Gallon of water weighs 8.34523 Pounds Avoirdupois at 4° C.

SUMMARY

In this chapter, you have been working problems that you will meet in your job. This chapter only presents the math basics. If you should need further help, see the references listed at the beginning of this chapter.

CHAPTER 15

PIPING SYSTEMS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Describe the two methods of manufacturing piping and tubing, and discuss the different types and sizes of each.*
- *Identify some of the fittings used for shipboard pipefitting operations, and describe the proper removal and installation procedures to follow.*
- *Identify the various valves used in piping systems.*
- *Describe the type, class, pressures, and number marking system of standard pipefittings and piping materials used on board U.S. naval ships.*
- *Describe the design, types, and sizes of piping systems, and the characteristics of liquids, gases, and vapors carried by shipboard piping systems.*
- *Identify, the hazards and safety precautions involved with piping systems.*
- *Describe the various materials used in insulation and lagging of piping systems, and explain the hazards and safety requirements involved.*

INTRODUCTION

As a Hull Maintenance Technician, you will repair or modify piping systems, and you may also install new systems. To do this, you will need to know the materials you should use. These include pipes, tubes, valves, traps, drains, strainers, connection fittings, expansion joints, packing, and gaskets. The type of system you are working on will determine whether you use iron, steel, copper, plastic, or alloy materials.

In this chapter, we will discuss pipefitting materials and the different types of piping systems.

PIPING AND TUBING

The Naval Sea Systems Command defines piping as an assembly that is composed of pipe or tubing, valves, fittings, and related components that form either a whole or part of a system that is to be used to transfer fluids (liquids and gases).

It is a little harder to define pipe and tubing. In commercial usage, there is no clear distinction between pipe and tubing. The correct designation for each tubular product is established by the manufacturer. If the manufacturer calls a product pipe, it is pipe. If the manufacturer calls it tubing, it is tubing.

In the Navy, however, a distinction is made between pipe and tubing. This distinction is based on the manner in which the sizes of the tubular products are identified.

There are three important dimensions of any tubular product: outside diameter (OD), inside diameter (ID), and wall thickness. A tubular product is called TUBING if its size is identified by actual measured OD and by actual measured wall thickness. A tubular product is called PIPE if its size is identified by a nominal dimension called iron pipe size (IPS) and by reference to a schedule designation for its wall thickness.

The size identification of tubing is simple because it consists of actual measured dimensions. However, the terms used for identifying pipe sizes will require some explanation. A nominal dimension such as IPS is close, but not necessarily identical, to the actual measured dimension. For example, a pipe with a nominal pipe size of 3 inches has an actual measured OD of 3.50 inches. A pipe with a nominal pipe size (NPS) of 2 inches has an actual measured OD of 2.375 inches. For pipe that is 12 inches or larger, the NPS and the actual measured OD are the same. For example, a pipe with an NPS of 14 inches has an actual measured OD of 14 inches. Nominal dimensions are used to simplify the standardization of pipe fittings and pipe taps and threading dies.

The wall thickness of pipe is identified by reference to wall thickness schedules established by the American Standards Association. As an example, table 15-1 shows four schedules: 40, 80, 120, and 160. Each of these schedules shows a different wall thickness and, therefore, a different ID for any given NPS.

Assume that you have a pipe with a nominal size of 4 inches. Using table 15-1, you can see that a 4-inch pipe can have the following ID and OD dimensions.

Schedule	DIA	OD	ID	Wall
40	4	4.500	4.026	0.237
80	4	4.500	3.826	0.337
120	4	4.500	3.624	0.438
160	4	4.500	3.438	0.531

Therefore, you can use a pipe schedule to select either a greater or smaller pipe thickness depending on the requirements of the job.

You may have seen pipe identified as STANDARD (Std), EXTRA STRONG (XS), and DOUBLE EXTRA STRONG (XXS). These designations also refer to wall thickness. Figure 15-1 shows the relative wall thickness of pipes having the same NPS (OD). Note that the ID is reduced as the wall thickness is increased. Pipe is manufactured in a number of different wall

Table 15-1.—Schedule Designations of Pipe Size

SCHEDULE 40				SCHEDULE 80			SCHEDULE 120			
DIA.	O.D.	I.D.	WALL	O.D.	I.D.	WALL	DIA.	O.D.	I.D.	WALL
1/8	0.405	0.269	0.068	0.405	0.215	0.095	4	4.500	3.624	0.438
1/4	0.540	0.364	0.088	0.540	0.302	0.119	5	5.563	4.653	0.500
3/8	0.675	0.493	0.091	0.675	0.423	0.126	6	6.625	5.501	0.562
1/2	0.840	0.622	0.109	0.840	0.546	0.147	8	8.625	7.189	0.718
3/4	1.050	0.824	0.113	1.050	0.742	0.154				
1	1.315	1.049	0.133	1.315	0.957	0.179	SCHEDULE 160			
1-1/4	1.660	1.380	0.140	1.660	1.278	0.191	1/2	0.840	0.466	0.187
1-1/2	1.900	1.610	0.145	1.900	1.500	0.200	3/4	1.050	0.614	0.218
2	2.375	2.067	0.154	2.375	1.939	0.218	1	1.315	0.815	0.250
2-1/2	2.875	2.469	0.203	2.875	2.323	0.276	1-1/4	1.660	1.160	0.250
3	3.500	3.068	0.216	3.500	2.900	0.300	1-1/2	1.900	1.338	0.281
3-1/2	4.000	3.548	0.226	4.000	3.364	0.318	2	2.375	1.689	0.343
4	4.500	4.026	0.237	4.500	3.826	0.337	2-1/2	2.875	2.125	0.375
4-1/2	5.000	4.506	0.247	5.000	4.290	0.355	3	3.500	2.624	0.438
5	5.563	5.047	0.258	5.563	4.813	0.375	4	4.500	3.438	0.531
6	6.625	6.065	0.280	6.625	5.761	0.432	5	5.563	4.313	0.625
8	8.625	7.981	0.322	8.625	7.625	0.500	6	6.625	5.189	0.718
							8	8.625	6.813	0.906

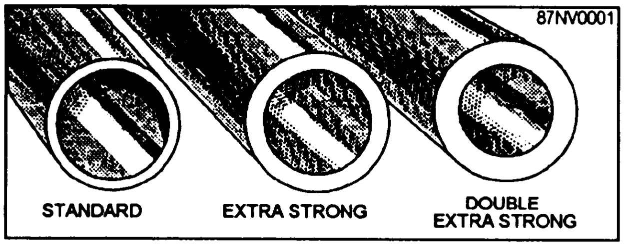


Figure 15-1.—Wall thickness designations.

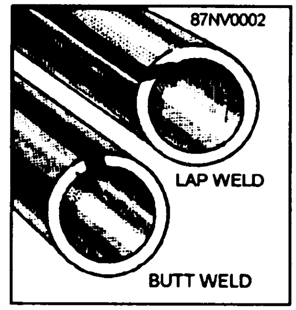


Figure 15-2.—Types of welded pipe construction.

thicknesses. You will find that some pipe will not fit into the standard, extra strong, and double extra strong classifications. Therefore, the wall thickness schedules are being used increasingly more because they identify more wall thicknesses than can be identified under the strong, extra strong, and double extra strong classifications.

The standard means of identifying the size and wall thickness of pipe and tubing have been briefly described here. However, you will sometimes see pipe and tubing identified by another means. For example, you may see some tubing identified by ID rather than by OD. And, you may see some pipe identified by NPS, by OD, by ID, by actual wall thickness, or by a combination of these measurements.

METHODS OF MANUFACTURE

There are two main processes used to manufacture pipes and other tubular products: the welding process and the seamless process. The welding processes are used primarily to manufacture iron and steel tubular products. The seamless processes are used to manufacture both ferrous and nonferrous tubular products.

Welding Processes

The welding processes used for the production of pipe and other tubular products are usually classified as butt-weld, lapweld, and electric-weld processes.

The butt-weld process is used in the manufacture of ferrous pipe up to about 4 inches in diameter. The edges of the material are usually squared off, as shown in figure 15-2, but they may be slightly beveled. The material is heated to welding temperature and drawn through a die that forms the material into a cylindrical shape and welds the seam.

The lap-weld process is used in the manufacture of ferrous pipe up to about 30 inches in diameter. The material is beveled or scarfed on the edges, as shown in figure 15-2. First, the material is heated to welding temperature. Then, it is passed over a mandrel and between two grooved rolls that press the lapped edges together, thus forming the welded seam.

Electric-weld processes used in the manufacture of ferrous tubular products include fusion welding and resistance welding. In fusion welding, the butting edges of the material form a V into which the electrode is melted. In resistance welding, the welding heat is generated by the resistance to the flow of an electric current across the seam.

Seamless Processes

The seamless processes used for the manufacture of ferrous and nonferrous tubular products are usually classified as piercing processes and cupping processes.

Piercing processes are used for forming pipe up to 26 inches OD. A solid round bar or billet is heated, pierced, and then worked to the required diameter and wall thickness.

Cupping processes may be used to form pipe between 3 inches and 20 inches OD. The tubular shape is formed by pressing a preheated solid round plate through cupping dies.

CHOICE OF MATERIAL AND SIZES

When you repair any piping system, you will have to be very careful in your selection of materials to be used. First, you need to know what particular type of pipe or tubing is best suited for the fluid it is to carry, and the operating pressures and temperatures the system is to withstand. Second, you must be able to identify the materials that will meet these requirements.

This section will provide general information on the piping and tubing that you will use to work on shipboard piping systems. For details on any specific system, see the ship piping plans (MIL-STD-777) and lists of materials.

SEAMLESS STEEL PIPE is available in standard and extra strong wall thicknesses and comes in lengths of 12 to 22 feet. In the standard wall thickness, it is available in sizes from l/8 inch to 16 inches IPS. Pipe sizes l/8 inch to 3/8 inch come with plain ends, while sizes l/2 inch to 16 inches come with beveled ends for welding. In the extra strong wall thickness, it is available in sizes from 2 inches to 16 inches IPS. It may or may not be galvanized. This pipe is ordinarily stocked with plain ends only. Seamless steel pipe is used aboard ship for diesel exhaust systems, overflow lines, sounding tubes, vents, and air intake systems.

WELDED STEEL PIPE, either galvanized or ungalvanized (black), is also available in standard and extra strong wall thicknesses. In the standard wall thickness, it is available in sizes l/8 inch to 12 inches IPS. The galvanized pipe comes in lengths of 16 to 22 feet, while the ungalvanized pipe comes in lengths of 12 to 22 feet. This pipe comes with beveled ends for welding. The extra strong wall thickness pipe is available in sizes from l/4 inch to 12 inches IPS. It comes in lengths of 12 to 22 feet and is ordinarily stocked with plain ends only. Welded steel pipe is used primarily for general service such as plumbing drain lines aboard ship.

STRUCTURAL STEEL TUBING is supplied in lengths of 12 to 24 feet. This tubing is not intended for pressure applications. It is normally used on such structural jobs as 20mm and 40mm gun mounts and searchlight platforms. Structural tubing made by the seamless processes has a tensile strength of 60,000 psi. The welded structural steel tubing has a tensile strength of 50,000 psi.

SEAMLESS STEEL TUBING is used in oil, steam, and waterline systems. This tubing is available in a variety of types. The type used will depend upon the working pressure and temperature that is to be maintained in the lines.

WELDED STEEL TUBING is available in two types. Their uses are as follows: Type A is used in steam and oil lines where the maximum working pressure is 150 psi. It is also used in water and gas lines that operate at a maximum working pressure of 225 psi. Type B is used in steam lines that operate at a maximum working pressure of 300 psi. It is also used in oil lines that operate at a maximum pressure of 350 psi and in water or gas lines that operate at a maximum pressure of 400 psi.

CARBON MOLYBDENUM (CMO) ALLOY SEAMLESS STEEL TUBING is used in high-pressure steam lines that work at pressures of 401 to 1200 psi and have an operating temperature of 875°F. CMO tubing is used extensively throughout ships' steam systems, but as the piping systems wear out, CMO tubing is being replaced with seamless chromium-molybdenum alloy steel tubing. It is usually used in 600 psi systems. This tubing comes in lengths of 12 to 24 feet.

SEAMLESS CHROMIUM-MOLYBDENUM ALLOY STEEL TUBING is used in high-pressure steam lines that work at pressures of 1201 to 1500 psi and have an operating temperature of 1000°F. This tubing also comes in lengths of 12 to 24 feet.

NONFERROUS TUBING is used for some shipboard piping systems and almost all shipboard heat exchangers. Nonferrous materials are used primarily where corrosion resistance and high heat conductivity are required. Typical shipboard applications of nonferrous tubing are described in the following paragraphs.

Several types of SEAMLESS ALUMINUM ALLOY TUBING are available. Tubing made of the aluminum alloy 6061 is used primarily for dry lines in magazine sprinkling systems. It is also used in some structural applications. Tubing made of the aluminum alloy 5052 is used for bilge and sanitary drain systems.

SEAMLESS BRASS TUBING (semi-annealed and light-annealed) is available in types and sizes suitable for operating pressures that range from 200 psi to 4000 psi. It is used in systems for either fresh water or another fluid. However, it is not approved for any seawater applications. The seamless hard-drawn brass tubing is used for voice and pneumatic tube installations.

SEAMLESS COPPER TUBING is intended for general use aboard ship. If it is not joined by threaded fittings, you may use flanged joints, soldered joints, or flared fittings. Other types of copper tubing are available for various uses such as refrigeration installations, plumbing and heating systems, gasoline systems, lubrication systems, and other shipboard uses.

COPPER ALLOY TUBING is available in a composition of either 70-30 or 90- 10. The first number of the individual composition is the percentage of copper and the second number is the percentage of nickel. Therefore, copper tubing with a 70-30 composition is actually 70 percent copper and 30 percent nickel. Some copper-nickel tubing may be used with Navy brazed tube fittings and butt-welded fittings. However, some types are not suitable for welding, while other types are not suitable for threading. The 70-30 composition has been used for some time in shipboard piping systems and heat exchangers. The Naval Sea Systems Command has authorized the use of the composition 90-10 copper alloy tubing for many applications for which the composition of 70-30 was formerly specified.

PLASTIC as a piping material has not been used to any great extent on naval ships. However, considerable interest has been shown in the Navy's present and future use of plastic piping for naval ships.

Of all the different types of plastic piping material commercially available, two groups have been investigated for shipboard use: (1) glass-reinforced polyester, or epoxy, and (2) polyvinyl chloride (PVC). Of the two types, the polyvinyl chloride has the best all-around characteristics for shipboard use.

PVC plastic piping has a number of advantages. It has an excellent resistance to saltwater corrosion. It is also lightweight, easy to install, and highly resistant to weathering. Some high grades of PVC pipe are highly resistant to shock. As for disadvantages, PVC piping material gives off hydrogen chloride gas when it burns. It cannot be used for carrying high temperature fluids, nor can it be used when surrounding temperatures are high. Due to these disadvantages, plastic piping is not currently used below decks on surface ships. However, PVC plastic piping is currently used in the interim and installed washdown systems aboard naval ships. For more information on plastic piping, refer to NAVSHIPS 250-548-2.

FITTINGS

Every shipboard piping system includes a variety of fittings made from a number of different metals and alloys. They are available in the same size range as the pipe and tubing used in the systems. The layout and the function of a system will determine the composition and the number of fittings used. The use of fittings is held to a minimum because each fitting is a possible source for leaks. However, some fittings are necessary in any piping system. Those normally used in shipboard piping systems are described in this section.

Figure 15-3 shows a variety of common fittings. For example, the return bend shown in view A has the centers of the openings as close together as possible; the elbow shown in view H makes a 90° bend; and the elbow shown in view D makes a 45° bend. This variety in the design of fittings allows you to select' the appropriate fittings for any system.

Some of the plugs, caps, bushings, and nipples used in shipboard piping systems are shown in figure 15-4. Plugs are used to close an opening in fittings or equipment. Caps are used for either temporary or permanent seals of pipe ends. One type of reducing bushing is used to connect two pieces of pipe or tubing together when they have different diameters. Another type is used to connect pipe or tubing to a piece of machinery. Nipples are used for connections to machinery and also in plumbing systems.

A shock-resistant piping nipple is used for root connections to machinery. This type of nipple has straight pipe threads instead of tapered pipe threads. Threaded root connections are used on all ships where piping and equipment are furnished with threaded bosses. A boss on a piece of machinery is a thick-wall socket that is part of the housing. The boss allows the connecting of an external pipe or nipple to the piece of machinery. If existing bosses have tapered pipe threads, it may be possible to retap them for straight pipe threads. Otherwise, it will be necessary to use a nipple with tapered threads. In this case, you must be careful when fitting the nipple to ensure that the gasket is compressed correctly and that the tapered threads are tightly seated. However, you should avoid the use of tapered thread nipples whenever possible.

Union fittings, and valves that have union ends, are used in piping systems to simplify repairs or alterations (fig. 15-5). The number of fittings and valves should be kept to a minimum and checked periodically for leaks.

Unions are available in bronze, iron, and steel, and are designed to withstand a wide range of temperatures and pressures. Bronze unions come in sizes up to 2 1/2 inches. Iron and steel unions (galvanized or black) come in sizes up to 3 inches. The straight, branch elbow, and run types of bronze unions are capable of withstanding 250 psi pressure. The union bulkhead fitting is designed for 3000 psi water, oil, or gas lines that pass through bulkheads.

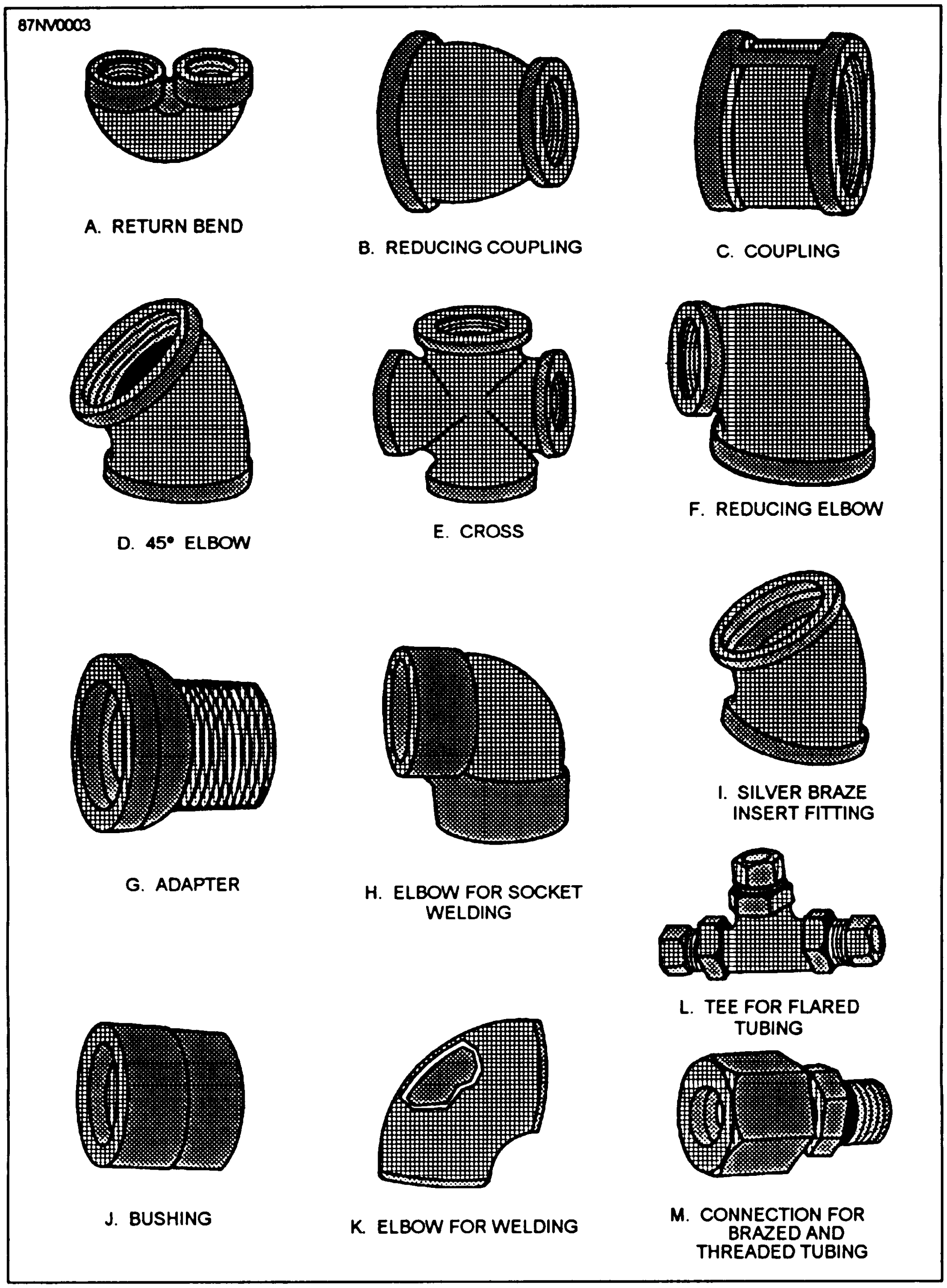


Figure 15-3.—Typical pipe fittings.

Another type of union is the malleable iron flange union shown in view A of figure 15-6. This union flange is intended for 150 psi steam lines, and is available in sizes up to 6 inches, galvanized or black.

The socket welded flange shown in view G of figure 15-6 is suitable for various services, pressures, and temperatures. This flange is slipped onto the pipe end and fillet-welded in place.

The Van Stone flange, shown in view H of figure 15-6, is used in high-pressure steam lines that are subjected to high temperatures and to expansion strains. It consists of a regular flanged upper portion and a

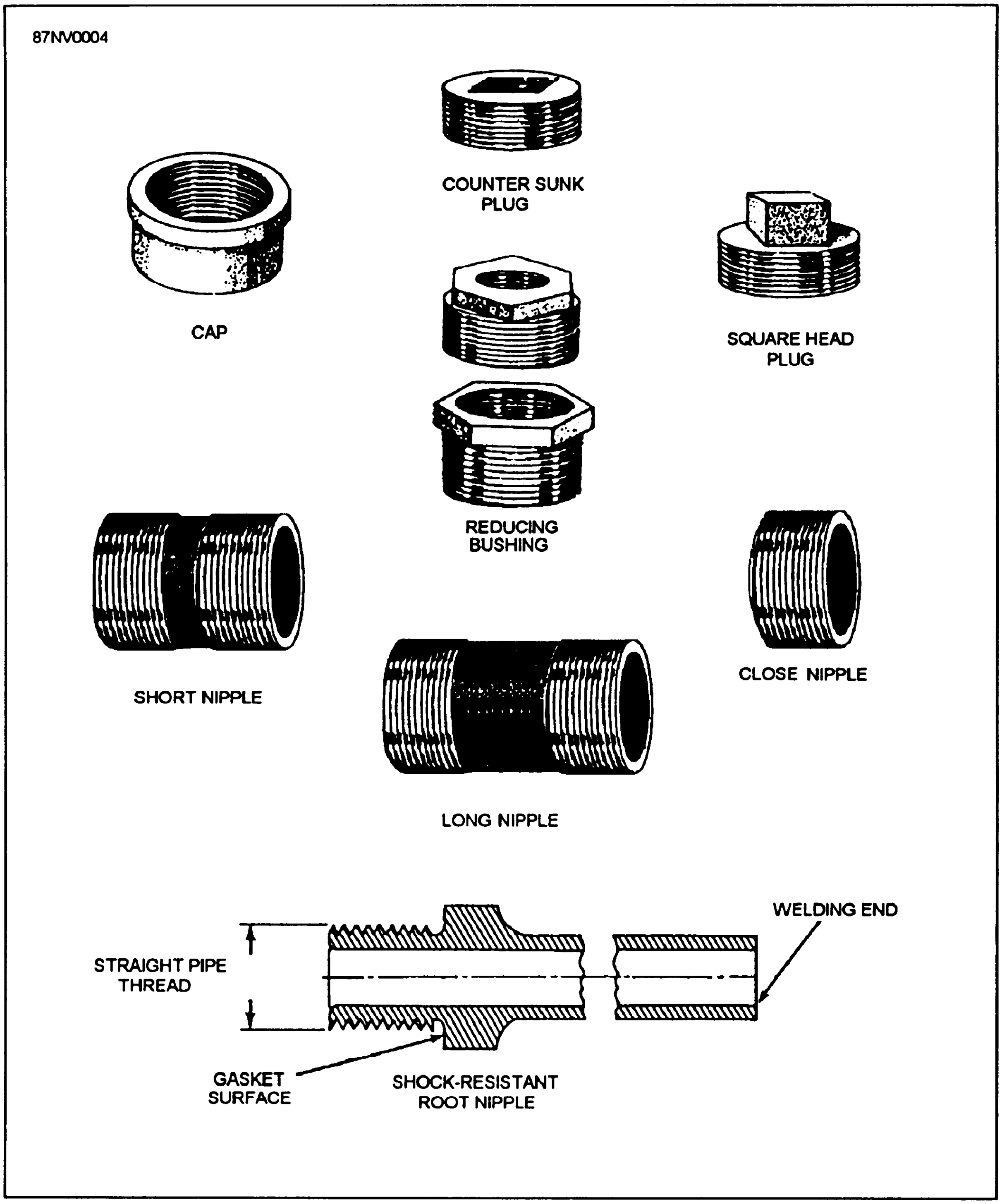


Figure 15-4.—Nipples, plugs, cap, and bushing.

ground lower portion, allowing for a leakproofjoint that will align itself when the flange bolts are tightened.

Flanges can be attached to pipes and tubing by welding, brazing, rolling, flaring, or (in some low-pressure systems) with screw threads. The method used will depend upon the size of pipe and the service of the system in which it is installed. It will also depend upon the construction period of the ship. The piping system index will give you useful information on this point. Flanged joints are sealed by the use of special gasket materials. The gasket materials will be discussed later in this chapter.

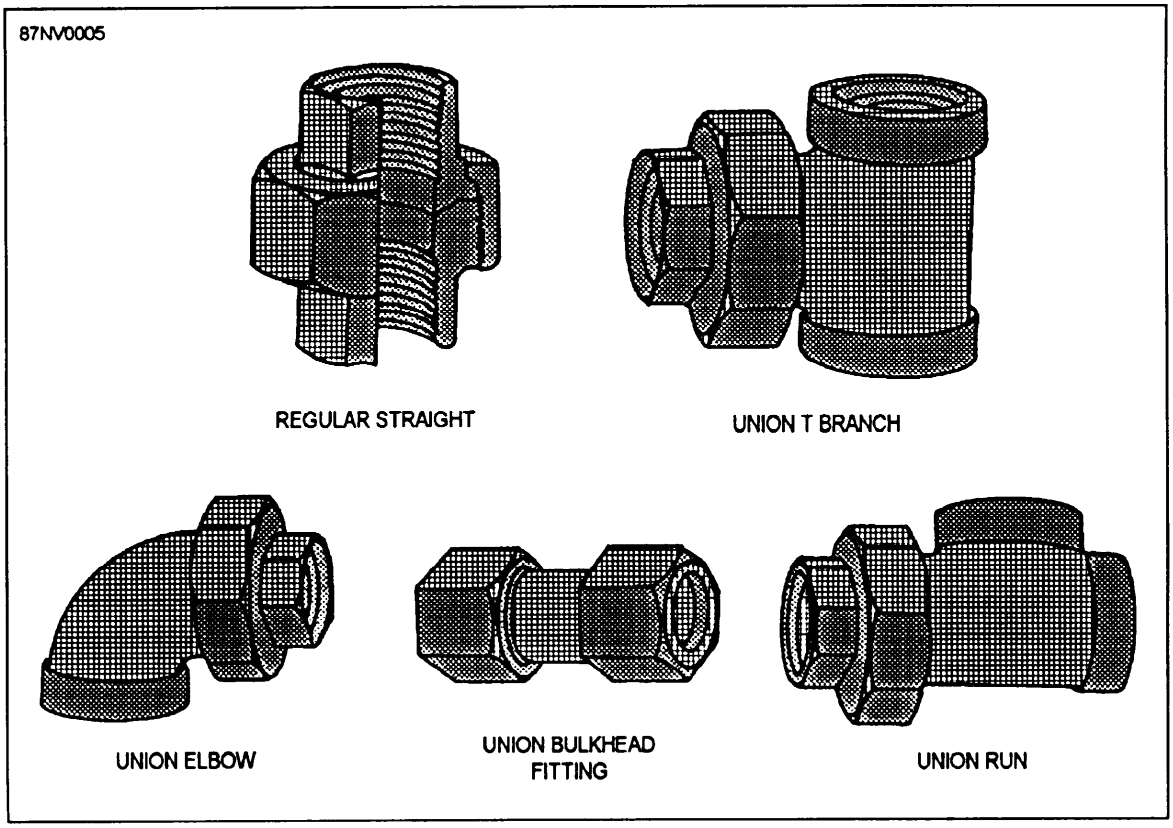


Figure 15-5.—Unions.

VALVES

Every piping system must have some means to control the amount and direction of the flow of liquids or gas through the lines. This is accomplished by installing valves, which can be opened or closed as required.

Valves are usually made of bronze, brass, cast or malleable iron, or steel. Steel valves are either cast or forged, and are made of carbon steel, low ahoy steel, or stainless steel. Alloy steel valves are used in high-pressure, high-temperature systems. The disks and seats of these valves are usually surfaced with a chromium-cobalt alloy known as stellite. This material is extremely hard.

Bronze and brass valves are not used in high-temperature systems, or in any system in which they would be exposed to severe pressure, vibration, or shock. Bronze valves are widely used in saltwater systems. The seats and disks of bronze valves used for saltwater service are often made of Monel, which is highly resistant to corrosion and erosion.

Many different types of valves are used to control the flow of liquids and gases. As described in *Fireman,* NAVEDTRA 12001, there are two main groups of valves: stop valves and check valves. Stop valves are used to shut off (or, in some cases, to partially shut off) the flow of fluid. These valves are controlled entirely by the movement of the valve stem. Check valves are used to permit the flow of fluid in one direction only. These valves are controlled by the movement of the fluid itself.

Valve designs vary considerably because of the different demands of services. Some valves are combinations of the more or less basic type just mentioned. Special valves, such as reducing valves, bear only a slight resemblance to the basic types. However, stop valves may include globe valves, gate valves, piston valves, plug valves, needle valves, and butterfly valves. Check valves may include swing-check valves and lift-check valves.

GLOBE VALVES

Globe valves are one of the most common types of stop valves. They get their name from the globular shape of their bodies. However, other types of valves may also have globe-shaped bodies, so do not jump to the conclusion that a valve with a globe-shaped body is

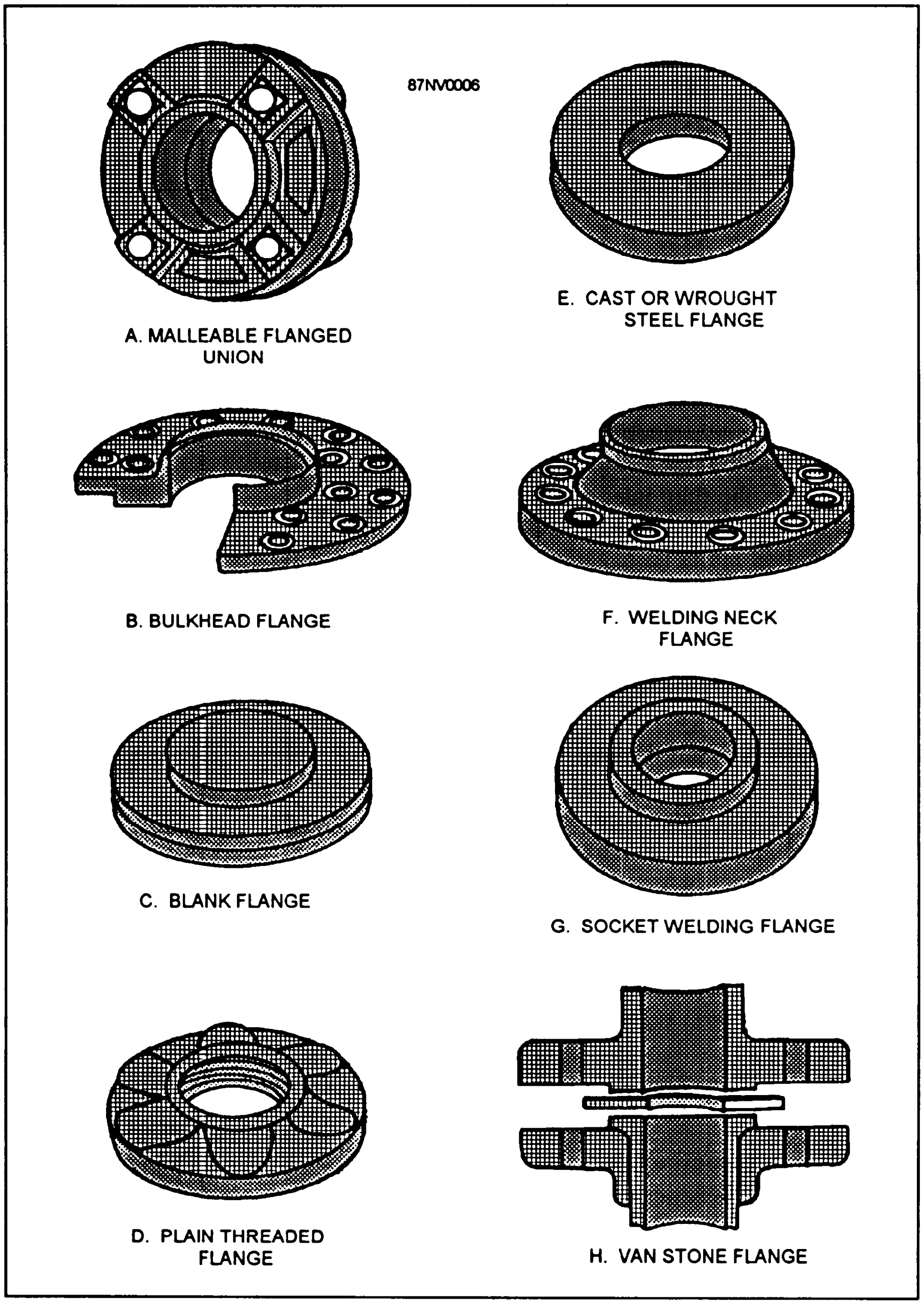


Figure 15-6.—Flanges.

actually a globe valve. The internal structure of a valve, not the external shape, is what distinguishes one type of valve from another.

In a globe-type stop valve, the disk is attached to the valve stem. The disk scats against a seating ring or a seating surface and therefore shuts off the flow of fluid. When the disk is removed from the seating surface, fluid can pass through the valve in either direction. Globe valves may be used partially open as well as fully open or fully closed.

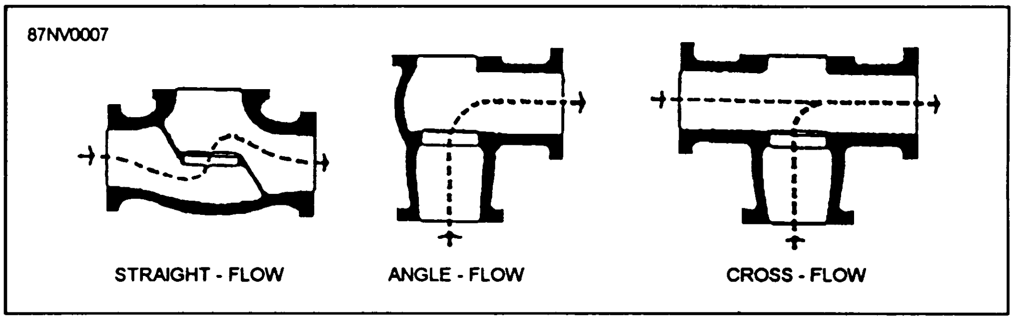


Figure 15-7.—Types of globe valve bodies.

Globe valve inlet and outlet openings are arranged in several ways to satisfy different requirements of flow. Figure 15-7 shows three common types of globe valve bodies. In the straight type, the fluid inlet and outlet openings are in line with each other. In the angle type, the inlet and outlet openings are at an angle to each other. An angle-type globe valve is commonly used where a stop valve is needed at a 90° turn in a line. The cross-type globe valve has three openings rather than two; it is frequently used in connection with bypass lines.

Globe valves are commonly used in steam, air, oil, and water lines. On many ships, you will find surface blow valves, bottom blow valves, boiler stops, feed stop valves, and many guarding valves and line cutout valves. Globe valves are also used as stop valves on the suction side of many fireroom pumps, as recirculating valves in the fuel oil system, and as throttle valves on most fireroom auxiliary machinery.

A cutaway view of a globe stop valve is shown in figure 15-8.

GATE VALVES

Gate valves are used in systems where a straight flow with the least amount of restriction is needed. Figure 15-9 is a cross-sectional view of a gate valve. You will find that most of the firemain cutout valves are gate valves. These valves are also used in steam lines, water lines, and fuel oil lines.

The part of a gate valve that serves the same purpose as the disk in a globe valve is known as the gate. The gate is normally wedge-shaped. However, some are uniform in thickness throughout. When the gate is wide open, the opening through the valve is equal to the size of the piping in which the valve is installed. Therefore, there is very little resistance in the flow of the liquid and also very little pressure reduction caused by the gate valve. Since regulating the flow of liquid would be difficult and could cause extensive damage to the valve, the gate valve is not to be used as a throttling valve.

The gate is connected to the valve stem. Turning the handwheel will raise or lower the valve gate. Some gate valves have nonrising stems. On these, the stem is threaded on the lower end and the gate is threaded on the inside. Therefore, the gate will travel up the stem when the valve is being opened. This type of valve will

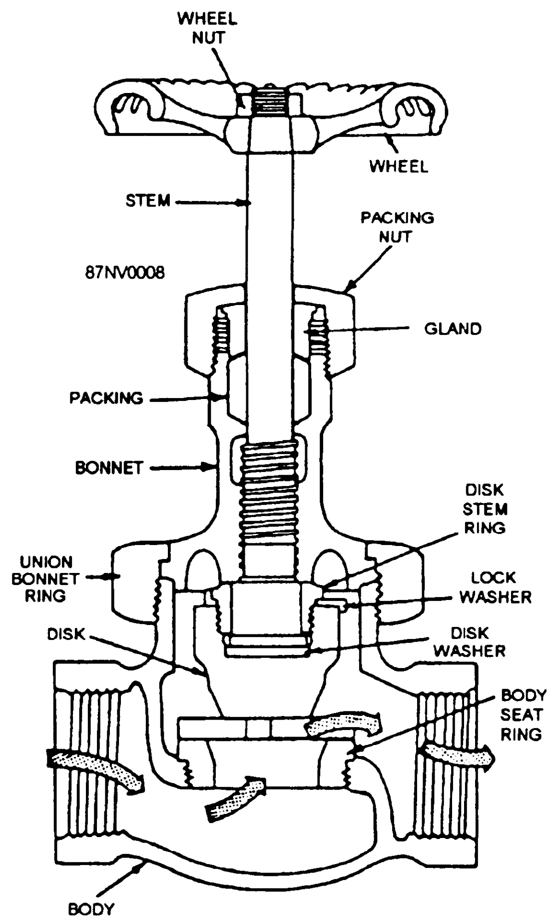


Figure 15-8.—Cutaway view of a globe stop valve.

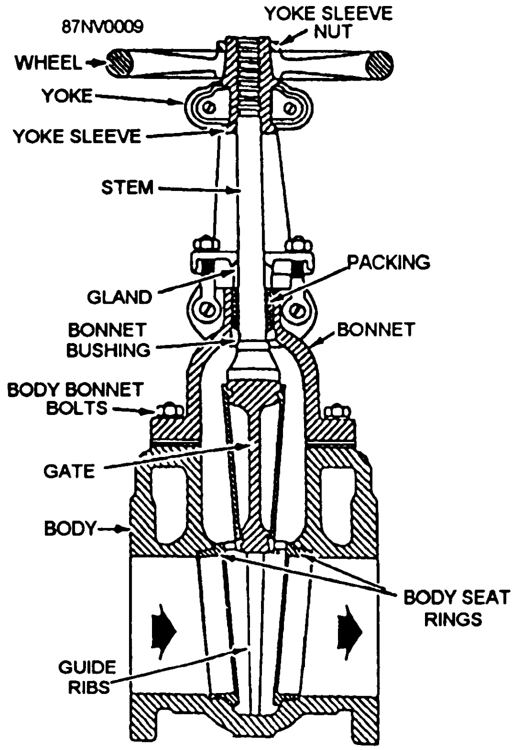


Figure 15-9.—Cross-sectional view of a gate stop valve rising stem.

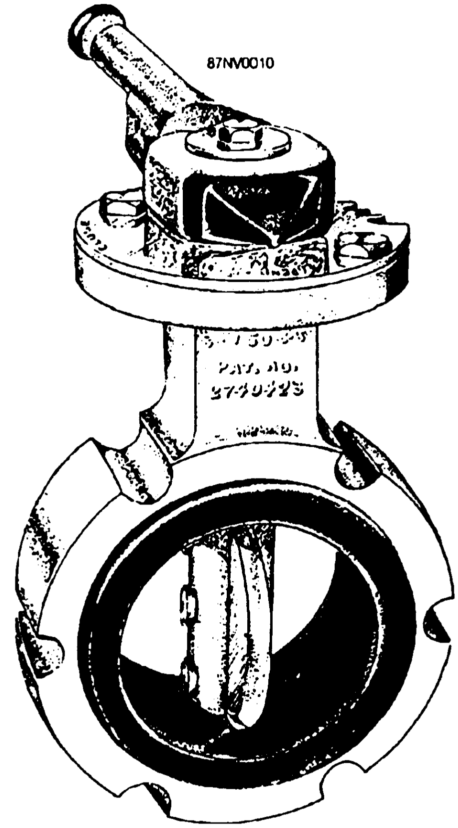


Figure 15-10.—Butterfly-type valve.

usually have a pointer or a gauge to indicate whether the valve is in the open or closed position. Some gauge valves have rising stems. In these valves, both the gate and stem will move upward when the valve is opened. In some rising stem valves, the stem will project above the handwheel when the valve is opened.

BUTTERFLY VALVES

The butterfly-type valve (fig. 15-10) in certain applications has some advantages over gate and globe valves. The butterfly valve is lightweight, takes up less space than a gate valve or globe valve, is easy to overhaul, and can be opened or closed quickly.

The design and construction of butterfly valves may vary, but a butterfly-type disk and some means of sealing are common to all butterfly valves.

The butterfly valve shown in figure 15-10 consists of a body, a resilient seat, a butterfly-type disk, a stem, packing, a notched positioning plate, and a handle. The resilient seat is under compression when it is mounted in the valve body. The compression causes a seal to form around the edge of the disk and both upper and lower points where the stem passes through the seat. Packing is provided to form a positive seal around the stem if the seal formed by the scat is damaged.

To close the valve, turn the handle a quarter of a turn to rotate the disk 90°. The resilient seat exerts positive pressure against the disk, which assures a tight shutoff.

You will find that butterfly valves are easy to maintain. The resilient seat is held in place by mechanical means. Therefore, neither bonding nor cementing is necessary. Since the resilient seat is replaceable, the valve seat will not require any lapping, grinding, or machine work.

Butterfly valves serve a variety of requirements. These valves are now being used in freshwater, saltwater, JP-5 fuel, Navy special fuel oil, diesel oil, and lubricating oil systems.

CHECK VALVES

Check valves permit liquids to flow through a line in one direction only. For example, they are used in drain lines where it is important that there is no backflow. Considerable care must be taken to see that valves are properly installed. Most of them will have an arrow, or the word *INLET*, cast on the valve body to indicate direction of flow. If not, you will have to check

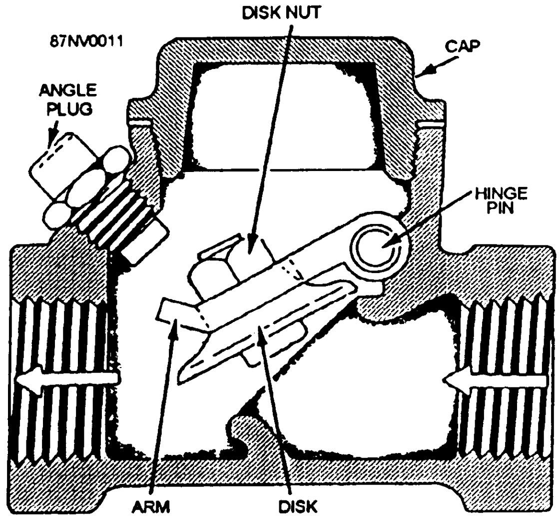


Figure 15-11.—Swing-check valve.

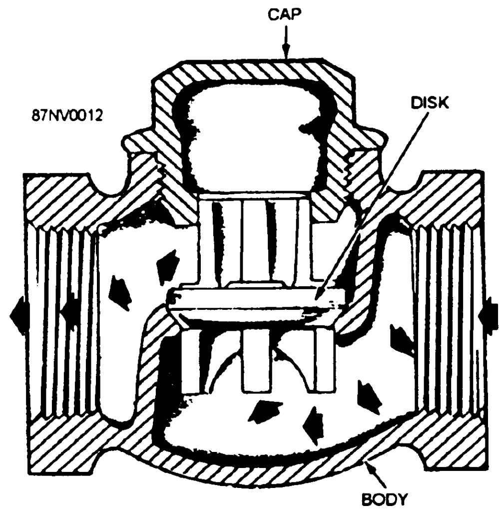


Figure 15-12.—Lift-check valve.

closely to make sure that the flow of the fluid in the system will operate the valve in the proper manner.

The port in a check valve may be closed by a disk, a ball, or a plunger. The valve opens when the pressure on the inlet side is greater than that on the outlet side. The valves also open and close automatically. They are made with threaded, flanged, or union faces, with screwed or bolted caps, and for specific pressure ranges.

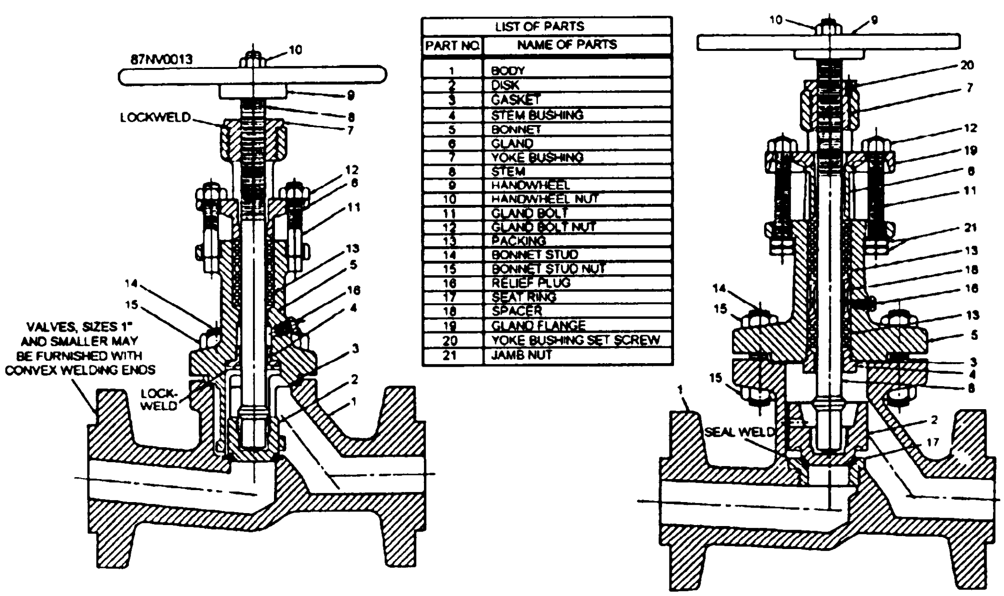
The disk of a swing-check valve (fig. 15-11) is raised as soon as the pressure in the line below the disk is of sufficient force. While the disk is raised, continuous flow takes place. If for any reason the flow is reversed, or if back pressure builds up, this opposing pressure will force the disk to scat, which in turn stops the flow.

The operation of a lift-check valve (fig. 15-12) is basically the same as that of the swing-check valve. The difference is that the valve disk moves in an up-and-down direction instead of through an arc.

STOP-CHECK VALVES

As we have seen so far, most valves may be classified as either stop valves or check valves. However, some valves function either as a stop valve or as a check valve, depending upon the position of the valve stem. These valves are known as stopcheck valves.

The cross section of two stop-check valves is shown in figure 15-13. As you can see, this type of



LIST OF PARTS	
PART NO.	NAME OF PARTS
1	BODY
2	DISK
3	GASKET
4	STEM BUSHING
5	BONNET
6	GLAND
7	YOKE BUSHING
8	STEM
9	HANDWHEEL
10	HANDWHEEL NUT
11	GLAND BOLT
12	GLAND BOLT NUT
13	PACKING
14	BONNET STUD
15	BONNET STUD NUT
16	RELIEF PLUG
17	SEAT RING
18	SPACER
19	GLAND FLANGE
20	YOKE BUSHING SET SCREW
21	JAMB NUT

Figure 15-13.—Stop-check valves.

valve looks very much like a lift-check valve. However, the valve stem is long enough so that when it is screwed all the way down it holds the disk firmly against the seat, thereby preventing the flow of any fluid. In this position, the valve acts as a stop valve. When the stem is raised, the disk can then be opened by pressure on the inlet side. In this position, the valve acts as a check valve and allows the flow of fluid in one direction only. The amount of fluid allowed to pass through is regulated by the opening. The opening is adjusted by the stem.

PRESSURE-REDUCING VALVES

Pressure-reducing valves are automatic valves that are used to provide a steady pressure lower than that of the supply pressure. Pressure-reducing valves can be set for any desired discharge pressure that is within the limits of the design.

There are several types of reducing valves in the Navy. However, you will be working mostly with those in the flushing system. These will normally be single-seated, direct-acting, and spring-loaded, as shown in figure 15-14. Water passing through this valve is controlled by means of a pressure difference on both sides of the diaphragm. The diaphragm is secured to the stem. Reduced water pressure from the valve outlet is then led through an internal passage to a diaphragm chamber that is located below the diaphragm. An adjusting spring acts on the upper side of the diaphragm. A leather cup washer or a neoprene O-ring makes the water seal between the valve inlet and the diaphragm chamber. This seal is located halfway down the valve stem.

The amount of water pressure applied to the underside of the diaphragm varies according to the discharge pressure. When the discharge pressure is greater than the spring pressure, the diaphragm is forced up. Since this is an upward-seating valve, the upward movement of the stem tends to close the valve or at least to decrease the amount of discharge. When the discharge pressure is less than that of the spring pressure, the diaphragm and the valve stem are forced down, opening the valve wider and increasing the amount of discharge. When the discharge pressure is equal to the spring pressure, the valve stem will remain stationary and the flow of water through the valve is not changed.

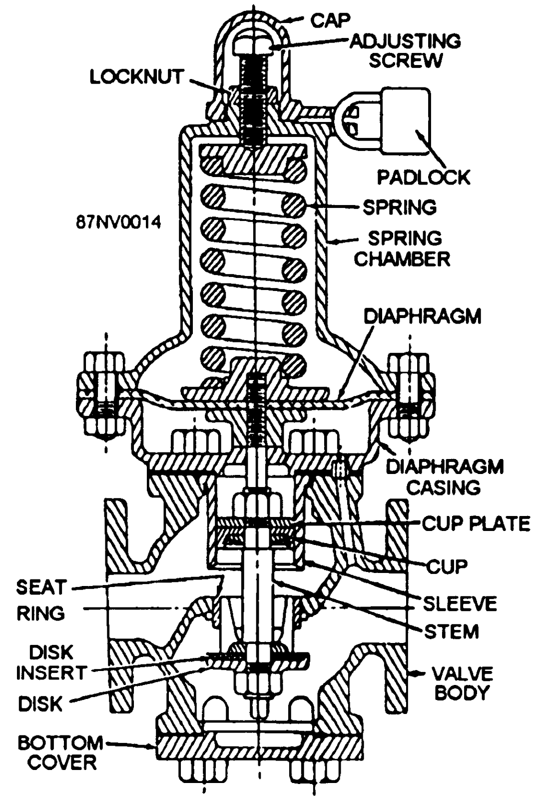


Figure 15-14.—Spring-loaded, diaphragm-type pressure-reducing valve.

The amount of pressure applied by the spring to the top of the diaphragm can be adjusted by turning an adjusting screw. Turning the adjusting screw clockwise will increase the pressure applied by the spring to the top of the diaphragm, which in turn opens the valve. Turning the adjusting screw counterclockwise will decrease the amount of spring pressure on top of the diaphragm, which in turn decreases the amount of discharge.

The opening and closing of the valve will continue as long as the discharge pressure fluctuates. For example, when a water closet is flushed, the pressure drops in the supply line. This line is on the discharge side of the pressure-reducing valve. Therefore, the diaphragm will move down and open the valve. As the flushometer closes, the pressure builds up again and closes the reducing valve.

PNEUMATIC-PRESSURE-CONTROLLED REDUCING VALVES

There are two types of the pneumatic-pressure-controlled (or gas-loaded) reducing valve. One type regulates low-temperature fluids, such as air, water, or oil (fig. 15-15). The other type (not shown) regulates high-temperature fluids, such as steam or hot water. The high-temperature fluid reducer is found only in older ships.

Air-controlled regulators operate on the principle that the pressure of an enclosed gas varies inversely to its volume. A reduction in volume results in an immediate increase in pressure. Conversely, an increase in volume results in an immediate decrease in pressure. A relatively small change in the large volume within the dome loading chamber produces only a slight pressure variation, while the slightest variation in the small volume within the actuating chamber creates an enormous change in pressure. The restricting orifice connecting these two chambers governs the rate of pressure equalization by retarding the flow of gas from one chamber to the other.

The dome loading chamber is charged with air or other compressible gases (such as nitrogen) at a pressure equal to the desired reduced pressure. When the chamber is loaded and when the loading valve is closed, the dome will retain its charge almost indefinitely. When the regulator is in operation, the trapped pressure within the dome passes into the actuating chamber through the small separation plate orifice. This pressure moves the large flexible diaphragm, which forces the reverse-acting valve off its seat. The pressure entering the regulator is then permitted to flow through the open valve into the reduced pressure line. A large pressure equalizing orifice transmits this pressure directly to the underside of the diaphragm. When the delivered pressure approximates the loading pressure in the dome and the unbalanced forces equalize, the valve will close. With

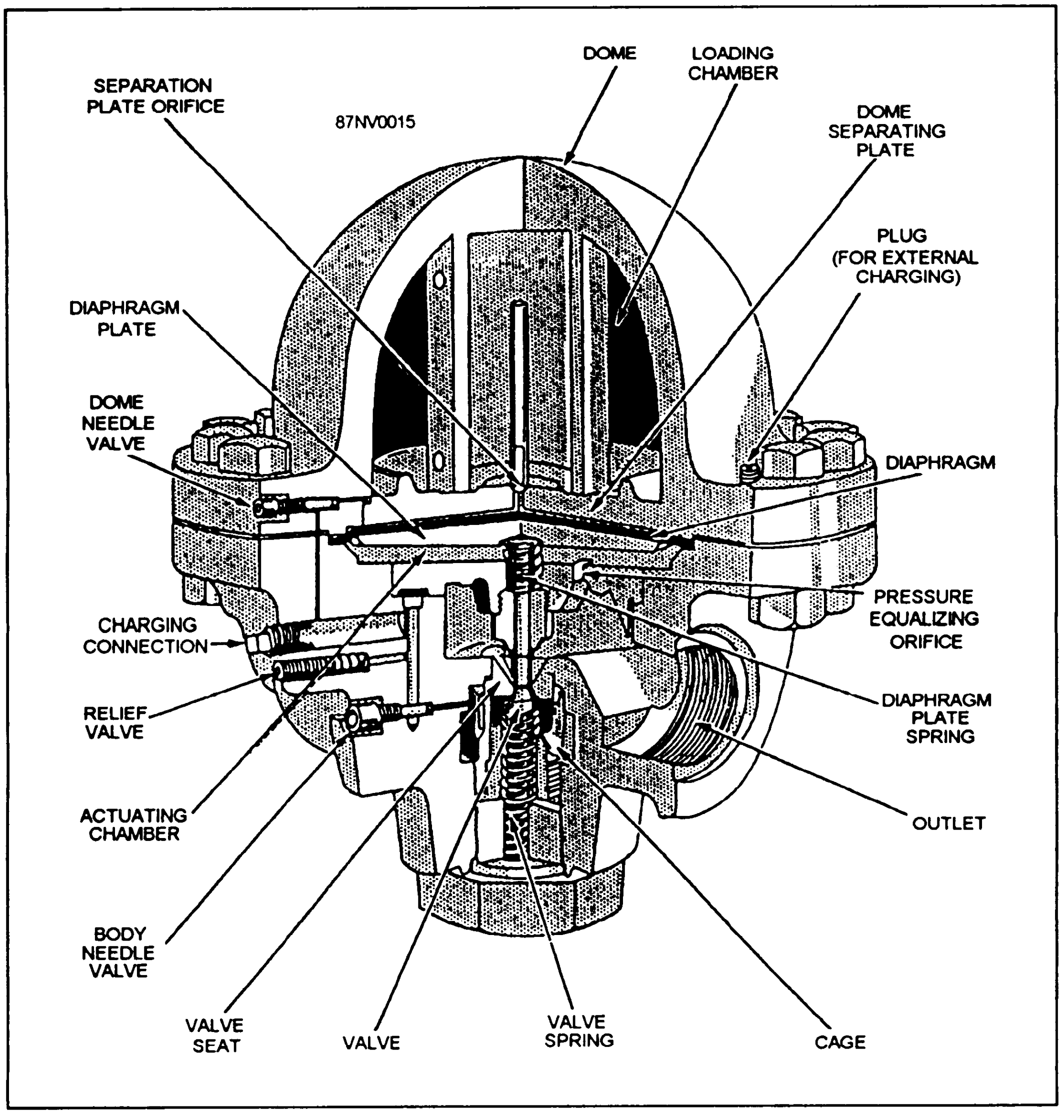


Figure 15-15.—Pneumatic-pressure-controlled reducing valve for low-temperature service.

the slightest drop in delivered pressure, the pressure charge in the dome instantly forces the valve open. This allows system fluid to pass through, thereby maintaining the outlet pressure relatively constant.

To charge the loading chamber, back off slightly on the dome needle valve. Connect the specially furnished hand pump (either 300 or 600 psi), and fill the dome to the desired outlet pressure. If the regulator is to handle a gas, charge the dome loading chamber with this gas via the dome needle valve and the body needle valve (fig. 15-15). If the regulator is to handle a liquid, charge the dome from an external source. Remove the plug on the dome loading chamber and connect the external source. This may be an air bottle or an air pump. Keep the body needle valve closed while you use the dome needle valve to adjust the dome pressure to obtain the desired outlet pressure.

HYDRAULIC CONTROL VALVES

Hydraulic control valves are used in many shipboard systems. On some ships, they are installed in the sections of firemain that supply water to the magazine sprinkling systems. This type of valve may be operated from one or more remote control stations by a hydraulic control system.

The hydraulic control valve shown in figure 15-16 is a piston-operated globe valve. It is normally held in the closed position by both a spring force and by the firemain pressure acting against the disk. When hydraulic pressure is admitted to the underside of the piston, a force is created that overcomes both the spring tension and the firemain pressure, thereby causing the valve to open.

When hydraulic pressure is released from under the piston, the spring acts to force the hydraulic fluid out of the cylinder and back to the remote control station, thus closing the valve.

A ratchet lever is fitted to the valve to allow the emergency opening of the valve by hand. After the valve has been opened by hand, you should first restore the stem to its normal CLOSED position with the ratchet lever. Then line up the hydraulic system from a remote control station so that the hydraulic fluid in the valve cylinder can return to the storage tank at the control station. The full force of the closing spring then acts to seat the disk, thereby closing the valve.

The valve shown in figure 15-16 is equipped with a test casting in the body of the valve. The bottom cover

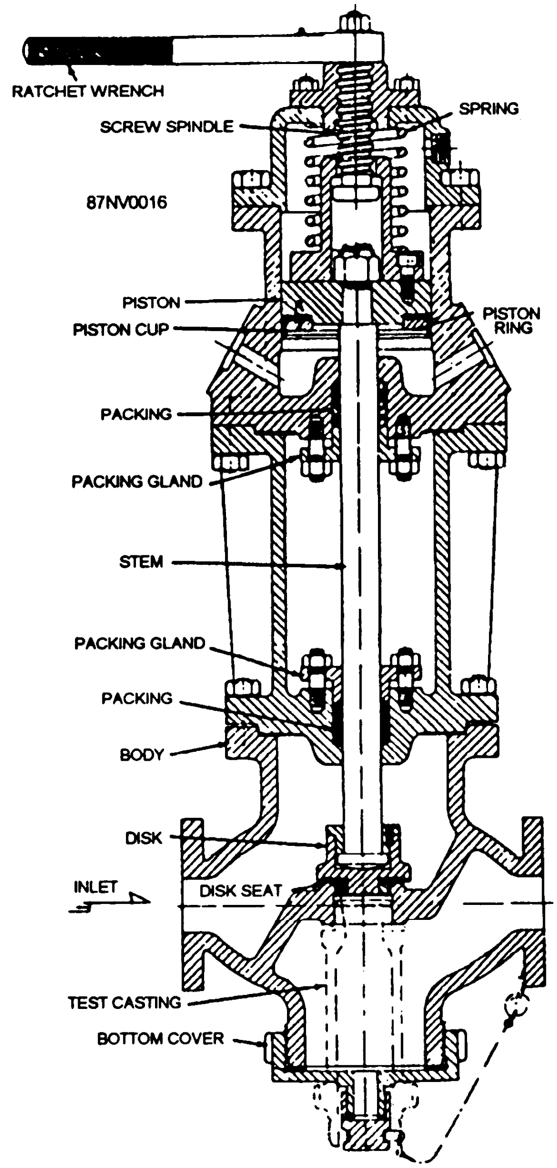


Figure 15-16.—Hydraulic control valve.

can be removed so that you can check the valve for leakage.

TRAPS AND STRAINERS

Traps are used to remove various undesirable materials from piping systems. In air lines, a trap is installed to remove the water that is usually present. In steam lines, traps are installed to remove condensate. Some types of steam traps are suitable for low-pressure use, while others are suitable for high-pressure use. However, any steam trap will consist of a valve and some device or arrangement that will cause the valve to open and close, as necessary to drain the condensate from the lines without allowing steam to escape. The

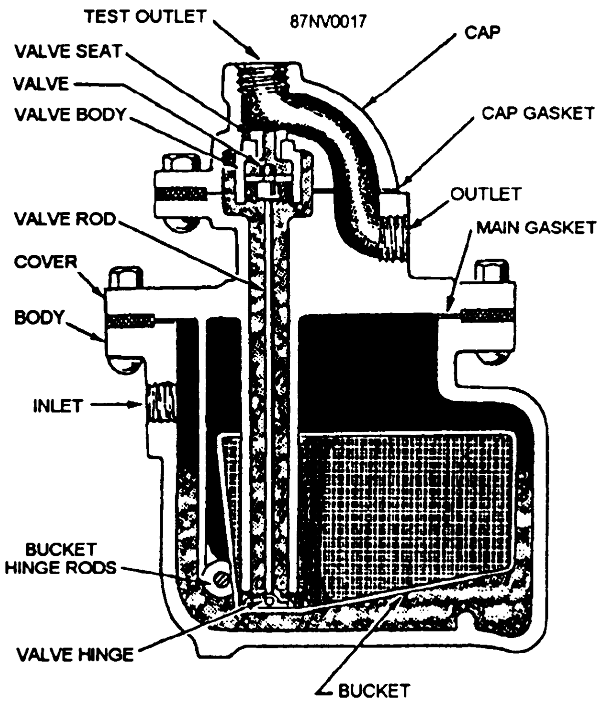


Figure 15-17.—Bucket-type steam trap.

three types of steam traps most commonly used are (1) mechanical, (2) thermostatic, and (3) flash, or impulse. You will be concerned primarily with the mechanical and the thermostatic types.

Mechanical steam traps may be of the ball float type or of the bucket type, which is suitable only for low-pressure use. The bucket-type steam trap (fig. 15-17) is suitable for pressures up to 150 psi. Operation of these traps is regulated by the condensate level in the trap body. The bucket, being buoyant, floats as condensate enters the trap body. The valve is connected to the bucket and therefore closes as the bucket rises. As condensate continues to flow into the trap body, the valve will remain closed until the bucket is filled. When the bucket is filled, it sinks and causes the valve to open. The valve will remain open until enough condensate is blown out to allow the bucket to float, thus closing the valve.

The thermostatic-type steam trap shown in figure 15-18 is often called a bellows-type steam trap. This type of steam trap has fewer moving parts, and is more compact than the mechanical steam traps just described. The bellows-type trap is used only for pressures up to 100 psi. Its operation is controlled by the expansion of vapor from a volatile liquid that is enclosed in a bellows-type element. Steam enters the trap body and heats the volatile liquid in the sealed bellows, which causes the expansion of the bellows. The valve is attached to the bellows, and therefore closes when the bellows expands. The valve remains closed and traps the steam in the trap body. Condensation of the steam then cools the bellows and causes it to contract; the valve then opens and allows the condensate to drain.

Figure 15-19 shows three types of lavatory traps. In views A and B, the P-type lavatory trap is shown with and without a cleanout plug. View C shows the S-type trap specified for shipboard use. This latter type, equipped with cleanout plug, is supplied only in 1 l/2-inch IPS. However, S-type traps without cleanout plugs are available in 1 l/4-inch, 1 l/2-inch, and 2-inch

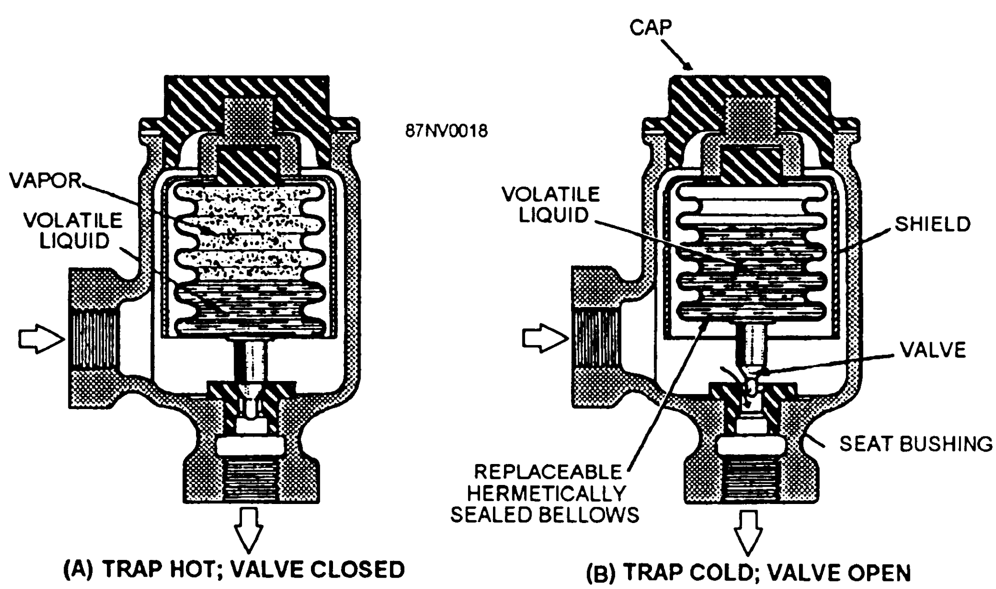


Figure 15-18.—Thermostatic steam trap.

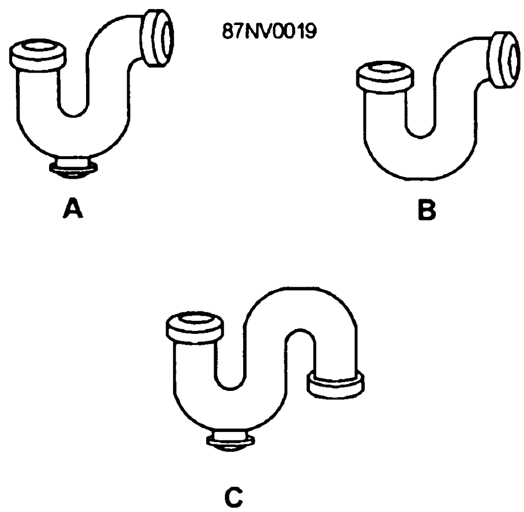


Figure 15-19.—Lavatory traps.

IPS, with inlet sizes of 1 l/4, 1 l/2, 2, or 2 l/2 inches. The 1 l/2-inch inlet trap is the one most commonly used for lavatories. These fittings are made from brass and are usually chrome plated. The lavatory trap acts as a check valve for the drainage system. The water that collects in the trap prevents se wage gases from escaping through the drain into the compartment where the fixture is located.

The deck drains shown in figure 15-20 are made from brass, and have a 2-inch IPS outlet. These types are used in tiled heads and washrooms. At shore stations, however, a combination drain and P-type trap made from cast iron is used extensively. It consists of a drain inlet, a drain outlet, and a P-type trap, all cast in one assembly, and with a clamping ring and a brass strainer disk completing the unit. This type of drain and trap assembly comes in two sizes. One has a 6-inch

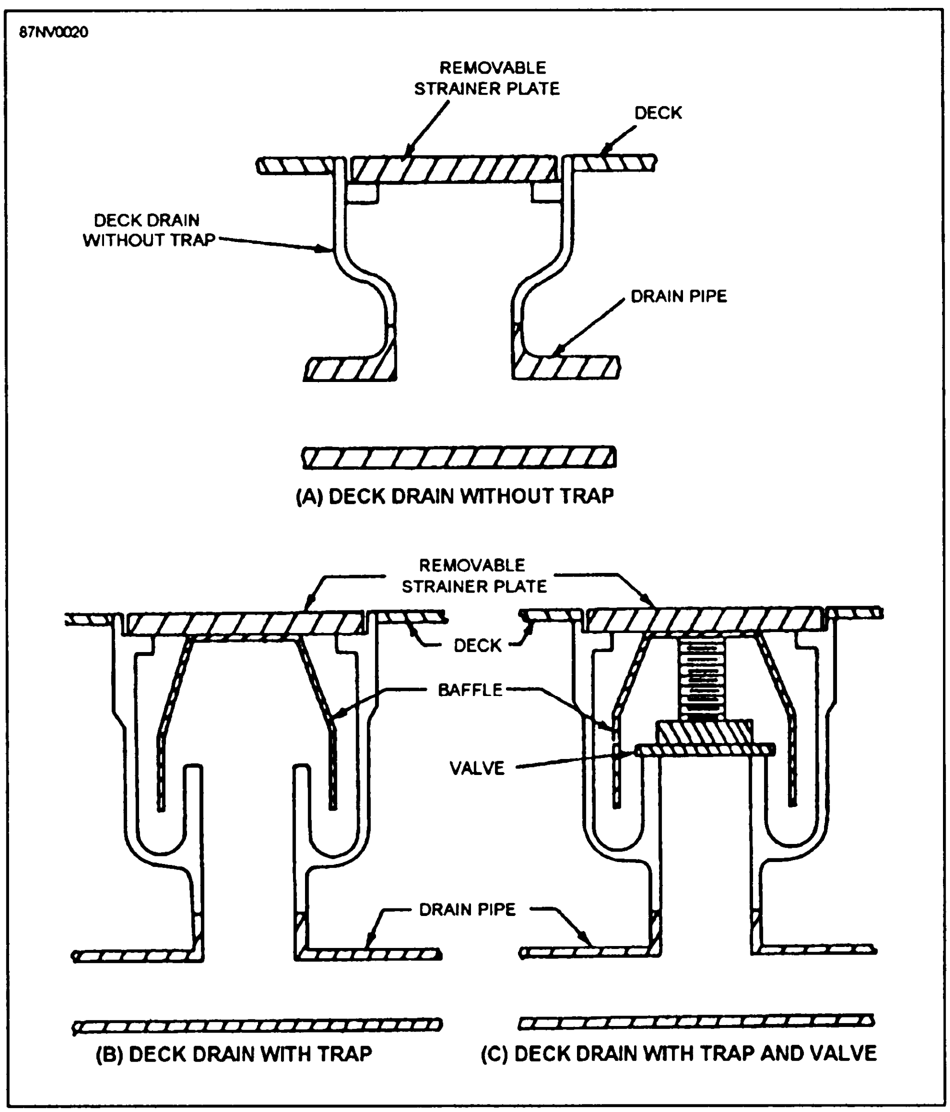


Figure 15-20.—Typical deck drains.

drain inlet and a 2-inch IPS outlet. The other has an 8-inch drain inlet and a 3-inch IPS outlet.

Strainers are located in all piping lines to prevent the passage of foreign matter. They must be installed so that the flow will be through the strainer element. The bilge suction strainer (fig. 15-21) is an example of a basket strainer. Some systems use duplex strainers. The duplex strainers allow the fluid to continue flowing while one of the strainers is removed for cleaning. Therefore, you do not need to secure the system to clean the strainers.

IDENTIFICATION OF VALVES, FITTINGS, FLANGES, AND UNIONS USING THE MANUFACTURERS STANDARDIZATION SOCIETY (MSS) MARKING SYSTEM

Many valves, fittings, flanges, and unions used on naval ships are marked with some sort of identification symbol. Valves and fittings made on board repair ships and tenders, or at naval shipyards are usually marked with symbols indicating the manufacturer (the ship's number or the insignia of the naval shipyard), the size, the pattern number, the melt or casting number, and the material. They may also be marked with the date (year) of manufacture and with an arrow signifying the direction of flow.

Many commercially manufactured valves, fittings, flanges, and unions are identified according to a standard marking system developed by the Manufacturers Standardization Society (MSS) of the

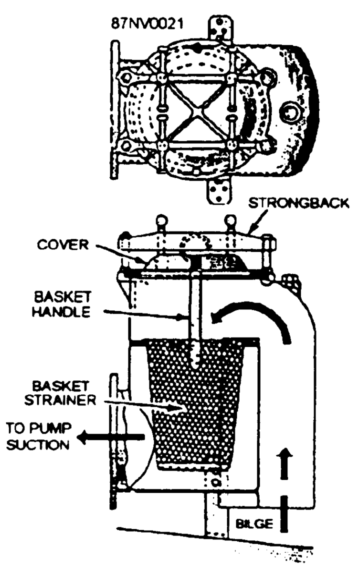


Figure 15-21.—Basket strainer.

valves and fittings industry. A standard identification marking in this system usually includes the manufacturer’s name or trademark, the pressure and service for which the product is intended, and the size (in inches). When appropriate, material identification, limiting temperatures, and other identifying data are included.

The MSS standard identification markings are generally cast, forged, stamped, or etched on the exterior surface of the product. However, in some cases, the markings are applied to an identification plate rather than to the actual surface of the product.

The service designation in the MSS system of marking usually includes a letter to indicate the type of service and numerals to indicate the service pressure rating in pounds per square inch. The letters used in service designations are A (air), G (gas), L (liquid), O (oil), W (water), and D-W-V (drainage, waste, and vent).

When the primary service rating is for steam, and when no other service is indicated, the service designation may consist of numerals only. For example, the number 600 marked on the body of a valve would indicate that the valve is suitable for steam service at 600 psi. If the valve is designed for liquid at 600 psi, the service designation would be 600 L. Service designations are also used in combination; for example, the marking 3000 WOG would indicate a product suitable for water, oil, or gas service at 3000 psi.

In the MSS marking system, the material designation may be either spelled out or abbreviated. Most cast, wrought, or forged steel products are marked with the word STEEL. Malleable iron is identified by the abbreviation MI on newer products. On older products, the abbreviation MAL or MALL is used. Ductile cast iron is identified by the word *DUCTILE* or by the abbreviation DI. Other symbols used for material identification include the following:

AL . . . . Aluminum

B . . . . Bronze

CS . . . . Carbon steel

CI . . . . Cast iron

HF . . . . Cobalt-chromium-tungsten alloy (hard facing)

CU NI . . . . Copper-nickel alloy

NI CU . . . . Nickel-copper alloy

SM	Soft metal (lead, babbitt, copper, and so on)
CR 13	13 percent chromium steel
CR 18	18 percent chromium steel
18 8	18-8 stainless steel
18 8SMO	18-8 stainless steel with molybdenum
18 8SCB	18-8 stainless steel with columbium
SH	Surface-hardened steel (Nitralloy, and so on)

Some examples of the MSS standard identification marking symbols are given in figure 15-22.

Systems may also be identified by their stencils and color codes. You will find information on the requirements for stenciling and color coding of pipes and valves in the *NSTM*, chapter 505, and the *General Specifications for Ships of the United States Navy*, section 507. Table 15-2 gives you the color codes and paint chip numbers, and table 15-3 is a list of the basic color codes for valve handwheels for the systems with which you will be involved.

PACKING AND GASKET MATERIALS

Packing and gasket materials are required to seal joints in steam, water, gas, air, oil, and other lines. They are also used to seal connections that slide or rotate

3-INCH CAST STEEL SCREWED FITTING SUITABLE FOR WATER, OIL, OR GAS SERVICE AT 1000 PSI:

Manufacturer's identification . . . . . . A B CO
Service designation . . . . 1000 WOG
Material designation . . . . STEEL
Size 3

2-INCH CAST IRON FLANGED FITTING FOR USE IN REFRIGERATION SYSTEM:

Manufacturer's identification . . . . . . A B CO
Service designation . . . . 300 GL
Temperature designation . . . . 300°F
Size 2

CAST BRASS FITTING FOR DRAINAGE, WASTE, AND VENT SERVICE:

Manufacturer's identification . . . . . . A B CO
Service designation . . . . D-W-V

2-INCH BRONZE VALVE RECOMMENDED BY THE MANUFACTURER FOR 200 PSI STEAM SERVICE:

Manufacturer's identification . . . . . . A B CO
Service designation 200
Size 2

4-INCH STEEL VALVE WITH 13 PERCENT CHROMIUM STEEL VALVE STEM, DISK, AND SEAT, SUITABLE FOR 1500 PSI STEAM SERVICE AT TEMPERATURE OF NO MORE THAN 850°F:

VALVE BODY MARRING:
Manufacturer's identification . . . . A B CO
Service designation 1500
Material designation . . . . STEEL
Size . . . .
IDENTIFICATION PLATE MARRING:
Manufacturer's identification . . . . A B CO
Service designation 1500
Limiting temperature . . . . MAX 850°F
Body material designation . . . . STEEL
Valve stem material designation . . . . STEM CR 13
Valve disk material designation . . . . DISC CR 13
Valve seat material designation . . . . SEAT CR 13
Size 4

Figure 15-22.—Examples of MSS standard identification markings for valves, fittings, flanges, and unions.

Table 15-2.—Color Codes for Valves and Piping

Fluid	Valve Handwheel and Operating Lever	FED STD 595 Color Number and chip
Steam and Steam Drams	white	17886
Potable Water	Dark Blue	15044
Nitrogen	Light Gray	16376
HP Air	Dark Gray	16081
LP Air	Tan	10324
Oxygen	Light Green	14449
Seawater (other than firemain, sprinkling, and washdown)	Dark Green	14062
JP-5	Purple	17141
Fuel Oil	Yellow	13538
Lube oil	Striped Yellow/Black	13538/17038
Fire Plugs	Red	11105
Foam Discharge Plugs (AFF)	Striped Red/Green	11105/14062
Gasoline	Yellow	13538
Feedwater	Light Blue	15200
Hydraulic	Grange	12246
Freon	Dark Purple	17100
Hydrogen	Chartreuse	23814
Amine	Brown	10080
Helium	Buff	10371
Helium/Oxygen	Striped Buff/Green	10371/14449
Sewage	Gold	17043
HALON	Striped Gray/White	16187/17886
Firemain (including root valves)	Red	11105
AFFF	Striped Red/Green	11105/14062

* Applies to valves on weather decks and interior piping only.

Table 15-3.—Color Codes for Valve Handwheels

Valve Handwheels	Color Code
Access fittings	Black
Fresh water	Blue
Firefighting equipment	Red
Freon and lithium bromide	Purple
Fuel and lube oil	Yellow
High-pressure air	Standard gray (dark)
Hydraulic	Grange
Hydrogen	Yellow-green (chartreuse)
Low-pressure air and salvage air	Tan
Moroethanolamine	Brown
Nitrogen	French gray (light)
Oxygen	Light green
Saltwater	Green
Steam	White

under operating conditions. There are many commercial types and forms of packing and gasket material. The Navy has simplified the selection of packing and gasket materials commonly used in naval service. The Naval Sea Systems Command has prepared a packing and gasket chart (Mechanical Standard Drawing B0153, Rev 9). This chart shows the symbol numbers and the recommended applications of all types and kinds of packing and gasket materials. A copy of the chart should be located in all engineering spaces.

A four-digit symbol number identifies each type of packing and gasket. The first digit indicates the class of service with respect to fixed and moving joints. For example, if the first digit is 1, it indicates a moving joint (moving rods, shafts, valve stems, and so forth). If the first digit is 2, it indicates a fixed joint (such as a flange or a bonnet). The second digit indicates the material of which the packing or gasket is primarily composed. This may be asbestos, vegetable fiber, rubber, metal, and so on. The third and fourth digits indicate the different styles or forms of the packing or gaskets made from the material.

Practically all shipboard packing and gasket problems can be solved if the correct material is selected from the listings on the packing and gasket chart.

CAUTION

NEVER use low-pressure packing in place of high-pressure packing; however, some high-pressure packing may be used to repack low-pressure steam valves.

The following examples show the kind of information you can get from the packing and gasket chart.

Suppose you are required to repack and install a valve in a 300-psi saturated steam line. By referring to the packing and gasket chart, you will find several materials that are suitable for repacking the valve:

Symbol 1103	Asbestos rod, braided, plain
Symbol 1104	Asbestos rod, braided, wire insertion
Symbol 1430	Metallic, flexible

Notice that the first digit is 1 in each case, to indicate that the packing is suitable for a moving joint.

To install a valve, you will need suitable gaskets. In this case, the first digit will be 2, indicating that the gasket material is suitable for fixed joints. By referring to the packing and gasket chart, you will find that you can use any of the following gasket materials:

Symbol 2150	Asbestos, sheet, compressed
Symbol 2151	Asbestos, metallic, cloth sheet
Symbol 2410	Gasket, metallic, asbestos, spiral wound

In addition to the standard packing and gasket chart, most ships have a packing and gasket chart made up specifically for that ship. The shipboard chart shows the symbol numbers and the sizes of packing and gaskets required in the ship's piping systems, machinery, and hull fittings.

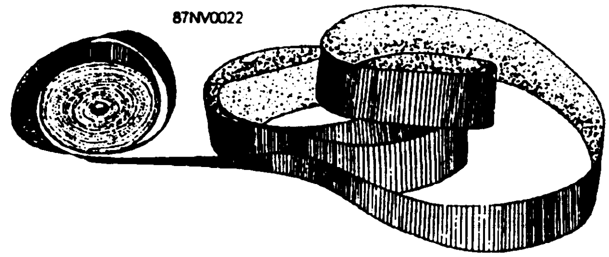


Figure 15-23.—Corrugated ribbon packing.

PACKING

Corrugated ribbon packing (CRP) is a relatively new packing material; it is a 100 percent graphite material expressly suited for installation in steam, feed, and condensate valves. CRP (fig. 15-23) contains no binders, resins, fillers, lubricants, or other additives. It has the lubricating quality typical of pure graphite with the capability for rapid heat dissipation, thus reducing wear. Unlike conventional graphite, which is brittle, CRP is flexible and highly resilient. When CRP is formed in a valve stuffing box, it restructures as shown in figure 15-24.

This restructuring capability allows CRP to be wrapped around the valve stem in any size valve stuffing box and to be formed into a ring by compression. It forms a solid endless packing ring when it is compressed.

CRP is easily cut to a predetermined length. It does not turn rock hard or shrink at any temperature. Once installed and after run-in, it normally needs no further adjustment. This means that maintenance is greatly reduced. The resiliency and no-lint structure of CRP remain unchanged at any temperature. There is no lubricant or additive to be squeezed out, vaporized, or carbonized. Also, it has a long shelf and service life.

WARNING

CRP conducts electricity. Identification and warning stickers must be clearly visible on all containers to assure prevention of its use for electrical insulation.

Use CRP with anti-extrusion rings made of graphite filament yarn (GFY) packing. Install the rings at the bottom (first ring) and at the top (last ring) of every stuffing box. Set the GFY to prevent the CRP from being forced out of the stuffing box (extruded) through

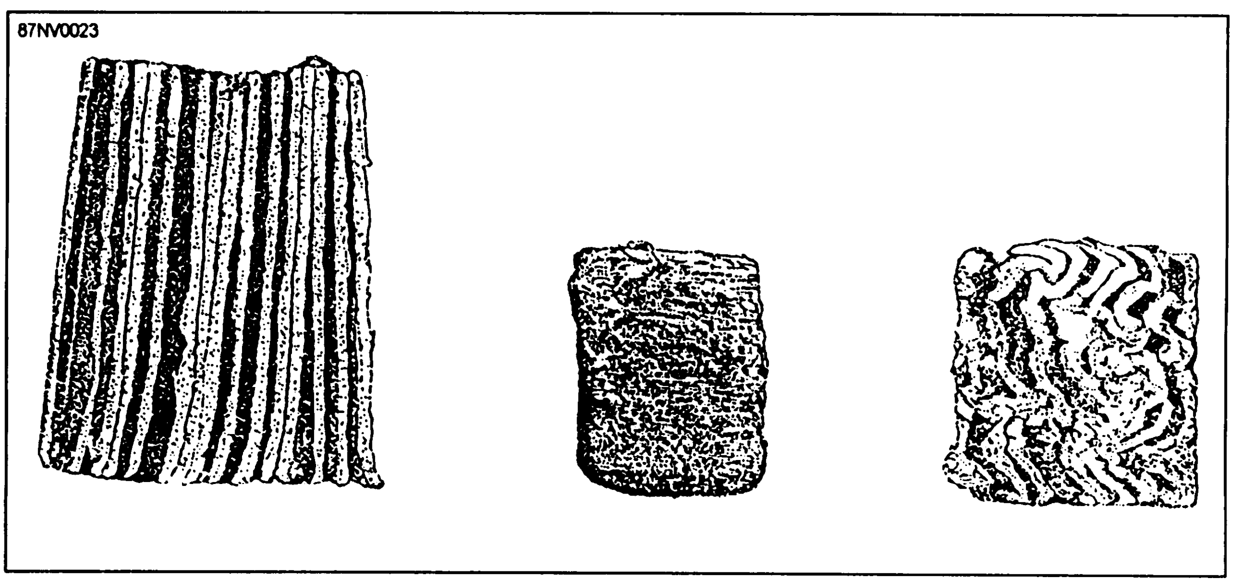


Figure 15-24.—Sectional views of corrugated ribbon packing after restructuring.

stem-stuffing, stem-gland, and gland-stuffing box clearances.

If GFY is not available, you can install a ring of conventional packing as anti-extrusion rings. However, the use must be temporary. At the earliest opportunity, disassemble, inspect, and repack the valve using GFY anti-extrusion rings with CRP.

GFY packing, figure 15-25, is a severe service packing ideal for use in difficult fluid-handling applications. It is unaffected by the most destructive corrosive fluid substances. It will withstand extreme temperatures of over 1000°F encountered in valve stuffing boxes. GFY packing is self-lubricating. It has exceptional heat dissipation characteristics. This allows tight packing adjustment to make leakage almost nonexistent. It also provides maximum protection against stem scoring. This packing greatly reduces system fluid loss, maintenance, and downtime to provide longer, trouble-free valve life. GFY is available in sizes from l/8 inch to 1 inch square on spools.

NOTE: Regardless of how good the packing material may be, if the surface of the shaft passing through the stuffing box is scored or damaged in any way, the packing will not last long. When replacing packing, carefully inspect the shaft in the area where it passes through the stuffing box. Inspect the interior of the stuffing box itself. Take whatever steps you can to ensure that the packing will make contact with the straightest, smoothest possible surface. (You may have to have the shaft repaired and refinished, or replaced.)

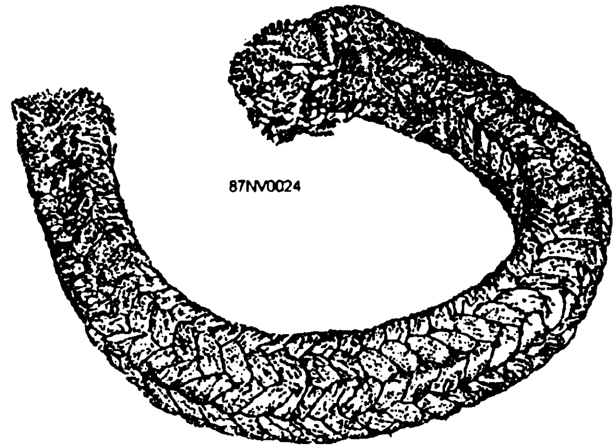


Figure 15-25.—Graphite filament yarn.

GASKETS

At one time, fixed steam joints could be satisfactorily sealed with gaskets of compressed asbestos sheet packing (fig. 15-26, view A). However,

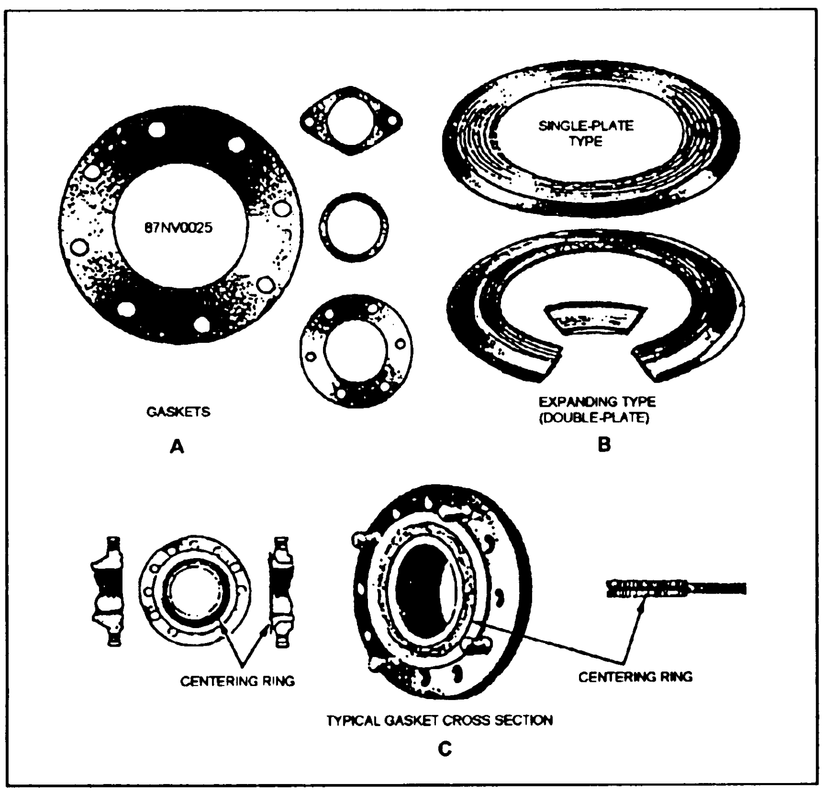


Figure 15-26.—Fixed joint gaskets. A. Sheet gaskets. B. Serrated-face metal gasket. C. Spiral-wound metallic gasket.

the 15 percent rubber content of the gasket makes it unsatisfactory for modem high-temperature steam equipment. Gaskets of corrugated copper or of asbestos and copper are sometimes used on low- and medium-pressure lines. The serrated-face metal gasket (view B) and the spiral-wound metallic gasket (view C) are used in present-day high-temperature, high-pressure installations.

Plain Full-Faced Gaskets

When cutting a plain full-faced gasket from compressed gasket sheet, lay an appropriate size piece of the gasket sheet on the flange. Scribe in the bolt holes and flange circle lines with light blows of a ball peen hammer. Using a gasket punch, about l/16 inch larger in diameter than the bolts, cut the bolt holes into the gasket material Use a piece of hardwood as the supporting and backing surface for the material while punching it to prevent damage to the lips of the punch. After the holes have been punched, use shears or a sharp knife to cut the center and outside circles to form the ring.

Serrated-Face Metal Gasket

Serrated-face metal gaskets (fig. 15-26, view B) are made of steel, Monel, or soft iron. They have raised serrations to make a better seal at the piping flange joints. These gaskets have resiliency; line pressure tends to force the serrated faces tighter against the adjoining flange. Two variations of serrated-face metal gaskets are shown: the single-plate type and the expanding type (double-plate).

Spiral-Wound Metallic Gaskets

Spiral-wound metallic gaskets (fig. 15-26, view C) are made of two parts. The first is interlocked piles of preformed corrugated metal and paper strips, spirally wound, called a filler. The second is a solid metal outer or centering ring, sometimes called a retaining ring. The filler piece is replaceable. When renewing a gasket, remove the filler piece from the retaining metal ring and replace it with a new refill. Do not discard the solid metal retaining outer ring unless it is damaged. Then place the gasket into a retainer or centering ring. The solid steel centering also acts as reinforcement to prevent blowouts. The gaskets can be compressed to the thickness of the centering ring.

Precautions

When renewing a gasket in a flanged joint, use special precautions. When breaking the joint, particularly in steam and hot water lines, or in saltwater lines that have a possibility of direct connection with the sea, be sure of the following conditions:

1. There is no pressure on the line.
2. The line pressure valves, including the bypass valves, are firmly secured, wired closed, and tagged.
3. The line is completely drained.
4. At least two flange-securing bolts and nuts diametrically opposite remain in place until the others are removed. These bolts are then slackened to allow breaking of the joint. They are removed after the line is clear.
5. Precautions are taken to prevent explosions or fire when breaking joints of flammable liquid lines.
6. Proper ventilation is ensured before joints are broken in closed compartments.

These precautions may prevent serious explosions, severe scalding of personnel, or flooding of compartments. Thoroughly clean all scaling and bearing surfaces for the gasket replacement. Then check the gasket seats with a surface plate. Scrape as necessary to ensure uniform contact. Replace all damaged bolt studs and nuts. In flanged joints that have raised faces, the edges of gaskets may extend beyond the edge of the raised face.

PACKING PRECAUTIONS

Observe the following general precautions with regard to the use of packing:

1. Do NOT use metallic or semimetallic packing on bronze or brass shafts, rods, plungers, or sleeves. If these materials are used, scoring may result. Use a braided packing that is lubricated throughout. Or, use a nonmetallic plastic packing in the center of the box with an end ring of the braided packing at each end of the box.
2. Do NOT use a packing frictioned with rubber or synthetic rubber of any kind on rotary or centrifugal shafts. Such packing will overheat.
3. Do NOT use braid-over-braid packing on rotary or centrifugal shafts. The outer layer will wear

through quickly and eventually the packing will become rags.

4. Do NOT use packing with a rubber binder on rotary-type compressors. It will swell and bind, thereby developing excessive frictional heat. The use of flexible metallic packing is recommended. Or, you may use a lead-base plastic packing alternated with the flexible metallic packing.

5. On hydraulic lifts, rams, and accumulators, use a V-type packing or O-ring. For water, this packing should be frictioned with crude, reclaimed, or synthetic rubber. For oils, the packing should be frictioned with oil-resistant synthetic rubber.

6. Do NOT use a plastic packing, such as symbol 1433 or 1439, alone on worn equipment or out-of-line rods; it will not hold. Use a combination of 1433 with end rings of plain braided asbestos (1103) or flexible metallic packing (1430). These will be satisfactory for temporary service until defective parts can be repaired or replaced.

7. Do NOT use a soft packing against thick or sticky liquids or against liquids having solid particles. This packing is too soft to hold back liquids, such as cold boiler fuel oil, and it usually gets torn. Some of the solid particles may be suspended in these liquids. They will embed themselves in the soft packing. These particles then act as an abrasive on the rod or shaft. Flexible metallic packing is best for these conditions.

INSULATION

The purpose of insulation is to retard the transfer of heat FROM piping that is hotter than the surrounding atmosphere or TO piping that is cooler than the surrounding atmosphere. Insulation helps to maintain the desired temperatures in all systems. In addition, it prevents sweating of piping that carries cool or cold fluids. Insulation also protects personnel from being burned by hot surfaces. Piping insulation is the composite piping covering that consists of the insulating material, lagging, and fastening. The insulating material offers resistance to the flow of heat. The lagging, usually of painted canvas, is the protective and confining covering placed over the insulating material. The fastening attaches the insulating material to the piping and to the lagging.

Insulation covers a wide range of temperatures. They range from the extremely low temperatures of the refrigerating plants to the very high temperatures of the ship's boilers. No one material could possibly be used to meet all the conditions with the same efficiency.

The following quality requirements for the various insulating materials are taken into consideration by the Navy in the standardization of these materials:

- Low heat conductivity
- Noncombustibility
- Lightweight material
- Easy molding and installation capability
- Moisture repellent
- Noncorrosive, insoluble, and chemically inactive
- Composition, structure, and insulating properties unchanged by the temperatures at which it is to be used
- Once installed, it should not cluster, become lumpy, disintegrate or build up in masses from vibration
- Verminproof
- Hygienically safe to handle

Insulating material is available in preformed pipe coverings, blocks, batts, blankets, and felts. *NSTM*, chapter 635, contains all of the insulating materials, along with their application and precautions.

INSULATION AND CEMENTS

The insulating cements are composed of a variety of materials. They differ widely among themselves as to the conductivity, weight, and other physical characteristics. Typical variations are the asbestos cements, diatomaceous cements, and mineral and slag wool cements. These cements are less efficient than other high-temperature insulating materials. However, they are valuable for patchwork emergency repairs and for covering small irregular surfaces, such as valves, flanges, and joints. The cements are also used as a surface finish over block or sheet forms of insulation, to seal joints between the blocks, and to provide a smooth finish over which asbestos or glass cloth lagging may be applied (fig. 15-27).

Removable insulation is usually installed in the following locations:

- Manhole covers, inspection openings, turbine casing flanges, drain plugs, strainer cleanouts, and spectacle flanges

- Flanged pipe joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul

- Valve bonnets of valves larger than 2 inches NPS that operate at 300 psi and above, or at 240°F and above

- All pressure-reducing and pressure-regulating valves, pump pressure governors, and strainer bonnets

A small unit of machinery or equipment, such as an auxiliary turbine, requires a different approach. It would be difficult to install both permanent insulation over the casing and removable and replaceable covers over the casing flanges. Therefore, the entire insulation may be made removable and replaceable. Covers should fit accurately and should project over adjacent permanent insulation.

Observe the following general precautions in the application and maintenance of insulation:

1. Fill and seal all air pockets and cracks. Failure to do this will cause large losses in the effectiveness of the insulation.

2. Seal the ends of the insulation and taper off to a smooth, airtight joint. At joint ends or other points where insulation is liable to damage, use sheet metal lagging. Cuff flanges and joints with 6-inch lagging.

3. Keep moisture out of all insulation work. Moisture is an enemy of heat insulation fully as much as it is of electrical insulation. Any dampness increases the conductivity of all heat-insulating materials.

4. Insulate all hangers and other supports at their point of contact from the pipe or other unit they are supporting. Otherwise, a considerable quantity of heat will be lost via conduction through the support.

5. Keep sheet metal covering bright and unpainted unless the protecting surface has been damaged or has worn off. The radiation from bright-bodied and light-colored objects

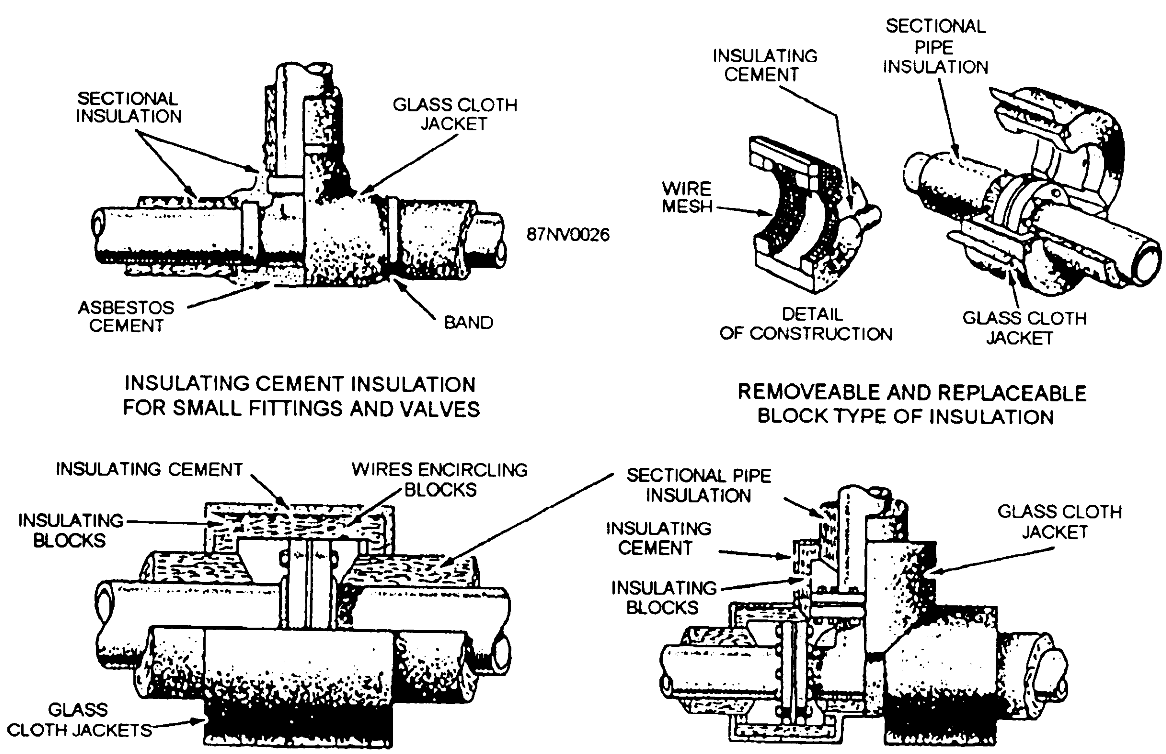


Figure 15-27.—Permanent-type insulation of pipe fittings, flanges, and valves.

is considerably less than from rough and dark-colored objects.

6. Carefully inspect, provide upkeep, and repair heat insulation once it is installed. Replace lagging and insulation removed to make repairs just as carefully as when it was originally installed. When replacing insulation, make certain that the replacement material is the same type that had been used originally.

7. Insulate all flanges with easily removable forms. These can be made up as pads of insulating material, wired or bound in place. The whole can be covered with sheet metal casings that are in halves and easily removed.

The main steam, auxiliary steam, auxiliary exhaust, feedwater, and steam heating piping systems are lagged to hold in the heat. The circulating drainage, fire, and sanitary piping systems are lagged to prevent condensation of moisture on the outside of the piping.

CAUTION

Lagging and insulation should be considered to contain asbestos unless certified not to contain it. Do not rip out asbestos lagging without a respirator or stay in the area of the ripout if you are unprotected. Inhaled asbestos tiller can cause severe lung damage in the form of disabling or fatal fibrosis of the lungs. Asbestos has also been found to be a causal factor in the development of cancer of the membrane lining the chest and abdomen. Lung damage and disease usually develop slowly and often do not become apparent until years after the initial exposure. Ripping out or handling asbestos is restricted to the trained emergency asbestos removal team or an intermediate maintenance activity (IMA). *NSTM*, chapter 635, and chapter B1 of OPNAVINST 5100.19B, *NAVOSH Program Manual for Forces Afloat*, include asbestos removal precautions and procedures.

PIPING SYSTEMS

Piping systems aboard ship are used to carry steam, salt water, fresh water, fuel oil, lubricating oil, gasoline, air, and many other fluids. All piping systems serve the same basic purpose, to transfer fluids from one place to another. An individual piping system may be used strictly for one type of fluid, or it may be used for several different types of fluids at separate times.

As a Hull Maintenance Technician, you will require some knowledge of most of the piping systems on board ship. The rest of this chapter will present some general information on the properties and characteristics of fluids and a general description of the most common piping systems on board ship.

GENERAL CHARACTERISTICS OF FLUIDS

The term *fluid* includes liquids, gases, and vapors. Fluids have no shape of their own. They will quickly conform to the shape of the container they are in, and they are easily pumped through piping systems.

Both gases and vapors are gaseous substances, but they differ in the ease with which they can be liquified. If a large change in pressure or temperature is required to liquefy a substance, it is called a gas. If a relatively small change in pressure, or temperature, changes a substance to a liquid, the substance is called a vapor. Air is an example of a gas. Steam is normally considered a vapor. When steam is superheated, however, it may be considered a gas rather than a vapor.

There are considerable variations in the properties of the liquids, gases, and vapors carried by shipboard piping systems. Some of these properties will be discussed briefly in the following paragraphs.

The property of compressibility is the main basis by which different liquids are distinguished from each other, and also by which gases are distinguished from vapors. It is almost impossible to compress liquids, but gases and vapors can be compressed rather easily. When a force is applied to a confined liquid, the liquid will act almost like a solid by transmitting a force equally in all directions. This example will show that water is not easily compressed: If a force of 15 pounds of pressure is applied to 1 cubic inch of water, the volume of the water will decrease only l/20,000 of what it was. Other liquids have similar resistance to compression. A liquid's resistance to compression is the characteristic that allows the transmission of applied forces in all hydraulic systems. At the same time, the ease with which gases and vapors may be compressed is the characteristic that makes them useful in various compressed gas systems.

The specific weight of a substance is the weight of that substance per unit volume. For most shipboard fluids, specific weight is expressed in pounds per cubic foot.

The specific volume of a substance is the volume that is occupied by a unit weight of the substance. For most shipboard fluids, the specific volume is expressed in cubic feet per pound.

The specific gravity of a substance is the ratio between the weight of that substance and the weight of a standard substance where both are measured under standard conditions of pressure and temperature. For solids and liquids, the standard substance used for comparison is pure water. Pure water has a specific gravity of 1. Therefore, a substance lighter than water will have a specific gravity that is less than 1. At the same time, a substance heavier than water will have a specific gravity that is greater than 1. Specific gravity is an important property for most petroleum products. As a rule, the specific gravity of petroleum products is expressed in degrees API, according to a scale established by the American Petroleum Institute using the hydrometer scale reading.

The viscosity of a fluid is a measure of its resistance to flow. A fluid has a high viscosity if it flows sluggishly. An example is cold molasses. A fluid that flows freely, like water, has a low viscosity. Gases and vapors have lower viscosities than liquids. The viscosity of liquids will vary a great deal. In general, fuel oils and lubricating oils have high viscosities. Raising the temperature of a fluid will lower the viscosity, while lowering the temperature will raise the viscosity.

The viscosity index of an oil is a number that indicates the effect of temperature changes on the oil's viscosity. An oil that becomes thin at a high temperature and thick at a low temperature has a low viscosity index. An oil that has relatively little change in viscosity with various changes in temperature has a high viscosity index.

The volatility of a liquid refers to the ease with which the liquid will vaporize or evaporate. If a liquid is both volatile and flammable, it must be handled with great care to prevent a fire or explosion. Gasoline is a good example of a liquid that is both volatile and flammable.

The operating conditions of a piping system are important because they have a definite effect on the fluid carried by the system. Pressure and temperature determine the physical state of a substance; that is, whether it is solid, liquid, or gas. Pressure and temperature also have definite effects on the specific weight, specific volume, viscosity, volatility, and other properties of the fluid.

The flashpoint of a liquid is the temperature at which the liquid gives off enough vapors to ignite momentarily, or flash, when a flame is applied. A hydraulic fluid with a high flashpoint is desirable because of its resistance to combustion and low degree of evaporation at normal temperatures.

The fire point of a liquid is the temperature at which a liquid gives off enough vapors to ignite and continue to bum when exposed to a spark or flame. A desirable hydraulic fluid requires a high tire point as well as a high flashpoint.

You will find more information on the characteristics of fluids in *Fluid Power,* NAVEDTRA 12964.

PIPING SYSTEM DESIGN

You should have some knowledge of the principles used to design and lay out piping systems. The information given in this chapter is general in nature. Detailed information can be found in contract specifications and in NAVSEA plans and drawings.

All shipboard piping systems have some corrosion caused by the fluids they carry, which act upon the metal of the pipe. You can minimize internal corrosion by using piping material that will resist the corroding effect of the fluid being carried. You can prevent external corrosion if you keep the outer surfaces dry and properly painted (except for brass and copper pipe).

The design, material, dimensional allowances, installation procedures, and safety codes for piping systems are governed by military standards and specifications. The following sections deal with some important aspects of piping system design.

PIPE SIZE

The size of pipe to be used in a system is based on the pressure drop as determined by the available pressure and the flow requirements of the system. The velocity used in the calculations usually is left to the judgment of the designer. However, special operating considerations may place limitations on the allowable velocity. For example, the velocity of seawater is restricted to a maximum of 15 feet per second to minimize the effect of erosion. Table 15-4 lists acceptable water velocities and flows used in piping system designs.

Table 15-4.—Volume Rate of Flow for Water (Not Feed)

NOMINAL PIPING SIZE *(inches)*	THICKNESS *(inches)*	INTERNAL DIAMETER *(inches)*	ALLOWABLE VELOCITIES *(feet per minute)*	VOLUME OF FLOW *(gallons per minute)*
314	0.065	0.920	210	7.26
1	0.065	1.185	270	15.47
1-1/4	0.065	1.530	343	32.76
1-112	0.065	1.770	403	51.51
2	0.065	2.245	500	102.82
2-1/2	0.072	2.73 1	592	178.48
3	0.083	3.334	685	3 10.66
3-1/2	0.095	3.810	753	445.97
4	0.109	4.282	803	600.72
5	0.134	5.295	860	983.52
6	0.156	6.313	887	1,442.16

The minimum thicknesses of pipe and tubing are determined by the stresses on the material. These stresses will vary with the difference in operating temperatures and pressures. A manufacturing tolerance is added to obtain a nominal wall thickness and to compensate for the decrease of the wall thickness caused by making bends in the pipe or tubing. Piping used to carry seawater will have an extra allowance added to compensate for corrosion. The various military specifications for piping and tubing will also include information on the wall thickness to be used for different applications.

DESIGN REQUIREMENTS

The requirements governing the design and arrangement of shipboard piping systems are covered in detail by contract specifications and by a number of NAVSHIPS plans and drawings. The information given here is not intended as a detailed listing, but merely as a general guide.

All shipboard piping systems must be installed so that they will not interfere with the operation of the ship's machinery or with the various doors, hatches, scuttles, manhole covers, or inspection plates. Also, the piping must not interfere with the maintenance or repairs of the machinery or ship's structure. If there is no way to prevent interference with other piping systems, machinery, or ship's structure, then the piping should be installed so that it can be removed easily for access to the material behind it. The location of cutoff valves, unions, and flanges must be carefully planned. These locations should isolate sections of piping with the least amount of interference to the operations of the rest of the system. Piping that is vital to the ship's propulsion system must not be installed where it would have to be dismantled to allow routine maintenance on machinery or on other systems.

When the type of cutout valve is not specified, select the one that is best suited for the service condition. Sometimes, the pressure drop or turbulent flow characteristics of globe and angle valves will be harmful to the components of the system. In these cases, a gate type is generally installed when no throttling will be required.

Avoid unnecessary high points and low points in piping systems. Where they are unavoidable, install vents, drains, or other devices to ensure proper functioning of the system and of the machinery and equipment served by the system.

Components welded in a piping system must be accessible for repair, reseating, and overhaul while in place. Complex assemblies such as valves, strainers, and traps in high-pressure drain systems must be removable as a group if they require frequent overhauling and cannot be repaired in place.

Valves should be designed so that they can be operated with a minimum amount of force and with maximum convenience. Sometimes you must stand on slippery deck plates to turn a valve handwheel, or you must reach over your head or around a comer. In these situations, you cannot apply the same amount of torque that you could if the handwheel was more conveniently located. Therefore, the location of the handwheels is a very important design consideration. (When possible, valves should be installed in the upright position.) Toggle mechanisms or other mechanical advantage devices must be used where the amount of torque required to turn a handwheel is more than could normally be applied by one person. Keep the mechanical advantage devices well lubricated. If they do not produce easy operation of the valve, then a power operation must be used.

Install locking devices if accidentally opening or closing a valve could endanger personnel or the ship. Any locking device installed on a valve must allow ease of operation and discourage unauthorized personnel from tampering with the valve.

Globe valves may be installed so that the pressure is applied either from the top or the bottom of the disk. The method used will depend on which one is best for operating, protecting, maintaining, and repairing the machinery served by the system. When a continuous flow is required and no harm will result if the disk of a globe valve becomes detached from the stem, the pressure should be below the disk. Where damage is likely to occur if the disk becomes detached from the stem and leaves the valve wide open, the pressure should be above the disk. Check valves must be installed so that the disk will open when the fluid flows in the correct direction, and close if back flow occurs in the line.

Flanged and union joints should be located where they are least affected by pipe line forces caused by thermal expansion or other causes.

Changes in direction of piping should be made by pipe bends and offsets where space permits. Otherwise, straight lengths of pipe and the fittings specified for the system should be used.

DESIGN RESTRICTIONS

Do not pierce decks and bulkheads unless it is absolutely necessary. This is particularly true of main subdivision bulkheads. When piercing is necessary, try to do it close to boundaries of compartments and avoid cutting bulkhead stiffeners, deck beams, and plating butts and seams.

Piping under pressure should be routed around voids, cofferdams, and other nonvented spaces. Bypass inner bottoms, ballast tanks, fuel tanks, freshwater trunks, and voids except when it is necessary to service these units.

Some piping systems other than those serving a tank are permitted to pass through fuel oil or diesel oil tanks. This piping must be of schedule 80 thickness if made of steel, and must have welded joints.

Combustible and flammable liquid piping is to be located at least 18 inches away from surfaces that have temperatures under their insulation greater than 450°F. This temperature limitation can be 650°F for surfaces in the vicinity of lubricating oil piping.

Do not install steam and liquid piping near electrical equipment if at all possible. Any drips or sprays from leaks along with condensation could damage the equipment. If the system has to be installed near electrical equipment, install adequate shielding to protect the equipment. Any flanges or unions in the system are to be installed away from the electrical equipment.

The amount of piping passing through messing and berthing spaces should be kept to a minimum. The piping in such spaces should be symmetrical, neatly arranged, inconspicuous, and should not interfere with the efficient functioning of the system.

Try to keep piping out of medical and dental spaces except where it is necessary to service the equipment in the space.

JOINTS AND CONNECTIONS

Welded joints are currently used whenever possible in carbon steel, alloy steel, and other weldable piping. These welded systems will have several types of valves with flanged connections to allow their removal for repairs. Some of the valves are throttle valves and valves that operate either automatically or semi-automatically, such as safety, relief, regulating, and governing valves. Use pipe bends to keep the number of joints down to a minimum.

EXPANSION JOINTS

Expansion joints must be kept in effective working condition. Indicators are often fitted on expansion joints to show whether or not the joint is functioning properly. Where such indicators are not fitted, a comparison of measurements taken on an expansion joint before and after the system has reached its operating temperature will indicate clearly whether or not the expansion joint is working properly.

Expansion joint bodies must be mounted securely so that the movement is confined only to the part that is supposed to move.

The expansion joint is absolutely necessary for high-temperature steam systems. Metal expands when heated and contracts when cooled. Steam lines are no exception. Unless steps are taken to allow for expansion and contraction, the tremendous stresses in the steam systems will cause failures.

Expansion joints used on board ship include slip joints and various corrugated and bellows-type joints.

Slip joints of the type shown in figure 15-28 are used for some low-pressure piping. A slip joint consists of a stuffing box, a packing gland, a male sliding tube, a female receptacle tube, and stop bolts that prevent separation of the male and female sections of the joint. The stuffing box and the male tube are flanged so that the assembly can be connected to the piping. The packing in the stuffing box is compressed by studs and nuts. The compression of the packing prevents leakage at the joint as the pipe moves in and out for a limited distance.

Slip-type expansion joints were once commonly used in shipboard steam piping systems. These joints are suitable only for low pressures, however, and the increasingly high steam pressures on naval ships has led to the use of other types of expansion joints in most steam systems. Slip-type expansion joints are still being used on many naval ships for steam escape piping systems.

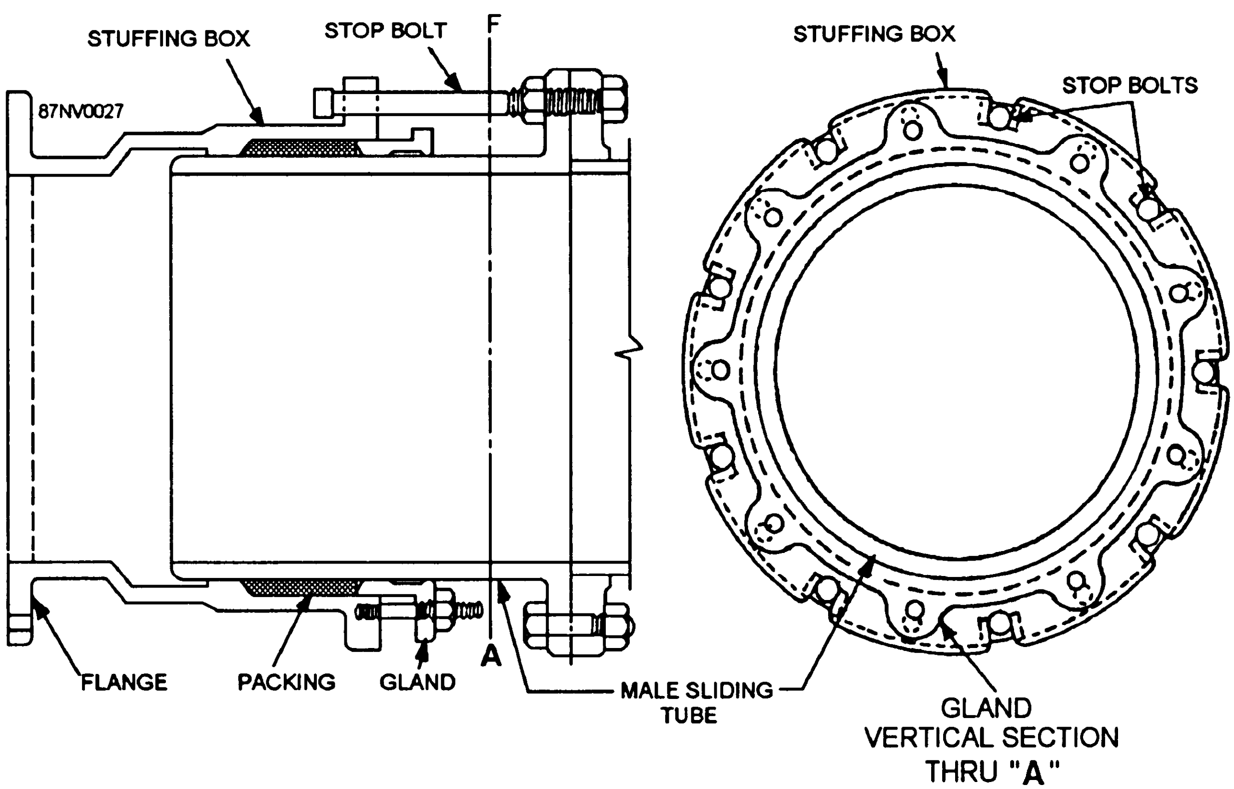


Figure 15-28.—Slip-type expansion joint.

Corrugated and bellows-type expansion joints (fig. 15-29) are used for both medium- and high-pressure piping systems aboard ship. These joints are used to allow both axial and radial movement of main steam piping where it passes through the bulkhead.

Corrugated and bellows-type expansion joints are made of various materials, including hard rubber, copper, nickel, and stainless steel. The accordion-like action of the corrugation or of the bellows allows the system to expand or contract. The movement of the pipe is absorbed by the changing curvature of the corrugations or of the bellows.

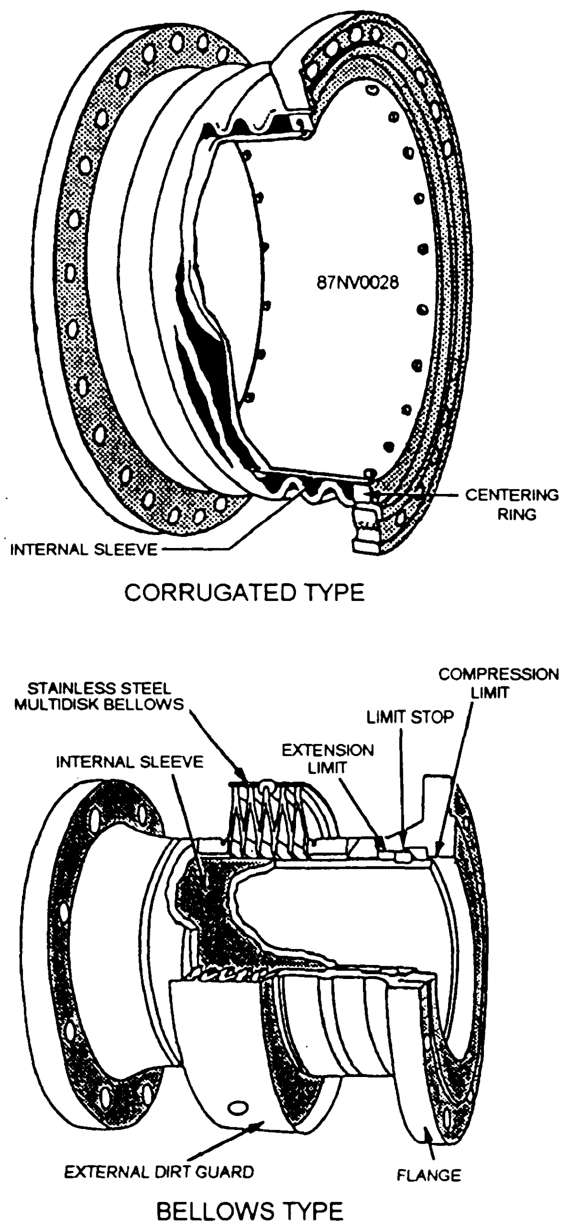


Figure 15-29.—Corrugated and bellows-type expansion joints.

EXPANSION BENDS

Loops, U-shaped bends, and offsets are fitted into piping systems so that the expansion or contraction will be absorbed by the bending in the pipe that forms the bend. Because expansion bends are more reliable and normally less expensive than expansion joints, they are preferred when conditions permit their use. Figure 15-30 shows a common type of expansion loop. Expansion bends and joints can be flexed in both directions from their normal position. They should be installed so that they are stressed in one direction when the piping is cold, and stressed in the other direction when the piping is hot. The amount and direction of the prestress or cold pull-up to be applied to piping and expansion bends or joints is indicated on the appropriate ship's plans. These instructions must be followed carefully to prevent failure of the expansion joints, piping, and connected equipment.

COLD SPRING JOINTS

Another method used to provide for expansion in high-pressure piping is the cold spring joint. The pipe for this joint is cut short an amount usually equal to one half the computed expansion. After the system is fabricated and ready for installation, a dutchman (an accurately machined blank flange), equal in thickness to the required amount of cold spring, is inserted between the flanges of the cold spring joint. When all other connections have been made, the dutchman is removed and the joint set up to about 40,000 psi with temporary pull-up bolts. The temporary bolts are then replaced one by one with permanent installation bolts set up to the required bolt stress.

WELDED AND BRAZED JOINTS

The majority of joints found in subassemblies of piping systems are welded joints, especially in high-pressure piping. The welding is done according to standard specifications that define the materials and

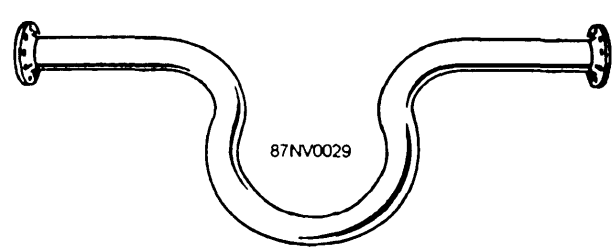


Figure 15-30.—Expansion loop.

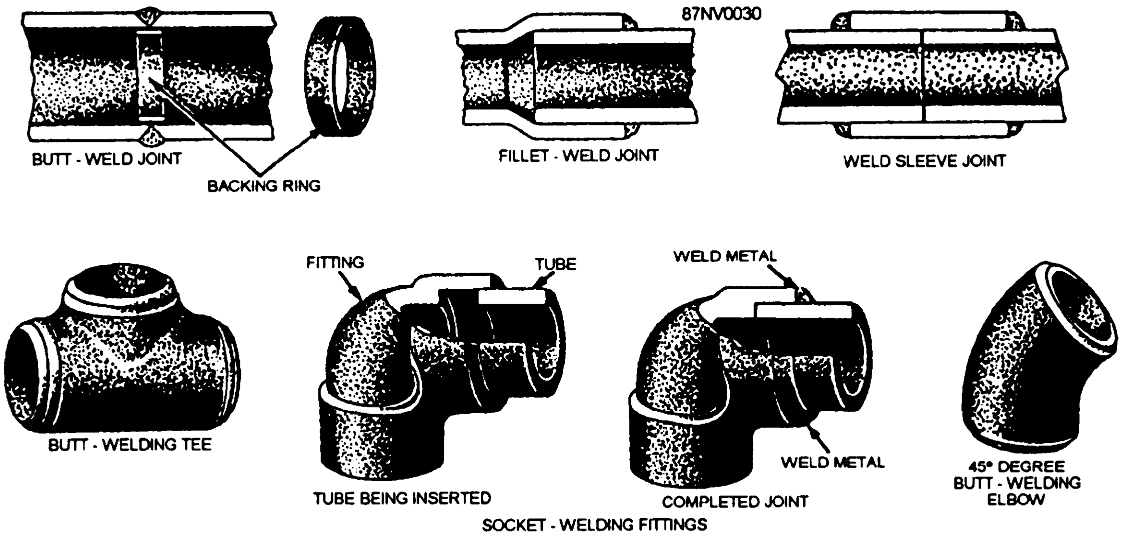


Figure 15-31.—Various types of welded joints.

techniques. There are three general classes of welded joints: butt-weld, fillet-weld, and socket-weld (fig. 15-31).

Welded joints normally permit welding from both sides. If not, backing rings should be used to ensure complete weld penetration.

Brazed joints must have sleeves or sockets. The fittings must have preinserted rings of silver brazing alloy. Also, the welded and brazed joints must meet the requirements established by MIL-STD 22. Examples of silver-brazed joints are shown in figure 15-32.

FLANGED JOINTS

Flanges are installed in piping systems to allow ready removal of piping. This provides for portability of machinery and equipment, access to equipment, and convenience for maintenance. The material and design of flanges are determined by service conditions.

PIPING STRESSES

The selection of piping material, size, and wall thickness was discussed earlier in this chapter. The type of service and flow rates determine material and size. Internal pressure determines wall thickness or strength of piping. If the strength is not to be exceeded, do not subject piping to any unusual stresses, such as would result from misalignment, vibration, improperly adjusted hangers, supporting chain falls, and so on.

THERMAL EXPANSION

All common piping materials will expand when heated and contract when cooled. If piping is confined

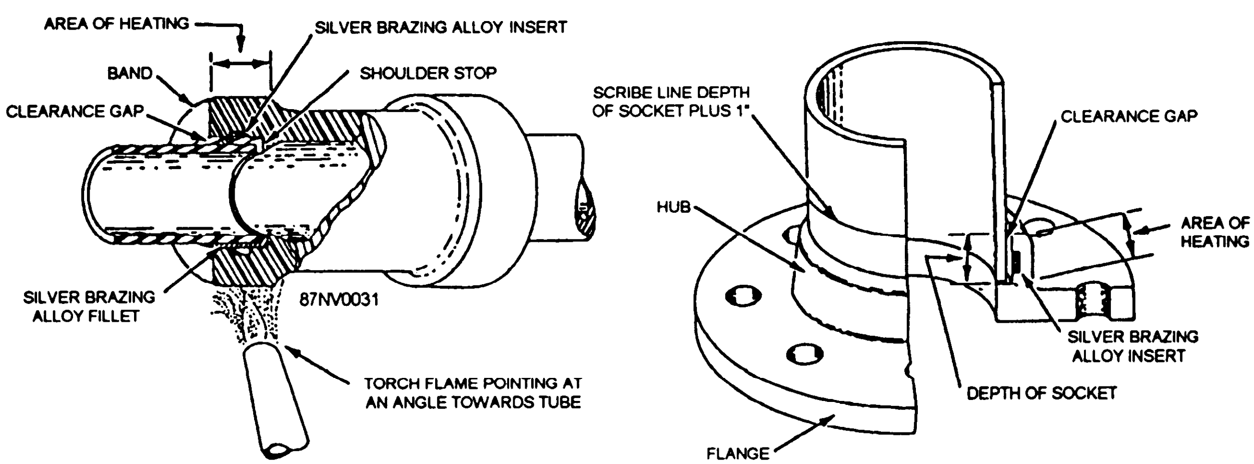


Figure 15-32.—Silver-brazed joints.

so this expansion and contraction cannot take place, large forces are generated. For example, a 40-foot long straight section of 6-inch, schedule 40, carbon-moly steel pipe will elongate about 3 inches when heated from ambient temperature to 454°C (850°F). If the pipe is confined so that expansion (or bending) cannot take place, a force of 870,000 pounds is generated within the piping material. As containment of a force of this magnitude is difficult, the procedure normally used is to allow the expansion or contraction to take place and absorb the motions in expansion bends or expansion joints.

PRESTRESS

Expansion bends and joints can be moved in both directions from their normal position. Install them so they are stressed in one direction when piping is cold, and in the other direction when piping is hot. The appropriate ship drawings indicate the amount and direction of this prestress or rold pullup to be applied to the piping and expansion bends or joints during installation in the cold condition. Carefully follow these instructions to prevent overstressing and possible failure of the expansion joints, piping, and connected equipment.

PIPE HANGERS, SUPPORTS, AND SWAY BRACES

Hangers and supports are used to describe the various devices used to carry the weight of piping systems. Although often used interchangeably and sometimes even together, the term *hanger* more correctly refers to a device that carries the piping weight from above, and the term *support* generally refers to a device that carries the piping weight from below. The term *support* is commonly used, in a broader sense and in this chapter, to include any device that carries the piping weight from above, from below, or even from the side.

Supports are generally arranged so that they carry an equal share of the piping weight so pipe stresses due to bending effects are minimized. When heavy load concentrations, such as vertical runs, valves, and strainers are present, additional supports are provided as close as practical to these items.

Design of supports are either of the rigid (solid) type or resilient type. Rigid types provide significant restraint in at least one direction. Resilient supports include one or more elastic members, such as springs or rubber elements, and are selected to permit limited pipe movements where movement is necessary to avoid overstress due to expansion or contraction of the piping. Rigid supports are generally used in cold piping systems. Cold systems in this context means systems where the fluid temperature does not exceed 120°F. One end is usually bolted or welded to a clamp on the pipe and the other end bolted or welded to the ship structure.

Similar alternate rigid-type designs using pipes and angles instead of flat bars are also commonly used. Since the flat bar is relatively weak in bending in one direction, it is often necessary to use supports incorporating either angles or pipe to provide the necessary rigidity to resist movement of the pipe that would occur due to ship motion or shock forces.

In hot piping systems, because of the movement of the piping due to thermal expansion, it is generally necessary to use resilient supports. In some locations where the pipe movement is small, it is sometimes possible to use rigid style supports. To balance the load between rigid style supports and resilient supports, it is necessary to make rigid types adjustable. Generally this is accomplished by using threaded rods or turnbuckles.

VARIABLE-SPRING PIPE SUPPORTS

Variable-spring supports are generally used in hot piping systems to carry the weight of the piping while allowing movement of the piping due to thermal expansion. The variable-spring pipe support consists of a heavy enclosed spring, generally attached to the pipe, using an adjustable rod and pipe clamp. The variable springs are marked by the manufacturer with hot and cold load indicator settings. The term *variable* comes from the characteristic of the unit that the force applied to the pipe is directly proportional to the movement of the pipe. The cold setting is calculated by the designer and it facilitates adjusting the spring support with the piping system cold. When the piping system is at its maximum operating temperature, the load indicator should be at the hot setting. Figure 15-33 indicates some applications and examples of this type of support.

CONSTANT SUPPORTS

Constant supports arc also used in hot piping systems and provide a constant supporting force for the piping throughout the expansion and contraction deflection cycle of the piping system. This is done by the use of a heavy encased spring working with a

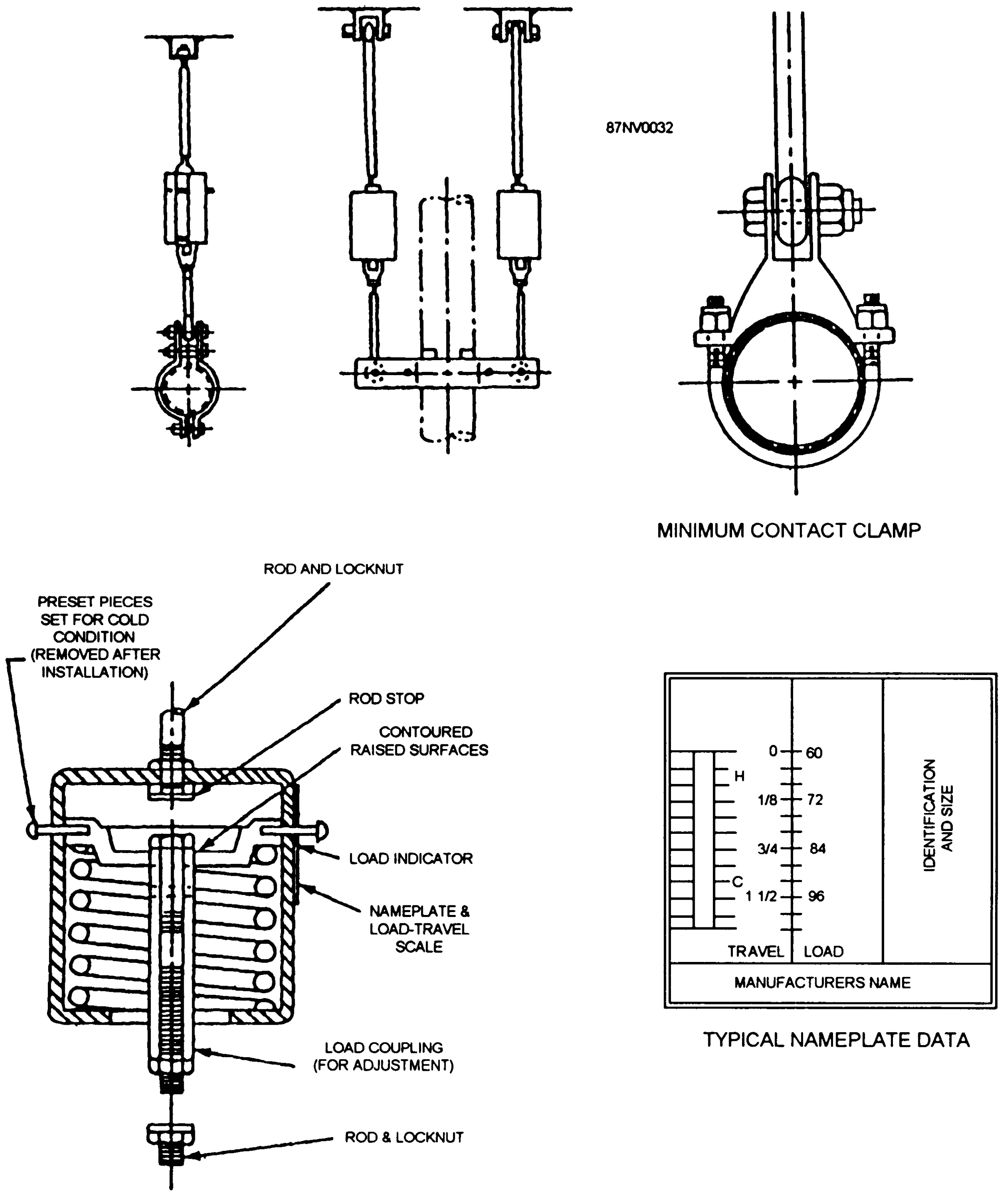


Figure 15-33.—Variable support pipe hangers.

mechanical bell crank lever. The frame portion of the hanger is secured to the ship's structure or foundation, whereas the lever is attached to the spring and to the pipe using an adjustable rod and pipe clamp. This support provides a constant force equal to the pipe weight regardless of the position of the pipe. Because these supports will allow pipe movement without varying the forces applied, they are used where pipe stresses are critical and where it is necessary to avoid transferring any load from the piping to equipment connections or other supports either in the hot or cold condition. Figure 15-34 shows some applications and examples of this type of support.

SWAY BRACES

To prevent swinging motions or vibration of piping or to resist shock or impact loads, anchors (rigid or sway braces, rigid and spring type) are normally installed. Anchors generally consist of structural members welded to the pipe and, in turn, to the ship structure such as a deck or bulkhead.

Sway braces are generally mounted horizontally and are not designed to support the weight of the piping system. Sway braces are adjusted so that no force acts on the pipe in the hot condition but will provide restraint

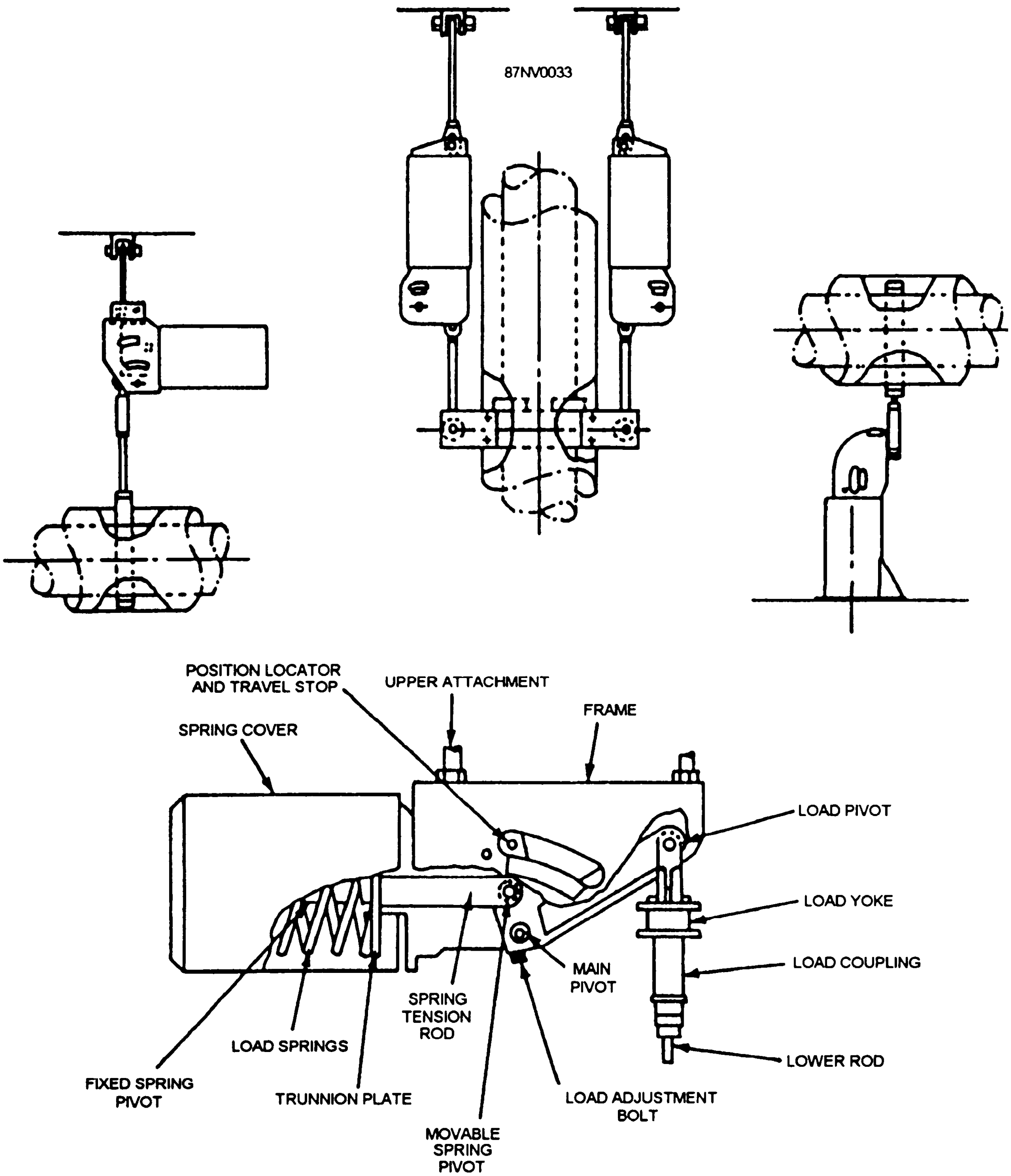


Figure 15-34.—Constant-support pipe hangers.

if any motion of the piping should occur along the axis of the sway brace. Figure 15-35 indicates some applications and examples of braces. As shown on the lower sketch, some old style sway braces are provided with tension test collars used to determine if the spring plates are against the end plates (neutral position) and whether there is clearance between the rod coupling and the spring plate. The tension test collar must be handtight when the piping system is hot, indicating the sway brace is in the desired neutral position.

SHIPBOARD PIPING SYSTEMS

As a Hull Maintenance Technician, you will be chiefly concerned with the maintenance and repair of the freshwater system, firemain system, flushing system, and low-pressure air piping. Therefore, you

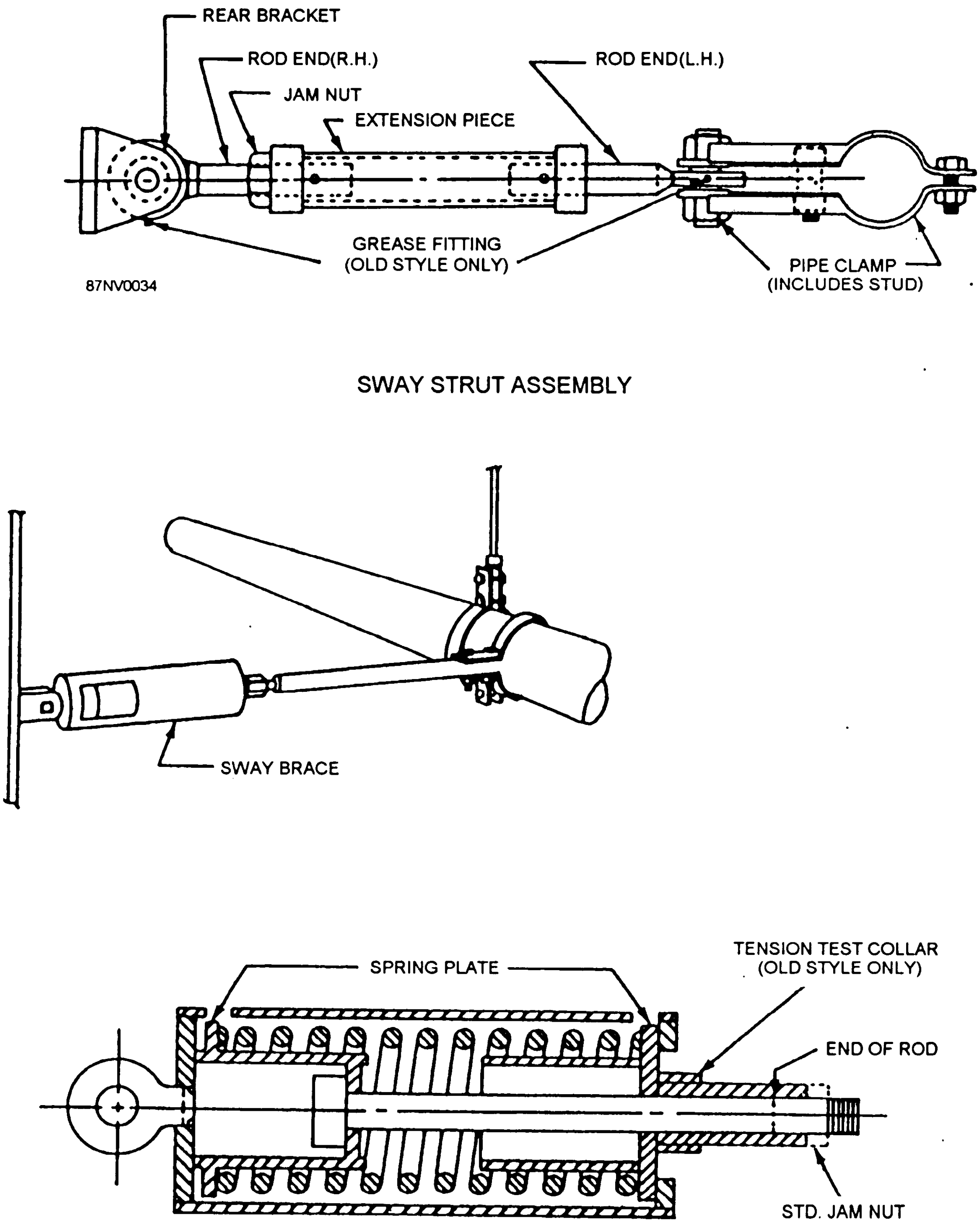


Figure 15-35.—Sway braces (single spring design).

should have a wide knowledge of shipboard piping systems.

Symbols make it easier to show piping systems on paper. These symbols represent the valves and other pieces of equipment. Figure 15-36 shows some of the symbols generally used in engineering plans and diagrams. There may be slight differences on some drawings; but, in general, the symbols will be like those illustrated. These symbols will help you to understand

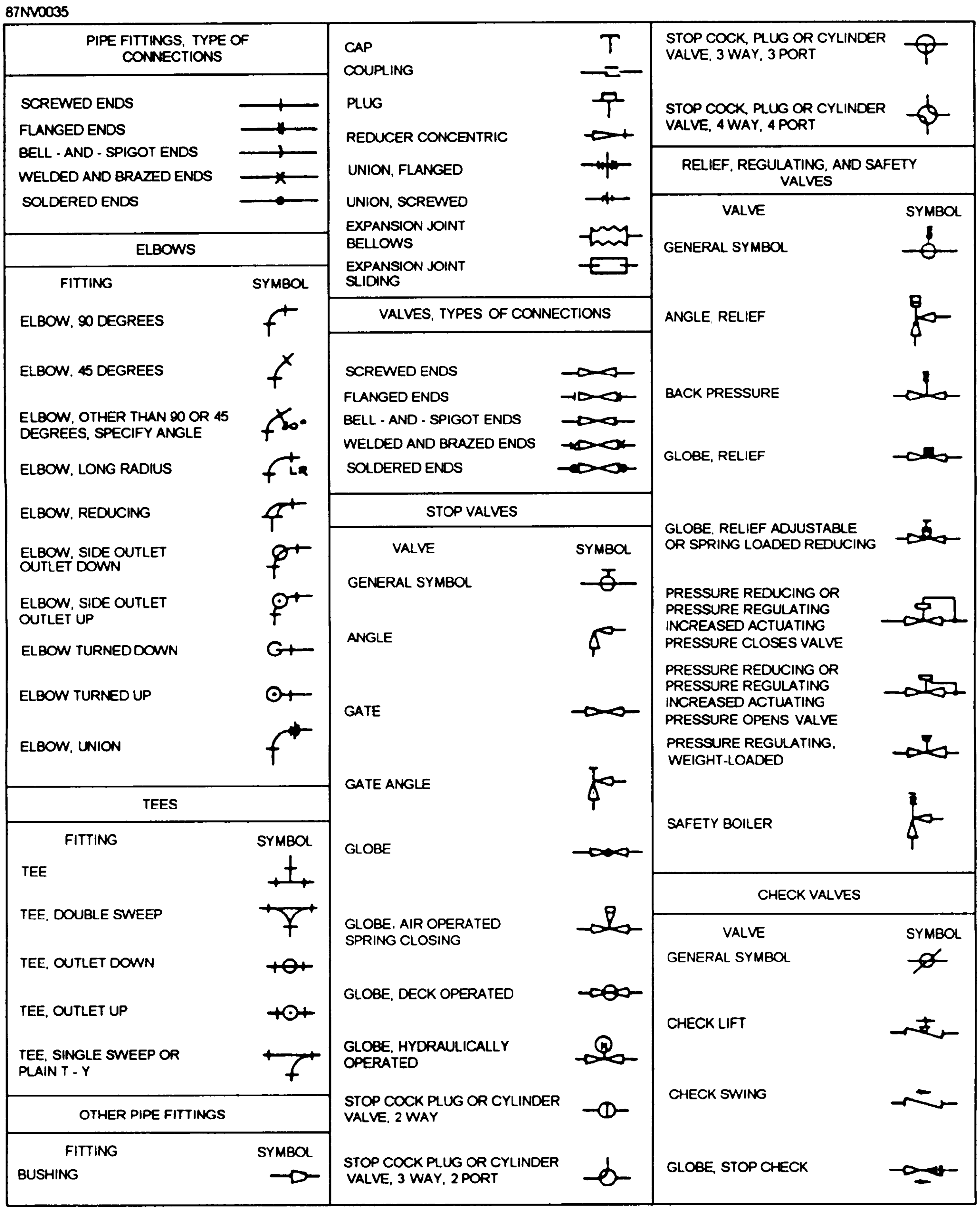


Figure 15-36.—Symbols used in engineering plans and diagrams.

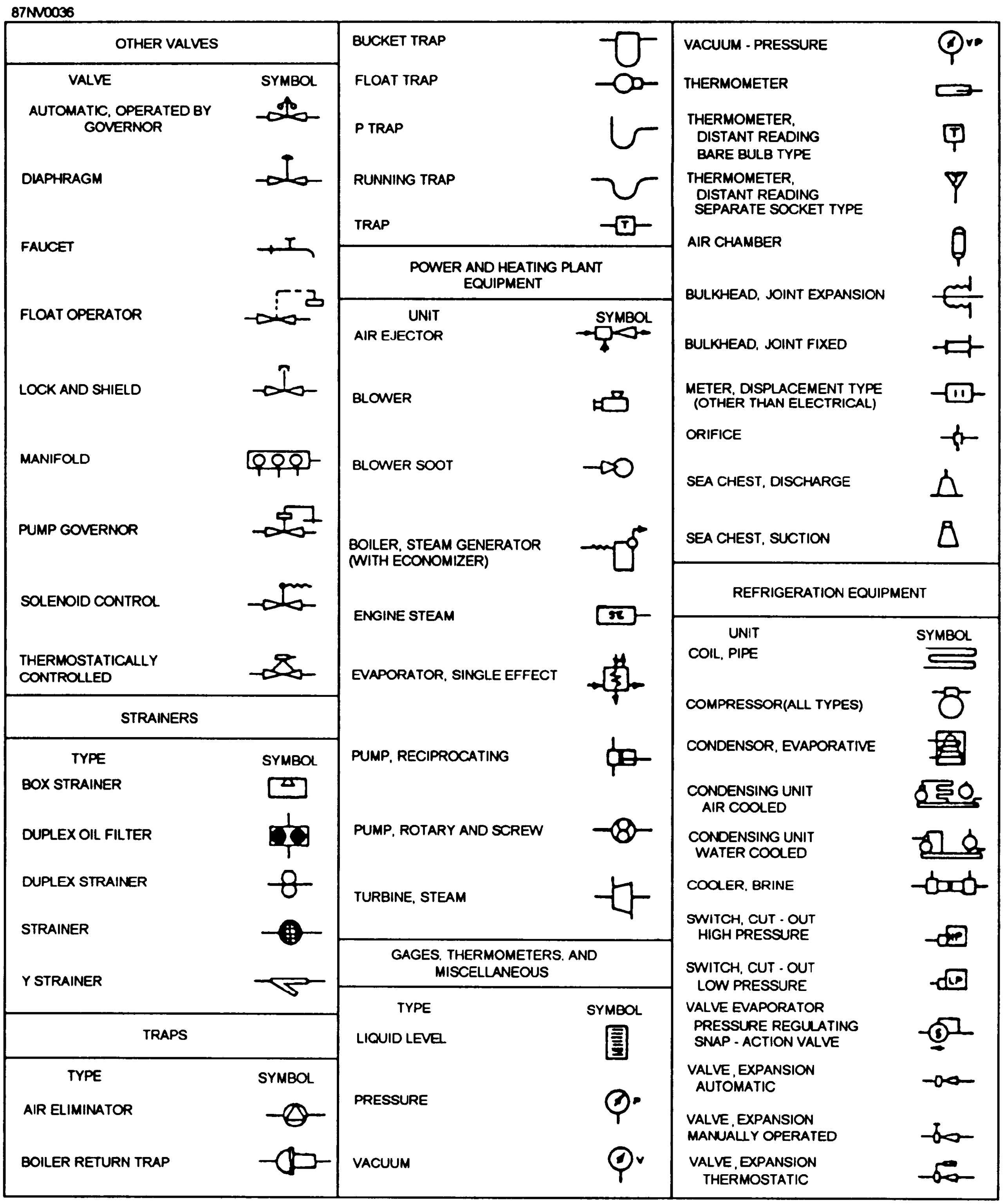


Figure 15-36.—Symbols used in engineering plans and diagrams—Continued.

the plans and diagrams you will study, and to draw your own rough sketches of the systems.

Remember that this chapter only gives general information on the various systems. Each ship is different, even sister ships. Therefore, to actually know your own ship's installation, you must check the details yourself.

STEAM SYSTEMS

Steam forms when water has been sufficiently heated. As heat is applied to a container partially filled with water, the temperature of the water rises until the boiling point is reached. At this temperature, small particles of water change to steam bubbles, which rise through the liquid to the surface and escape from the liquid. Although heat is continually being applied, the temperature of both the water and the steam remains constant at the boiling point until all water in the container has been converted to steam. About five times as much heat is needed to completely convert a given quantity of water to steam at the boiling point without an increase in temperature, as is needed to raise the temperature of the same quantity of water from 32°F to 212°F. The heat required to convert water at the boiling point to saturated steam at the same temperature is called latent heat.

There are two kinds of steam: saturated and superheated. Saturated steam is a vapor; superheated steam is generally considered a gas. As long as steam is in contact with water, it contains moisture in suspension. Steam in this condition and at the boiling point corresponding to its pressure is called saturated steam. Steam at the boiling point, but containing no suspended moisture, is called dry saturated steam. Saturated steam that has been heated to a temperature above the boiling point is called superheated steam.

Main Steam System

The main steam system is a comparatively short system but a very important one. Steam is generated in the boiler, then routed to the propulsion turbines, to the turbogenerators, and to the soot blowers via lines that are made of alloy steel piping. On older ships, flanged joints were used in the main steam system. On newer ships, welded joints are used whenever possible. The flanged takedown joints would be used only where the line goes to major units such as the turbines. The pressures and temperatures maintained in the main steam system are high. Some ships use pressures up to 600 psi and temperatures up to 850°F. Others go as high as 1200 psi and 975°F.

Auxiliary Steam Systems

Auxiliary steam systems are either high pressure or low pressure, depending upon the units that they serve. The high-pressure auxiliary steam system serves fire and bilge pumps, various service pumps, and fuel oil heaters. The piping and tubing is of the same material as that used in the main steam system.

The low-pressure auxiliary steam system is used for steam heat and for air ejectors in the distilling plant and main plant. Seamless steel, copper pipe, or copper tubing is used, and the fittings and flanges are either welded or silver-brazed. The auxiliary steam system is routed in the form of a loop, with cross connections at suitable intervals. Branch lines serve the various units of auxiliary machinery.

Auxiliary Exhaust System

The auxiliary exhaust system receives exhaust from all noncondensing steam-driven auxiliaries and uses this exhaust to supply the deaerating feed tanks (DFTs), the distilling units, and the turbine gland sealing system. The pressure in the auxiliary exhaust system is maintained at 15 psig. If the pressure goes above 15 psig, automatic unloading valves (dumping valves) allow the excess steam to go to either the main condenser or to the auxiliary condenser. If these unloading valves fail, relief valves allow the steam to escape to the atmosphere. If the pressure in the system drops too low, makeup steam is supplied from the auxiliary steam system through an augmenting valve.

Service Steam Systems

Service steam systems are low-pressure systems that serve compartment heating units, galley equipment, freshwater heaters, and laundry equipment. These are either constant service or intermittent service systems. Constant service steam systems are those in use the year around. Intermittent service steam systems are for heating services not required except in cold weather. Constant and intermittent service lines are usually cross-connected. Reducing valves in the branch lines leading from the 150-psi auxiliary steam system make it possible to reduce the steam to a suitable working pressure. Most service steam systems operate at 50 psi. The constant service system for laundry and tailor shop equipment operates at 100 psi.

WATER SYSTEMS

Generally speaking, there are two classes of water: fresh water and seawater. The term *fresh water* is used on board ship to refer to potable water, feedwater, reserve potable water, and reserve feedwater. Potable water is water known to be of drinking water quality. Feedwater is water known to be suitable for use in the ship's boilers.

The principal difference between fresh water and seawater is salinity. This difference leads to many other differences in characteristics. For example, under normal atmospheric pressure fresh water freezes at 32°F and boils at 212°F. Under the same pressure, seawater freezes at 27°F and boils at 213 1/2°F. Seawater and fresh water also differ in specific weight and in specific heat in Btu. (A Btu is the amount of heat required to raise 1 pound of a substance 1°F.) Fresh water is the standard of comparison for specific gravity and specific heat, and therefore has a specific gravity of 1 and a specific heat of 1. These factors will vary with the salinity of seawater. On the average, though, seawater weighs about 64 pounds per cubic foot (specific gravity varies from 1.0043 to 1.0463) compared with 62.4 pounds per cubic foot for pure fresh water. The specific heat of seawater varies from 0.903 to 0.980, depending on salinity.

The properties of water are influenced by temperature and pressure. For example, specific weight and viscosity of water change with temperature. The boiling and freezing points of water vary with pressure. At atmospheric pressure, fresh water boils at 212°F, but at an absolute pressure of 10 psi (equivalent to a vacuum of 9 l/2 inches of mercury) water boils at 193.1°F. At an absolute pressure of 30 psi, the boiling point is 250°F. At an absolute pressure of 900 psi, the boiling point is 531.9°F.

Water exists as a solid, a liquid, and a gas—that is, as ice at low temperatures and as steam at high temperatures. One of the peculiar characteristics of water is that it expands from 8.5 to 10 percent in volume when it freezes, and creates a pressure that would burst most piping and equipment. We have said that the specific weight of fresh water is 62.4 pounds per cubic foot. This is its maximum specific weight. At a temperature above or below 39.1°F, assuming 1 atmosphere pressure, the specific weight of fresh water is less than 62.4 pounds per cubic foot.

Condensate and Feed Systems

The condensate system and the boiler feed system, together, are usually known as the feedwater system. The condensate system includes all the apparatus and piping used to collect and condense steam. The condensate system includes the main and auxiliary condensers, a pump or a combination of pumps, and the piping required to carry the condensate from the condenser to the DFT. The main and auxiliary condensers recover feedwater by condensing exhaust steam from propulsion turbines, generator turbines, and various auxiliary machinery units.

The boiler feedwater system includes the DFT, the feed booster pump, the main feed pump, and the piping required to carry the feedwater from the DFT to the boilers. A small amount of additional water, called makeup feed, is usually required to make up for any loss that occurs in the cycle. This makeup feed is taken from the reserve feedwater tanks. All lines that carry water to the boilers, either from DFTs or the reserve feed tanks, are part of the feedwater system.

Steam and Freshwater Drains

Most of the feedwater in a shipboard steam plant is recovered so that it can be used over and over again for the generation of steam. As steam is condensed in the main and auxiliary condensers, the condensate is returned to the feed system. Also, the steam exhausted from auxiliary machinery is collected in the auxiliary exhaust system and is returned to the feed system. But steam is used throughout the ship in a good deal of machinery, equipment, and piping that does not exhaust either to a condenser or to the auxiliary exhaust system. Therefore, steam and freshwater drain systems are provided so that water can be recovered and put back into the feed system after it has been used (as steam) in fuel oil heaters, distilling plants, steam catapult systems, water heaters, whistles and sirens, and many other units and systems throughout the ship. The systems of piping that carry the water to the feed systems, and also the water carried in the systems, are known as drains.

There are four steam and freshwater drain systems on ships built to Navy specifications: (1) high-pressure steam drainage systems, (2) service steam drainage systems, (3) freshwater drain collecting systems, and (4) contaminated drainage systems. Most drain lines are fitted with steam traps to keep steam from passing into the drain systems. High-pressure drains are generally a mixture of steam and water, even after they have passed through steam traps. All of the other drains are in the form of water after they have passed through steam traps.

HIGH-PRESSURE STEAM DRAINAGE SYSTEM.—High-pressure drains generally include drains from superheater headers, throttle valves, main and auxiliary steam lines, steam catapults (on carriers), and other steam equipment or systems that operate at 150 psi or above. High-pressure drains are returned to the feed system by way of the DFT.

SERVICE STEAM DRAINAGE SYSTEM.—The service steam drainage system collects drains from low-pressure (below 150 psi) steam piping systems and steam equipment outside of the machinery spaces. Space heaters and equipment used in the laundry, the tailor shop, the galley, and the pantry are typical sources of drains for the service steam drainage system. On some ships, these drains discharge into the most convenient freshwater drain collecting tank. On other ships, particularly on large combatant ships such as carriers, the service steam drains discharge to two special steam drain collecting tanks located in the machinery spaces. One is in a forward machinery space, while the other one is in an after machinery space. The drains are then returned from the service steam drain collecting tanks to the feed system.

Note that the service steam drainage system collects only clean drains that are suitable for use as boiler feed. Contaminated service steam drains (such as those from laundry presses) are discharged as authorized.

FRESHWATER DRAIN COLLECTING SYSTEM.—The freshwater drain collecting system (sometimes called the low-pressure drain system) collects drainage from various piping systems, machinery, and equipment that operate at steam pressures of less than 150 psi. As we have seen, both the service steam drainage system and the oil heating drainage system can discharge to the freshwater drain collecting tank. However, they normally discharge more directly to the condensate of the feed system. In general, the freshwater drain collecting system collects gravity drains, turbine gland seal drains, auxiliary exhaust drains, air ejector condenser drains, and a variety of other low-pressure drains that result from the condensation of steam during warming up or operating machinery and piping. Freshwater drains are collected in freshwater drain collecting tanks that are located in the machinery spaces. The contents of these tanks are discharged to the feed system.

CONTAMINATED DRAINAGE SYSTEM.—A contaminated drainage system is installed in each main and auxiliary machinery space where dry bilges must be maintained. The contaminated drainage system collects oil and water from machinery and piping that normally have some leakage, and drainage from any other services that may at times be contaminated. The contaminated drains are collected in a bilge sump tank located in the same machinery space. The contents of the bilge sump tank do not go to the feed system; instead, they are removed by the bilge drainage system.

On recently constructed ships, drains that contain contamination are collected by separate waste water and oily water drain systems. Separating the drains permits discharging waste water drainage as authorized.

Freshwater Systems

Practically all fresh water used aboard ship is made by boiling seawater in the evaporators and condensing the resulting vapor. Fresh potable water is stored in potable water tanks at a distance from the machinery spaces. The water intended for boiler use is stored in feed tanks located in the double bottoms or in wing tanks adjacent to the machinery spaces. The potable water system supplies hot and cold potable water to scuttlebutts, sinks, showers, scullery, sick bay, and the galley. The normal operating pressure is approximately 35 psi. In some ships, water pressure is maintained by automatic electric pumps that take suction on the ship’s potable water storage tanks. Constant pressure is maintained by admitting compressed air to the pressure tank. When there is a decline in tank pressure, the pump starts automatically. In some systems, the potable water pumps discharge directly to the distribution system. The pressure in the system is provided by the continuous operation of a motor-driven centrifugal water pump taking suction from the ship’s tanks. When potable water is supplied to other systems, the supply to the nonpotable system is through an air gap. There should not be any direct cross connection between the potable water system and any other system. An air gap in a water supply system is the unobstructed vertical distance through free atmosphere between the lowest opening from any pipe or faucet supplying water to a tank or plumbing fixture and the flood-level rim of the tank or plumbing fixture. Each hose connection in the potable water system should be provided with a vacuum breaker backflow preventer on the downstream side of the hose control valve.

Some ships use instantaneous coil-type heaters in the hot water system. Other ships are of the circulating type, in which a circulator forces the water to move continuously through the system. This allows hot water to be available at the taps at all times and prevents the waste of potable water. The water is heated in a hot water tank by low-pressure auxiliary steam coils. This system will be secured during battle conditions when each battle dressing station is served by a separate storage tank and a small hot water heater. The water is routed from the tank to the electric water heaters at the stations.

Electronics Cooling Water System

Cooling water systems are now provided on most ships to cool electronics equipment. In this system, fresh water is usually circulated through the electronics equipment to carry away the heat generated during operation. Potable water taken on from shore should not be used to replenish the system. Only distilled water (0.065 equivalents per million (epm) chlorides maximum) should be used for replenishment. Where demineralizers are installed, electronics equipment should not be operated until the water conductivity is at or below the prescribed limit. For specific information on the system, the ship's information book or other sources of ship information should be consulted.

Firemain System

In ships built to Navy specifications, the firemain material must be made of copper-nickel alloy with copper-nickel or bronze fittings and bronze valves. There are, however, a number of older ships with firemain systems made of ferrous materials.

The pumps used to maintain pressure in the firemain system may be steam-driven reciprocating pumps or centrifugal pumps driven by steam turbines, electric motors, or (in some cases) diesel engines. These pumps are classified according to their use as tire pumps; fire and bilge pumps; fire and flushing pumps; or fire, flushing, and drainage pumps. Firemain working pressures vary from 50 psi on small craft to 175 psi on recently built ships.

You must be thoroughly familiar with the location of the firemain, the pumps, the riser piping, the fireplugs, the cross connections, and the principal isolation valves. Study the system aboard your ship by tracing the piping from bow to stern, from deck to deck, compartment by compartment. Then study the blueprints and diagrams of the system, and the information given in the Engineering Casualty Control Book, the Damage Control Book, and the General Information Book for your own ship.

Sprinkling Systems

Sprinkling systems are installed aboard ship in magazine turrets, turret handling rooms, hangar decks, missile spaces, and other spaces where flammable materials are stowed. Water for these systems is supplied from the firemain through branch lines. A gate valve is installed in each branch line, as close to the firemain as practicable, and ahead of the sprinkling control valves. The gate valve is normally kept in the open position by a securing device (NOT a padlock).

Most sprinkling systems aboard ship are of the dry type, that is, they are not charged with water beyond the sprinkling control valves except when they are in use.

Some missile magazines are equipped with a wet type of sprinkling system. These systems are charged with water up to the spray head valves. The sprinkling control valves in some systems are operated automatically, by heat-actuated devices. Others are operated manually or hydraulically, either locally or from remote stations. Figure 15-37 shows a hydraulic oil-operated control system for operating magazine sprinkling control valves. On more recent ships, the sprinkling control valves are actuated by a hydraulic saltwater control system supplied by the firemain system.

In the space being protected, the piping, fitted with spray nozzles, is installed in such a manner that no portion of the installation will form an obstruction to handling or stowing material in the space. On older ships, the piping does not have spray nozzles. Instead, holes are drilled in the upper portion of the distribution piping to permit water to spray on the overhead and bulkheads.

Most piping material used in sprinkling systems is copper-nickel. An exception is the piping grid in dry systems, which is made of aluminum alloy. The operating pressure is the same as that of the firemain.

For more complete details of sprinkling systems, consult your ship's General Information Book and Damage Control Book.

Water Washdown Systems

Water washdown systems are essentially dry pipe sprinkler systems. They have specially designed nozzles that are installed so that they will throw a large spray pattern of water. These systems are installed

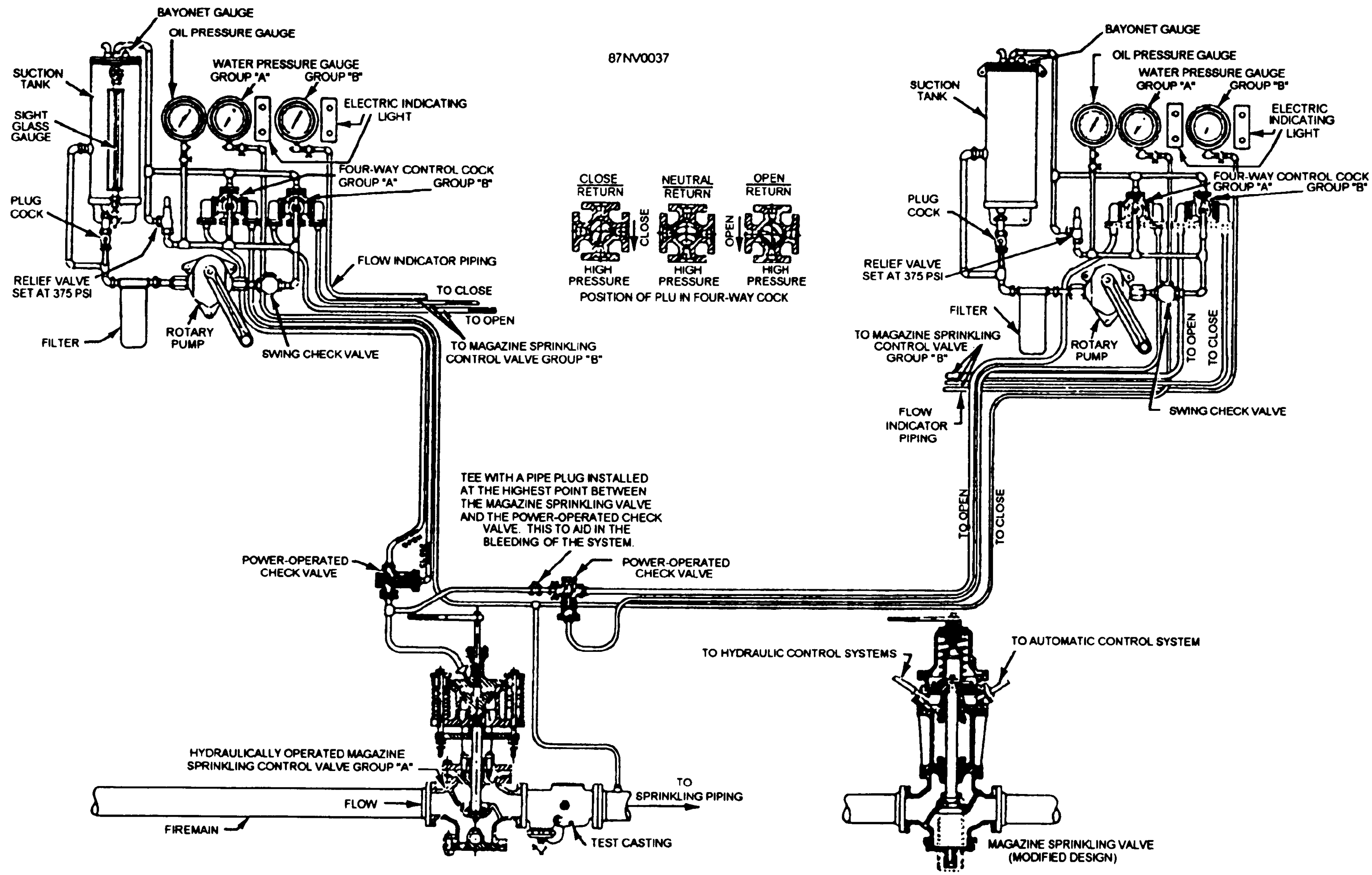


Figure 15-37.—Hydraulic control system for operating magazine sprinkling control valves.

aboard ship to provide a film of flowing water over all of the exterior surfaces of the ship. This flowing film of water prohibits chemical, biological, and radiological (CBR) agents or particles from adhering to the ship's exterior surfaces. For maximum effectiveness, the water washdown system should be activated before a CBR attack.

A permanent washdown system is now installed on any ship under construction or when it enters a shipyard for conversion. If a ship already in service does not have a washdown system, it will receive a kit to be installed by the ship's force as an interim measure. Both types are supplied from the firemain.

The interim water washdown system consists of a number of separate arrays (or pipe lines) connected to topside fireplugs by short sections of firehose, as shown in figure 15-38. Thus, the water washdown system, instead of being a continuous topside piping system, is rather a series of small piping arrays with each array supplied by its individual fireplug.

Each array consists of a series of plastic or aluminum pipes connected together and secured to topside structures. Each array is fitted with appropriately spaced nozzles, and the array and nozzles are arranged to ensure an effective coverage of weather decks by the water washdown spray. In general, each fireplug supplies the washdown nozzle array in its immediate vicinity. A 1 l/2-inch fireplug can supply an eight-nozzle array and a 2 l/2-inch fireplug can supply a maximum of 22 nozzles.

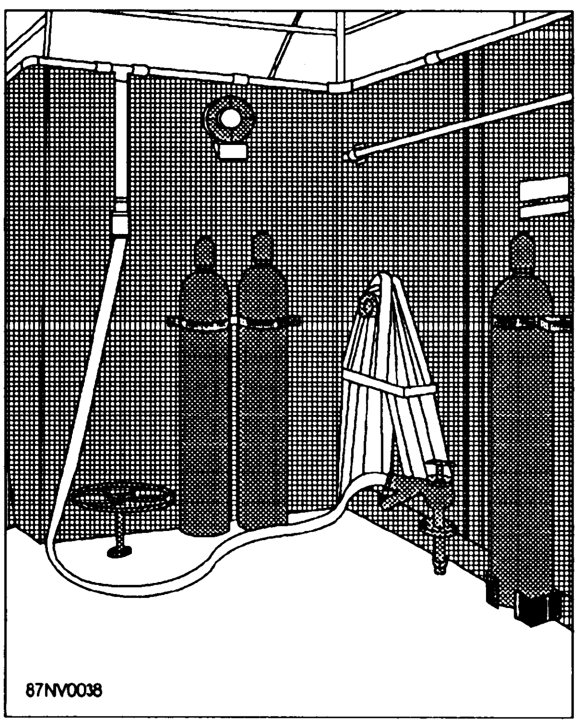


Figure 15-38.—Interim washdown system array connected to a topside fireplug.

In addition to the installed sections of the interim water washdown system, portable manifolds with spaced nozzles are provided to cover areas where fixed installations would be difficult to install or would interfere with normal operations. When not in use, they should be stowed as near their point of use as possible. Figure 15-39 shows a portable manifold stowed while not in use.

In FY-84, the improved water washdown system nozzles of LHSs and DD-963 class destroyers were replaced with NATO nozzles.

Flushing System

The flushing system for commodes and urinals is supplied with seawater either by a branch from the firemain or by a separate sanitary and flushing pump taking suction from the sea. When this system is supplied from the firemain, the branch is taken as near the top portion of the main as possible so that sediment from the firemain will not enter the flushing system. Since the firemain pressure is too high for a flushing system, the water is led through a strainer to a reducing valve, which reduces the pressure to 35 psi.

Air chambers are installed in the flushing system where it runs to urinals and water closets. These air chambers absorb water hammer caused by the quick closing of the flush valves and spring-closing faucets. If it were not for this provision, water hammer might rupture pipes, break joints, and damage valves.

Drainage System

The drainage system aboard ship is divided into two categories: the main and secondary systems, and the plumbing and deck drains. Between them, these systems collect and dispose of all the shipboard waste fluids as authorized. The main drainage system consists of piping installed low in the ship, with suction branches to spaces to be drained and direct connections to eductors or drainage pumps. This system generally serves the main machinery spaces and a few other spaces.

The secondary drainage systems supplement the main drainage system wherever the main system cannot be extended through spaces where piping is prohibited, or because the length of piping would be too great for

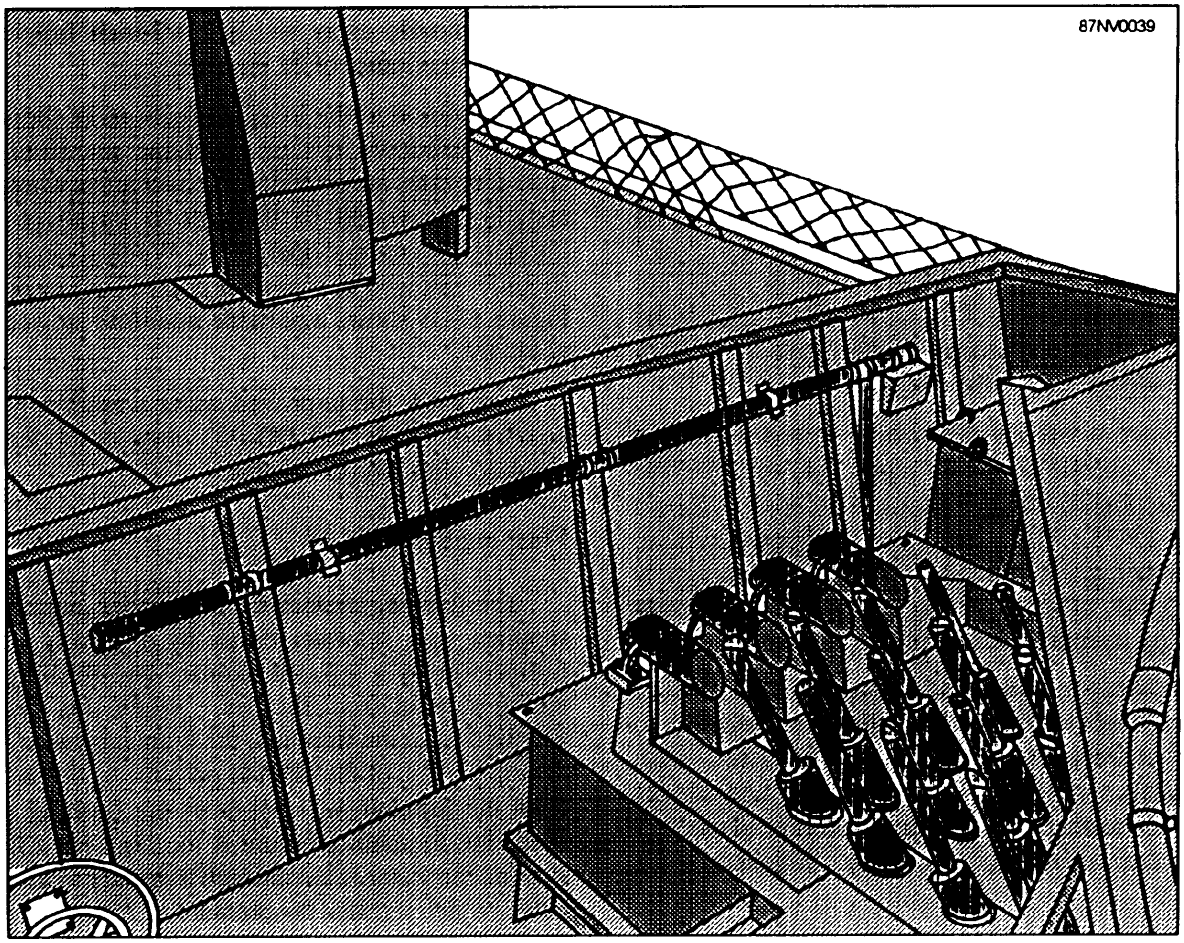


Figure 15-39.—Stowage of portable manifold for interim washdown system.

efficient drainage. Each secondary drainage system is independent of the main drainage system and has its own pumps or eductors and its own disposal connections.

Plumbing and deck drains are classified according to their type; either as soil or sanitary waste drainage. Drains from water closets, urinals, and similar fixtures flushed with seawater are soil drams. Most of the other plumbing drains are waste drams.

Since shipboard flushing systems use salt water, the soil drainage piping is usually of a copper-nickel alloy. This prevents the rapid deterioration caused by the corrosive effect of the salt water. The joints in copper-nickel piping are silver-brazed. The sanitary waste drains are usually made up of brass or copper.

All plumbing drainage systems must be vented. A vent line prevents the siphonage of traps and allows sewer gas to escape. As long as a system is properly vented, the air required for drainage is taken in through the vent line instead of through the drain receptacle of the fixture, and proper drainage of the trap will result.

FUEL OIL SYSTEMS

Naval ships now use a fuel oil known as fuel, naval distillate as their primary fuel. This fuel oil meets the requirements of specification MIL-F-16884. Other NATO countries have similar, if not identical, naval shipboard fuel specifications. Therefore, the NATO code number F-76 was assigned to the fuel, naval distillate.

The use of F-76 has increased the amount of time between fireside cleanings. Cleaning can be extended from one overhaul to the next, with periodic inspections held during the operational period. Fireroom maintenance and topside maintenance is reduced, while the reliability of the equipment has increased.

Therefore, the amount of time that the ships are available for operations has been increased significantly.

For the latest information concerning F-76, characteristics, handling, and testing, consult current technical manuals, instructions, directives, and notices, along with *NSTM*, chapter 541.

All fuel oil comes from petroleum. Crude petroleum consists of a number of different hydrocarbons-that is, compounds of hydrogen and carbon. Crude petroleum quite often contains traces of sulfur, nitrogen, oxygen, and other impurities.

Fuel oil itself is nonexplosive, difficult to ignite in bulk, and not capable of spontaneous combustion. Its vapors, however, form an explosive mixture with the oxygen in the atmosphere. The vapor is heavier than air and tends to collect in bilges and tank bottoms. Fuel oil vapor is always present in partially filed tanks or empty tanks from which the vapor has not been removed. Since this vapor is highly flammable, safety precautions must be continuously observed to prevent a fire or explosion.

The fuel oil system is arranged to allow the transfer of fuel oil from fueling connections to storage tanks, from storage tanks to service tanks, and from service tanks to the burners at the boiler. It also allows the transfer of fuel oil from one storage tank to another. These transfers are made with pumps, manifolds, and sometimes sluice valves, which permit gravity flow from one storage tank to another.

The filling and transfer system usually consists of two large lines, one on each side of the ship, running forward and aft. Cross-connections join these mains to the fuel oil booster and transfer pumps. Risers are provided fore and aft for taking on or delivering fuel.

The fuel oil service system consists of a service main, manifolds, fuel oil service pumps, meters, heaters, strainers, burner manifolds, the burner lines, and the burners at the boiler fronts.

LUBRICATING OIL SYSTEMS

The lubricating oil system supplies clean, cool oil to machinery bearing surfaces. Lube oil is routed from the filling connection to the storage or sump tank located within the engine room. From this tank it is pumped through a series of strainers and coolers to the bearing surfaces. Used oil is routed to a settling tank, then through purifiers, and back to the sump tank. The pressures to be carried at the various parts of the lubricating system differ with the type of installation.

HYDRAULIC SYSTEMS

Hydraulic systems work on the principle that liquids are noncompressible. Therefore, pressure or force exerted at any point on an enclosed liquid is transmitted equally in all directions. Hydraulic systems operate remote control valves for flooding, counter-flooding, and ballasting. Other examples of the transmission of power aboard ship by hydraulics are the operation of the steering gear, small hydraulic presses in the shop, and hydraulically operated pipe benders. The design and arrangement of the cylinders, pistons, pumps, reservoir fluid tanks, and piping that make up a hydraulic system permit a great deal of work with little effort on the part of shipboard personnel.

A satisfactory liquid for a particular hydraulic installation must have chemical stability, freedom from acidity, lubricating power, rust inhibiting qualities, a high flash point, a pour point well below minimum operating temperature, and a high viscosity index. If a hydraulic fluid did not possess chemical stability, operating the system for considerable periods at high temperatures would result in the formation of sludges, gums, and carbon deposits. These deposits, in turn, would clog openings, cause valves and pistons to stick or leak, and give poor lubrication to the moving parts. In petroleum-based fluids, chemical stability is improved by the use of chemicals called additives or inhibitors. Such chemicals are also used to attain freedom from acidity, improve lubricating power, improve the viscosity index, and lower the pour point.

A satisfactory fluid for a given hydraulic system must have enough body to give a good seat at pumps, valves, and pistons; but must not be so thick that it offers excessive resistance to flow. In other words, the viscosity of the fluid must be suitable for the system in question.

The medium used to transmit and distribute forces in hydraulic systems may be a petroleum-base product (hydraulic oil) or the recently approved pure phosphate ester fluid. Phosphate ester fluid is more fire resistant and explosion resistant than the petroleum-base oil used exclusively in hydraulic systems for many years. Phosphate ester fluid is now used in aircraft carrier elevators, surface ship missile systems, jet blast deflectors, seaplane servicing booms, high-pressure submarine systems, and for all new construction and conversion surface ships in which the hydraulic systems operate at pressures above 500 psi. Hydraulic systems may operate at pressures as high as 3000 psi. Those with maximum design pressures in excess of 300 psi may be fabricated from stainless steel tubing or from the copper or steel used for lower pressure systems.

GASOLINE SYSTEMS

Gasoline is a highly volatile mixture of liquid hydrocarbons. It is used as a fuel for internal combustion engines in aircraft, automotive equipment, and various other applications. Gasoline vapor, when combined with air in the proper proportions, forms an explosive mixture which can be set off by a slight spark or flame. Gasoline vapor is heavier than air. Therefore, it tends to collect at the bottom of storage spaces or it may travel along an air current a considerable distance. If the vapor is then ignited, it flashes back to the source, causing an explosion. If liquid gasoline is present along with the vapor, the explosion is followed by fire. The volatility of gasoline is demonstrated by the fact that one quart of uncovered gasoline upon complete evaporation will mix with 520 cubic feet of air to form an explosive mixture. This amount of air is normally contained in a space 10 by 6 l/2 by 8 feet. Air can absorb 28 percent gasoline vapor at normal atmospheric pressure. However, an explosive mixture exists only when the percentage of gasoline vapor in the air is between 1.4 and 2.5 percent.

Remember that gasoline is not only a potential source of an explosive mixture, but is also a toxic hazard. Keep it away from your skin, and do not inhale the vapors. Do not smoke or use naked lights in the vicinity of gasoline.

Remember also that a leaktight gasoline piping system is essential to the safety of your ship. To ensure that gasoline piping systems are leaktight, inspect all joints and valves frequently. Always use nonsparking tools when you are repairing gasoline piping systems.

Some ships have a gasoline system designed to prevent explosions resulting from the ignition of gasoline vapor during the fueling of aircraft and small boats. This system may be either an inert-gas blanket system or a saltwater displacement system. In the first type, inert gas is admitted to the storage tank and forms a blanket over the gasoline, thus preventing the formation of an explosive vapor. In the second type, the storage tank is first filled with salt water so that all air is excluded. Then gasoline is pumped into the tank, forcing a corresponding amount of salt water out at the bottom and into a gravity tank. As gasoline is pumped from the tank, salt water reenters from the gravity tank or from some other source of salt water supply. The storage tank is thus kept completely filled at all times, preventing the formation of gasoline vapor.

Some ships are provided with a specially constructed inert-gas piping system for lines running inside the ship. A double-pipe gasoline line is formed by running brass piping inside a steel tube, and filling the space between with an inert gas. The brass piping carries the gasoline. The free passage of the inert gas throughout the system is ensured by installing bypass tubes at each joint.

COMPRESSED AIR SYSTEMS

Air is a mixture (not a chemical combination) of several gases. The most important of these are nitrogen and oxygen, with small amounts of argon and neon.

Compressed air is neither poisonous nor flammable, but it should be handled carefully. Air tanks, lines, and fittings can rupture from too much pressure. Carelessness with compressed air can also cause eye injuries.

Compressed air systems are fabricated from brass and copper piping materials, bronze silver-brazed fittings, and bronze valves. Moisture and oil must be kept out of compressed air systems. Moisture is damaging to the piping and causes excessive wear in air-operated equipment. Oil is dangerous in high-pressure (600 psig and above) compressed air systems because it can form an explosive mixture with the air. Oil and moisture separation filters and, where necessary, air dryers are provided to remove these contaminating substances from the system.

The major air systems found aboard ship are (1) the high-pressure air system, (2) the ship's service air system, (3) gas ejecting systems, (4) starting and control systems for diesel engines, and (5) combustion control air systems.

The High-Pressure Air System

The high-pressure air system provides air at 3000 psi or 4500 psi for charging air banks. This system is also used at required pressure for services such as counterrecoil, diesel engine starting, gas ejection, torpedo charging, and torpedo workshops. When the service requires air at less than 3000 psi, the outlet from the high-pressure system is equipped with a reducing valve.

The Ship's Service Air System

The ship's service air system is a low-pressure compressed air system installed on practically all surface ships. This system normally uses a working pressure of 100 to 150 psi. This system supplies air at required pressures to operate pneumatic tools and oil burning forges and furnaces, to clean equipment, to pressurize electronic equipment wave guides with dehydrated air, and many other uses. The ship's service air system is normally supplied from a low-pressure air compressor. However, on some ships air may be supplied from the medium- or high-pressure system, through appropriate pressure reducing valves.

Gas Ejecting Systems

Gas ejecting systems, where required, supply air at the required pressure to the breeches of guns for removing gases and unburned solid matter. The standard working pressure of a gas ejection system is determined by the type of battery it supplies. Normally these systems will range from 100 to 200 psi. Air for the gas ejection system is supplied from the medium- or high-pressure system, through appropriate reducing valves.

Starting and Control System

A starting and control air system for diesel engines is installed on each ship that requires air for diesel engine starting and the control of equipment such as clutches, engine selector valves, turning gear, and propeller brakes. Air for this system is provided by a medium-range compressor at a pressure of 600 psi or from the high-pressure system, through appropriate reducing valves.

Combustion Control Air System

A compressed air system is installed on some steam-driven ships to provide air for the automatic combustion control system on the boilers. This compressed air system consists of an air compressor, air receiver, and piping to supply air for pneumatic units of the automatic combustion control system.

REFRIGERATION SYSTEMS

According to NAVSEA policy, refrigerants used in the Navy are no longer identified by trade names. Instead, they are identified by the letter *R* followed by the appropriate number, or else they are identified simply as refrigerants.

Most Navy refrigeration systems use R-12 as the refrigerant. Because of its low boiling point (-21.7°F at atmospheric pressure), R-12 is well suited for use in refrigeration systems designed for only moderate pressures. R-12 is neither flammable nor explosive. It is also noncorrosive to iron, steel, copper, brass, and Monel. Although the R-12 is practically nontoxic, you still have to be careful when using it. When it gets hot, it decomposes and produces products that are toxic, and can even kill you. Do not let anyone tell you that it is absolutely safe.

In the operating cycle of a refrigerating plant, the refrigerant gas is compressed and cooled to a liquid. It is then permitted to expand and become a gas again. The heat necessary to expand the liquid to a gas is obtained from the surrounding atmosphere of the space being cooled. It is this absorption of heat by the refrigerant that lowers the temperature of a refrigerated compartment. The amount of heat absorption is controlled by expansion valves and thermostats. The complete cycle is gas compression, condensation, controlled expansion in the space to be cooled, and return to the compressor.

The principal components of the system are the compressor, the condenser, the receiver, and the cooling coils (evaporator). Additional equipment required to complete the system includes piping, pressure gauges, thermometers, various types of control switches and control valves, strainers, relief valves, sight-flow indicators, dehydrators, and charging connections.

You are not responsible for maintaining and operating a refrigeration system. However, you may be required to assist a Machinist's Mate or an Engineman in making repairs or alterations to the refrigeration piping system.

PIPING SYSTEM MARKINGS

To make identification easy, piping systems are marked in some conspicuous location (preferably near control valves) and at suitable intervals so that every line carries at least one marking in each compartment through which it passes.

The identification markings include the name of the service, destination (where feasible), and direction of flow. These markings may be painted on by stencil or hand lettering, or on adhesive-backed tape that has been previously printed, stenciled, or lettered. These identifying marks are in letters 1 inch high for 2-inch or larger outside diameter pipe or insulation. For smaller sizes, the size of the letters may be reduced or label plates may be attached by wire or any other suitable means. In addition, a 3-inch arrow leads from the identification marking, with the arrowhead pointing in the direction of the flow. Where flow is reversible, arrows are shown on each end of the identification and destination markings.

Valves are marked by inscribing the rims of handwheels, on a circular label plate secured by the handwheel nut, or on label plates attached to the ship's structure or to the adjacent piping. Each valve label gives the name and purpose of the valve. For example, a valve may be labeled as follows:

DRAIN BULKHEAD STOP
2-85-1

The purpose of the valve is indicated in the first line. The location of the valve is indicated by the numbers in the second line. The first number in the location code indicates the deck (in this example, the second deck). The next number indicates the frame (in this example, frame 85). The last number indicates the side (in this example, starboard). Odd numbers are always used for the starboard side, while even numbers are used for the portside.

SUMMARY

As you work within the HT rating, you will gain more experience in pipefitting. You have learned in this chapter that a lot of factors need to be considered before you install or modify a piping system. This chapter gave you information on which materials to use, the types of hangers used, and the identification of piping and valves. Most shops have old and new valves and fittings on hand. Look over the valves and fittings to see how they operate. It will also be helpful to ask an experienced HT to help you. When working with insulation and lagging, make sure that you follow the procedures set forth in chapter 635 of *NSTM* and chapter B1 of OPNAVINST 5100.l9B, *NAVOSH Program Manual for Forces Afloat,* which include asbestos removal precautions and procedures.

CHAPTER 16

PIPING SYSTEM REPAIRS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Describe the types of piping system repairs.*
- *Discuss some of the equipment used for piping system repairs.*
- *Describe the various techniques and procedures used in piping system repairs.*
- *Describe the repair and installation of piping system components.*
- *Describe the different types of marine mechanical pipe fittings.*
- *Discuss the procedures for shaping piping and tubing.*
- *Describe the procedures used in the maintenance and repair of valves used in piping systems.*
- *Describe the basic safety precautions to follow, and the hazards involved when performing piping system repairs on board ship.*

INTRODUCTION

As a Hull Maintenance Technician, you may repair fire main, flushing, steam, low-pressure air, fuel-oil, and other shipboard piping systems. Some repairs need nothing more than a composition seat in a water tap or a new gasket. Others are more complex. You may take down sections of the system, and fabricate and install entire assemblies or subassemblies.

When you repair any piping system, the requirements that governed the design and layout of the original system also govern the replacement sections. Before starting a repair job, be sure you know what that job requires. Do not substitute any unauthorized materials or change any fabrication and installation procedures.

As with any work you do, be sure to follow all of the proper safety precautions. Here are some of the standard precautions for piping repairs:

1. Make sure all piping systems are tagged-out, depressurized, and drained before you cut into the pipe or disconnect a joint.

2. Follow all OPNAV and shipboard instructions when performing tag-outs.

3. Ensure all piping systems open to the sea are properly isolated, gagged, or blanked off before working on the system.

4. When breaking a flanged joint, remove all bolts except the two opposing bolts. Gradually loosen the two remaining bolts to ensure that the system is properly depressurized and drained.

5. Ensure all flammable and toxic fluid or gas piping systems are properly drained, cleaned, and gas-free prior to working on the system.

6. NEVER exceed the operating capacities of shop equipment or hand tools.

7. Observe all safety precautions for welding, brazing, and other potentially dangerous processes used to repair piping systems.

8. NEVER substitute any material in a piping system without first obtaining proper authorization from competent authority. The use of unauthorized

material could cause the failure of the system and result in flooding, fire, equipment damage, even the loss of life.

9. Report any unsafe act or condition to your immediate supervisor before proceeding with the task at hand.

REPAIR OF PIPING

Repairs to piping systems are classified as permanent or temporary. The type of repair used depends upon the circumstances at the time the repairs are made. If the system can be secured, isolated, drained, and the necessary material is available, you should make permanent repairs. If not, then you should make a temporary repair to restore the system for use until permanent repairs can be made. Since temporary repairs are a damage control function in nature, this chapter will only discuss permanent repairs to piping systems. For further information on temporary repairs and to become proficient in their uses, it is highly recommended that you study the *Damage Controlman* training manual and qualify in DC PQS for pipe patching and repair.

PERMANENT REPAIRS

A repair is considered permanent if it meets two requirements. First, it must restore the piping system to its original service requirements. Second, it must be expected to last the life of the system.

The method of repair depends on several things. First, evaluate the nature of the damage. Next, consider the operating conditions of the system. Finally, consider the materials from which the system is made. Normally, you will replace the complete section of damaged piping or the damaged fitting. However, if the damage is minor, you can often make the repair by brazing, welding, or even patching. Permanent minor repairs made in this way will normally save you time and expense when compared with the replacement of the entire section of the system.

LAYOUT

Numerous details are involved in replacing a system or part of a system with new material. You will normally work from a blueprint, if available. If not, you will have to make your own plans or sketches. Whether you use blueprints or sketches, visualize what the completed job will look like. When you make your own plans, make sure your completed repairs will not interfere with other fixtures or the operation of other piping systems. Also, be sure you have enough of the materials on hand to complete the job before you start it. Blueprints contain lists of materials needed and the amount of each material required for that system or subsystem. If blueprints are not available, you will have to compute the amount of materials you need.

Measurements

Before you begin the work, make a diagram, and note on it the measurements of the new assembly. These measurements can be taken in any one or all of four ways: end-to-end, face-to-face, center-to-center, and end-to-center. Figure 16-1 illustrates these four methods of measuring pipe. The center-to-center method, by which a large number of measurements can be taken, is the method most commonly used.

Measurements give the overall picture. However, when actually cutting a length of pipe, you must add allowances to the “as taken” measurements. For example, a l/8-inch IPS threaded pipe will screw 1/4 inch into a threaded fitting. When computing the pipe length, you need to allow for that extra 1/4 inch. Figure 16-2 shows the amount of allowance required to make a tight joint for other sizes of pipe.

NOTE: Threaded fittings have a limited use in shipboard piping systems. They are not permitted in critical or hazardous systems.

A critical or hazardous system is defined as a system where a joint may fail and cause one of the following situations:

- Major damage to the ship

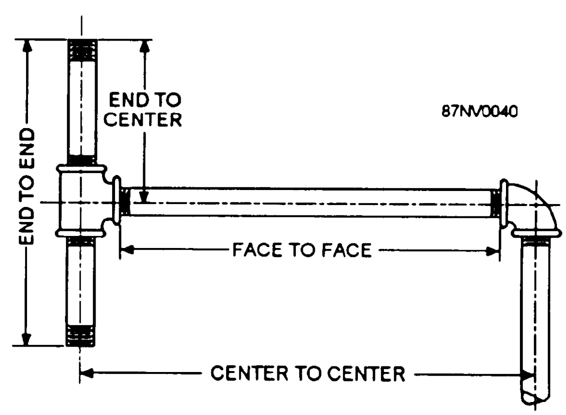
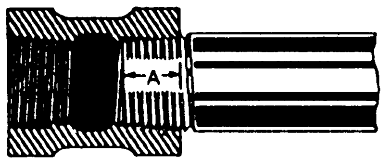


Figure 16-1.—Methods of measuring pipe.



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Size of Pipe, Inches	Dimension A, inches	Size of Pipe, Inches	Dimension A, inches	Size of Pipe, Inches	Dimension A, inches
1/8	1/4	1 1/2	1 1/16	5	1 1/4
1/4	3/8	2	3/4	6	1 5/16
3/8	3/8	2 1/2	15/16	7	1 3/8
1/2	1/2	3	1	8	1 7/16
3/4	9/16	3 1/2	1 1/16	9	1 1/2
1	1 1/16	4	1 1/8	10	1 5/8
1 1/4	1 1/16	4 1/2	1 3/16	12	1 3/4

Figure 16-2.—Length of thread on pipe required to make a tight joint.

- Serious injury to personnel
- Loss of a vital system that has no standby system

Where threaded fittings are not authorized, you will use a socket fitting. As in threaded pipe, you must add allowances to the "as taken" measurement of socket fittings before cutting a length of pipe. The allowances vary from brazed and welded socket fittings. In brazed fittings, you must add the depth of the socket to the length of pipe before cutting. In welded fittings, there are several special allowances to take into consideration when measuring your pipe. All welded piping systems, regardless of material or service, require the use of a small end gap clearance of l/l6 to l/8 inch between the pipe end and the fitting. This end gap clearance allows for thermal expansion of the pipe end in the socket. You must also take into consideration the reduced socket depth if you are reusing a welded socket fitting. When you remove the pipe from the fitting, you must remove part of the fitting to eliminate the fusion area of the weld, thereby reducing the socket depth. Refer to MIL-STD-22 for exact fit-up of welded joint designs. As you can see, allowances and measurements for socket fittings are more exact than those for threaded fittings.

Pipe Length Problems

The amount of pipe needed for a bend in a piping system must be computed during the layout stage. If the system permits bends to be used instead of elbows, make the necessary allowance for the extra pipe required to make the bend before you cut the pipe to size. The first step is to determine the bend radius, which should be as large as possible to prevent weakening of the pipe and restriction of fluid flow. Six times the pipe's diameter is a good rule, but there will be times when a smaller radius is required. Too small a radius will flatten the heel and wrinkle the throat of the pipe at the bend.

90-DEGREE PIPING BENDS.—You may determine the total developed length (TDL) of a section of piping with a 90-degree bend in three easy steps.

NOTE: All dimensions and points for the following excercise are taken from figure 16-3.

1. Subtract the bend radius from the straight section of pipe. Using the dimensions in figure 16-3, subtract 18 inches (bend radius) from 48 inches (straight section of pipe), which leaves 30 inches, the distance from points A to C. To get the distance from B to D, subtract 18 inches from 72 inches, which leaves 54 inches.

2. To figure out the total length of pipe for the bent 90-degree section of pipe, simply multiply the bend radius by a constant of 1.57. In this case, our bend radius of 18 inches multiplied by 1.57 gives us a total length of 28.26 inches for dimension AB in figure 16-3.

3. To get the TDL, the final step is to add the length of the legs to the length of the bent section (30" + 54" + 28.26" = 112.26"). At this point, you may convert the decimal measurement into a fraction for easier use in measuring a section of pipe.

PIPING BENDS OTHER THAN 90 DEGREES.—To compute the TDL for bends other than 90 degrees, a slightly different process is used. This

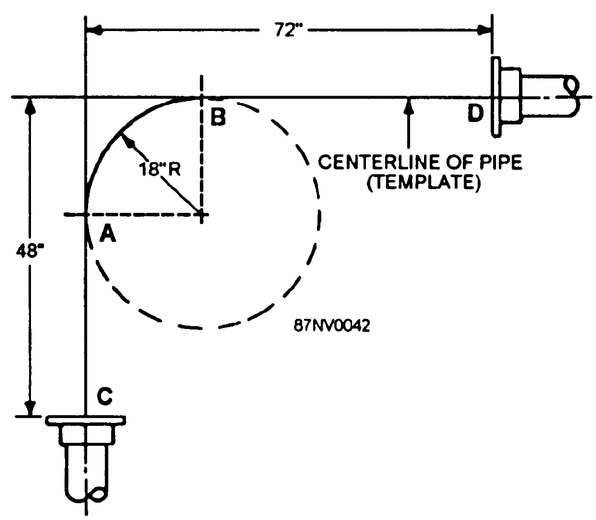
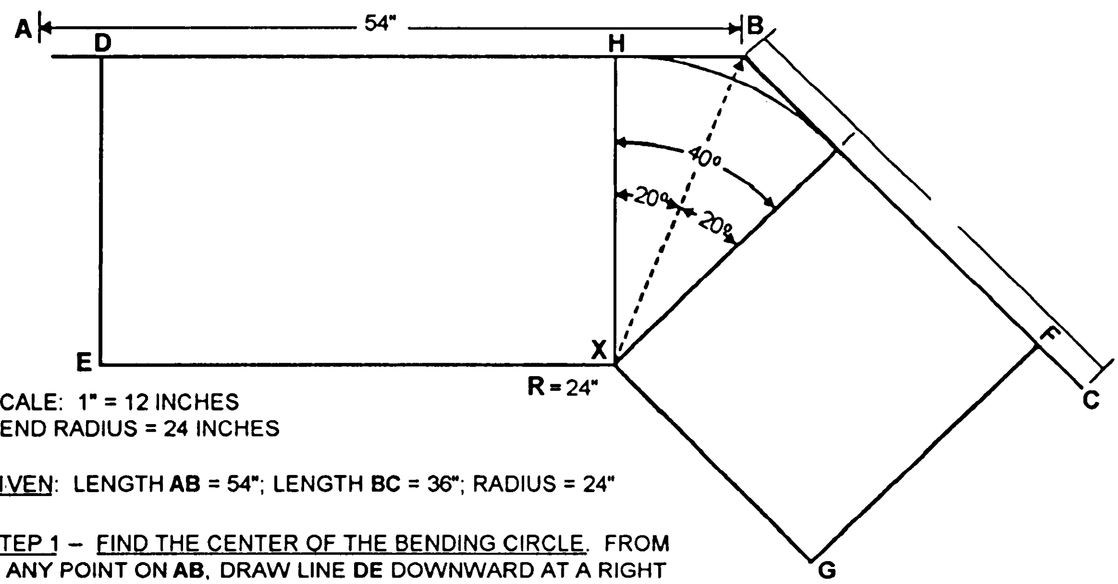


Figure 16-3.—Figuring the approximate length of pipe for a 90-degree bend.

BEND ALLOWANCE: LESS THAN 90°

PROBLEM: FIND THE TOTAL DEVELOPED LENGHT (TDL) OF PIPE NEEDED.



SCALE: 1" = 12 INCHES
BEND RADIUS = 24 INCHES

GIVEN: LENGTH **AB** = 54"; LENGTH **BC** = 36"; RADIUS = 24"

STEP 1 – FIND THE CENTER OF THE BENDING CIRCLE. FROM ANY POINT ON **AB**, DRAW LINE **DE** DOWNWARD AT A RIGHT ANGLE. (USE A PROTRACTOR FOR ACCURACY.) MEASURE A DISTANCE ALONG LINE **DE** EQUAL TO THE BEND RADIUS. CHECK THE SCALE (IN THIS PROBLEM, **DE** = 2"). AT POINT **E**, CONSTRUCT LINE **EX** AT A RIGHT ANGLE TO **DE** AND PARALLEL TO **AB**. FROM ANY POINT ON **BC**, DRAW **FG** DOWNWARD. AT POINT **G**, CONSTRUCT A LINE AT A RIGHT ANGLE TO **FG** AND PARALLEL TO **BC**. WHERE THESE TWO LINES INTERSECT, POINT **X**, IS THE CENTER OF THE BENDING CIRCLE.

STEP 2 – FIND THE LENGHT OF THE BEND SECTION. FROM POINT **X**, CONSTRUCT LINES AT RIGHT ANGLES TO **AB** AND **BC** TO POINTS **H** AND **I**. USING A COMPASS, DRAW AN ARC FROM **H** TO **I**. MEASURE ANGLE **X** – 40°.

FORMULA: BEND SECTION = $\frac{2\pi R \times \text{ANGLE}}{360} = \frac{6.2832 \times 24" \times 40°}{360}$ = **HI** = 16.76"

STEP 3 – FIND THE LENGTH OF OF **AH** AND **IC**.

AH = AB - HB; IC = BC - BI

NOTE: IN A RIGHT TRIANGLE, THE TANGENT OF AN ANGLE IS THE NUMERICAL RATIO OF THE LENGTHS OF THE SIDES OPPOSITE AND ADJACENT TO THE ANGLES.

$\text{TAN (ANGLE)} = \frac{\text{OPP}}{\text{ADJ}}$

FROM STEP 2, ANGLE X = 40°

$\text{TAN}\frac{X}{2} = \text{TAN}\frac{40°}{2} = \text{TAN } 20° = .3640$

$.3640 = \frac{\text{OPP}}{\text{ADJ}} = \frac{\text{HB}}{\text{BEND RADIUS}} = \frac{\text{HB}}{24"} = \frac{\text{BI}}{24"}$

HB = BI = .3640 (24") = 8.74"

AH = 54" - 8.74"	= 45.26"
IC = 36" - 8.74"	= 27.26"
HI (FROM STEP 2) =	16.76"
TDL	**89.28"**

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Figure 16-4.—Bend allowance less than 90 degrees.

process is shown in figure 16-4 and in the following step-by-step exercise. Before continuing with this exercise, you will need a tangent table (table 16-l), compass, straight edge, calculator, protractor, paper, and a pencil.

NOTE: All dimensions and points for the following exercise are taken from figure 16-4. In this figure, a scale of 1 inch = 12 inches is used.

1. Find the center of the bending circle by drawing line DE down at a right angle from any point on line AB

Table 16-1.—Tangent Table

ANGLE	TANGENT	ANGLE	TANGENT	ANGLE	TANGENT	ANGLE	TANGENT
1°	0.0175	24°	0.4452	47°	1.0724	70°	2.7475
1°30′	0.0262	24°30′	0.5447	47°30′	1.0913	70°30′	2.8239
2°	0.0349	25°	0.4663	48°	1.1106	71°	2.9042
2°30′	0.0437	25°30′	0.4770	48°30′	1.1303	71°30′	2.9897
3°	0.0524	26°	0.4877	49°	1.1504	72°	3.0777
3°30′	0.0612	26°30′	0.4986	49°30′	1.1708	72°30′	3.1716
4°	0.0699	27°	0.5095	50°	1.1918	73°	3.2709
4°30′	0.0787	27°30′	0.5206	50°30′	1.2130	73°30′	3.3759
5°	0.0875	28°	0.5317	51°	1.2349	74°	3.4874
5°30′	0.0963	28°30′	0.5430	51°30′	1.2572	74°30′	3.6059
6°	0.1051	29°	0.5543	52°	1.2799	75°	3.7321
6°30′	0.1139	29°30′	0.5658	52°30′	1.3032	75°30′	3.8667
7°	0.1228	30°	0.5774	53°	1.3270	76°	4.0108
7°30′	0.1317	30°30′	0.5890	53°30′	1.3514	76°30′	4.1653
8°	0.1405	31°	0.6009	54°	1.3764	77°	4.3315
8°30′	0.1495	31°30′	0.6128	54°30′	1.4019	77°30′	4.5107
9°	0.1584	32°	0.6249	55°	1.4826	78°	4.7046
9°30′	0.1673	32°30′	0.6371	55°30′	1.4550	78°30′	7.9152
10°	0.1763	33°	0.6494	56°	1.4826	79°	5.1446
10°30′	0.1853	33°30′	0.6619	56°30′	1.5109	79°30′	5.3955
11°	0.1944	34°	0.6745	57°	1.5399	80°	5.6713
11°30′	0.2035	34°30′	0.6873	57°30′	1.5700	80°30′	5.9758
12°	0.2126	35°	0.7002	58°	1.6003	81°	6.3138
12°30′	0.2217	35°30′	0.7133	58°30′	1.6319	81°30′	6.6912
13°	0.2309	36°	0.7265	59°	1.6643	82°	7.1154
13°30′	0.2401	36°30′	0.7400	59°30′	1.6977	82°30′	7.5958
14°	0.2493	37°	0.7536	60°	1.7321	83°	8.1443
14°30′	0.2586	37°30′	0.7673	60°30′	1.7675	83°30′	8.7769
15°	0.2679	38°	0.7813	61°	1.8040	84°	9.5144
15°30′	0.2773	38°30′	0.8243	61°30′	1.8418	84°30′	10.3854
16°	0.2867	39°	0.8098	62°	1.8807	85°	11.4301
16°30′	0.2962	39°30′	0.8243	62°30′	1.9210	85°30′	12.7062
17°	0.3057	40°	0.8391	63°	1.9626	86°	14.3007
17°30′	0.3153	40°30′	0.8541	63°30′	2.0057	86°30′	16.3499
18°	0.3249	41°	0.8693	64°	2.0503	87°	19.0811
18°30′	0.3346	41°30′	0.8847	64°30′	2.0966	87°30′	22.9038
19°	0.3443	42°	0.9004	65°	2.1445	88°	28.6363
19°30′	0.3541	42°30′	0.9163	65°30′	2.1943	88°30′	38.1884
20°	0.3640	43°	0.9325	66°	2.2460	89°	57.2900
20°30′	0.3739	43°30′	0.9490	66°30′	2.2998	89°30′	114.5887
21°	0.3839	44°	0.9657	67°	2.3559		
21°30′	0.3939	44°30′	0.9827	67°30′	2.4142		
22°	0.4040	45°	1.000	68°	2.4751		
22°30′	0.4142	45°30′	1.0176	68°30′	2.5386		
23°	0.4245	46°	1.0355	69°	2.6051		
23°30′	0.4348	46°30′	1.0538	69°30′	2.6746		

using a protractor or compass for accuracy. Always draw your lines toward the inside of the bend. Measure a distance along line DE that is equal to the bend radius (point E). At point E, draw a line parallel to line AB. Repeat the same process for the other leg of your piping section to get line FG, point G, and a line parallel to line BC. The point where the two lines you have constructed cross is the center of the bending circle and should be labeled X.

2. Lay out the bend section by constructing lines that are at right angles from lines AB and BC that cross at point X. Label these points H and I. Now set your compass to the bend radius and strike an arc that touches points H and I on lines AB and BC. This arc is your bend section.

3. Use a protractor to determine angle X. Angle X should be 40 degrees. Use the formula (bend section = 2 × pi × radius × angle + 360) to determine the total length of the bend section. In this case, the bend section equals 2 × 3.1416 × 24 × 40 ÷ 360 or 16.76 inches.

4. To find the TDL, you still need to know the length of the remaining straight sections. You divide angle X (40 degrees) by 2 for an angle of 20 degrees. Now refer to table 16-1 to find the tangent for an angle of 20 degrees or 0.3640. Multiply the tangent (0.3640) by the bend radius (24) and you get 8.74 inches or the distance from BH and BI. Next subtract 8.74 inches from the distance of AB (54 inches) and from BC (36 inches) or 45.26 inches for AB and 27.26 for BC, respectfully.

5. The final step is to add the length of the legs to the length of the bend section (45.26" + 27.26" + 16.76" = 89.28") to get the TDL in inches. At this point, you may convert the decimal measurement into a fraction for easier use in measuring a section of pipe.

Therefore, a straight section of pipe 89 9/32 inches long, after proper bending, would fit the dimension AC of figure 16-4.

Flange Bolthole Layout

When you get ready to lay out boltholes in a flange, check your plan for the number of boltholes needed and the diameter of the pitch circle. A pitch circle is the circumference of the circle that will connect the center points of the boltholes. A pitch chord is the distance from the center of one bolthole to the center of the next. Here are the steps that you should use to lay out the boltholes in any given flange:

1. Scribe the pitch circle using the radius given in the plan.

2. Determine what the pitch chord is to be. This may be done geometrically or mathematically, or it may be listed in the plan.

3. Divide the circle into the desired number of equal parts as called for in the plan.

When the circle has been accurately divided, the points on the circumference of the circle will locate the centers of the boltholes. You can locate the center of the boltholes with a pair of dividers by adjusting the points. But this trial-and-error method is time consuming and not very accurate. Use the proper geometric construction described in the following paragraphs, and you can locate the bolthole centers more accurately and in less time.

The following problems illustrate the constructions used to lay out flange boltholes.

PROBLEM I—Lay out a five-hole flange. (See fig. 16-5.)

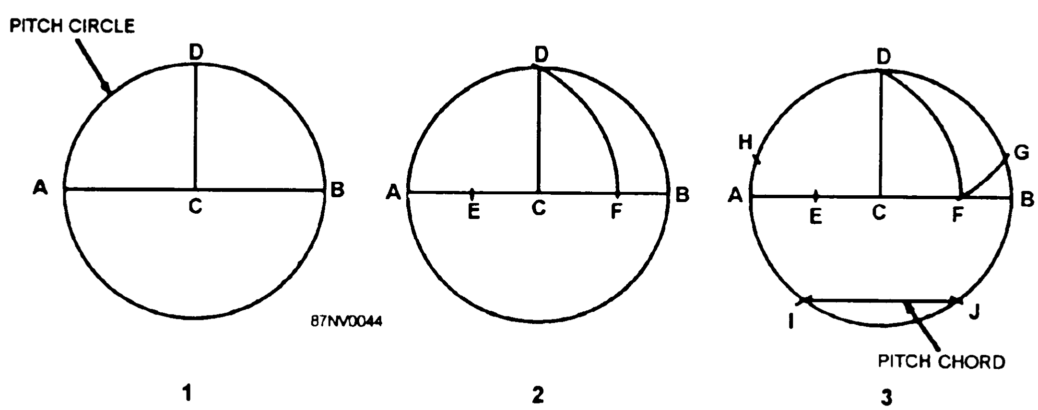


Figure 16-5.—Layout for a five-hole flange.

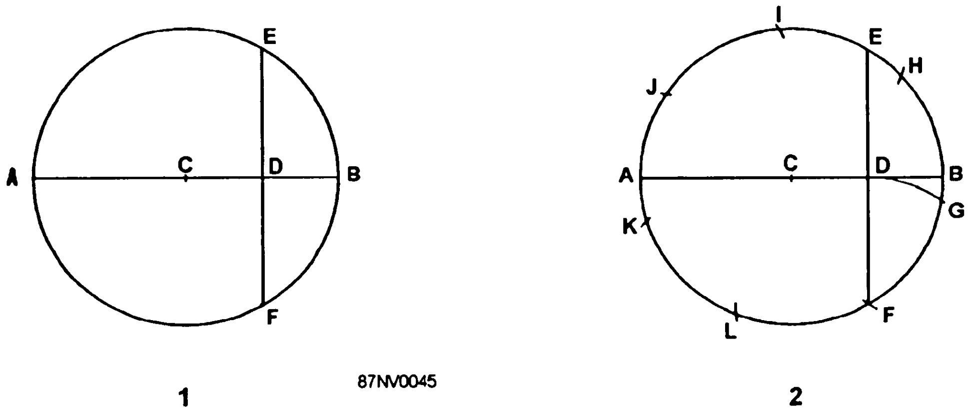


Figure 16-6.—Layout for a seven-hole flange.

SOLUTION:

1. Draw a circle of the required diameter (AB) and construct CD perpendicular to AB at center point C.

2. Bisect line AC, locating point E. Then with E as a center and distance ED as the radius, draw arc DE

3. With D as the pivot point and distance DF as a radius, scribe arc FG. Distance DF (or DG) is the length of the pitch chord and one-fifth of the circumference of the circle. Step off this distance (DF) around the circumference. Points G, D, H, I, and J are centers for the holes of a five-hole flange.

If you step off the circumference using measurement GB instead of DG, you get a 20-bolthole flange. Each spot where your dividers make an arc on the circle's circumference will be the center point for a bolthole.

PROBLEM II—Lay out a seven-hole flange. (See fig. 16-6.)

SOLUTION:

1. Draw a circle with the required pitch diameter (AB). Then construct a line that bisects and is perpendicular to radius CB (point D). Extend this line until it intersects the circumference at E and F.

2. With F as the center and distance DF as a radius, locate point G. Distance FG (also FD and DE) is one-seventh of the circumference or the true length of the pitch chord. With the dividers set for this distance, step off the circumference and locate points F, G, H, I, J, K, and L. These points are the centers for a seven-hole flange of the given pitch circle.

PROBLEM III—Lay out a nine-hole flange. (See fig. 16-7.)

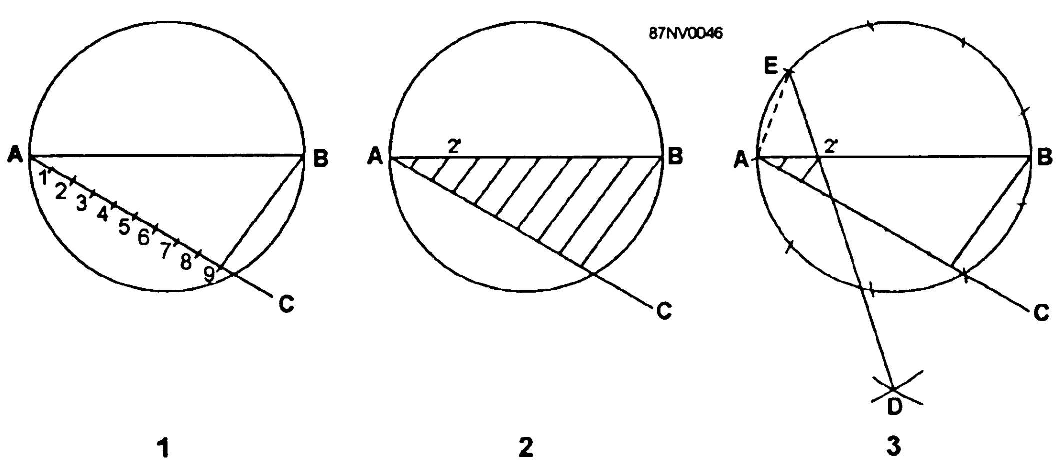


Figure 16-7.—Layout for a nine-hole flange or flanges having any number of holes.

SOLUTION:

1. Draw a circle with the specified pitch diameter. From A, at any convenient angle to the pitch diameter (AB), draw a line of indefinite length (AC). Adjust the dividers at any convenient setting and step off nine spaces along line AC. Draw line B9.

2. From points 1, 2, 3, 4, 5, 6, 7, and 8, construct lines parallel to B9, which intersect line AB. This procedure divides line AB into nine equal parts. The same principle can be used to divide a line of a specified length into any number of equal parts.

3. With distance AB as a radius, scribe arcs from A and B, establishing point D. From D, draw a line that passes through 2´ (on line AB) to the circumference at E. Distance AE is the pitch chord and the length of arc AE is equal to one-ninth of the pitch circle.

The principles illustrated in figure 16-7 and discussed in problem III may be used to lay out a flange with any number of holes. The division of line AC is the variable of the layout. Just set the dividers to a convenient distance and step off spaces equal to the number of boltholes desired. If you want 13 boltholes, divide line AC into 13 equal spaces. The second space point (2´ in fig. 16-7) is al ways used for the construction of line D2'E and the location of point E. If a pitch circle is difficult to divide into the required number of spaces, this method can be used to advantage. However, it is a lengthy construction. The layouts for five- and seven-hole flanges are easier to develop and have greater accuracy.

Developments for four-, six-, eight-, and ten-hole flanges are relatively simple. To determine the length of the pitch chord for a four-hole flange, construct two bisectors that intersect at 90-degree angles. For six-hole flanges, the radius of the pitch circle is equal to the length of the pitch chord. Step off that distance on the pitch circle to lay out the flange boltholes. For eight- or ten-hole flanges, bisect the pitch chords of the four- or five-hole layouts.

The exact distance to set dividers for a certain number of holes on a specified pitch circle can be determined by simple multiplication. However, a constant value for the desired number of boltholes must be known. The diameter of the pitch circle multiplied by the constant value equals the length of the pitch chord. The constant value for a specified number of holes is given in table 16-2.

Here is an example of the use of table 16-2. Assume that you need a flange with 11 boltholes and a pitch diameter of 10 inches. From the table, select the constant value for an 1 l-hole flange. The pitch diameter (10 inches) multiplied by the constant (0.28 17) equals the length of the pitch chord (2.817). Set your dividers to measure 2.817 inches, from point to point. Now step off the circumference of the pitch circle to locate the centers of the flange boltholes.

Table 16-2.—Constant Values for Locating Center of Flange Boltholes

Boltholes	Constant
3	0.866
4	0.7071
5	0.5 878
6	0.5
7	0.4338
8	0.3827
9	0.342
10	0.309
11	0.2817
12	0.2588
13	0.2394
14	0.2225
15	0.2079
16	0.195
17	0.184
18	0.1736
19	0.1645
20	0.1564

You will find the mathematical method using table 16-2 to be a rapid and convenient way to lay out flange boltholes. However, you should also be able to use the geometric construction method. You will not always have a table of constant values available, and some problems are not easily solved by the simple multiplication process.

Boltholes are not the only holes you will have to lay out. At times, pipe will pass through decks and bulkheads at an angle other than 90°. When this happens, you will need to develop an ellipse. This can be done in several ways; however, problem IV illustrates the geometric development.

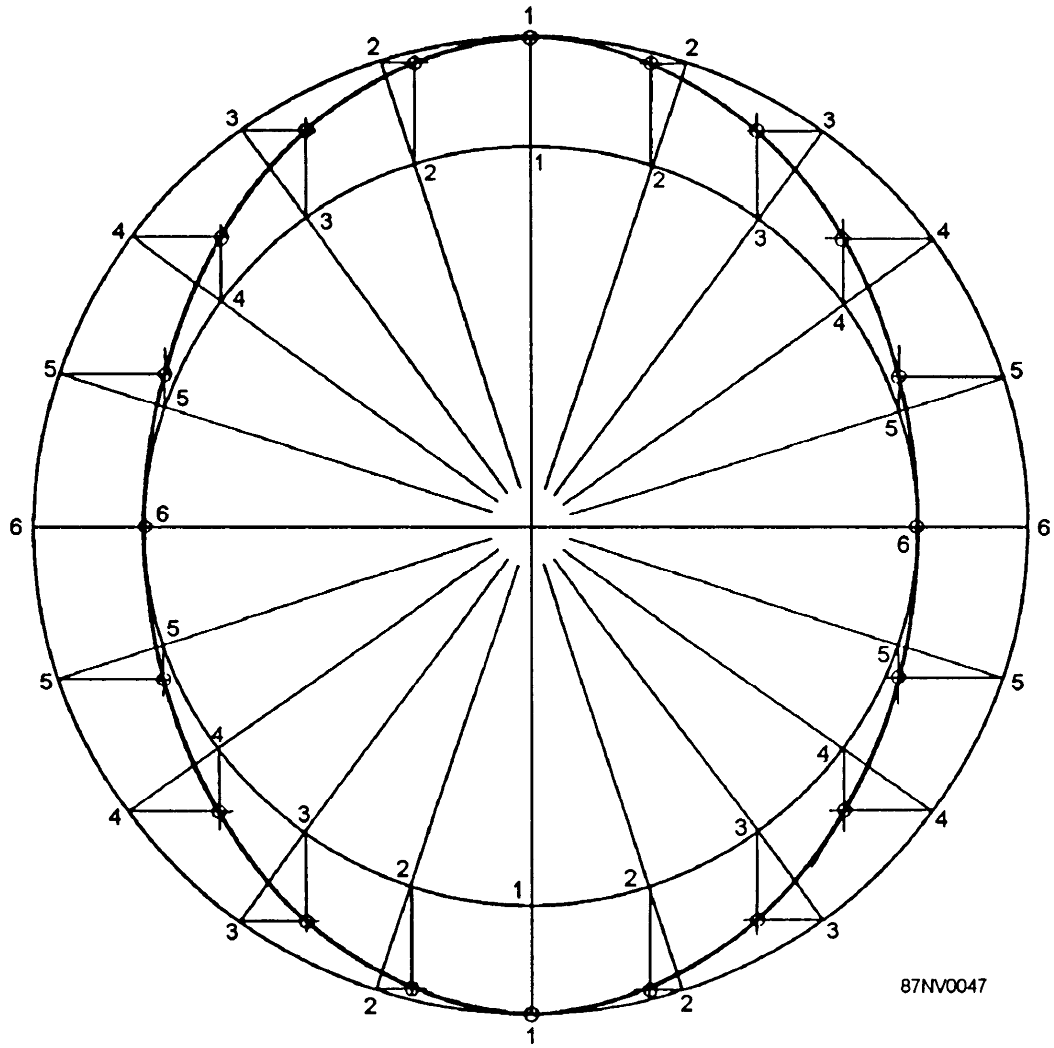


Figure 16-8.—Construction of an ellipse.

PROBLEM IV—Develop an ellipse with a vertical diameter of 6 l/4 inches and a horizontal diameter of 4 7/8 inches. (See fig. 16-8.)

SOLUTION:

1. Scribe a circle with a 6 l/4-inch diameter.

2. Use the same center and scribe a circle with a 4 7/8-inch diameter.

3. Develop the inner circle so that each quadrant or quarter-circle is equally divided into five parts. (See problem I and fig. 16-5 .)

4. Locate the equal-space division points on the outer circle circumference by radiating lines from the center point. These lines are to pass through the division points on the inner circle's circumference. Number these points as indicated in figure 16-8.

5. From each point on the inner circle, and parallel to diameter l-l, draw a line toward the outer circle.

6. From all points on the outer circle, draw lines parallel to diameter 6-6 so that they intersect with the lines drawn in step 5.

7. The points of intersection of the vertical and horizontal lines in each quadrant are points on the ellipse.

8. Sketch in the outline of the ellipse by freehand drawing, or use a french curve. A true and perfect ellipse must be developed geometrically. The greater the number of points established, the more nearly perfect the ellipse will be.

Sometimes the ellipse does not have to be perfect. In such cases the ellipse is laid out directly on the deck

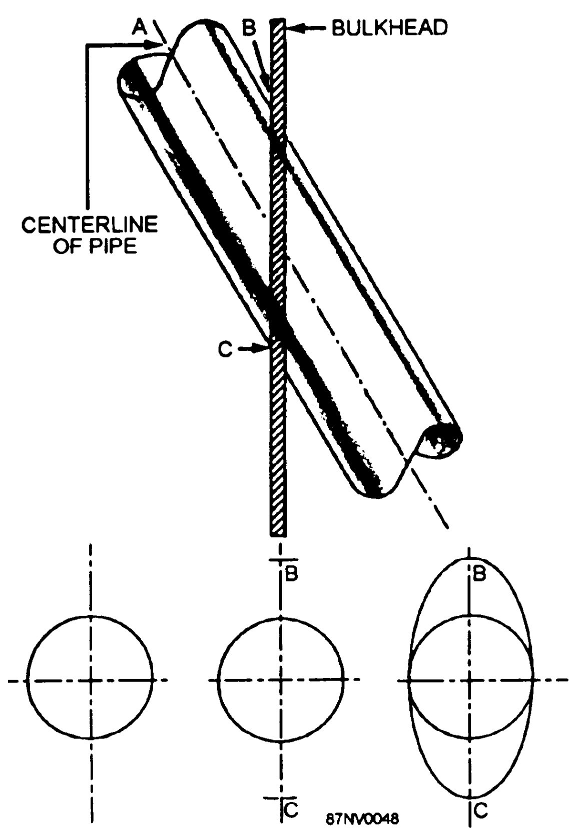


Figure 16-9.—Finding the length of an elliptical hole.

or bulkhead. The method used is shown in figure 16-9 and described in the following paragraphs.

Draw a line to represent the deck or bulkhead that the pipe will pass through. Use a protractor to lay out and draw a line at the angle that the pipe will pass through the deck or bulkhead. Draw this line as the centerline (A) to represent the center of the pipe. Then draw a parallel line on each side of the centerline. The distance between the parallel lines and the centerline is equal to one-half the outside diameter of the pipe or tube. This measurement must be made perpendicular from the pipe centerline. Measure the distance from B to C on the bulkhead line. This distance is the long axis of the elliptical hole.

Locate the halfway point between the two points marked B and C. This is the center point of the hole to be cut. Through this point, draw a horizontal line at right angles to the line representing the bulkhead. With a pair of dividers, scribe a circle equal to the outside diameter of the pipe. Then set the dividers at a radius equal to one-half the distance from B to C. Now scribe an arc across the long axis of the ellipse above and below the center point. Sketch in the remainder of the ellipse. You now have a useable layout for a pipe to pass through a deck or bulkhead at an angle.

MAKING TEMPLATES AND TARGETS

Frequently, the section of pipe to be replaced will have a bend in it. The replacement section will have to be exactly like the portion that is removed. You can get an exact fit by using templates and targets.

Templates are made from wood, wire, or small tubing. You will find them valuable in preparing new installations, as well as in repair work When properly made and correctly used, they provide an exact guide for bends and flange positions. The method of making and using a template is illustrated in figure 16-10.

A wood template is formed by securing blank wooden disks to the flanges of the fixed-position pipes. This is shown in view A of figure 16-10. Insert gaskets of the proper thickness between the wooden disks and the fixed flanges. This will provide the proper clearance for the permanent gasket installation. Next cut a 2 by 4 to fit snugly between the flanges. Secure the 2 by 4 by nailing triangular wood braces to the wood flanges and to the 2 by 4. The template can now be taken to the shop. A target (or reverse template, as it is sometimes called) can now be made. (See fig. 16-10, view B.)

Targets can be made of wood, but metal is the preferred material (fig. 16-10, view C) due to its durability, strength, and flame resistance. The targets are constructed of ordinary or blank flanges welded to angle iron or pipe. The target is then welded a minimum of 12 inches off of a target deck (a large metal slab) to make it easier to work on the new section of pipe. The target is then braced to prevent movement while working with the target. Remember, the target is your permanent pattern by which you are working off of and any movement, however so slight, will cause misalignment in your finished product. Only after the piping assembly has been manufactured, tested, and installed may you remove the target from the target deck. The target deck can then be used over again for another target.

In repair work, the target is usually made directly from the section being repaired. The pipe section then serves as the template. This procedure is illustrated in view D of figure 16-10.

A centerline template is made to conform to the bend, or bends, of the pipe to be made. It is used to lay

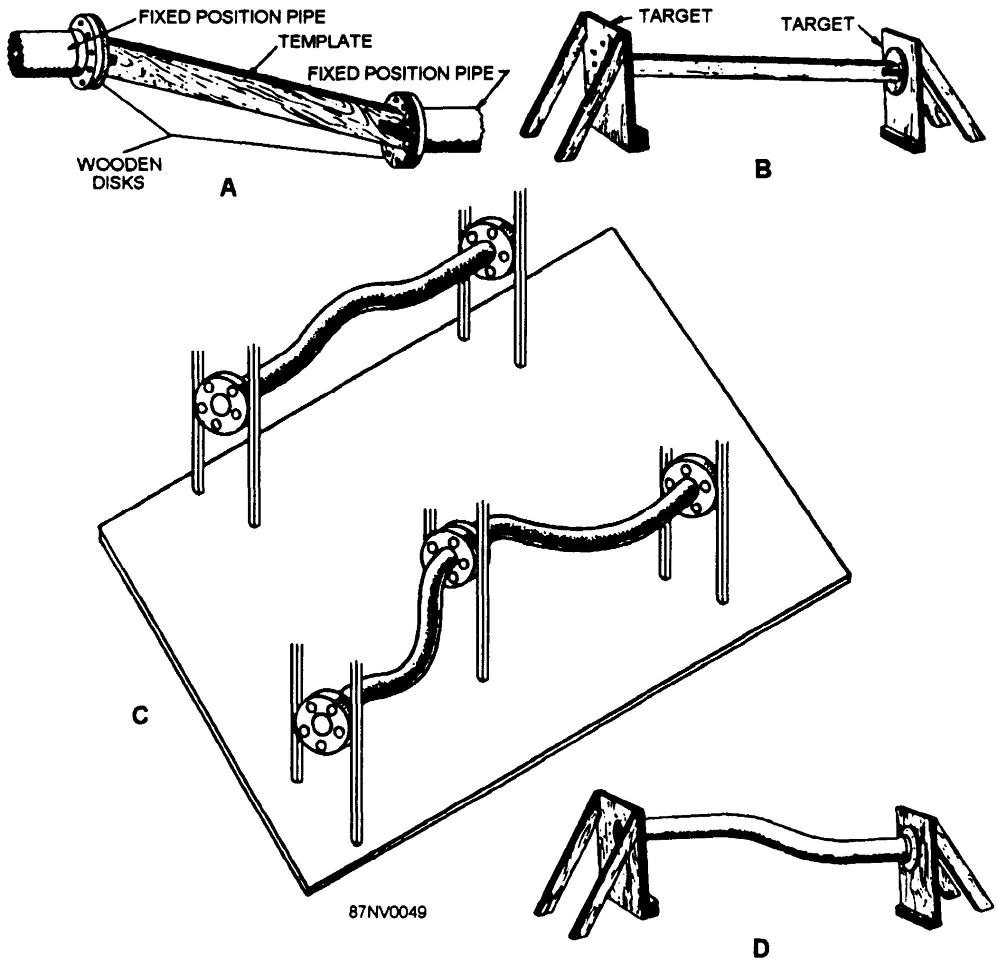


Figure 16-10.—Templates and targets.

off the bend areas on the pipe. It is also used as a guide during the pipe or tube bending operation. Figure 16-11 illustrates the use of a centerline template. These templates are made of rod (one-fourth or three-eighths inch in diameter), and are shaped to establish the centerline of the pipe to be installed. The ends of the rod are secured to special clamps called flange spiders. A sheet metal clearance disk is used if there is any doubt about the clearance around the pipe. The clearance disk must be the same diameter as the pipe being installed.

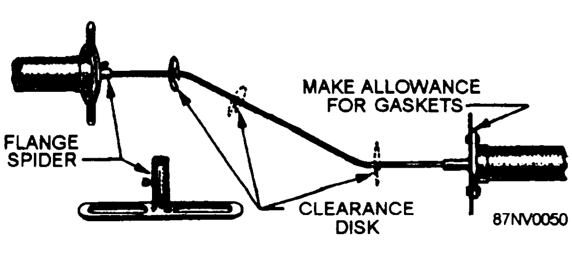


Figure 16-11.—Centerline template.

PIPE BENDING

Pipe made of steel, aluminum, nickel-copper, or copper-nickel should not be bent to a radius less than two times the diameter of the pipe. Copper and brass pipe may be bent to a radius one-and-a-half times the diameter.

Pipe may be bent using a power pipe bender or hot bent on a slab.

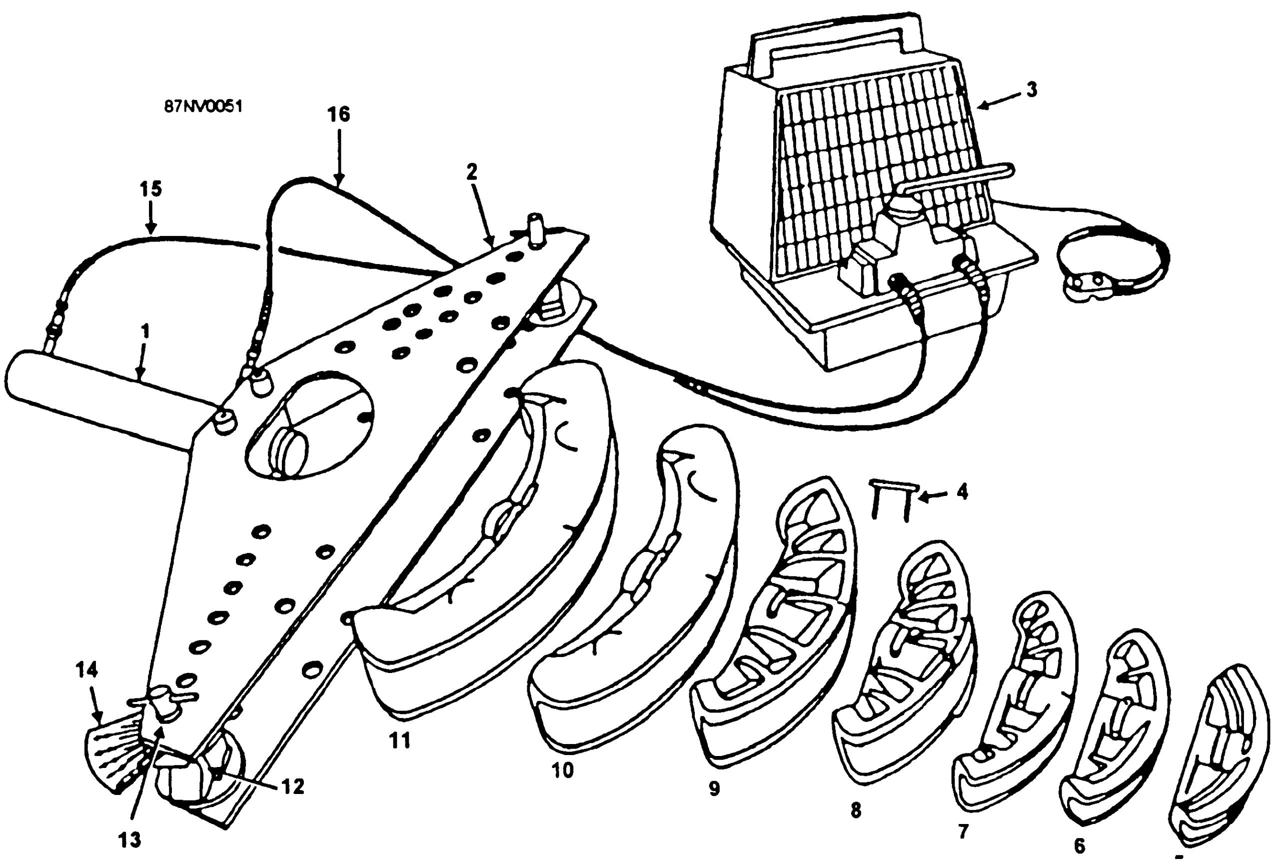
Power Pipe Benders

Cold bends in pipe or tubing are usually made in a bending machine, rather than on a slab. Various types of bending tools are available. They range from portable hand sets to large hydraulically driven machines that can bend up to 16-inch pipe. In this section, we will discuss the portable pipe bender and the rotary bender. Hand-held tubing and pipe benders will be discussed later in this chapter.

PORTABLE PIPE BENDERS.—Portable pipe benders, commonly referred to as one-shot benders, are lightweight, hydraulic-powered, portable units that can be taken to the job site so that pipe can bent on site rather than in the shop. Portable pipe benders are designed to work with pipe up to 5 inches and are capable of being operated by one person. If properly used and maintained, they can produce acceptable bends in all types of pipe and tube.

The portable pipe benders have two major components: the bender frame, with a removable hydraulic cylinder, and a hydraulic power unit (see fig. 16-12). The hydraulic power unit is connected to the hydraulic cylinder with flexible hydraulic hoses. Bender control is accomplished by a three-position (off, advance, and retract) valve located on the hydraulic unit. Bending is accomplished by the use of a bending shoe attached to the ram of the hydraulic cylinder and two pivot shoes pinned in the frame. Bending shoes must be changed to match the size of pipe being bent. Pivot shoes are marked for various pipe sizes and are simply rotated in the frame to match the size of pipe being bent. They may also be required to be moved to different settings in the frame to match pipe diameter. An optic angle gauge is provided to measure the degree of bend in the pipe.

After the machine is set up, you are ready to bend a section of pipe. Simply mark the center of your bend on a section of pipe and insert it into the bending shoe. Ensure that it extends beyond the pivot shoes a sufficient distance. If the pipe is cut too short, it could slip off the pivot shoes while being bent due to the stretching of the pipe. Align the mark on your pipe with the arrow on the bending shoe and snug the pipe into the shoes. Check your angle gauge; it should read zero along the line scribe on the bender frame. Proceed to bend your pipe, watching the optical angle gauge until the desired angle of bend is reached. When the bend is complete, retract the cylinder and remove the section of pipe.



1. **Hydraulic cylinder**
2. **Bender frame**
3. **Pump and hoses**
4. **Shoe lock pin**
5. **1 l/4-in. shoe**
6. **1 1/2-in. shoe**
7. **2-in. shoe**
8. **2 1/2-in. shoe**
9. **3-in. shoe**
10. **3 l/2-in. shoe**
11. **4-in. shoe**
12. **Pivot shoes**
13. **Pivot pins**
14. **Optic angle gauge**
15. **Bend pipe hose**
16. **Eject pipe hose**

Figure 16-12.—Portable pipe bender components and assembly.

After removing the section of pipe, check for defects such as flat spots, wrinkles, out-of-roundness, pitting, marring of the pipe surface, and the bend angle. To correct overbend in a section of pipe, simply reverse the pipe in the bender frame. Reposition the pivot shoes and pins to the overbend correction holes. One pivot shoe should be on the straight end of the pipe and one at the other end of the bend to provide proper support for the pipe as shown in figure 16-13. Inch the bending shoe forward a few degrees at a time until the desired correction is made.

Flat spots, wrinkles, and out-of-roundness is a common problem encountered when using a portable bender since the pipe is usually bent without any internal support. To eliminate these defects, you may find it easier to make several smaller bends than one large bend. By making several smaller bends, you spread the stress of bending over a larger area and reduce the amount of force required to make the bend. Care must be taken to reposition the pivot shoes after every bend so that they are always in contact with the pipe.

ROTARY PIPE BENDERS.—Rotary pipe benders are capable of bending 16-inch diameter pipes or larger. Most tenders and shore facilities are equipped to bend pipe in the 4- to 6-inch diameter range. Shipyards are equipped with machines of larger capacity. This installed machinery must be operated by three or more persons. Rotary pipe benders are the preferred machine to bend pipe due to their accuracy, versatility, and quality of bend.

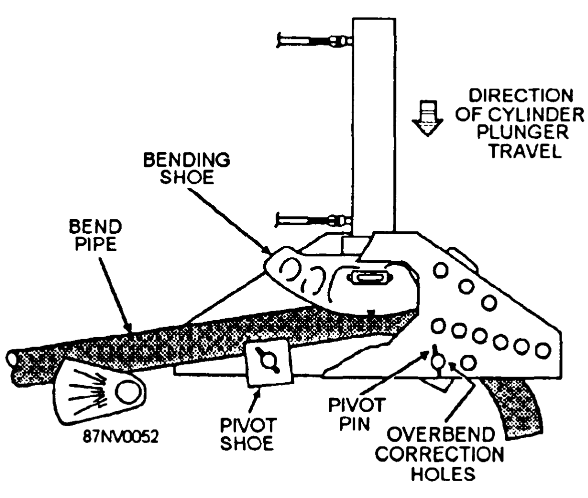


Figure 16-13.—Correcting overbend.

Rotary pipe benders are larger and much more complex machines than the portable pipe bender. They use up to four dies and a hydraulic cylinder to perform the bending operation. These benders also may use a mandrel to provide internal support to the pipe wall during the bending evolution to prevent collapse and wrinkling of the pipe.

To properly set up a rotary bender, you must become familiar with the different dies used on these machines and their functions (see fig. 16-14). They are as follows:

- BEND DIE—The centrally located die that is rotated by a hydraulic cylinder to bend the pipe.
- CLAMP DIE—The die that clamps the pipe to the bend die.
- PRESSURE DIE—The die that provides support and acts as a backstop to the pipe during the bending evolution.
- WIPER DIE—The die that provides support in the throat of the pipe and guides the pipe into the bend die. Proper use of this die greatly reduces winkles in the throat of the bend.

Choose the dies according to the diameter of the pipe and the bend radius. These measurements should be stamped on the die. Since pipe and tube have different outside diameters for the same size of material, choose your dies carefully to prevent damage to the equipment, pipe, or personnel.

After choosing your die, you are ready to set up the rotary bender. Place the bend die over the die stud and align the keyway on the die with the die key on the machine. Tap the bend die gently in place, install the nut on the die stud, and tighten. Next, install the clamp die.

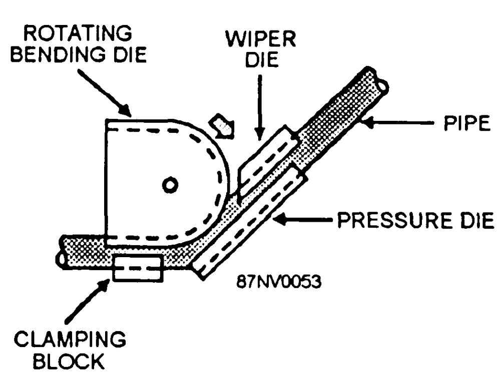


Figure 16-14.—Positioning of rotary pipe bender dies.

There arc two basic types of clamp die installation: manual and hydraulically actuated. The manual-actuated clamp die is a simple-hinged die holder that is swung up into place. The holding power is provided by a yoke assembly and setscrew that is fastened to a retaining post that is bolted to the bend die. The hydraulically actuated clamp die is also bolted to the bend die and uses a series of linkage to operate the clamp die. A small hydraulic cylinder applies pressure to the linkage to firmly clamp the pipe to the bend die. When setting up and adjusting the clamp die, use a sample piece of pipe of the same diameter as the pipe to be bent to act as a gauge. Ensure that the face of the clamp die is not bottomed against the bend die. If it is bottomed, no clamping pressure will be applied to the pipe to be bent.

The next step is to install the pressure die. The pressure die is mounted to a movable pressure die holding bar to allow the pressure die to slide forward with the pipe as it is bent. The die holding bar is mounted on a slide keyway and is either manually or hydraulically operated. Loosely mount the pressure die on the holding bar and bring the die up to a sample pipe clamped in the clamp die. Align the pressure die to the pipe and tighten the pressure die mounting bolts. The pressure die is never adjusted with as much pressure as the clamp die. It is designed to provide support to the pipe not clamping action. Ensure that there is clearance between the pressure die and the bend die.

The final die to bc installed is the wiper die. The wiper die is an optional die, and its use is determined by the wall thickness of the pipe, the degree of bend, and operator preference. It is mounted in front of the bend die to guide the pipe into the bend die. There are no special adjustments for the wiper die.

If you are bending thin wall pipe or tubing, or making short radius bends, you may want to USC a mandrel to support the wall of the pipe. By supporting the pipe wall, the mandrel reduces the flattening and wrinkling of the pipe during the bending evolution. Mandrels may either be rigid or flexible. The rigid type provides support only at the tangent (start) of the bend. The clearance between the rigid mandrel and the pipe should not exceed 20 percent of the wall thickness of the pipe. Flexible mandrels, on the other hand, provide support throughout the bend area. Clearance for flexible mandrels range from 0.001 to 0.095 inch. Choose the mandrel that best meets the requirements of the job at hand.

After choosing the proper mandrel, thread the mandrel onto the mandrel rod and tighten. Again, the mandrel may be adjusted hydraulically or manually, depending on the type of machine used. You should position the tip of the mandrel at approximately the tangent point of the bend. Once the mandrel is positioned, do not change its setting during the bending evolution. If using a flexible mandrel, ensure that all segments of the mandrel bend in the directionof the pipe bend. After the machine is set up, you are ready to bend your pipe.

Select your pipe carefully, ensuring that it is free of noticeable defects and blemishes. The pipe should then be cleaned to remove all grease, oil, scale, and rust. If using a mandrel, use a lard- or a lanolin-based lubricant to coat the mandrel before inserting the pipe over the mandrel. Never use petroleum-based products to lubricate the mandrel. Insert the pipe over the mandrel, if used, ensuring that it slides freely, and clamp the pipe in place. Next, bring the pressure die in contact with the pipe. Before bending, draw a pencil mark around the pipe at the face of the clamp die. During the bending operation, watch the pencil mark for signs of slippage. If slippage is allowed, you will get wrinkles in the pipe. Severe wrinkles will break the pipe and damage the mandrels if the bending motion is not stopped immediately. Set the automatic stop on the machine 2 or 3 degrees over the desired degree of bend (this allows for spring-back in the pipe after the pressure die is removed), and slowly bend the pipe. After bending the pipe, back out the mandrel and remove the pipe from the dies.

POWER PIPE BENDER SAFETY.—The following are some of the more common safety practices used with power pipe benders:

- Always wear proper safety equipment, especially safety glasses and hearing protection.
- Know your specific equipment and qualify on its operation.
- Never exceed equipment capacity.
- Cycle the machine through a complete cycle prior to loading the pipe. Check for smooth operation and ensure all installed equipment is firmly fastened.
- Never attempt to bend pipe alone, especially on rotary benders.
- When using the portable pipe bender, do not stand in front of the ram during the bending evolution. If the pipe slips or the frame and pins Fail, you could be seriously hurt.

Hot Bending

For hot bends, the bending slab (fig. 16-15) will probably serve you best. This slab requires little maintenance beyond a light coating of machine oil to keep rust under control. As a preliminary step in hot bending, pack the pipe with dry sand. Drive a tapered wooden plug into one end of the pipe (as shown in fig. 16-16). Place the pipe in a vertical position with the plugged end down. Then fill it with dry sand, leaving just enough space at the upper end to take a second plug. This will help to prevent the heel or outside of the bend from flattening. If flattening occurs, it will reduce the cross-sectional area of the pipe, and restrict the flow of fluid through the system. Ensure that the sand is tightly packed. This is done by tapping the pipe continually with a wooden or rawhide mallet during the filling operation. A good rule of thumb is to tap 1 hour for each inch of pipe diameter. The second plug is identical with the first, except that a small vent hole is drilled through its length. This vent permits the escape of any gases (mostly steam) that may form in the packed pipe when

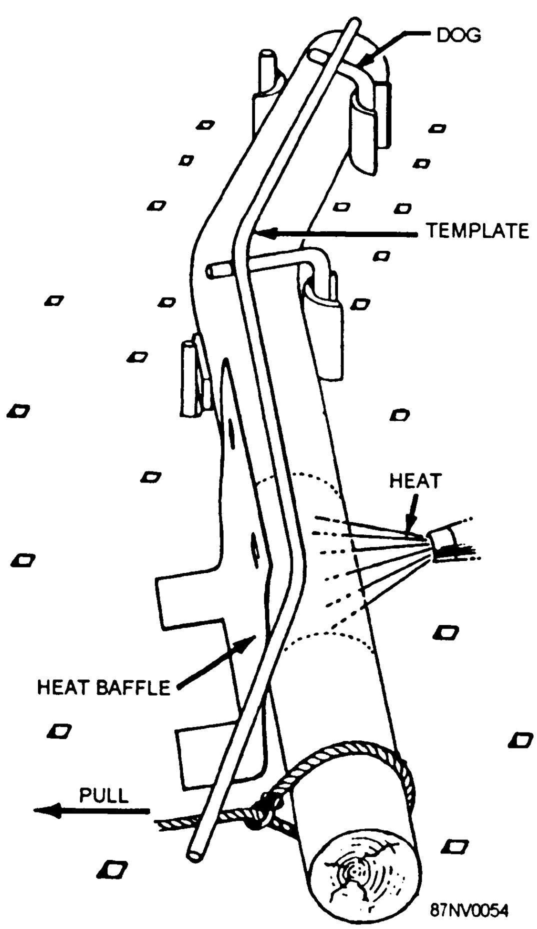


Figure 16-15.—Bending on a slab.

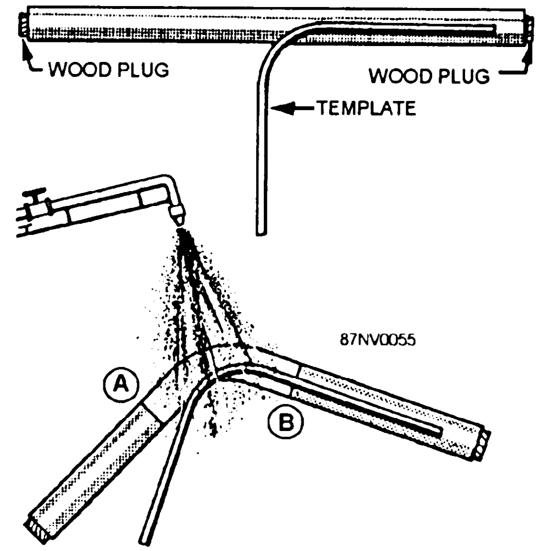


Figure 16-16.—Heating and bending pipe to conform to the wire template.

it is heated. No matter how dry the sand may appear, there is always a possibility that some moisture is present. This moisture will form steam, which will expand and build up pressure in the heated pipe. If you do not provide a vent, one of the plugs will blow out before you can get the pipe bent.

Once you have packed the pipe with sand, mark the bend area of the pipe with chalk or soapstone. Then heat the pipe to an even red heat along the distance indicated from A to B in figure 16-16. Apply heat to the bend area first on the outside of the bend and then on the inside. When an even heat has been obtained, bend the pipe to conform to the centerline template. The template is also used to mark the bend area on the pipe. When bending steel and some other piping materials, you can control wrinkles and flat spots by first overbending the pipe slightly, and then pulling the end back as shown in figure 16-17.

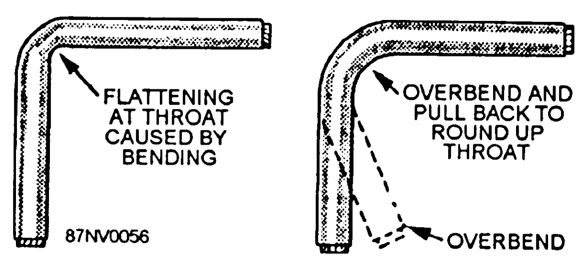


Figure 16-17.—Overbending to prevent flattening of pipe.

Most hot bends are made on a bending slab (as shown in fig. 16-15). To make the bend, exert the pull in a direction parallel to the surface of the bending slab. The necessary leverage for forming the bend is obtained by using chain-falls or block and tackle. Or you can use a length of pipe that has a large enough diameter to slip over the end of the packed pipe. Bending pins and hold-down clamps (dogs) are used to position the bend at the desired location.

Be sure to wear gloves when you are working on hot bending jobs. You will occasionally need to move the pins, clamps, and baffles during the bending operation. These items absorb heat radiated from the pipe as well as from the torch flame itself. You cannot safely handle these bending accessories without gloves.

Each material has its peculiar traits. You will need to know about these traits to get satisfactory results. The following hints for bending different materials should prove helpful :

WROUGHT IRON—This material becomes brittle when hot, so always use a large bend radius. Apply the torch to the throat of the bend instead of to the heel.

BRASS—Do not overbend. Brass is likely to crack or break when the bend direction is reversed.

COPPER—Hot bends may be made in copper, although the copper alloys are more adaptable to cold bending. This material is not likely to give you any trouble.

ALUMINUM—Overbending and reverse bending do not harm aluminum. However, there is only a small range between the bending and melting temperatures. Therefore, you will have to work with care. Keep the heat in the throat at all times. You will not be able to see any heat color. You will have to depend on "feel" to tell you when the heat is right for bending. You can do this by keeping a strain on the pipe while the bend area is being heated. As soon as the bend starts, flick the flame away from the area. Play it back and forth to maintain the ending temperature and to avoid overheating.

CARBON-MOLYBDENUM and CHROMIUM-MOLYBDENUM—These may be heated for bending, if necessary. However, use caution so you do not overheat the bend area. These metals are easily crystalized when extreme heat is applied. Pipes made from these materials should be bent cold in either manual or power bending machines.

Post Pipe Bending Inspection

All piping, regardless of the method used to bend the pipe, should be inspected after bending for defects and to meet the requirements of MIL-STD-1627. The surface should be free of pits, gouges, scratches, or tool marks. Defects are acceptable if they are less than 0.010 inch or 5 percent to the nominal thickness of the pipe, whichever is greater. The depth of the defect should not reduce the pipe wall thickness below its minimum requirement. You may remove defects exceeding the depth limits by faring in, grinding, or buffing to a radius 3 times the depth. The final pipe wall thickness after defect removal must meet minimum thickness requirements.

Wrinkles in the pipe wall are unacceptable. However, buckles, bulges, and dents may be acceptable if they meet the following criteria:

- Buckles, bulges, and dents must blend in smoothly.
- The maximum vertical height of any buckle, bulge, or dent must not exceed 3 percent of the nominal pipe outside diameter.
- The diameter-to-height ratio must equal or exceed 12 to 1.

Out-of-roundness is another common defect found in pipe bends. To find out-of-roundness, use the following formula:

NOTE: All measurements should be taken with either vernier or dial calipers.

OD max - OD min $\times$ 100 divided by OD nom.

where:

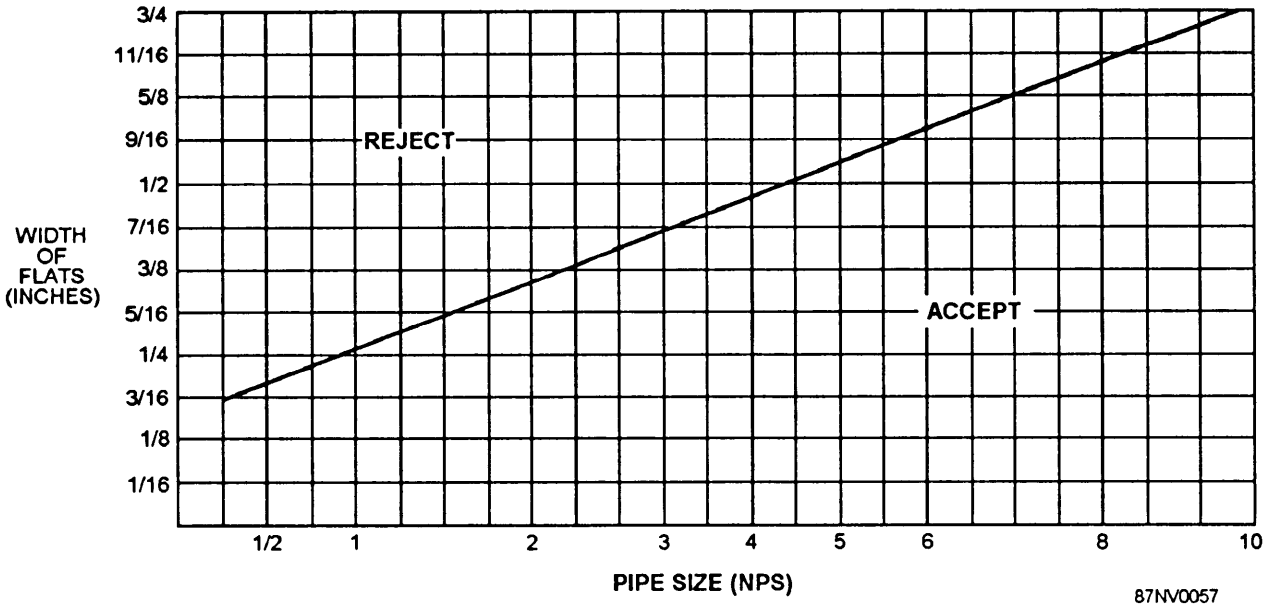
OD max = Maximum measured OD at the bend

OD min = Mimimum measured OD at the bend

OD nom = (OD max + OD min) divided by 2.

The maximum allowable out-of-roundness for pipe with a working pressure of 600 lb/in^2 and greater is 5 percent. For a pipe with a working pressure of less than 600 lb/in^2, the maximum allowable out-of-roundness is 8 percent.

Flat spots are the last defect you want to inspect the pipe for. Flatness is acceptable if it falls within the limits established by a flatness limits graph (see fig. 16-18). By measuring the width of the flat and knowing the pipe size, you can determine if the flat spot is acceptable or



PIPE SIZE EQUIVALENTS (NPS = OUTSIDE DIAMETER)

1/4 = 0.540	1 = 1.125	2 = 2.375	4 = 4.500	10 = 10.750
3/8 = 0.675	1-1/8 = 1.315	2-1/2 = 2.875	5 = 5.563	
1/2 = 0.840	1-1/4 = 1.660	3 = 3.500	6 = 6.625	
3/4 = 1.050	1-1/2 = 1.900	3-1/2 = 4.000	8 = 8.625	

Figure 16-18.—Flatness limits graph.

rejectable. If any pipe bend is rejected for any of the previously mentioned reasons, the pipe should be discarded and a new section of pipe bent.

ASSEMBLY AND DISASSEMBLY OF PIPING

A great many joints are used in shipboard piping systems. When standard fittings are used, such as couplings, elbows, and T-joints, threads must be cut on pipes and tubing. Pipe threads cause frequent failures and it is often difficult to remove threaded joints. For this reason, welded or brazed connections fitted with flanges or unions are used whenever possible. However, you will find threaded fittings used in flexible piping, in low-pressure systems, and with pipe of 2 inches IPS or less. Actually, a joint capable of withstanding 1000 psi can be made if perfect threads are cut and if the joint is properly assembled.

Threaded Joints

Pipe threading is a precise machining operation. Perfect threads are possible only if the threading dies are in good condition and properly used. Even with a perfectly cut thread, you will not get a sufficiently tight joint unless every step is done properly.

Sometimes a leaking threaded joint can be tightened with a reasonable amount of pull-up. If it cannot, you will have to take the joint apart, clean it, correct any bad thread conditions, recoat it with a suitable thread compound, and then reassemble it. When you do this, be careful to avoid new damage to the threads.

When you cut the pipe to the required length, there will be a burr on the inside. This will be true whether you use a cutting torch, a saw, or a pipe cutter. You will have to remove this burr with a file or a pipe reamer. (For more information on threading and reaming pipe, refer to chapter 5 of this manual.)

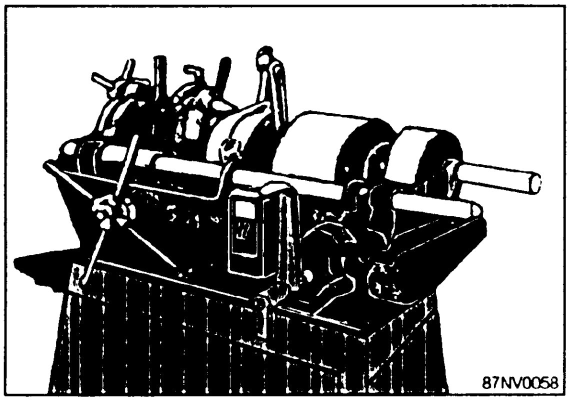


Figure 16-19.—Pipe cutting, burring, and threading machine.

The threading machine shown in figure 16-19 has the ability to perform threading, cutting, and reaming functions on pipe or bolt stock. The pipe or stock is inserted through the back of the machine into a motor-driven chuck or vise that securely holds and rotates the pipe or bolt stock. Several attachments are on the carriage assembly to perform the threading, cutting, and reaming functions of the threading machine.

The threading dies are mounted in a movable threading assembly. The assembly is fully adjustable and can accommodate pipe from l/8 to 2 inches (nominal) in size. As you move from one pipe size to the next, you will need to replace the dies as required for the work you are doing. All dies are stamped according to the range of pipe they can accommodate. Once you have selected the proper dies and set up the machine, you are ready to thread your pipe. As the pipe rotates in the chuck assembly, the die assembly is brought up to the stock to start the threading action by means of a handwheel on the side of the machine. You should not have to apply too much pressure to the handwheel to get the dies to engage the pipe since the dies are tapered to match the taper threads being cut on the pipe. Lubricant will flow from the sump as soon as the machine is started. If you fail to get a lubricant flow, check the petcock valve on the supply tube to ensure that it is on. Proper lubricant flow is required to ensure lubrication and cooling of the dies. Once the threading action is started, the die assembly will automatically draw itself along the length of the pipe until the desired amount of thread is cut. After you have cut the desired length of thread, disengage the die assembly by releasing the die clamp at the top of the die assembly.

Cut-off functions are performed by a pipe cutter (similar to hand-held pipe cutters) that is lowered onto the pipe from the carriage assembly. Reaming functions are performed by a reamer attached to the carriage assembly and inserted into the end of the pipe. All carriage attachments are mounted to swing out of the way when not being used. You can use the pipe threading machine to manufacture various size nipples as short as 4 inches and close nipples with the use of a nipple chuck.

When manufacturing nipples, you need to have an understanding of what constitutes a nipple. A nipple is a piece of pipe no longer than 12 inches and is threaded on both ends. Any pipe over 12 inches in length is a cut piece of pipe and not a nipple. A close nipple has threads the entire length of the nipple with no shoulders.

Another type of pipe and bolt threading machine is shown in figure 16-20. Here the pipe or bolt stock is held stationary and the dies are revolved. The arms of the machine may turn the handles of the die stock either by electric or pneumatic power. The thread is cut in the same way as by hand.

The tightness of a threaded joint depends upon good metal-to-metal contact. Use a wire brush to remove any dirt in the threads of either the male or female ends.

The secret of the proper assembly of a threaded pipe joint is to avoid friction between the metal parts. Friction during assembly produces heat, which in turn causes expansion. The threaded pipe, with its thinner wall, is more affected than is the fitting. When the parts

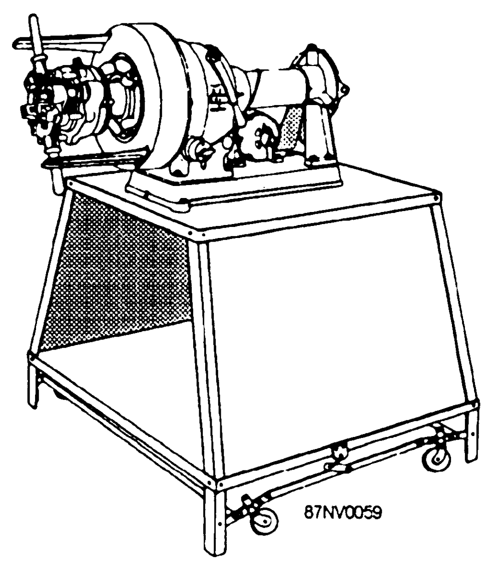


Figure 16-20.—Pipe and bolt threading machine.

cool, the pipe contracts more than the fitting, and a loose joint results.

Use good lubricant or pipe dope to overcome friction and make it easier to assemble parts. Paint the pipe dope on the male thread only. This is to keep it from getting into the pipe and damaging valve seats and other parts of the system.

White lead or red lead is generally used to lubricate and make up threaded joints in plumbing work. A special paste made from oil and filler material is used on some low-pressure steam lines. A compound or mixture of white lead and spar varnish is recommended for freshwater systems.

In assembling the joint, you will have to depend on feel to tell whether the male and female threads are properly started. Make up the joint by hand and turn the fitting as far as it will go. A few turns with the proper size pipe wrench should complete the job. It may be necessary to use a large wrench or a wrench handle extension when you are taking down lines with stubborn joints. But, an oversize wrench used to assemble the joint may crack the walls of the fitting.

Flanged Joints

The methods used to join a flange to a pipe are the same as those used with other fittings; that is, the flange may be welded, brazed, or screwed to the pipe. Male and female flanged joints are not generally used in steam piping. The initial cost of these joints is high, and it is difficult to disconnect them to replace gaskets. However, this type of joint is still used in hydraulic and other high-pressure lines, and for steel piping connections in high-temperature turbine lubrication systems. To get enough play in the line to break the joint, you will have to slack a slip joint or spring the line.

Flange faces must be in perfect alignment and free from all dirt and grit, which might cause trouble in the joint. In some instances, you may need to build up eroded areas of the flange by welding. Then the flange faces will need to be refaced before you can make a satisfactory joint. However, a thorough cleaning job will be enough for most flanges.

All faced and grooved flanges are assembled with gaskets. When choosing a gasket, always refer to the applicable system blueprint for the correct gasket. If the applicable blueprint is not available, refer to MIL-STD-777 or MIL-STD-438 to select a proper gasket. If none of these references are available, your gasket choice will depend on the characteristics, operating conditions, and mechanical features (bolting, flange shape, and so forth) of the flanged assembly. Since these factors are interdependent, carefully examine and weigh all factors for each installation.

Gasket cutters are made to cut gaskets from sheets of gasket material such as paper, cork, rubber, leather, and asbestos and fiber composition. One type of gasket cutter is shown in view A of figure 16-21. To use this cutter, place the gasket material on a wood surface and adjust the two cutters-one for the inside cut, the other for the outside cut. Place the shank in a brace and insert the center pin in the gasket material and rotate the brace, thereby forming the gasket. If the gasket is to have boltholes, punch them out with a gasket punch of the type shown in view B of figure 16-21. These punches are available in various sizes. Punching the boltholcs a bit larger than the bolts will eliminate a tendency toward bulging along the bolt circumference. The center material should be cut so that the inside diameter is the same as the inside diameter of the pipe at the flange surface.

Gaskets may also be cut with shears, snips, or a sharp knife. When using any of these tools, you must mark the material appropriately before cutting out the gasket. You can mark the gasket by laying the material over the flange and marking the cutting limits by light blows with a ball peen hammer. (This procedure should be used only for MARKING the gasket; do not cut the gasket completely by this procedure.)

You can also mark a gasket by chalking the face of the flange, laying the gasket material over the flange,' and applying pressure to the material. This will transfer the chalked impressions of the flange to the material. Gaskets may also be laid out using the procedure previously described for laying out a flange.

FLANGE MAKEUP.—Much of the trouble experienced with leaky joints in piping is due to poor alignment or improper allowance for expansion. Though you won't be able to correct expansion problems in existing piping, you can correct alignment

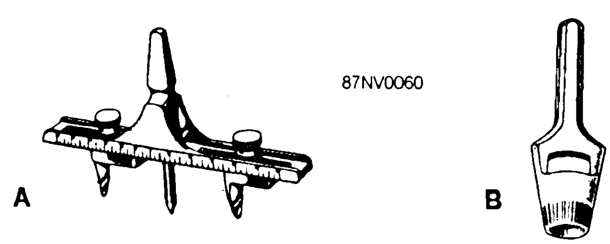


Figure 16-21.—Gasket cutter and gasket punch.

problems. Most piping systems have installed pipe hangers or supports that can be adjusted to properly support the pipe. Adjust the hangers by loosening up on the supports and then adjusting them to carry their share of the load. By adjusting pipe hangers and supports, you should be able to align piping sections so that flange bolts may be inserted freely without forcing.

Plain Flange Makeup.—This section will address the makeup of plain flanges using flexible gasket material. After you have aligned the flanges, choose the proper gasket material for the job at hand. When choosing gasket thickness, keep the following factors in mind:

- The thinner the gasket material the better the joint, especially in high-pressure joints.
- If the flanges are too far apart to be brought together, use a spacer and two thin gaskets (except for spiral wound, buna, and cork gaskets) rather than one that is thicker than l/16 inch.
- With the use of thinner gaskets, you may have to use stronger bolts to obtain required gasket compression.

After obtaining the correct gasket material, you should check the new gasket for brittleness and imperfections before installation. Replace bolts and nuts that show signs of corrosion, damage, or other imperfections. Before inserting the gasket between the flanges, you should coat one side of the gasket with graphite. By coating one side of the gasket with graphite, you will lessen the danger of tearing the gasket when the joint is broken. After installing the gasket, insert all the bolts and nuts and tighten as required.

Buna and Cork Gaskets.—These gaskets require special precautions when making up flanged joints. Buna and cork gaskets should be compressed between 20 and 30 percent of the original thickness but never more than 70 percent. If you compress the gasket more than 70 percent, you could cause excessive side flow, permanent set, or loss of resiliency. After you assemble a buna- or cork-gasketed joint, tighten setup nuts in approximately 180- and 90-degree sequence from the starting point. After final seating of the gasket, you should use feeler gauges at 90-degree intervals to measure gasket compression.

Raised Face Flange Makeup.—Raised face flanges are designed for use in high-pressure and temperature systems using spiral-wound metallic gaskets. Spiral-wound metallic gaskets are designed so that when the mating flanges are brought up against the outer metal ring, the gasket will not be crushed and an adequate preload is imparted on the gasket. After aligning the joint, inserting the gasket, and installing the bolts as previously discussed, you are ready to tighten the joint. Tighten the bolts in sequence according to the applicable technical documentation until you bring the flanges in contact with the gasket's outer ring. After flange contact is made, you should torque the bolts to the required tension. An alternate technique would be to measure the thickness of the outer ring of the gasket. You should then tighten the joint until the distance between the flanges is equal to the ring thickness plus 0.003 inch. Check this dimension with a feeler gauge at four points, 90 degrees apart. Remember to tighten all joints evenly and maintain proper alignment.

Bolt-Stud Stress.—To ensure that the gasket has been compressed the correct amount and that the bolt-stud has not been overstressed, measure the elongation of each bolt stud. The bolt-stud stress required for proper compression of gaskets is shown in table 16-3. These bolt-stud stresses have been selected to provide a reasonable factor of safety based on the yield point of the material and to ensure a tight joint.

Table 16-3.—Bolt-Stud Stress Required for Correct Compression of Metallic-Asbestos Spiral-Wound Gaskets

Type Gasket	Operating Pressure (psi)	Size of Pipe or Tubing	Bolt-Stud Stress (psi) (based on cross-sectional area at root diameter of thread)
MIL-G-16265	150	All	30,000 ± 10%
	300 400	l/4″ to 1″ IPS and 16″ OD	25,000 ± 10%
	600	1-1/4″ to 12″ IPS and 14″ to 15″ OD	30,000 ± 10%
MIL-G-21032	150 300 400 600 900 1500	1/4″ to 1″ IPS	25,000 ± 10%
		1-1/4″ IPS and larger	30,000 ± 10%
	2500	All	25,000 ± 10%

Table 16-4.—Approximate Torque Required to Obtain Bolt-Stud Stress of 25,000 psi and 30,000 psi in Various Sizes of Alloy Steel Bolts and Studs (UNC)

Nominal Size (inches) of Alloy Steel Bolt or Stud	Approximate Torque (foot-pounds) Required to Obtain 25,000 psi Stress	Approximate Torque (foot-pounds) Required to Obtain 30,000 psi Stress
1/2	25	30
5/8	50	60
314	83	100
718	133	160
1	205	245
1-M	295	355
1-1/4	416	500
1-3/8	567	645
1-1/2	667	800

The approximate torque required for bolt-stud stresses of 25,000 psi and 30,000 psi is shown in table 16-4.

These figures assume that the threads (UNC) are well lubricated. Torque wrenches should be used to apply the initial bolt-stud stress. The dial of the torque wrench indicates the torque (in foot-pounds) applied. The torque values given in table 16-4 should be applied to obtain the required stress.

Bolt-stud stress must be checked by measuring the bolt-stud elongation. This check ensures that the gasket has been compressed enough, and it prevents excessive compression of the gasket and overstressing of the bolt-stud.

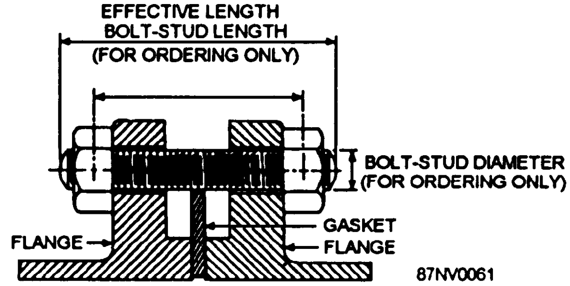


Figure 16-22.—Bolt-stud measurements.

Bolt-stud stress is checked by measuring the overall length of the bolt-stud before and after installation to determine the total amount of stretch (elongation). The total amount of stretch is then divided by the effective length of the bolt-stud to determine the stretch per inch of effective length.

The effective length of a bolt-stud is generally considered to be the distance from the center of one nut to the center of the other nut (fig. 16-22).

Naval shipyards and repair ships are equipped with strain gauges for measuring bolt-stud elongation. When strain gauges are not available, use the best micrometer calipers available. If you do not have micrometer calipers, use a C-frame, such as the one shown in figure 16-23.

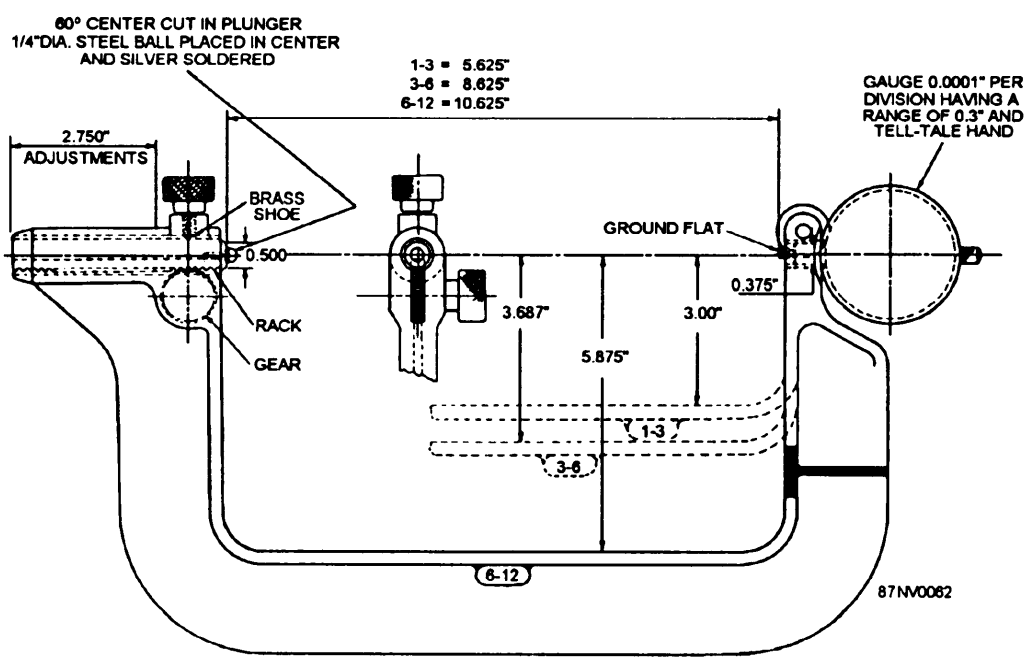


Figure 16-23.—C-frame gauge for measuring bolt-stud elongation.

Table 16-5.—Bolt-Stud Elongation Table

Stress (psi), based on cross-sectional area at root dieter of thread	Stretch (inches per inch of effective length)
1,000	0.000033
20,000	0.000660
25,000	0.000833
30,000	0.00100
40,000	0.001320
45,000	0.001485

The C-frame spans the bolts-studs, and the amount of elongation is measured with a dial micrometer. Table 16-5 is a bolt-stud elongation table.

The following example illustrates the use of tables 16-3, 16-4, and 16-5. Suppose you are required to make up a flanged joint in a 150-psi system. You are using a metallic-asbestos spiral-wound gasket of the type covered in specification MIL-G-16265, high-temperature alloy steel, and studs 1 inch in diameter with an effective length of 6 inches. Table 16-3 shows that the amount of stress required for proper compression of the gasket is 30,000 psi 10 percent. Table 16-4 tells you that approximately 245 foot-pounds of torque must be applied to obtain a stress of 30,000 psi in a l-inch alloy steel bolt or stud. From table 16-5, you find that the elongation of 30,000 psi should be 0.001 inch per inch of effective length. Since the effective length is 6 inches, the elongation of the stud when stressed to 30,000 psi should be 0.006 inch.

After applying 245 foot-pounds of torque with a torque wrench, check the elongation of the stud. If the elongation is 0.006 inch, then a 30,000 psi stress has been applied and the joint is properly sealed. If the elongation is less than 0.006 inch, increase the torque until the stud is elongated to 0.006 inch.

Cold Pull-up Joints.—Some flanged joints were originally assembled during the cold springing of the piping system. These joints are specified on ships' drawings. By remaking these joints first, you will avoid excessive misalignment of gasket seats. When remaking cold pull-up joints, install temporary pull-up bolts-studs and torque to specified tension. The purpose of installing temporary pull-up bolts-studs is to avoid damage to the threads of permanent bolts-studs. After cold pull-up is completed, replace temporary pull-up bolts one by one with permanent bolts-studs, and torque to proper tension.

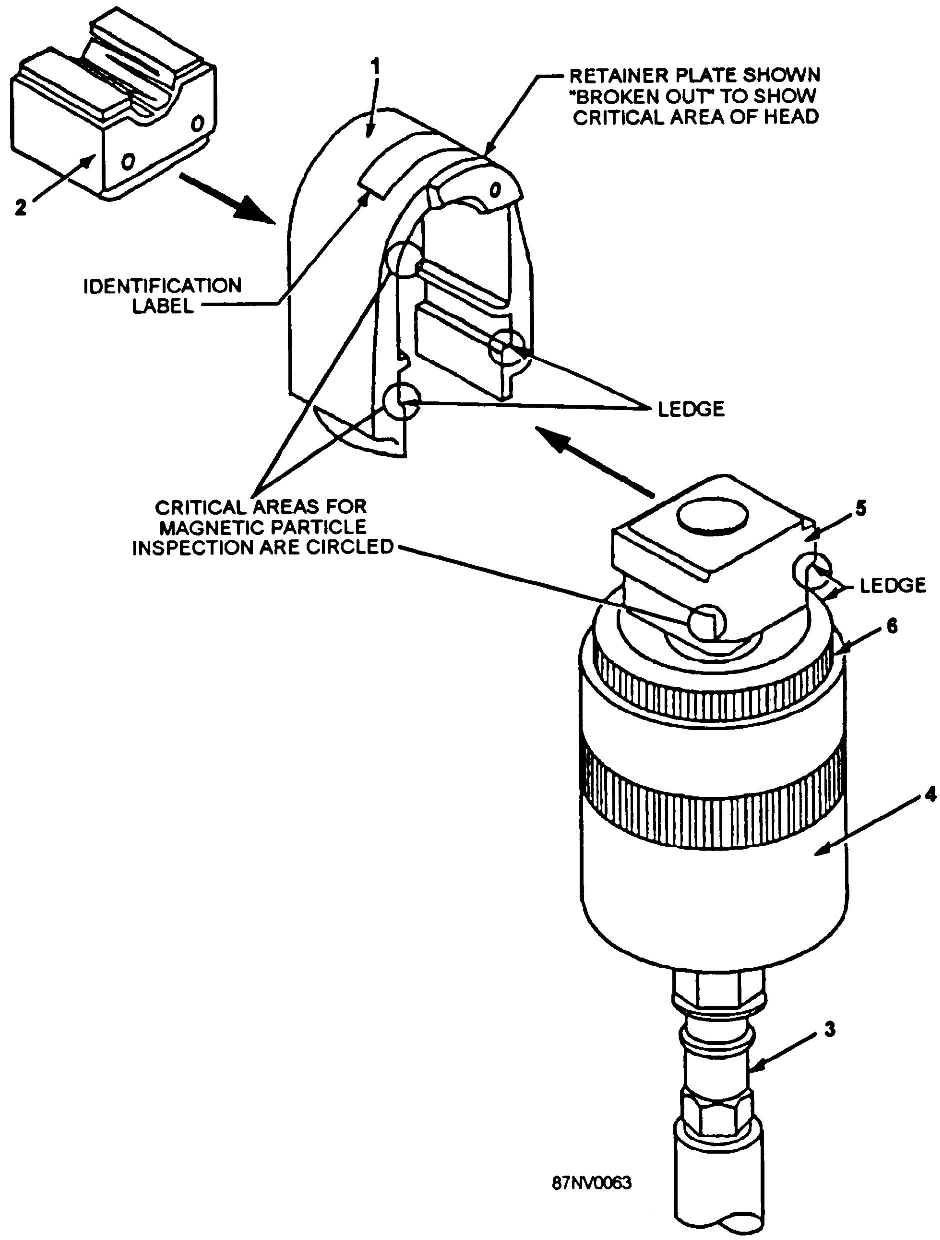
MARINE MECHANICAL PIPE FITTINGS

Swage maine fittings (SMF) and elastic strain preload (ESP) fittings are new processes that have been approved by NAVSEA for the mechanical joining of pipe and tubing. These two processes employ mechanical fittings vice welding and brazing to join pipe. They have several advantages over welding and brazing. They may be used when "hot work" is not allowed. It is a lightweight, portable, one person operation that greatly reduces the man-hour requirements of a job. The absence of flux, slag, or oxides eliminates the need to flush pipe interiors. SMFs and ESP fittings may be used on high-pressure, low-temperature systems. The following sections will discuss both of these methods in greater detail.

SWAGE MAINE FITTINGS

The tools used to install swage fittings are portable and require only one operator. The major tool is a hydraulic pump, which is normally air-powered. The pump drives an actuator that converts hydraulic pressure to linear travel and sufficient force to swage the fittings onto the pipe. Different die sets are used with the different types and sizes of fittings. Specific gauges are used to measure the pipe, locate fittings on the pipe, and ensure that the fitting has been swaged completely. The following equipment is necessary to install swage marine fittings:

- Power unit—Comes in 13-, 31-, 40-, 70-, and 100-ton units. Requires 5,500 to 10,000 psi of hydraulic pressure.
- Swage head assembly—Consists of a die holder assembly to hold the lower die half and the yoke assembly to hold the upper die half (fig. 16-24).
- Die set—Two dies. The halves contract radially when force is applied to the die holder assembly.
- Retention positioning sleeves—Used for 6,000-psi fittings in size 3/8 inch NPS and 3/4 inch OD tubing or above.
- Marking/inspection gauge—Used to verify the OD of pipe or tube, to locate installation and inspection marks, and to verify seal retention of after-swage dimensions.



1. Yoke assembly
2. Die holder assembly (with lower die half shown)
3. Pressure line to hydraulic power supply
4. Power unit
5. Strut
6. Knurled nut

Figure 16-24.—Swage tool component parts.

- Portable hydraulic power supply—Converts mechanical, electrical, or pneumatic energy to hydraulic energy.

Pipe Preparation

Pipe end preparation is improtant to ensure a good contact area between the pipe and and the elastomeric seal within the fitting. The SMF must be installed in a straight section of pipe with no wrinkles, bulges, or dents. If the pipe is galvanized, you should remove the galvanization with emery cloth until a smooth round surface is obtained. The pipe end should be cut no more than 3 degrees off square, but a cut of 5 degrees off square is acceptable. Apply a chamfer of l/16 inch at approximately 30 degrees of the cut end and deburr the inside of the pipe, using 120 or 150 grit aluminum-oxide cloth to remove surface defects.

Pipe Inspection and Insertion Marking

Using the proper marking/inspection gauge, verify the OD of the pipe and fitting as shown in figure 16-25. The P-MAX gauge must fit over the pipe/fitting in the region of the pipe/fitting contact; the P-MIN must not make three-point gauge contact or have two points 90 degrees apart. Check two places on the pipe 90 degrees apart for ovality. Refer to figure 16-26 for gauge usage.

After checking and verifying the pipe diameter and roundness, use the marking/inspection gauge to lay out the inspection and insertion marks. Refer to the manufacturer's technical manual for proper insertion depth. If the pipe wall thickness is greater than 0.125 inch, use a scriber to mark the pipe. For pipe wall thickness of less than 0.125 or stainless steel material use a chloride-free marking pen.

System Fit-up

After marking the pipe, you are ready to install the SMF. Apply a lubricant compatible with the system fluid to the pipe end and insert the pipe end into the fitting. Keep rotation and twisting to a minimum when inserting the pipe. A slight resistance should be encountered during insertion of the pipe into the fitting. If no resistance is encountered, recheck the pipe to the fitting match-up and the fitting for placement and damage of the elastomeric seal. Position the end of the fitting over the pipe installation mark so that some portion of the mark is visible. You must position the pipe in the fitting to ensure an acceptable joint (fig. 16-27). Assemble the swage head assembly according to the manufacturer's directions and swage the fitting. After swaging, inspect the swage fitting dimensions according to the latest manufacturer's technical manual.

ELASTIC STRAIN PRELOAD (ESP) FITTINGS

ESP fittings provide the same advantage as the SMF. There are many similarities in installation procedures of the two fittings. However, the basic design of the ESP fittings is different from that of the SMF. The hydraulic pressure is applied in a horizontal position, as opposed to vertical. Their installation is limited to copper pipe, class 200 90/10 copper nickel pipe up to 2 l/2 inches nominal and 3 16 stainless steel l/4 inch schedule 80 pipe used in Halon systems. The following equipment is necessary to install ESP fittings:

- Locking power head—Consists of a stationary and a movable jaw assembly.
- Marking/inspection gauge—Used to verify the OD of pipe or tube, to locate installation and inspection marks, and to verify seal retention of after-swage dimensions.
- Portable hydraulic power supply—Converts mechanical, electrical, or pneumatic energy to hydraulic energy.

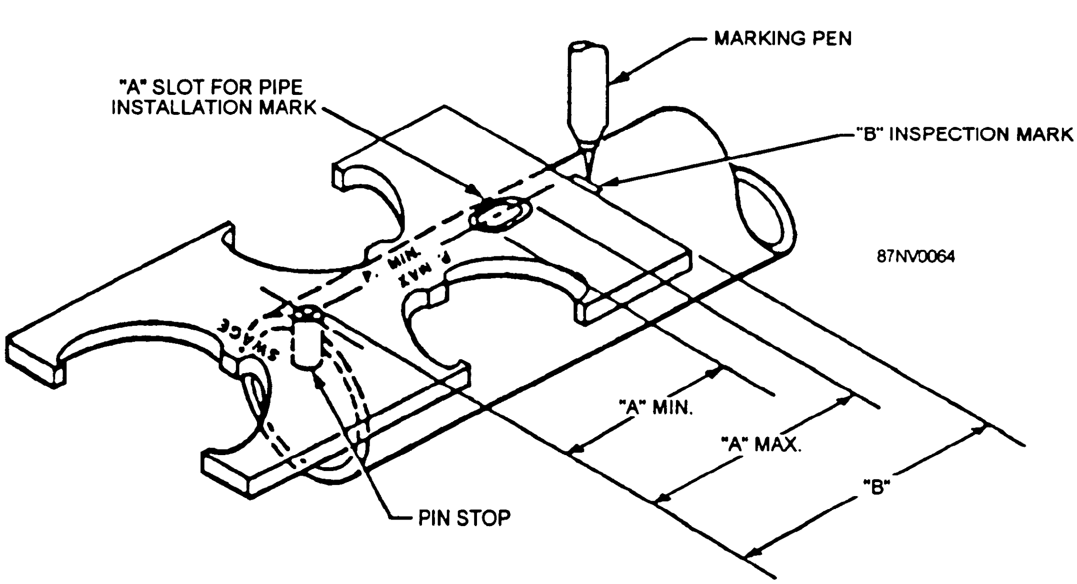


Figure 16-25.—Using marking/inspection gauge to mark pipe.

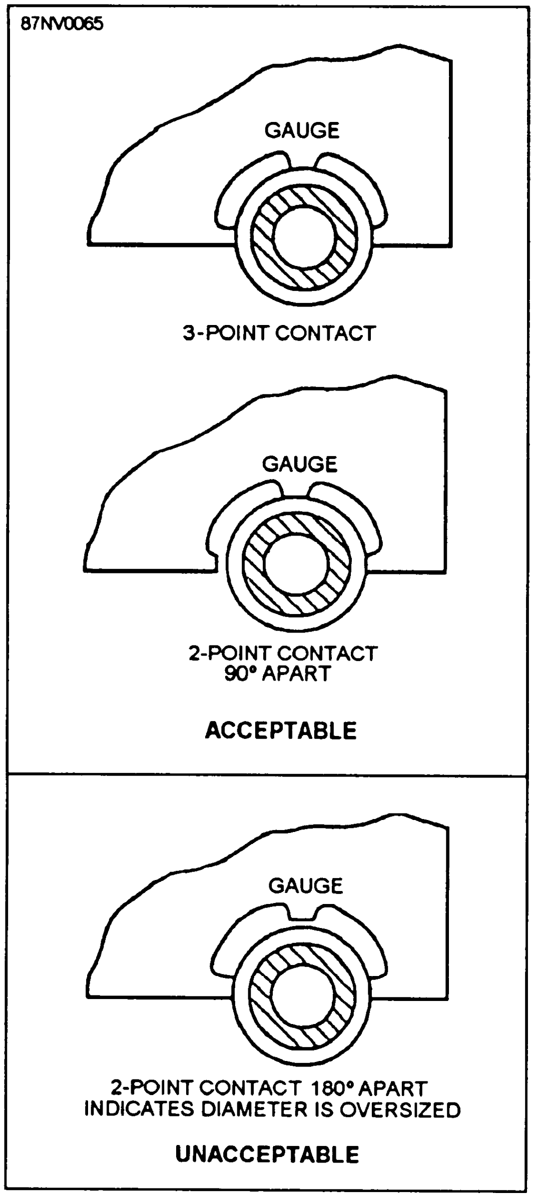


Figure 16-26.—Using marking/inspection gauge for pipe/tubing verification.

Pipe Preparation and Marking

The pipe is prepared in the same manner as previously discussed for SMFs. Use the multipurpose marking gauge (fig. 16-28) to verify the pipe end squareness and pipe outside diameters. Check the pipe diameters at two points 90 degrees apart to get true dimension readings. After obtaining acceptable pipe diameters, use an indelible marking pen to mark the installation and inspection markings.

Installation and Inspection

Installation of the ESP fittings is an easy and quick process. Slide the fitting onto one pipe end. It should slide easily over the pipe end. DO NOT FORCE the fitting over the pipe end because the sealing surface could be damaged or scratched. Align the fitting on the installation mark as shown in figure 16-29. Using the locking power head and following the manufacturer's instructions, lock the fitting onto the pipe. Remove the tool head and inspect the installation. The swage fitting should be checked for the following criteria (as shown in fig. 16-30).

- The swage ring should be seated against the fitting body tool.
- The inboard inspection marks should be partially covered by the fitting body.
- The fitting body should extend from underneath the ESP fitting.

If the fitting fails inspection, the joint should be cut out and replaced.

SHAPING TUBING AND PIPE

Bending is the shaping operation that you probably will use the most when working with tubing or pipe. Other shaping operations include flaring tube ends,

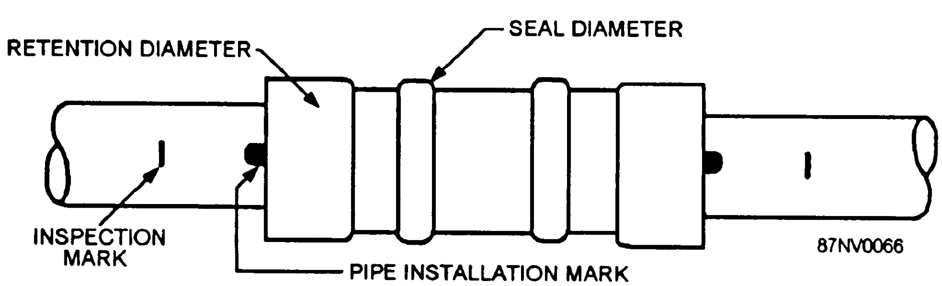


Figure 16-27.—Correct position of swage marine fitting for swaging.

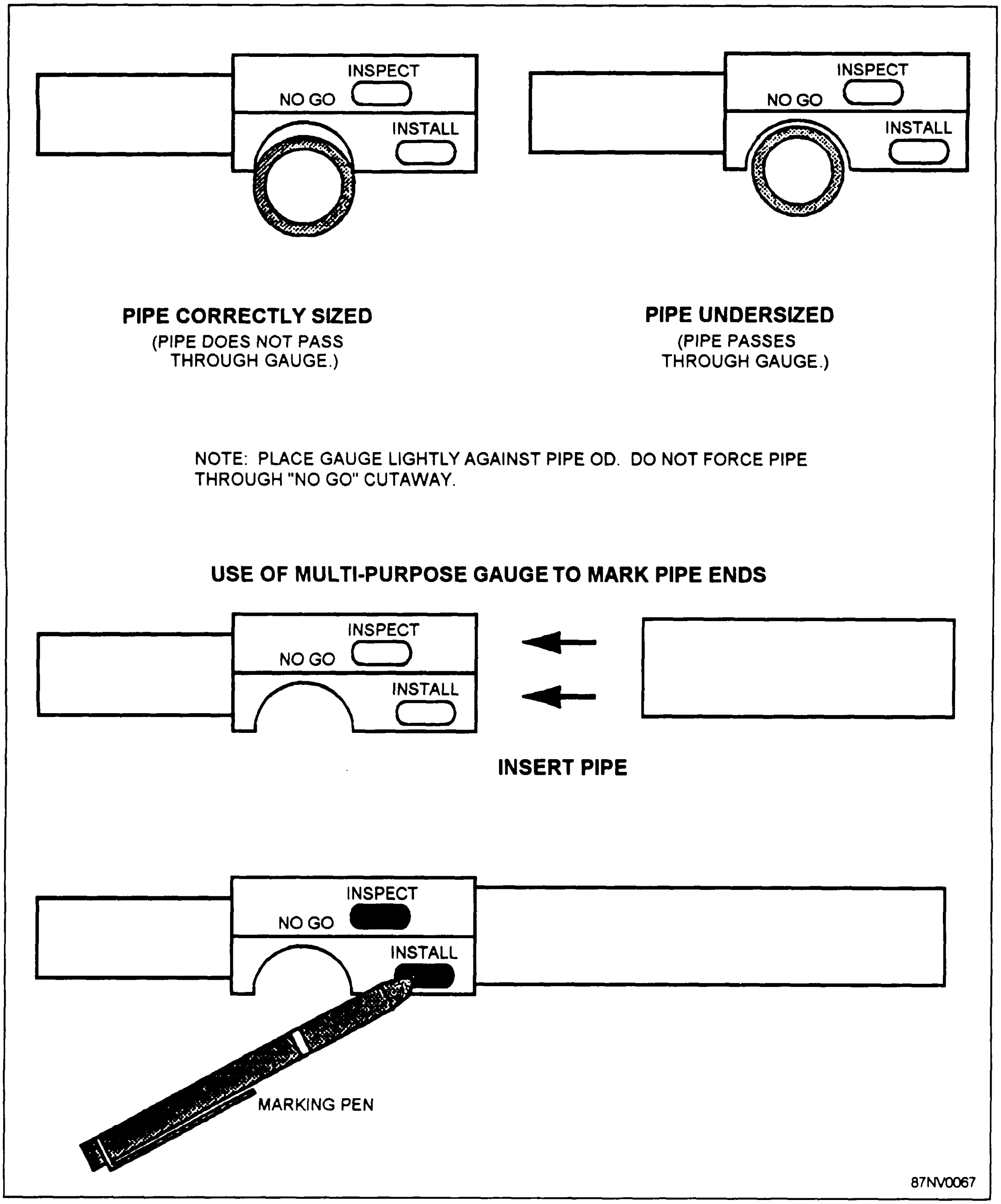


Figure 16-28.—Use of the multipurpose gauge.

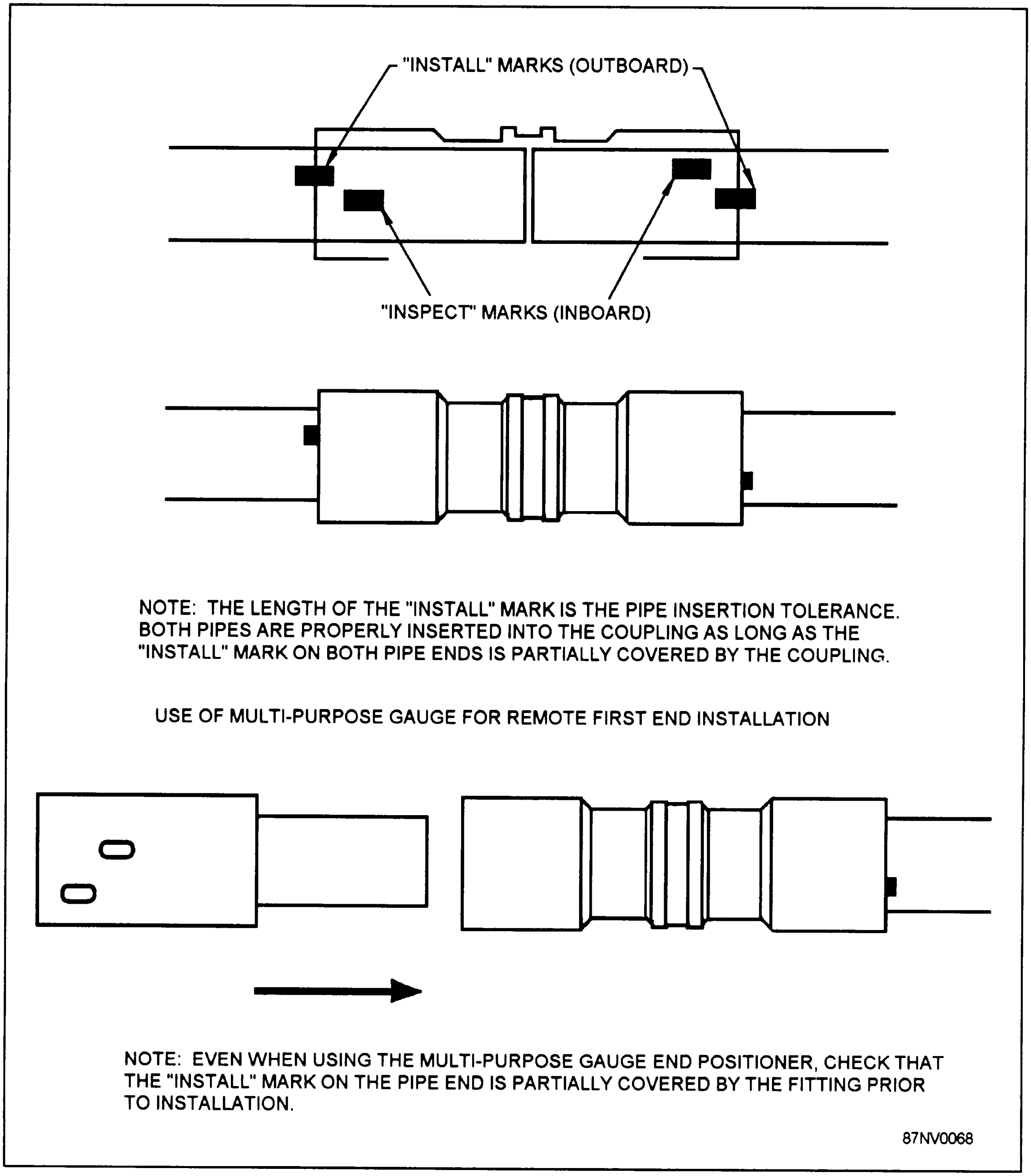


Figure 16-29.—Proper alignment and fit-up of pipe ends in the coupling.

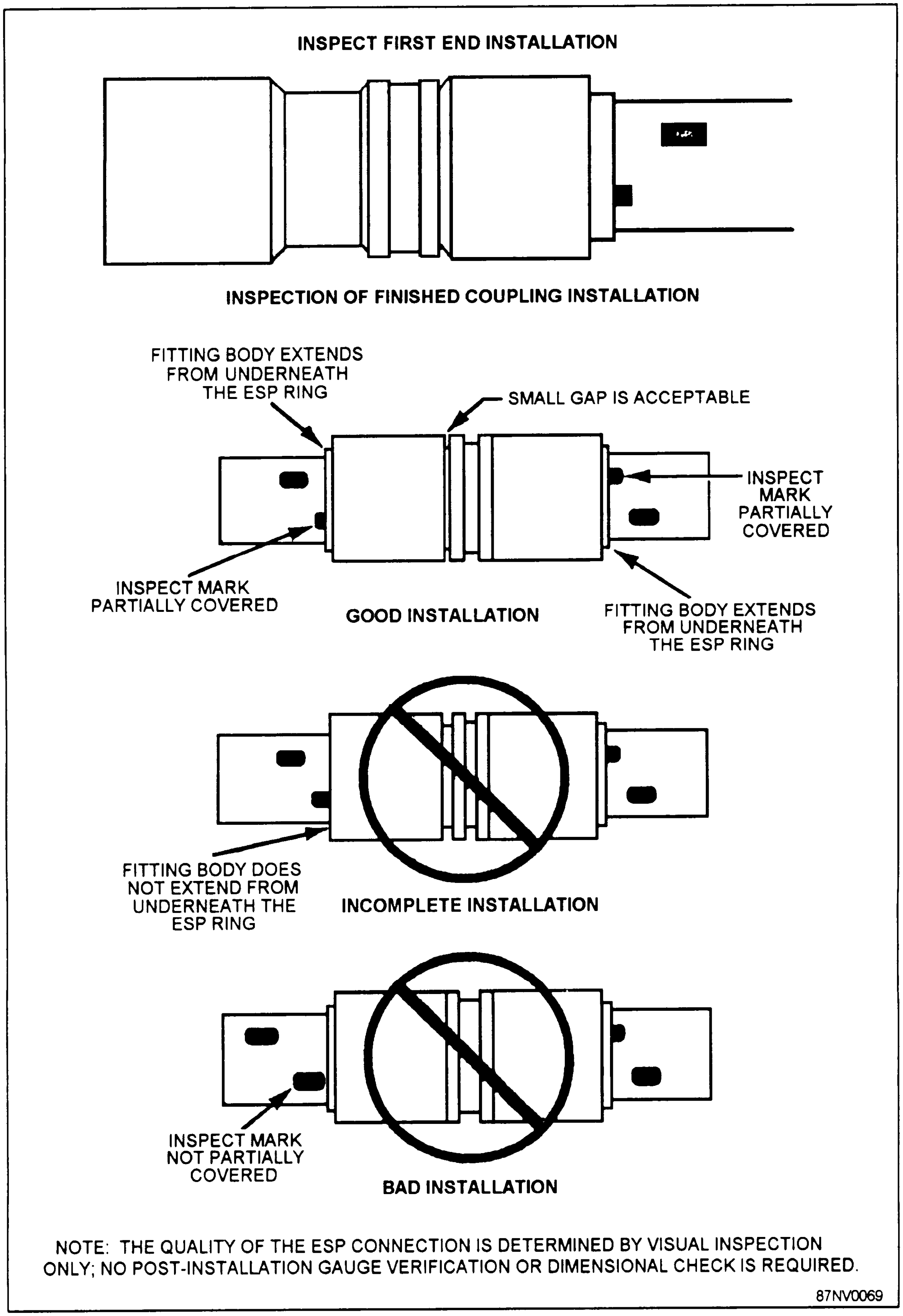


Figure 16-30.—Quality control inspection.

reducing tube ends, sizing tube ends, and joining tube ends.

BENDING TUBING AND PIPE

Tubing and pipe can be bent by the methods described earlier in this chapter. Your main problem will be to prevent wrinkles and flat spots. Wrinkles are caused by compression of the pipe wall at the throat (inside) of the bend. Flat spots are caused by lack of support for the pipe wall, by stretch in the heel (outside) of the bend, or by improper heating.

If the pipe is properly packed and properly heated, you can prevent wrinkles and flat spots. You can do this by bending the pipe in segments so that the stretch is spread evenly over the whole bend area. When a pipe is bent, the stretch tends to occur at the middle of the bend. If the bend area is divided into a number of segments and then bent in segments, the stretch will occur at the center of each segment. Therefore, the stretch will be spread fairly evenly over the whole bend area. Another advantage of bending in segments is that this is about the only way you can follow a wire template accurately.

Use the following procedure to make a segmented 90-degree cold bend in copper-nickel tubing:

1. Lay out the bend area from the wire template.

2. Divide the bend area into a number of segments, as shown in figure 16-31. Remember, the more segments you use, the smoother the bend will be. The number of segments that will work best in any particular case will depend on the size (diameter) and wall thickness of the tubing, the degree of the bend, and other factors that you will learn on the job.

3. Bend each segment slightly. Bend the last two or three segments less than the others to allow for adjustments.

4. Check the bend with the wire template.

5. Starting at the first segment again, bend each segment to a slightly greater angle than you did the first time.

6. Check the tubing again with the wire template.

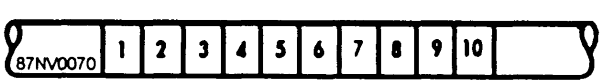


Figure 16-31.—Layout for bending tubing in segments.

7. As you bend the segments, you will probably have to move the template out of the way. Be sure to keep it on the centerline of the piping when you move it.

8. Continue bending the segments and check the tubing with the template until the tubing has been bent to the angle of the template.

You can also use the segment method of bending to make hot bends in sand-filled pipe. Suppose, for example, that you need to bend a piece of copper tubing to a 180-degree bend and then to a 90-degree bend, as shown in figure 16-32. Treat the total bending operation as though it consisted of three separate 90-degree bends, and follow this procedure:

1. Properly pack the tube with sand and use the wire template to lay out the bend area of the first bend. Do NOT mark the area of the second bend until the first bend has been made; some stretch will occur when the first bend is made. Also, the third bend area cannot be laid out until after the first and second bends have been made.

2. Divide the first bend area into four segments and mark them as shown in figure 16-33. Use chalk or soapstone to mark the numbers.

3. Place a baffle behind the first segment and heat the segment to a full red.

4. Apply pressure and bend the first segment about one-fourth of the required amount (about 22 1/2°).

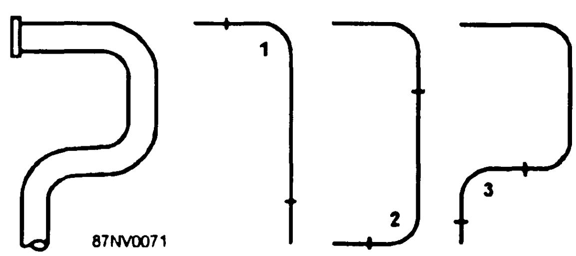


Figure 16-32.—Tubing bent to 180° and then to 90°.

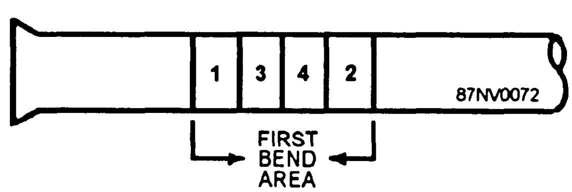


Figure 16-33.—Layout for first 90-degree bend.

5. Move the baffle to the second segment. Heat the second segment while the first segment is cooling.

6. When the second segment has been heated to a full red, bend it approximately the same number of degrees that you bent the first segment. Do NOT bend the second segment until the first one has cooled. If the first one is still hot, it will also bend when you bend the second segment.

7. Repeat these steps for the remaining segments.

After you have made the first 90-degree bend, lay out the second bend area and divide it into four segments. Starting with the first segment, repeat the bending process described for making the first bend. After all four segments have been bent and the second bend checks with the template, the return bend is complete.

The last 90-degree bend is laid out as shown for the preceeding bend. Bend the tubing in segments in the same way that the first two bends were made.

Various types of hand tools are available to make bends in small copper tubing. One commonly used type of hand tube bender is shown in figure 16-34, together with the steps for using the bender.

One very simple device for bending small tubing is nothing more than a coil spring. It is slipped over the tubing and centered at the middle of the bend area. To make the bend, you merely grasp the coil spring in both hands and bend the tubing as far as necessary. The effect of this type of bender is to divide the bend area into a large number of segments. The finished bend is smooth, without sharp creases or collapsed areas. A similar device is available for inserting inside copper tubing that is to be bent. The internal spring bender can be used to bend tubing that is already flared at both ends. It can also be used for other bending work where the external spring bender would not be feasible. Both internal and external coil spring benders are available in a number of different sizes to fit different sizes of tubing.

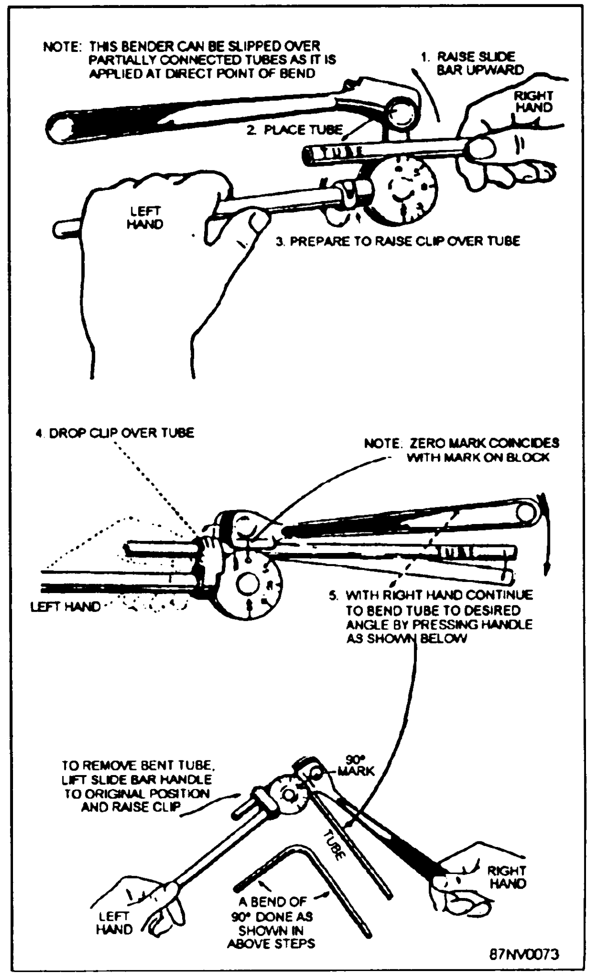


Figure 16-34.—Hand tube bender.

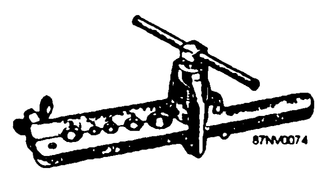


Figure 16-35.—Hand flaring tool.

FLARING TUBING

Flaring, often called belling, is done by stretching the end of the tube into a funnel shape that can be held by a fitting. If both ends of the tube are to be flared, be sure to slip all necessary fittings over the tube before you flare the second end. After both ends have been flared, the fittings will not go on the tubing.

Tubing can be flared in several ways. If special flaring tools are not available, you can put the tubing on a stake or mandrel and shape it with hammers or mallets.

An easier way to flare copper tubing is to use a hand flaring tool of the type shown in figure 16-35. The procedure is as follows:

1. Check to be sure that the tubing has been cut off squarely and evenly. Remove all burrs from inside and outside the tubing.

2. Open the flaring tool so that you can insert the tubing in the opening of the correct size. Most hand flaring tools have openings of several different diameters to accommodate different sizes of tubing.

3. Insert the end of the tubing so that it extends a short distance above the surface of the flaring block. The distance that the tubing must extend above the block is different for different diameters of tubing.

4. When the tubing is in the proper hole and extends the required distance above the surface of the flaring block, close the flaring tool. Now tighten the block by turning the wing nut.

5. Place the yoke over the end of the tubing and tighten the handle of the yoke. This forces the flaring pin into the end of the tubing.

The completed flare must be square and true at the end and it must be the right length. Figure 16-36 shows three mistakes that are commonly made in flaring tubing.

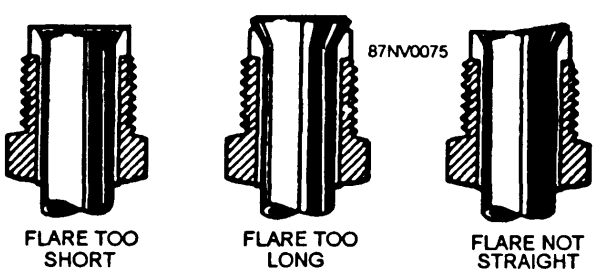


Figure 16-36.—Examples of incorrect flares.

SIZING TUBING AND PIPE

Tests have shown that if optimum strength is to be achieved between pipes and fittings, correct clearances must be obtained. This is particularly important when preparing silver-brazed joints. Sometimes the ends become enlarged when the pipe or tubing is bent. Other operations may cause the ends to become considerably smaller. In either case, the dimensions must be corrected to obtain proper fit between the tubing and the fitting. Pipe expanding tools (figs. 16-37 and 16-38) are designed to correct out-of-roundness and expand pipe ends to correct clearances. These tools are manufactured in sizes to fit most standard size pipes.

Pipe Sizing Machine

Pipe sizing machines (expanders) use a series of hardened rollers that are forced against the pipe wall by a mandrel and thrust nut (fig. 16-37). By rotating the mandrel, the rollers revolve around the inside of the pipe to bring the pipe into roundness. These types of machines may be used on all types of piping material.

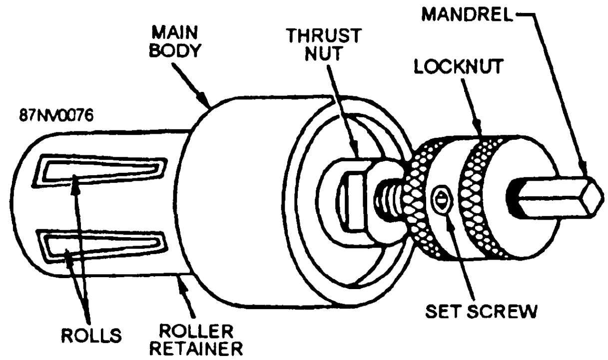
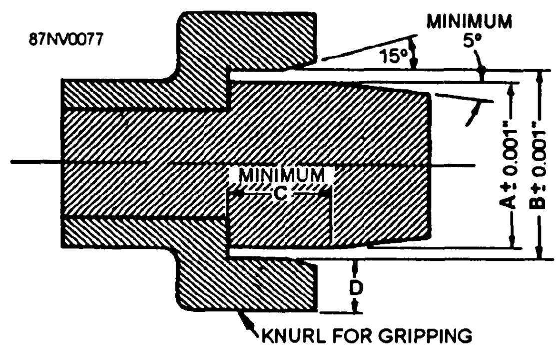


Figure 16-37.—Pipe sizing machine.



FITTING SIZE (INCHES)	DIMENSIONS			
	A	B	C	D
1/4	0.400	0.500	33/64	1/4
3/8	0.535	0.675	9/16	1/4
1/2	0.700	0.840	5/8	1/4
3/4	0.910	1.050	21/32	1/4
1	1.175	1.315	11/16	3/8
1 1/4	1.520	1.660	3/4	3/8
1 1/2	1.760	1.900	7/8	7/16
2	2.235	2.375	27/32	1/2

Figure 16-38.—Shaping and sizing tool.

If the pipe needs to be expanded, you must first determine the amount of expansion required. This is done simply by subtracting the OD of the pipe from the inside diameter (ID) of the fitting. In braze joints, you may be required to expand pipe to within 0.005 inch of the fitting.

After the pipe is cut and the pipe end deburred, simply insert the roller body into the pipe end. Back off the locknut and rotate the mandrel until the rollers contact the wall of the pipe. You may need to hold the thrust nut with a wrench while turning the mandrel to keep it from rotating until the rollers contact the pipe wall. Adjust the locknut until it seats against the thrust nut and tighten the setscrew. Rotate the mandrel several turns to round out the pipe, then remeasure the clearance between the fitting and pipe. If further expansion is required, back off the locknut one or more turns and tighten the setscrew. The amount of expansion for one turn of the locknut is usually stamped on the locknut. As you rotate the mandrel, the rollers will automatically be expanded by the mandrel and thrust nut until the locknut seats against the thrust nut. Repeat the process until proper diametrical clearance is obtained.

Drift Pins or Plugs

Pipe or tubing may also be expanded using a drift pin or plug of hardened, ground, and polished tool steel (fig. 16-38). They are usually made on site to a specific dimension and cannot be adjusted. They are simply driven into the pipe end, causing the pipe to be rounded and expanded. Pins and plugs can only be used on pipe up to 2 inches in diameter.

Pipe Sizing Restrictions

If the diametrical clearance between the fitting and pipe must be reduced, do so by filing the pipe wall. If the pipe end is expanded, the maximum diametrical expansion allowable is 0.060 inch. The maximum allowable diametrical expansion may be increased to 0.120 inch if the expanded pipe surface is checked for cracks after sizing using a dye penetrant inspection. If pipe sizing evolutions are performed, ensure that the pipe wall in the sized area does not fall below minimum wall thickness.

JOINING TUBING AND PIPE

You can join tubing and pipe by threading, silver brazing, braze welding, or by gas shielded-arc welding. Welded and silver-brazed joints are most commonly used. Use threaded joints only when (1) the tubing or pipe is hard enough to be threaded, (2) the wall thickness is thick enough to allow satisfactory threading, and (3) threaded joints are permitted in the system for which the tubing or pipe is to be used. Threaded joints are not permitted in many shipboard piping systems.

Tubing or pipe must be thoroughly cleaned before it is joined. You can use acids to clean copper, but all traces of the acids must be removed from the work.

Making a Cup Joint

You can often use cup joints to join the ends of copper pipes or tubes that do not ordinarily need to be taken down. Pipes under 5 inches in diameter should have a cup length about equal to the pipe diameter. Cups for larger pipe are usually smaller in relation to the pipe diameter.

NOTE: These types of joints may only be used where authorized by competent authority.

Figure 16-39 shows a cup joint that is used to join the ends of two lengths of copper pipe. The cup is made at the end of one piece of pipe. The end of the other piece fits down into the cup. The cup must always be made in such a way that there will be the least possible interference with the flow of fluid in the system.

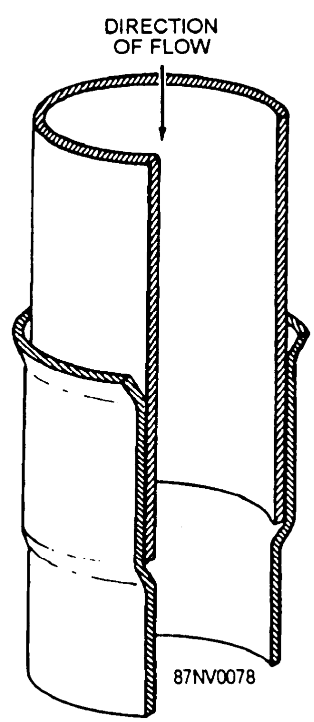


Figure 16-39.—Cup joint for joining ends of two copper pipes.

The pipe end in which the cup is to be made must be annealed before the work is begun and annealed frequently as it is worked. To form the cup, lay the annealed pipe on a grooved wooden block. Insert a round steel bar in the pipe. The outside diameter of the bar should be about 0.003 inch greater than the outside diameter of the inner pipe. Hold the bar firmly against the pipe, with the inserted end of the bar exactly at the place where the cup is to begin. Then hammer the steel bar. Revolve the pipe slightly and hammer the steel bar again. Continue to revolve the pipe and hammer the steel bar until the cup is formed. Stop whenever necessary to anneal the pipe end.

When the cup has been formed so that the inside pipe will fit into the cup, flare the end of the cup slightly. Then anneal and clean the cupped end of the pipe. Immediately after cleaning, apply flux evenly to each joint surface to be brazed.

After the two pipes have been fitted together, caulk the bottom edge of the cup tight against the inside pipe (fig. 16-39). Then braze the joint.

Making a Cup Branch

You will often use a cup branch to fit a branch line into a main line. One procedure for making a cup branch is shown in figure 16-40. First, drill a small hole in the main line pipe at the center of the intersection.

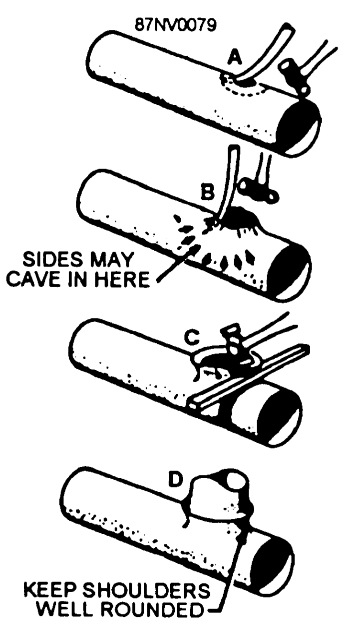


Figure 16-40.—Steps in making a cup branch.

Anneal the area of the pipe that is to be formed. Then, while the metal is still red hot, work the edge up with a raising bar, as shown in view A of figure 16-40. The sides may tend to cave in, as shown in view B. They can be bumped out with a bumping ball.

Shape the cup by the method shown in view C of figure 16-40 until it fits snugly around the end of the branch. Then peen the end of the branch to fit the contour of the cup. Flux and braze the joint. If necessary, peen the inside to ensure a smooth surface that will not interfere with the flow of fluid in the system.

MAINTENANCE AND REPAIR OF VALVES

Preventive maintenance is the best way to extend the service life of valves and fittings. As soon as you observe a leak, determine the cause, then apply the proper corrective maintenance. Maintenance may be as simple as tightening a packing nut or gland. A leaking flange joint may need only to have the bolts tightened or to have a new gasket or O-ring inserted. Dirt and scale, if allowed to collect, can ultimately cause leakage. Loose hangers permit sections of a line to sag, and the weight of the pipe and the fluids in these sagging sections may strain joints to the point of leakage. Always refer to the applicable PMS procedures and the *Navy Standard Valve Technical Manual.* When making valve repairs on more sophisticated valve types, you should refer to the manufacturer's technical manual.

Whenever you install a valve, be sure you know the function the valve is to perform; that is, whether it must prevent back flow, begin flow, stop flow, regulate flow, or regulate pressure. Inspect the valve body for information that is stamped on it by the manufacturer: type of system (oil, water, or gas), operating pressure, direction of flow, and other information.

You should also know the operating characteristics of the valve, the type of metal from which it is made, and the type of end connection it has. Operating characteristics and the type of material are factors that affect the length and kind of service that a valve will give. End connections indicate whether or not a particular valve is suited for installation in the system.

Valves should be installed in accessible places and with enough headroom to allow for full operation. Install valves with the stem pointing upward, if possible. A stem position between straight up and horizontal is acceptable, but avoid the inverted position (stem pointing downward). If the valve is installed with the stem pointed downward, sediments will collect in the bonnet and score the stem. Also, when a line is subjected to freezing temperatures, liquid trapped in the valve bonnet may freeze and rupture it.

Valves that have been in constant service over a long period of time will eventually require gland tightening, repacking, or a complete overhaul of all parts. If a valve is not doing the job for which it is intended, it should be dismantled and all parts inspected for corrosion, scarring, and erosion of seating surface and valve body. All defective parts must be repaired or replaced.

GLOBE VALVE

The repair of globe valves (other than routine renewal of packing) is generally limited to refinishing the seat and disk surfaces.

When refinishing the valve seat, do not remove any more material than is necessary. Valves that do not have replaceable valve seats can be refinished only a limited number of times.

Before you begin any repair work on the seat and disk of a globe valve, check the valve disk to make certain it is secured rigidly to and is square on the valve stem. Also, check to be sure the stem is straight. If the stem is not straight, the valve disk cannot seat properly. Carefully inspect the valve seat and valve disk for evidence of wear, for cuts on the seating area, and for improper fit of the disk to the seat. Even if the disk and the seat appear to be in good condition, they should be spotted-in to find out whether they actually are in good condition.

Spotting-in Valves

The method used to visually determine whether the seat and the disk of a valve make good contact with each other is called spotting-in. To spot-in a valve seat, first apply a thin coating of prussian blue evenly over the entire machined face surface of the disk. Then insert the disk into the valve and rotate it a quarter turn, using light downward pressure. The prussian blue will adhere to the valve seat at those points where the disk makes contact. Figure 16-41 shows what correct and imperfect seats look like when they are spotted-in.

After you have noted the condition of the seat surface, wipe all the prussian blue off the disk face surface. Apply a thin, even coat of prussian blue to the contact face of the seat. Again place the disk on the valve seat and rotate the disk a quarter of a turn. Examine the blue ring on the valve disk. The ring should be unbroken and of uniform width. If the blue ring is broken in any way, the disk is not making a proper fit.

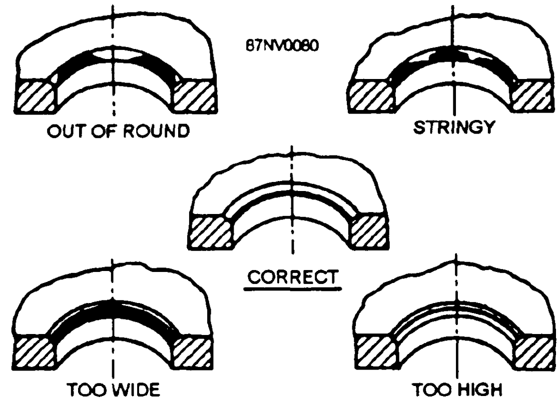


Figure 16-41.—Examples of spotted-in valve seats.

Grinding-in Valves

The manual process used to remove small irregularities by grinding together the contact surfaces of the seat and disk is called grinding-in. Grinding-in should not be confused with refacing processes in which lathes, valve reseating machines, or power grinders are used to recondition the seating surfaces.

To grind-in a valve, first apply a small amount of grinding compound to the face of the disk. Then insert the disk into the valve and rotate the disk back and forth about a quarter of a turn. Shift the disk-seat relationship from time to time so that the disk will be moved gradually, in increments, through several rotations. During the grinding-in process, the grinding compound will gradually be displaced from between the seat and disk surfaces. Therefore, you must stop every minute or so to replenish the compound. When you do this, wipe both the seat and the disk clean before applying the new compound to the disk face.

When it appears that the irregularities have been removed, spot-in the disk to the seat in the manner previously described.

Grinding-in is also used to follow up all machining work on the valve seats of disks. When the valve seat and disk are first spotted-in after they have been machined, the seat contact will be very narrow and will be located close to the bore. Grinding-in, using finer and finer compounds as the work progresses, causes the seat contact to become broader. The contact area should be a perfect ring covering approximately one-third of the seating surface.

Do not overgrind a valve seat or disk. Overgrinding tends to produce a groove in the seating surface of the disk. It also tends to round off the straight, angular surface of the disk. Machining is the only process by which overgrinding can be corrected.

Lapping Valves

When a valve seat contains irregularities that are slightly larger than can be satisfactorily removed by grinding-in, you can remove them by lapping. A cast-iron tool of exactly the same size and shape as the valve disk is used to true the valve seat surface. Two lapping tools are shown in figure 16-42.

Observe the following operating instructions when you use a lapping tool:

- Do not bear down heavily on the handle of the lapping tool.
- Do not bear sideways on the handle of the lapping tool.
- Rotate the lapping tool so that the lap will gradually and uniformly cover the entire seat.
- Keep a check on the working surface of the lapping tool. If a groove develops, have the tool refaced.
- Always use clean compound for lapping.
- Replace the compound frequently.
- Spread the compound evenly and lightly.
- Do not lap more than is necessary to produce a smooth, even seat.
- Always use a fine grinding compound to finish the lapping job.
- Upon completion of the lapping job, spot-in and grind-in the disk to the seat.

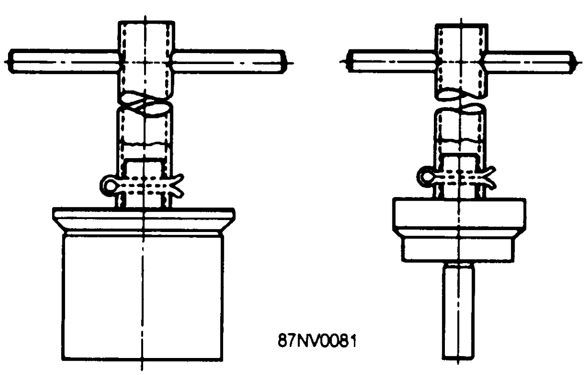


Figure 16-42.—Lapping tools.

Use only approved abrasive compounds to recondition valve seats and disks. Compounds for lapping and grinding valve disks and seats are supplied in various grades. A coarse grade compound is used when extensive corrosion or deep cuts are found on the disks and seats. A compound of medium grade is used to follow up the coarse grade; it may also be used to start the reconditioning process on valves that are not too severely damaged. A fine grade compound should be used when the reconditioning process nears completion. A microscopic-fine grade should be used for finish lapping and for all grinding-in.

Refacing Valves

Badly scored valve seats must be refaced in a lathe, with a power grinder, or with a valve reseating machine. However, the lathe rather than the reseating machine should be used to reface all valve disks and all hard-surfaced valve seats. Work that must be done on a lathe or with a power grinder should be turned over to machine shop personnel This discussion applies only to refacing seats with a reseating machine.

To reface a seat with a reseating machine (fig. 16-43), attach the correct 45-degree facing cutter to the

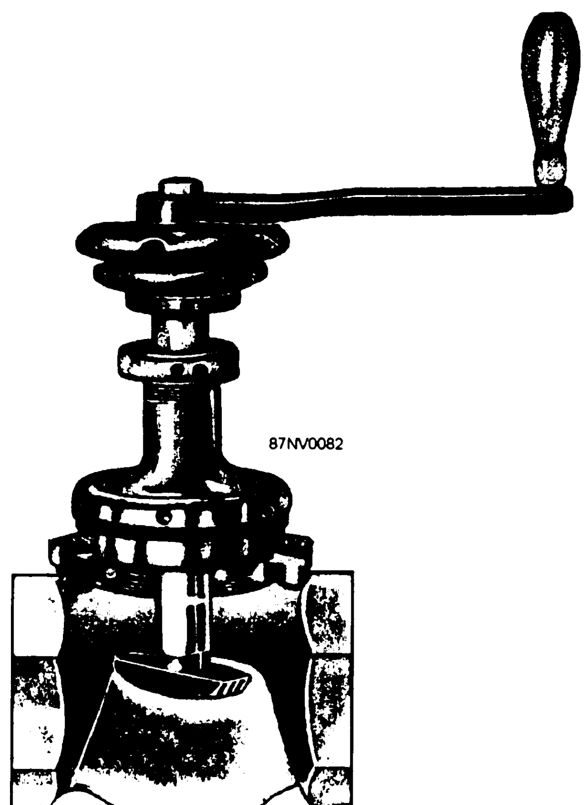


Figure 16-43.—Valve reseating machine.

reseating machine. With a fine file, remove all high spots on the surface of the flange upon which the chuck jaws must fit. Note that a valve reseating machine can be used ONLY with a valve in which the inside of the bonnet flange is bored true with the valve seat. If this condition does not exist, the valve must be reseated in a lathe, and the inside flange bored true.

Before placing the chuck in the valve opening, open the jaws of the chuck wide enough to rest on the flange of the opening. Tighten the jaws lightly so that the chuck securely grips the sides of the valve opening. Tap the chuck down with a wooden mallet until the jaws rest firmly and squarely on the flange. Then tighten the jaws further.

Adjust and lock the machine spindle in the cutting position and start the cutting by turning slowly on the crank. Feed the cutter slowly so that very light shavings are taken. After some experience, you will be able to know by the feel whether or not the tool is cutting evenly all around. Remove the chuck to see if enough metal has been removed.

Be sure the seat is perfect. Then remove the 45-degree cutter and face off the top part of the seat with a flat cutter. Dress the seat down to the proper dimensions, as follows:

Width of Seat	Size of Valve
1/16 inch	1/4 to 1 inch
3/32 inch	1 1/4 to 2 inches
1/8 inch	2 1/2 to 4 inches
3/16 inch	4 1/2 to 6 inches

After the refacing, grind-in the seat and disk. Spot-in as necessary to check the work. A rough method of spotting-in is to place pencil marks at intervals of about one-half inch on the bearing surface of the seat or disk. Then place the disk on the seat and rotate the disk about a quarter of a turn. If the pencil marks in the seating area rub off, the seating is considered satisfactory.

Repacking Valve Stuffing Boxes

If the stem of a globe valve is in good condition, stuffing box leaks can usually be stopped by setting up on the gland. If this does not stop the leakage, repack the stuffing box. The gland must not be set up or packed so tightly that the stem binds. If the leak persists, a bent or scored valve stem may be the cause of the trouble.

Coils (string) and rings are the common forms of packing used in valves. The form to be used in a particular valve will be determined, in part, by the size of the packing required. In general, rings are used in valves that require packing larger than one-fourth inch. When a smaller size is required, string packing is generally used.

When you repack a valve stuffing box, place successive turns of the packing material around the valve stem. When strong packing is used, coil it around the valve stem. Bevel off the ends to make a smooth seating for the bottom of the gland. Then put on the gland and set it up by tightening the bonnet nut or the gland bolts and nuts. To prevent the strong packing from folding back when the gland is tightened, wind the packing in the direction in which the gland nut is to be turned. Usually, where successive rings are used, the gaps in the different rings should be staggered.

Gate, globe, angle, and stop check valves are made to back seat the stem against the valve bonnet when the valve is fully opened. Back seating of these valves is a safety feature to eliminate the possibility of the stem being forced out under pressure while the valve is fully opened. Back seating makes possible the repacking of the stem stuffing box under pressure. However, you should attempt this only in emergencies and with extreme caution.

GATE VALVES

The manner in which a gate valve is used has a great deal to do with its service life. Gate valves should always be used either wide open or fully closed; never in a partially opened position. When a gate valve is partly open, the gate is not held securely, but swings back and forth with the pulsation of the flow. As the gate swings, it strikes the valve body and the finished surfaces, nicking and scoring them. When these surfaces are imperfect, the valve gate cannot set accurately and seal off the flow. A gate valve should never be installed in any position where a throttling or flow-regulating valve is required. A globe valve should be used in those situations.

Lapping is the best way to correct gate valve defects such as light pitting or scoring and imperfect seat contact. The lapping process is basically the same for gate valves as it is for globe valves. The exception is that the lap is turned by a handle that extends through the end of the valve body. Remove the valve from the system. Insert the lapping tool, without its handle, into the valve so that it covers one of the seat rings. Then attach the handle to the lap and begin the lapping. The wedge gate can be lapped to a true surface, using the same lap that is used on the seat rings. (**CAUTION:** DO NOT use the gate as a lap.)

Do not remove any more material than is necessary. You can resurface a gate valve only a limited number of times. By removing too much material, you will reduce the number of times the surface can be refinished and the life of the valve.

Leakage around the stem of a gate valve is caused by troubles similar to those in leaking globe valves. The same procedure is used to stop these leaks in both valves.

CHECK VALVES

Leaks are the principal trouble found in check valves. Leakage is caused by a pitted disk or valve seat. Pitting is usually caused by abrasives caught between the disk and the seat.

When a check valve requires maintenance because of pitting, the work will depend upon the type of disk in the valve. With a ball-type disk, you will have to replace the ball and grind the seat. A flat or conical disk can be repaired by grinding in the disk to its seat with a fine grinding compound.

Remember that fluid will flow through them in only one direction. Be sure they are installed correctly.

FLUSH VALVES

Any flush valve will give years of adequate and trouble-free operation if it is properly maintained. However, there are two major problems that may occur in flush valves: (1) the valve may run continuously instead of shutting off at the right time, or (2) the valve may fail to deliver the desired amount of water (short flushing). Both of these defects can waste a lot of water. One of the reasons for a flush valve is to reduce water waste; therefore, proper maintenance is important. Once you understand the principle and the operation of a valve, you will know what to look for when anything goes wrong. The internal working parts of a typical piston-type flushing valve are shown in figure 16-44.

Continuous flow through a piston-type flush valve is almost always caused by one of two things. Either the relief valve fails to seat properly, or the bypass valve is corroded. In both cases, there is not enough force on the piston to seat it.

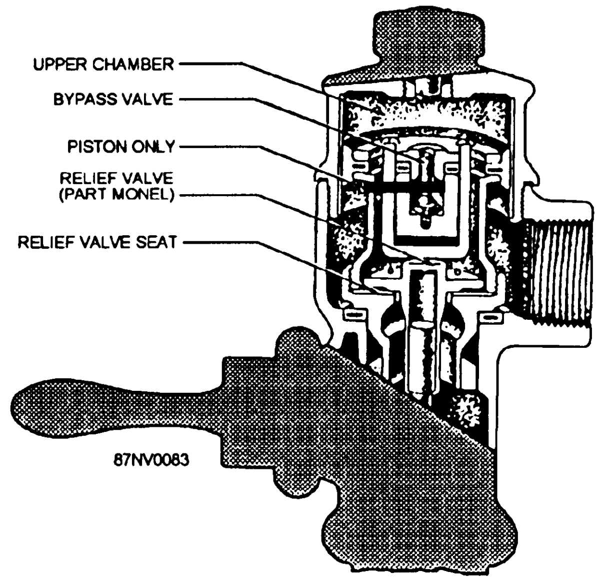


Figure 16-44.—Piston-type flushing valve.

If the relief valve fails to seat properly, there may be enough leakage to prevent the upper chamber of the valve from filling. The piston will therefore remain in the open position. Inspect the relief valve seat for dirt or other foreign substances that may be causing the relief valve to tilt. If these substances are present, disassemble the piston, wash the parts thoroughly, and reassemble. Replace wornout washers, making sure that the surface upon which the washer sits is perfectly clean. If any old rubber sticks to the metal surface, scrape it off.

Corrosion of the bypass valve in the center of the top plate will also cause continuous flow. The water is unable to pass into the upper chamber of the valve. Therefore, no force is exerted on the piston to move it downward to its seat. Very dirty water passing through the system can clog the bypass and deprive the upper chamber of water. Pipelines in a new installation should be thoroughly flushed out before they are placed in operation. If not, the pipe dope or dirt accumulated in them can also stop up the bypass valve.

The same condition can arise in a diaphragm valve. If chips or dirt carried by the water lodge between the relief valve and disk, the relief valve will not seat securely. The leakage will then prevent the upper chamber of the valve from filling with water. The valve will then remain in the open position, since there will be no pressure to force the diaphragm to seat.

Short flushing can occur only in a diaphragm-type valve. If the disk, diaphragm, and guide have not been assembled tightly, you may have to reassemble them to get proper operation. Sometimes you may find that someone has tampered with the bypass tube. It may be enlarged so that the water passes so rapidly into the upper chamber that it closes off the valve before the desired volume has been delivered. Also, someone may have oiled or greased the valve parts. It may have been done to make the valve operate more easily. However, the oil or grease ruins the rubber parts and interferes with the action of the valve. You may be called upon to correct short flushing in a water closet.

You should first check to see if the correct type of valve has been installed. If a urinal valve has been installed by mistake, the valve will not be short flushing. It is merely delivering the three-fourths gallon of water for which it is set.

PRESSURE-REDUCING VALVES

Pressure-reducing valves are installed in branch lines of the firemain to reduce the water pressure to a working level for the flushing system. You will probably do the maintenance and repair on these pressure-reducing valves.

The most common problems in these valves are ruptured diaphragms, binding of the O-ring or cup washer, and chattering. A Monel insert is now used to prevent the erosion of the valve body where the O-ring seals.

A ruptured diaphragm is easily detected, for water from the small hole in the spring chamber casing will be evident.

When you have a drop in water volume, check the valve's O-ring or cup washer. If the discharge pressure of a reducing valve becomes greater than the spring pressure, the volume will drop to almost nothing.

Chattering is more of a nuisance than a real problem. It is caused by the fast opening and closing of the reducing valve. This occurs when only one or two water closets are flushed at the same time and water supply is greater than demand. Usually most reducing valves are designed to handle the larger systems. When the demand is small, volume is supplied quickly and the valve, in turn, closes quickly. This rapid opening and closing is what causes the noise. A constant flow in the urinals will probably stop the chattering.

VALVE LEAKAGE AND STICKING CAUSES

During normal operation of valves, the use of a wrench to open or close a valve is prohibited. However, if a valve is jammed in the open or closed position, a wrench may be used to unjam the valve. However, because of the danger of damaging the valve disk due to overloading of the stem and disk, you should take extreme care when using a wrench. Where extreme difficulty is experienced in opening and closing a valve, isolate the valve and disassemble for inspection to determine the cause of the problem. Inability to open high-pressure steam, flexible wedge, gate valves with the normal operating mechanism or handwheel may be an indication of body overpressurization. If the steam supply to the valve is not shut down immediately, the results may be catastrophic.

Seating Problems

Leakage through the valve is generally caused by the disk and seat failing to make a tight joint, and may result from conditions described in the following paragraphs. Additional information on seating problems can be found in *NSTM,* chapter 505.

—Foreign Substances. Foreign substances, such as scale, dirt, waste, or heavy grease may become lodged on the seat so the disk cannot be seated. If obstructing material cannot be flushed through, disassemble and clean out the valve.

—Scoring. Scores in the seat or disk are caused by attempting to close the valve on scale or dirt, or by erosion. If damage is slight, the valve may be made tight by grinding; if damage is more extensive, reseat the valve and then grind or replace.

—Cocked Disk. The disks may be cocked if the feather guides fit too tightly or if the spindle guide or valve stem is bent.

—Damaged Seat or Disk. The valve body or disk may be too weak, permitting distortion of the valve seat or disk under pressure or closing force.

—Improper Disk-to-Seat Contact. The disks and seat may not have been machined properly, preventing tight disk-to-seat contact.

—Extraneous Leakage. Leakage paths may occur behind inserted seats or threaded seat rings.

—Casting Defects. Casting defects may be present in the valve disk or body, particularly in new valves.

—Seat Warping. In brazed valves, seat warping results from excess heat applied to the valve body during brazing.

Stuffing Box

Stuffing box leaks may be remedied by tightening gland nuts, or by adding rings of packing as required. Continued leakage may indicate a need to replace all packing in the valve. Do not set up or pack the gland so tightly that the stem sticks. Persistent stuffing box leaks are usually caused by a bent or scored valve stem. Considerable trouble with stuffing box leaks may be avoided if valves are installed with the valve stem pointing up. Before you alter the position of a valve stem, you should consider convenience of operation and availability of space for removing the bonnet, stem, and disk.

EXTERNAL PRESERVATION OF VALVES

Now we will discuss the external surfaces of valves that require painting, with the following exceptions:

- Valvestem
- Valve stem bushing
- Valve gland
- Any threaded surfaces

For valves that operate above 300°F (when the fluid contained is above 300°F), two coats of high-temperature aluminum paint should be used. No primer should be used on these high-temperature valves.

For valves that operate below 300°F, primer paint should be applied to match the surrounding area. Note that all steam valves operate above 300°F. Valves made of noncorrosive material (stainless steel, bronze, Monel, and so forth) do not require painting.

Solid film lubricant conforming to MIL-L-23398B is authorized for valve preservation where temperatures do not exceed 500°F.

After you have finished painting, check the valve to ensure that no paint has inadvertently been placed on any of the excepted surfaces noted earlier. If so, remove all such excess paint.

INSTALLATION AND REPAIR OF INSULATION

A basic rule for repair of insulation is that you do not allow the insulating material to become moist. Moisture reduces the effectiveness of the material, and may cause long-term disintegration. Large air pockets in the insulation cause large heat losses, so be sure to fill and seal all cavities or cracks. Hangers or other supports should be insulated to prevent loss of heat by conduction.

All sections of pipe coverings should be tightly butted at the joints. They should be secured with wire loops, metal bands, or lacing. Secure the block insulation with 18 gauge steel wire and galvanized mesh wire, or expanded metal lattice. Use insulating cement to fill all crevices, to smooth all surfaces, and to coat wire netting before you apply final lagging.

MOISTUREPROOFING is just as important in high-temperature insulation as it is in low-temperature insulation. In the former case, heat is lost because of evaporation. In the latter case, condensed moisture may freeze. Either case reduces insulating efficiency and eventually the insulating material disintegrates. Wet insulation also tends to corrode the piping.

Pipe fittings, flanges and valves may be insulated with the same material used for piping, but they require different methods.

REMOVABLE INSULATION is usually installed in the following locations:

- Manhole covers, inspection openings, turbine casing flanges, drain plugs, strainer cleanouts, and spectacle flanges
- Flanged pipe joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul (fig. 16-45)
- Valve bonnets of valves larger than 2 inches IPS that operate at 300 psi and above, or at 240°F and above
- All pressure-reducing and pressure-regulating valves, pump pressure governors, and strainer bonnets

Some small units of machinery or equipment, such as an auxiliary turbine, are located in tight places. It would be difficult to install both permanent insulation over the casing and removable and replaceable covers over the casing flanges. In these situations, the entire insulation may be made removable and replaceable.

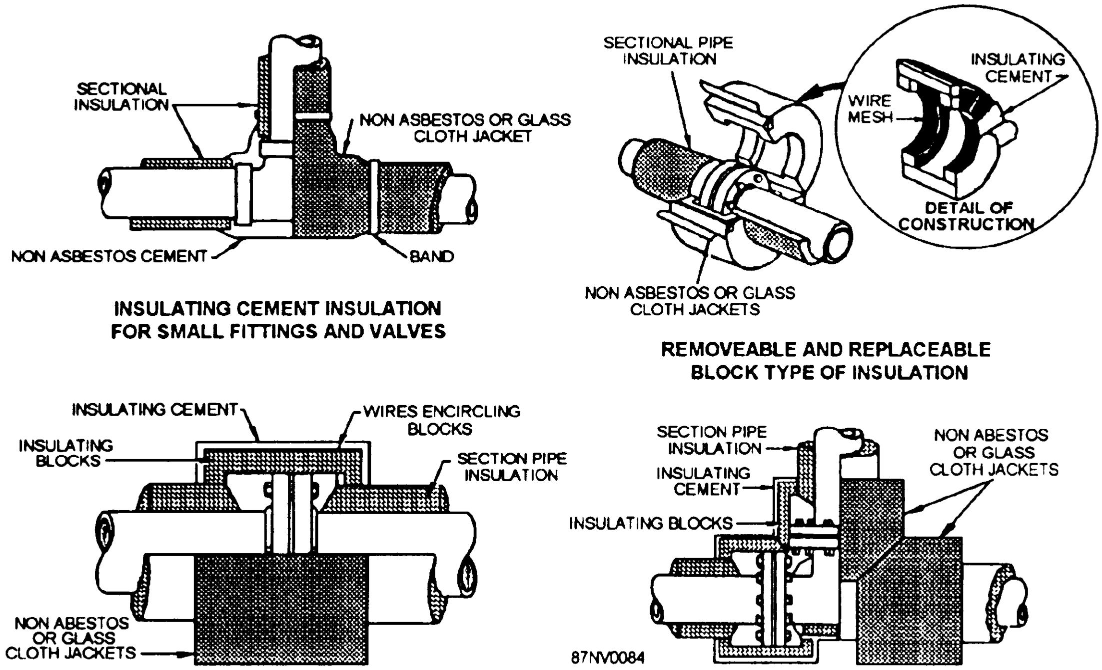


Figure 16-45.—Permanent-type insulation of pipe fittings, flanges, and valves.

Covers shouild fit perfectly and should project over adjacent permanent insulation.

Any one of the following methods of fabrication is acceptable for piping components:

1. Covers may be made in two halves out of thermal insulating felt enclosed with 0.008-inch diameter knitted wire mesh on the inside and end surfaces. The outside of the covers will have a fibrous glass fabric conforming to MIL-C-20079, class 9. Each half cover may be sewn and quilted with polyetrafluoroethylene (PTFE) coated fibrous glass yarn or thread. The covers may also be fastened with stainless-steel staples to provide uniform thickness, strength, and rigidity.

2. Covers exposed to temperatures of 450°F and above must have a 0.008-inch diameter knitted wire mesh on the inside surface and on the ends. Fibrous glass cloth conforming to MIL-C-20079, class 9, must be used on all outside surfaces. Covers for use at temperatures of 850°F and above must have a filling consisting of fibrous glass felt, MIL-I-23128. The knitted wire mesh must be made of 304 annealed stainless steel.

Either of the following methods of fabrication is acceptable for removable and replaceable covers for machinery and equipment:

1. Covers may bc similar to the flexible fiberglass type described for piping components.

2. Covers should be made in sections formed of insulating block and held together with wire and adhesive cement. These sections should be covered with a 1/2-inch thickness of finishing cement, and lagged. Lace with hooks, rings, washers, and wire, or brass snap fasteners to secure the covers.

Observe the following general precautions when you apply and maintain insulation:

1. Fill and seal all air pockets and cracks. Failure to do this will cause large losses by conduction and by convection currents.

2. Seal the ends of the insulation and taper off to a smooth, airtight joint. Use sheet metal lagging at joint ends or other points where insulation is liable to damage. Cuff flanges and joints with 6-inch lagging.

3. Fibrous glass cloth covering fitted over insulation should be tight and smooth. It may be sewed with yarn or may be cemented on.

4. Keep moisture out of all insulation work. Moisture is an enemy of heat insulation. Any dampness increases the conductivity of all heat-insulating materials.

5. Insulate all hangers and other supports at their point of contact from the pipe or other unit they are supporting. Otherwise a considerable quantity of heat will be lost through the support via conduction.

6. Sheet metal covering should be kept bright and not painted unless the protecting surface has been damaged or has worn off. The radiation from bright-bodied and light-colored objects is considerably less than from rough and dark-colored objects.

7. Once installed, heat insulation requires careful inspection, upkeep, and repair. When you remove lagging and insulation to make repairs, replace it just as carefully as when it was originally installed. When replacing insulation, make certain that the replacement material is the same as the original. Old magnesia blocks and sections broken in removal can be mixed with water and reused in the plastic form for temporary repairs. Save all old magnesia for this use.

8. Insulate all flanges with easily removable forms, which can be made up as pads of insulating material wired or bound in place. Cover the whole thing with sheet-metal casings, which are in halves and easily removable.

Lag the main steam, auxiliary steam, auxiliary exhaust, feed water, and steam heating piping systems to hold in the heat. Lag the circulating drainage, fire, and sanitary piping systems to prevent condensation of moisture on the outside of the piping.

Inspect pipes, machinery, and allied equipment periodically for evidence of broken or loose insulation or lagging materials. The insulating and lagging materials used and the method of installation will vary according to the service. Guidelines for insulation requirements, installation, and repairs are covered in MIL-STD-769 and in the *NSTM*, chapter 635.

MISCELLANEOUS REPAIRS

Most of your trouble will be in flushing and firemain systems. This section tells you how to locate trouble spots and how to correct troubles in these systems.

On ships built during and since World War II, these two systems have been made of copper-nickel pipe and tubing with bronze fittings. The valves for the most part are bronze-bodied with Monel seats and disks. These systems are assembled by brazing with a silver-base alloy.

When brazing on these systems, you need to be sure that all water is secured. It is impossible to get a satisfactory braze with water in the line. Never try to braze until the line has been drained and completely secured. You may want to break the line at a union or flange and slip a piece of sheet metal between the faces. This will divert a trickle of water before it reaches the section on which you are working.

REPAIRING DRAINAGE SYSTEMS

Trouble calls on drainage systems are frequent, but most of the troubles can be readily fixed. However, you must know how and where the drain lines run.

Snakes, suction cups, air pressure, and water pressure are usually used to free lines of obstructions. The use of a snake or a suction cup usually involves no danger. But when you use air or water pressure, you will have to be careful. Make sure that all the other drains connected to the line you are working on are closed. If there are outlets in which no closure is installed, you will have to drive a wooden plug into the drain. The plug may be in a compartment other than the one in which you are working. If so, have someone watch the plug to let you know if it blows out. Otherwise, you may think that the drain you are repairing is satisfactorily discharging water, when you are actually flooding another compartment.

Locating the exact trouble spot in a clogged line is simply a matter of knowing what drains run into a common discharge line. When you are called to a job, you should first check the drain line to see what sanitary facilities drain into it. Then go back along the line to determine what is free and running and what is stopped up.

Figure 16-46 is a diagram that should help you understand how to check back along a drain line to

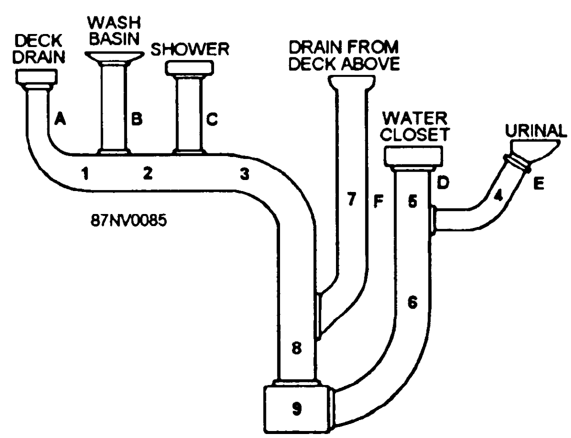


Figure 16-46.—How to check for the location of trouble spots in a drain line.

locate the source of trouble. If drain A is stopped but B and C are running, the trouble is located somewhere in section 1 of the drain line. If the A and B drains are stopped but C is running, the trouble is in section 2. If A, B, and C are stopped but F is running, 3 is the section that needs attention. If A, B, C, and F are stopped but D and E are working, check section 8. If D is working and E is stopped up, check section 4. If E is running but D is stopped, check section 5. If both D and E are stopped but A, B, C, and F are running, the trouble will lie somewhere in section 6. If all these facilities are stopped, the trouble will be located at section 9.

REPAIRING STRAINERS

Strainers are installed in piping systems to prevent the passage of foreign matter that could obstruct valves or damage the machinery or appliances.

Use these procedures to clean a strainer fitted with a drain in the bottom and an air cock vent in the top or cover. Close the valves leading to the strainer and open both the drain and the vent cock. This permits the discharge of oil and sludge and purges the chamber of air. Close the drain before you reopen the valves. Then close the vent after you have reopened the valves. When no air cock vent is provided in the strainer cover, first close the valves leading to the strainer and then open the strainer cover. Do the latter step gradually because, if the strainer is air bound, oil and foreign matter will spray out. Remove the strainer basket, replace it with a clean one, secure the strainer cover, and open the valves. Check to make sure there are no leaks.

Clean, spare strainer baskets of the necessary size and type, plainly marked or tagged, should be kept in a rack convenient to each strainer. The removed basket can usually be cleaned with a jet of steam. If it is heavily encrusted, it should be boiled in a solution of boiler compound.

REPAIRING TRAPS

Traps must be located below the lowest point to be drained. Also, they should be easily accessible for inspection and repair.

The capacity of a trap is determined by the ejection pressure, the pressure against which it is discharged, and the area of the discharge orifice. Proper observance of pressure limits is necessary if traps are to function efficiently. They should not be subjected to pressures higher than those that they are designed to carry. A trap will normally discharge condensate against a head of 24 inches of water for each pound of pressure differential between the trap and the drainage system.

Inefficient trap operation is usually caused by one of the following problems:

- The discharge valve is leaking because of scoring by dirt or scale.
- The discharge valve is leaking because of a punctured float or basket.
- The working parts are adrift.
- The discharge valve is too small.
- The discharge valve does not seat properly.
- The trap is air bound.
- The sediment has collected in the bottom of the trap.
- The trap does not accumulate enough water to close.
- The bypass valve is open or leaking.

If the discharge valve is too small, it may be possible to enlarge the discharge orifice, but only if the float leverage will handle a larger valve. If the internal load on the valve equals or exceeds the pulling power of the leverage, the valve will not open. It may be possible to raise the leverage, or it may be easier to direct part of the discharge to another trap. However, never overload a trap by leading too many additional drains to it. Keep this in mind when you make alterations in a piping system.

As a temporary remedy for a trap that is discharging at less than capacity, you can crack the bypass valve just enough to carry off the excess water. Remember that if the quantity of condensate diminishes, the bypass valve will deliver steam. If a trap does not accumulate enough water, pour one or two buckets of water on the trap. This should cause enough condensation to overcome the trouble. If not, you will have to shut off the trap, remove a fitting, and prime with water through the opening.

Inspect drainage systems regularly to detect leaks that could easily pass unnoticed. In freezing weather, the drains for auxiliary machinery in exposed locations should be drained. If necessary, they should be broken to prevent possible damage to the machinery.

MATERIAL REPLACEMENT

When a section of an existing piping system must be renewed, select the materials according to the following general considerations.

Choose replacement materials of the same material, size, and wall thickness as the original. This will ensure that the original design of the system's capacity, thermal expansion, and contraction is not changed. It will also prevent the setting up of a galvanic couple between dissimilar materials, with its attendant electrolytic corrosion.

Materials used in piping systems on ships built to specifications should be built to military standards. Military standards require that materials used in piping systems on naval ships have a higher resistance to corrosion and shock damage. They also must be of the lightest weight possible.

In the past, there have been numerous incidents involving the failure of piping system components. Several of these incidents have resulted in lost of equipment and even the death of shipmates. Most of these incidents have resulted from the careless maintenance practices and incorrect materials used while performing maintenance or repairs. Therefore, you should always consult the applicable ships and system drawings when choosing replacement or repair materials. If the applicable blueprint is not available, consult other MIL-STDS, technical manuals, operator manuals, or repair manuals for correct materials and repair procedures. If you deviate from original design specifications, obtain prior approval from competent authority before proceeding with the repair.

SYSTEM AND EQUIPMENT ISOLATION WHEN CONDUCTING MAINTENANCE AND TESTING

Pressure barriers, which prevent the escape of a pressurized fluid from a system, are necessary when conducting maintenance on piping systems to prevent endangering personnel and equipment. These dangers include personnel injury due to high temperatures, projectures from high-pressure systems, wetting of electrical equipment, or unintentional venting or draining of adjacent systems.

When isolating a system for component repair or replacement, the type of barrier used for isolation is an important consideration. Examples of allowable pressure barriers are a closed valve, blind (blank) union, blind (blank) flange, or spectacle flange, all of which must be capable of withstanding system pressure and temperature during performance of the maintenance evolution. Some gate valves are equipped with internal or external bypass features and may be used as a barrier only in one direction if the bypass is open. A gagged relief valve may unseat with sufficient reverse pressure, so consider a gagged relief valve a pressure barrier only for maintenance performance downstream of the relief valve. Solenoid-operated valves that have a fail to shut feature tend to seat with system pressure, and do not have internal bypasses that cannot be isolated. These valves may be used as barriers for maintenance performance downstream in the direction in which pressure tends to seat the valve. Do not use other solenoid-operated valves as pressure barriers. Do not use lift, swing, or stop check valves seated by pressure only, ungagged relief valves, four-way valves, or feed regulating valves as pressure barriers. Valves used for throttling are subject to erosion and may not be good pressure barriers.

At least two pressure barriers are required between the maintenance area and any high-temperature (200°F or more) fluid. Where possible, open a tell-tale drain valve between the two barriers to warn if one barrier is leaking. Provide at least two pressure barriers, since high-temperature (above 200°F), high-pressure liquid will flash, providing a continuing pressure source, causing discharge of large quantities of high-temperature fluid and endangering personnel in the maintenance area if leakage should occur. If necessary, an exception to this requirement may be made if the source of high-temperature liquid is separated from the maintenance area by a single-pressure barrier and a sufficiently large volume of low-temperature (below 200°F) liquid. The volume of the low-temperature liquid must be sufficient to allow personnel performing the maintenance to get clear and to secure the source of high-temperature liquid in time to prevent its discharge into the maintenance area if the single-pressure barrier should fail.

A potential danger in component repair or replacement lies in inadvertent or accidental operation of the isolation valves. Tag out all valves and their controls to prevent inadvertent operation. If the control valve of an actuator is electrically operated, have the fuses removed from the circuit or disconnect the electrical connector so that the operator of the control valve cannot be accidentally energized. If the control valve of an actuator is air operated, shut and tag out the air supply isolation valve so that the control valve cannot be accidentally operated by air.

When piping is under repair, secure and tag out the isolation and cutout valve connecting the dead portion(s) with the live portion to indicate that personnel are working on the dead portion(s). Do not remove the tags until it is determined that this will not create a hazard to personnel working on the dead portion or until the work on the dead portion is completed. Open drain connections to atmosphere on all the dead interconnecting systems for visual drainage observation.

PRECAUTIONS FOR BREAKING LINE AND VALVE BONNET

Before breaking a line or valve bonnet joint, or cutting into a line, ensure that the following conditions are in effect:

1. Shut and secure valves isolating the section in such a manner that they cannot be opened accidentally, either locally or remotely.

2. Completely drain the line or vent with no pressure on the line.

3. Take precautions to prevent fire or explosion from flammable fluid.

4. Shut and tag out valves isolating the section according to current shipboard and applicable OPNAV instructions.

5. Provide adequate ventilation.

6. Provide any compartment that contains a fluid energy accumulator (or to which a large volume of fluid energy can be released) with two-barrier protection if the released volume, in standard cubic feet, is twice the compartment volume.

In breaking flanged joints, make sure that the two diametrically opposite securing nuts remain tight while the remainder are slackened. Then slacken these two nuts sufficiently to permit breaking the joint. After the joint is broken and the line or valve proven clear, remove all nuts.

PROTECTION OF ELECTRICAL EQUIPMENT

Before working on any piping system, make a survey to ensure that under no condition can any liquids splash on exposed electrical equipment. If there is any possibility of splashing a switchboard or other electrical equipment, take the following steps:

1. De-energize electrical equipment and cover with a waterproof material.

NOTE: If it is not possible to de-energize the electrical equipment before work on the piping system begins, completely cover with a rubber sheet or other nonconductive waterproof material. Do not restrict ventilation to the point that equipment will overheat.

2. Open piping away from electrical equipment, at a lower level if feasible, to ensure that the line is completely drained and unpressurized.

Early detection and correction of defects will reduce the amount of effort required for repair and will provide more satisfactory operating conditions.

LEAKAGE

Take up small leaks in gaskets immediately. If allowed to persist, the leaks will become progressively worse and may eventually cause a blowout. In addition, flange faces in high-pressure joints will become cut and require rebuilding and refacing.

When continuing or repeated leakage, breakage, or failure occurs in a piping system, determine and correct the cause. Common causes are as follows:

- Misalignment
- Inadequate allowance for thermal expansion, working of the ship, and other movements
- Vibration
- Hydraulic transients (water hammer)
- Rapid temperature changes
- Corrosion
- Erosion
- Galvanic action

CAUTION

It is of the utmost importance that NO explosive conditions exist prior to using spark-producing tools or burning equipment.

THREAD LEAKS

All leaking threaded joints that cannot be tightened with a reasonable amount of pull-up should be taken apart, cleaned, and examined to remove bad thread conditions. Recoat with a compound suitable for the intended service, and carefully reassemble to avoid any other thread damage. Poorly cut threads are a constant source of trouble with threaded joints. Therefore, it is essential that thread cutters receive proper use and care.

Various thread leak causes and corrective measures to be taken are listed in table 16-6.

PREPARATION OF PIPES FOR REPAIR

Prepare pipes requiring repair according to the procedures described in the following paragraphs:

1. Remove all foreign material such as paint, heavy scale, grease or other contaminants from the area of pipe or tubing for at least 6 inches on each side of the repair area; it is not necessary to polish the pipe. The pipe or tubing should be clean, dry, and free of solvents and flammable vapors.

2. Pipe or tubing requiring repair may show cracks or other defects indicative of incipient failure. In the area to be repaired where such defects are not obvious, liquid-penetrant test the area before pressurizing to ensure that undetected defects are not present.

For additional information on the characteristics, special requirements and procedures, and the types and frequency of tests and inspections to be conducted on specific piping systems, refer to *NSTM*, chapter 505. For more information on the repair of hydraulic systems, consult *NSTM*, chapter 556.

Table 16-6.—Thread Leak Causes and Corrective Measures

Cause of Trouble	Correction
Rough Threads:	
Dull chasers	Sharpen
Insufficient lubrication	Use plenty of good oil
Excessive or insufficient lead cutting	Grind properly Grind to correct angle
Broken tooth in chaser leader	Grind out entire tooth
Chaser not set to form true cutting circle	Clean slots, set chasers to true cutting circle, grind chasers, if necessary, to a uniform length
Shaved Threads:	
Improper lead of chaser	Regrind lead
Chasers not tracking properly	Keep slots clean
Chasers not set in correct rotation	Correct setting
Carriage travel retarded (machine only)	Repair carriage
Wavy Threads:	
Die or chasers not true (manual only); loose chasers (machine)	Center die or chasers; get new die head
Thumb screws not tight (manual only); worn cam in head (machine)	Tighten with wrench; get new die head
Worn-out lead screws (manual only)	Get new die stock
Cuttings or dirt in chaser slots (manual only)	Keep slots clean
Shoulders:	
Pipe ends not square (manual only)	Recut square and rethread
Die and chuck not aligned (machine)	Check and realign

EQUIPMENT TAG OUT

Whenever you make repairs to piping systems, you will be required to isolate and tag out that section of the system. The tag-out program provides a procedure to be used when a component, apiece ofequipment, a system, or a portion of a system must be isolated because of some abnormal condition. The tag-out program also provides a procedure to be used when an instrument becomes unreliable or is not operating properly. The major difference between equipment tag-out and instrument tag-out is that labels are used for instrument tag-out and tags are used for equipment tag-out.

Detailed information on equipment tag-out procedures can be found in chapter 1 of this manual.

SUMMARY

You will make repairs to piping systems and valves frequently during your naval career. Normally you will make permanent repairs that require you to make templates, targets, and flanges. But, you need to know how to use the Metallic Pipe and General-Purpose Damage Control Kit to make a temporary repair in the event of an emergency.

When you have gained experience, you will make bends in piping and tubing without affecting the quality of the material or the operation of the system. However, always remember that safety comes first. Use the tag-out system to prevent the injury of personnel or other damage from occurring.

CHAPTER 17

SEWAGE SYSTEMS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Explain the ways local waters become polluted, and recognize the means of controlling pollution aboard ship.*
- *Identify the pollution control acts and discuss the contents of each.*
- *Identify the components of the collection, holding, and transfer (CHT) system, and describe the function of each component.*
- *Identify the different types of CHT systems used aboard Nay ships, and describe the modes of operation.*
- *Describe the procedures for performing preventive maintenance on holding tank systems.*
- *Describe the basic sanitation precautions and safety procedures for the prevention of disease and personnel injury.*

INTRODUCTION

One of our major concerns is the pollution of U.S. waters. Our streams, lakes, and coastal waters are being contaminated by vessels, factories, and individuals through careless dumping of harmful materials. These materials include everyday trash and refuse, oil, chemicals, sewage, and waste water.

In this chapter, you will learn about the administrative actions that have been taken to help eliminate the pollution of our waters. Most of the chapter will deal with systems used by the Navy, the health hazards, and the safety guidelines used in operating and maintainingsewage systems.

ENVIRONMENTAL POLLUTION CONTROL

It was once routine for ships to discharge sewage directly overboard. Then on October 18, 1972, Public Law 92-500 was passed by the Senate and the House of Representatives. It is known as the Federal Water Pollution Control Act Amendments of 1972. The objective of PL 92-500 is to restore and maintain the chemical, physical, and biological quality of the nation's waters. The goals set by PL 92-500 are as follows:

- To eliminate the discharge of pollutants into our nation's navigable waters by 1985.
- To attain water quality, where possible, for the protection of fish, shellfish, and wildlife, and to provide for recreation in and on the waters by July 1, 1983.

- To prohibit the discharge of toxic pollutants in toxic amounts.

- To provide federal financial assistance to construct publicly owned waste treatment plants.

- To develop and implement regional waste treatment management planning processes.

- To research, develop, and demonstrate the technology necessary to eliminate the discharge of pollutants into our nation's waters.

PL 92-500 covers the dumping of oil, chemicals, trash, and other materials into our streams and navigable waters. The section of the law that we are concerned with is section 312, which is the guideline for marine sanitation devices (MSDs). Revisions to PL 92-500 are listed in PL 95-217 of December 27, 1977. Other notices, directives, specifications, and instructions that govern MSDs are as follows:

- Department of Defense Directive 6050.4

- Code of Federal Regulations (CFR) 33 CFR 159 and 40 CFR 140

- United States Code, Title 33, Section 1322

- OPNAVINST 4700.31

- OPNAVINST 5090.1, Chapter 12

- *NSTM*, chapter 593

When you refer to these publications, be sure you have the current editions.

Since 1972, the Navy has been persistent in installing MSDs in naval vessels. All vessels were to be in compliance with the laws and regulations by April 1, 1981. However, some exceptions have been made. Department of Defense vessels may discharge overboard within the U.S. navigable waters (3-mile limit) if the vessels meet one of the following requirements:

- The vessel cannot keep all ship-generated sewage on board until it can be disposed of properly.

- The vessel is participating in military operations and exercises within the navigable waters and retaining the sewage on board would interfere with the operational effectiveness or pose a health hazard to the personnel on board.

- The vessel is anchored or moored and sewage reception facilities are not available or foul weather, poor visibility, or unsafe environmental conditions make the use of services unfeasible.

- The vessel is in overhaul, and operation of the MSD would interfere with ongoing repairs.

- The vessel's MSD is inoperable because of equipment malfunction or equipment installation or repairs within the system.

The health and safety of the crew is to be the primary consideration. If the sewage is to be discharged overboard, the commanding officer must ensure that the discharge is as far from land as possible and the amount being discharged is kept to a minimum. Sanitation is a major concern. It needs to be addressed before we discuss the various sewage systems.

SANITATION

Sewage is defined as a mixture of all liquid domestic wastes, especially human body wastes (fecal matter and urine). Sewage contains large numbers of microorganisms (hundreds of millions per milliliter), some of which are disease bearing, such as typhoid, polio, and infectious hepatitis.

Bacteria and viruses enter the human body through openings such as the mouth, nose, and open sores. Therefore, you should observe the following basic precautions when working in sewage handling areas:

—NEVER eat, drink, or smoke while working in sewage spaces or on sewage equipment.

—NEVER work on sewage handling equipment if you have open cuts or sores.

—Keep equipment clean at ALL times.

—Wash down ANY spilled sewage immediately before it dries. Use hot water and stock detergent initially and then follow with an authorized disinfectant where required. Do NOT use liquid soaps or unauthorized disinfectants. They may temporarily disguise inadequate cleanup procedures.

—Always follow recommended personal hygiene routines after working in a sewage handling area or after being in contact with sewage handling equipment.

—Install drip pans under comminutors and pumps located off the deck.

—Install drip pans under all valves, flanges, and take-down joints located in food preparation spaces, messing areas where eating utensils are washed, and living spaces.

—Keep a close watch on the sewage system and take immediate corrective action on all leaks.

—If you handle or connect sewage transfer hoses, do not handle any potable water hoses until you wash yourself and change into clean clothing.

—Have the gas-free engineer check spaces, such as holding tanks and voids, before you use any open flames, flashlights, or other electrical equipment in or near them.

INSPECTIONS

Various inspections must be conducted periodically on the sewage systems and associated equipment. These inspections are required by type commander instructions, NAVMED P-5010-7, and *NSTM*, chapter 593, and are as follows:

—A visual inspection of MSD componenets by a Medical Department representative (MDR) as part of the routine habitability and sanitation inspection program. The MDR's routine inspection should be limited to those spaces where there is an interface between MSD components and the food service areas, living spaces, and medical spaces. Contamination of these spaces are likely to result in disease outbreaks if undetected or not properly cleaned and disinfected.

—Regular inspection of MSD components for leaks by appropriate engineering personnel responsible for the compartment in which MSD components are located.

All leaks, spills or other sources of contamination observed during these inspections or at any time shall be promptly reported to the executive officer, engineering officer/damage control officer, and the MDR. Immediate and appropriate action should be taken to stop the leak and properly clean and disinfect the contaminated area.

DISINFECTANTS

If equipment or personnel are located in sensitive areas or are contaminated with sewage to an extent that disinfection is required, the items listed in the following paragraphs should be used for shipboard use. A disinfectant will do little good unless sewage solids are removed from the equipment or surface.

NOTE: If in doubt concerning the use of disinfectants, consult the medical officer or senior MDR.

Use care when you store, mix, and use any of the following items. Follow all of the manufacturers' instructions exactly. While other disinfectants presently in the stock system may perform equally as well, you should not make substitutions unless properly authorized.

Decks, Bulkheads, and Equipment

When you are required to disinfect a compartment and the installed equipment, use one of these authorized disinfectants:

PHENOL BASE: Germicidal and fungicidal concentrate phenolic, dry type; NSN 6840-00-753-4797.

IODINE BASE: Providone-iodine solution, NSN 6505-00-754-0374.

IODINE BASE: Disinfectant, germicidal, and fungicidal concentrate (iodine type); NSN 906840-00-526-1192.

Hands

After working on sewage systems, sewage equipment, or cleaning up from a sewage spill, disinfect your hands. The following two cleansers are authorized for this purpose:

IODINE BASE: Detergent, surgical antiseptic sudsing skin cleanser; Prepodyne surgical scrub (use like liquid hand soap-full strength with water and lather); NSN 9P7930-00-282-9699, 1 gallon, NSN 9P7930-00-985-6911, 5 gallons, NSN 9P 7930-00-282-9700, 50 gallons.

SURGICAL SOAP: Betadine; NSN 9G 6505-00-914-3593.

HYGIENIC PRACTICES

The following housekeeping, sanitary, and hygienic practices must be followed:

—If you connect or disconnect sewage transfer hoses, you must not handle potable water hoses until after you have washed your hands and changed clothes.

—If you perform maintenance activities where sewage contamination is a possibility, or if you connect or disconnect sewage hoses, you must wear rubber gloves, rubber boots, coveralls, and a faceshield.

—Use standard stock detergent and hot water to wash down areas, surfaces, and fittings that are contaminated with sewage. If required, follow with an authorized disinfectant.

—Make regular use of the washup facilities provided in or adjacent to the CHT pump spaces to minimize the spread of contaminated products.

—If your shipmates work in sewage spaces or on CHT equipment, caution them against smoking, eating, or drinking before they wash up thoroughly with hot water and soap.

When you complete any CHT maintenance, you must wash affected areas with a solution of hot water and stock detergent.

CONTAMINATION PREVENTION PROCEDURES

The following standards have been established as guidance to those responsible for maintaining CHT sewage systems aboard ship.

Equipment for Personnel

The following equipment must be used by personnel who maintain CHT systems:

- Coveralls (one set for each individual)
- Goggles and faceshield (one set for each individual)
- Hood-type hats (one set for each individual)
- Rubber boots
- Plastic bags (one for rubber boots and gloves and one for coveralls)
- Respirator

Equipment/Facilities Within CHT Spaces

The following equipment/facilities must be available within all CHT spaces:

- Hand washing sink with potable water
- At least one of the disinfectant or detergent items listed in the Decks, Bulkheads, and Equipment section and one listed in the Hands section
- Hand drying facilities
- Plastic trash can bags

PERSONNEL CONTAMINATION PREVENTION PROCEDURES

You must not enter contaminated spaces/tanks without protective equipment and clothing.

Put on protective clothing and equipment. You should use an approved respirator (1) before entering a contaminated compartment and (2) when entering CHT tanks. Before leaving contaminated spaces, take the following precautions:

1. Scrub the affected areas with hot water and stock detergent. Then follow with an authorized disinfectant if necessary.

2. Remove protective clothing and equipment.

3. Place clothing in plastic bags maintained outside the space, using caution not to contaminate the outside of the bag.

4. Secure the plastic bag. (**NOTE:** The plastic bags must not be allowed in an immediate maintenance area.)

5. Clean boots, goggles, and respirators with hot water and a stock detergent. Then disinfect with one of the solutions listed in the Disinfectants section. Disassemble equipment for complete cleaning.

6. Place disinfected equipment outside the contaminated space as it is cleaned.

7. You must completely scrub your hands, lower arms, and face in that order with hot water and soap and dry them with equipment provided in the space.

8. Place paper towels or other remaining waste or cleaning materials in doubled plastic trash can liners and then discard them with the ship's trash.

9. After completing these necessary actions, you may leave the space.

10. Immediately transfer the plastic bag with the contaminated clothing enclosed to the laundry for washing.

LAUNDRY PROCEDURE

After you have completed your work on the sewage system or cleanup of a sewage spill, deliver the plastic bag containing your clothing to the laundry. The laundry personnel should clean the clothing used during maintenance or cleanup procedures using standard laundering procedures.

CERTIFICATION OF SPACE HABITABILITY

When a contaminated space has been sanitized, the senior MDR inspects the space and certifies, in writing to the commanding officer, that it has been adequately decontaminated. Until the space has been certified, consider it contaminated. All personnel entering the space should follow the decontamination safety procedures outlined in the previous paragraphs.

WATCH AND TRAINING REQUIREMENTS

Once each watch, conduct an inspection of CHT tanks, pumping systems, and piping. Ensure watertight integrity and the absence of contamination leaks, overflow, or spillage. Log these inspections. Report any discrepancies immediately to the CDO in port and to the OOD when underway.

Training should be provided for personnel who decontaminate spaces contaminated by raw sewage or effluent from the CHT system. This same training should also be provided to personnel whose duties require them to enter spaces subject to contamination.

NOTE: Notify the DCA and senior MDR on the status of any holding or other MSD whenever there is a threat to the ship by reason of hostilities, fire, flooding, or conditions that could turn the tank into a biological hazard to the ship's crew. Each ship should have developed plans and drills to eliminate or control the biological hazards from these occurrences.

COLLECTION, HOLDING, AND TRANSFER (CHT) SYSTEM

In 1972, the Navy began installing the CHT sewage collection system in ships that could use this method of water pollution control. The CHT concept is the cheapest and safest way to solve the sewage disposal problem aboard ship.

Most operational ships of the fleet will be equipped with CHT. These systems can hold sewage produced over a 12-hour period. If the CHT system is not feasible, another type of MSD will be installed. This TRAMAN will only discuss the CHT type of sanitation system.

CHT ELEMENTS

The CHT system accepts soil and waste drains from water closets, urinals, showers, laundries, and galleys. It is made up of three elements-the collection element, the holding element, and the transfer element-which are described and discussed in the following paragraphs.

The collection element consists of separate soil and waste drains that are equipped with diverter valves. Depending on the position of these diverter valves, the soil and waste drains can be diverted or directed overboard or into the CHT tank.

The holding element is a holding tank. The tank is designed large enough to hold all of the ship's sewage that would normally be generated over a 12-hour period.

The transfer element includes sewage pumps, overboard and deck discharge piping, and deck discharge fittings.

Collection Element

The CHT system plan requires that waste drains be kept separate from soil drains wherever practical until they reach the overboard diverter valve. From this point, they may be combined into a single drain line. All drains above the waterline may be diverted overboard by gravity. Drains located below the waterline cannot be diverted directly overboard and must use the CHT system as an ejection system. In this case, the CHT system must operate continuously.

NOTE: Waste drains are plumbing drains that service sinks, showers, galleys, and other similar drains that transport their waste water, which is known as gray water. Soil drains are plumbing drains that service commodes, urinals, and other drains that transport human wastes, also known as black water.

All drain piping is pitched to ensure rapid and complete drainage of the waste and soil drain systems. The piping pitch is l/4 inch per foot whenever possible, but not less than l/8 inch per foot relative to the ship's trim.

Garbage grinder drains connected to the waste drains have a minimum slope of 3 inches per foot. These drains also have a check valve to prevent backflow from the waste drain system.

Plumbing drains may pass through watertight bulkheads. Normally, each bulkhead penetration has a bulkhead stop valve. Each bulkhead stop valve is a full-port, plug-, or ball-type valve. The valve should be operable both at the valve and from the damage control deck. In some installations, diverter valves (three-way valves) are used to prevent progressive flooding through the CHT system drains. This eliminates the need for bulkhead stop valves.

Where CHT system valves are designated as damage control closures, the valve bonnet and handwheel are labeled, The labels are X-BAY, YOKE, or ZEBRA, with the direction to be turned marked by an arrow. Similar marking or labeling is shown on the remote valve operators, located at the damage control deck.

The piping primarily used in CHT systems is made of copper-nickel (90 to 10). The main drain headers are normally 4-inch pipe. However, some larger ships will have 6- or even 8-inch pipe.

For identification purposes, the piping will be stencilled as either a soil drain or waste drain. An arrow will also be stencilled on the piping to indicate the direction of flow. It is not necessary to color-code the piping. However, the valves and valve handles should be painted gold according to the color coding system.

Holding Element

We said earlier that the CHT tank is normally designed large enough for a 12-hour holding period, but the ship's size, shape, and mission will affect the volume of the tank. The number of tanks will vary from ship to ship. Each tank has inside surfaces that are generally free of structural members such as stiffeners, headers, and brackets. However, very large tanks may have swash bulkheads to dampen the movement of the contents of the tank. The tank bottom slopes about 1.5 inches per foot toward the pump suction. All internal surfaces of the tank are coated to prevent corrosion. (See *NSTM*, chapter 631 (9190).) Each CHT tank has a vent to the atmosphere, an overflow to the sea, and a manhole for internal maintenance.

The firemain connection is used to flush and clean the CHT tank. Seawater is sent into the top of the tank through washdown nozzles, which spray the inside of the tank. The tank should be flushed each week for 30 minutes whether in port or at sea. The firemain is used also to flush the discharge piping and the transfer hose when the ship is preparing to leave port but while it is still connected to the shore sewage fittings.

Transfer Element

Each CHT tank has two nonclog marine sewage pumps connected in parallel. The pumps may discharge sewage to a tender, barge, shore facility, or directly overboard, depending on the position of the discharge pump diverter valve. Each pump has a full-port, plug-, or ball-type suction and discharge valve and a discharge swing-check valve with a hold-open device. See *NSTM,* chapter 503, for an explanation of sewage pumps.

TYPES OF CHT SYSTEMS

There are two types of CHT systems, depending on the capacity of the holding tank. Systems with a tank capacity greater than 2,000 gallons use a comminutor (com-MIN-u-tor). A comminutor chops, chews up, and grinds fragments, and softens thick material into a semifluid consistency. Systems with a tank capacity of less than 2,000 gallons use strainers.

Comminutor-Type System

In comminutor-type systems, the comminutor, located in the soil drain or in the combined soil and waste drain, macerates (chews up) solids passing into the CHT tank. If the comminutor jams or plugs, a bypass line provides drainage around the comminutor into the tank. If a valve is fitted in the bypass line, it must always remain open during routine operation of the system. Isolationvalves are fitted directly before and after the comminutor to allow for maintenance. Also, most installations have an access opening for removing foreign objects that may jam or plug the comminutor.

The major components of the comminutor-type CHT system are discussed in the following paragraphs and shown in figure 17-1 (at the end of this chapter).

1. CHT tank: Each tank will have a capacity of 2,000 gallons or more.

2. CHT pump set: There is one set per tank; a pump set consists of the following components:

   a. Two motor-driven (mixed flow) centrifugal pumps

   b. Two plug- or ball-type suction valves

   c. Two plug- or ball-type discharge valves

   d. Two pump discharge check valves with a hold-open device

   e. A duplex pump controller

   f. A high-level alarm

   g. Liquid-level sensors

3. Comminutor: There is one in each soil drain or combined soil and waste drain entering each tank.

4. Aeration supply and diffusers.

5. Firemain flushing connections and washdown nozzle for spray cleaning the interior of the tank.

6. Piping, valves, and fittings.

COMMINUTOR SUBSYSTEM.—The comminutors are installed in the soil drain lines. They may be installed in any position as long as gravity flow can take place. However, a 20-inch clearance is required on the belt side to allow for the removal and repair of the cutter assembly.

The cutter assembly breaks up solids into smaller particles. Be sure that no metal objects go down the drains. Any metal over 0.010 inch thick can damage the cutter blades.

The comminutor is electrically operated. The shafts operate at different individual speeds for more effective breaking up of solids and for self-cleaning.

The comminutor does not have to be removed for scheduled planned maintenance. If the cutter assembly is to be removed, it should first be either hosed down or steam-cleaned. (Follow the sanitation procedures listed earlier under the Sanitation heading.) The assembly can then be removed by using extreme care. The inside diameter of the housing is a sealing surface, and damage to it could cause leakage.

AERATION SUBSYSTEM.—In the comminutor-type CHT system, air is supplied to the tank to prevent the contents from generating hydrogen sulfide gas (odor of rotten eggs) and also to keep solids in suspension. (See fig. 17-2, at the end of this chapter.) Air enters the tank at or near the top and is piped to nonclog air diffusers located at the bottom of the tank. These diffusers are spaced 2 feet apart. Air pressure of 5 to 12 psi from motor-driven blowers is supplied at the diffusers to overcome the hydrostatic head of the overlying liquid. In some systems, ship's service air is provided as a secondary source of the aeration. CHT systems in some aircraft carriers do not use blowers for aeration. Instead, they use ship’s service air as the primary source of air for tank aeration. The aeration subsystem is operated when the CHT system is in any operational mode except the at-sea mode.

Strainer-Type System

The strainer-type system is basically the same as the comminutor system except that the strainer system does not have a comminutor or an aeration subsystem, and the holding tank is less than 2,000 gallons in capacity.

The strainer-type system has an overflow strainer within the CHT tank and an inflow strainer mounted on the discharge side of each pump. The drain collection pipe directs sewage flow through the overflow strainer where liquids may overflow into the CHT tank in the event the inflow strainer or the pumps become clogged. Solid and liquid wastes flow through the ball or plug valve and check valves until they reach the pump discharge piping. At this junction, the sewage flow passes through the inflow strainer where large solids are collected. Then they pass through the pump and back into the CHT tank. The inflow strainer limits the flow of solids, but liquids are allowed to pass through the pump into the tank. Each time the pump operates, its inflow strainer is cleaned by the reverse flow of liquid being pumped from the tank.

The major components of the strainer-type system are shown in figure 17-3 (at the end of this chapter) and are discussed in the following paragraphs.

1. CHT tank: The capacity of each strainer system tank is less than 2,000 gallons.

2. CHT pump set: There is one pump set per tank. A pump set consists of the following components:

   a. Two motor-driven (mixed flow) centrifugal pumps

   b. Two plug- or ball-type suction valves

   c. Two plug- or ball-type discharge valves

   d. Two pump discharge check valves with a hold-open device

   e. A pump controller

   f. A high-level alarm

   g. One liquid-level sensor for the high-level alarm

3. Inflow strainers with plug- or ball-type stop valves and swing-check valves

4. Overflow strainer inside the CHT sewage tank

5. Firemain flushing connections and washdown nozzle for spray cleaning the interior of the tank

CHT COMMON COMPONENTS

There are definite differences between the comminutor system and the strainer system, but the two systems are similar in several ways. The operational modes, hoses, pumps, alarms, level sensors, and controls are basically the same. The manufacturer and the size may differ from one system to the other, or even from one ship to the next. However, the operation of the equipment will vary only slightly.

Sewage Pumps

Each CHT system has a set of two sewage pumps. The pumps may be operated both at the same time or by alternating with each other. The pump transfers the sewage from the tank to the pier connection, or directly overboard. The destination of the sewage depends on the lineup of the piping and the diverter valves.

The pump suction is located one pipe diameter off the bottom of the tank. This maintains a flooded suction. The pump's impeller is a nonclog marine type. The semi-open impeller allows solids up to 2 l/2 inch in diameter to pass through. Double mechanical seals are used to prevent leakage. The oil reservoir of the seal is filled with 2190 TEP oil.

Drip pans or a coaming are installed to contain any leaks at the pump or pipe connections. The drip pans and coaming areas should be inspected regularly; if they have been contaminated, they must be cleaned and disinfected.

Full-ported suction and discharge valves are installed in the piping on the respective sides of the pump. These valves will either be ball or plug valves.

A spool piece consisting of a short flanged pipe is installed in the suction line near the pump. The spool is a convenience item to allow maintenance personnel to inspect the pump. If the pump is clogged or jammed, you can remove the spool and gain access to correct the situation.

Most of the new installations are fitted with oil-filled diaphragms to keep the sewage out of the sensitive parts of the pressure gauges. The pump has a vacuum/pressure gauge on the suction side, and a discharge/pressure gauge.

A special swing-check valve is installed in each pump discharge line to prevent one pump from pumping sewage back to the tank through the adjacent pump. The swing-checkvalve also prevents sewage from another nested ship from being pumped into the tank. These swing-check valves have a manual hold-open device to permit drainage of the discharge piping.

Piping Systems

The piping assembly for the CHT system should be straight with as few elbows as possible. A slight downward slope is needed to allow for gravity flow. The piping transfers soil and waste water from the source to the overboard discharge or to the CHT tank, depending on the operational mode.

The piping in the pump room should not be lagged. However, the piping outside the pump room should be lagged. Valves or flanges within the CHT system should not be lagged. This will allow ready detection of leaks. A drip pan will be installed under any valve or flange located in food preparation or food storage areas, medical spaces, or spaces where leakage can reach any bilges that comes into contact with potable water tanks. This will help detect leakage and prevent the spread of contamination.

A firemain washdown system is used to flush the tank, discharge piping, and hoses. The pump room can also be washed down. The water left in the pump room can be disposed of through the pump-room sump using the installed eductor.

A relief valve set at about 125 psi is installed in the discharge piping system. This valve prevents excessive pressure in the hose during the flushing process.

Controller, Alarms, and Level Sensors

The CHT system provides for both manual (MAN) and automatic (AUTO) operation. In the MAN 1 mode, the operator may start either or both pumps independently of the tank liquid level sensors. In the MAN 2 mode, the pumps stop at the low-liquid level (10 percent). In the AUTO mode, the pump controller automatically performs the following functions as a result of signals from the level sensors in each tank:

- The controller alternates the duty or operating pumps.
- The low-liquid level sensor stops the duty pump when the liquid level reaches approximately 10 percent of the tank volume to maintain flooded pump suction.
- The 30 percent liquid level sensor signals the controller to start the duty pump.
- The 60 percent liquid level sensor signals the controller to start the standby pump in the event of failure or inadequacy of the duty pump.
- The 85 percent liquid level sensor provides a visual (sight) and audible (sound) high-level alarm signal. The high-liquid level alarm operates both audibly and visually in the CHT pump area, in damage control central, and on the quarterdeck. The sound alarm in the pump room can be silenced

locally while the system is being serviced. In some installations, the CHT pump-room area is equipped with a flooding alarm that is monitored at a remote location.

The level sensors are the mercury-float type. However, pressure diaphragm sensors were used on earlier systems. The mercury-float type is the better of the two. Mercury is contained in two metal capsules (switches) that are encased in each polyurethane float. Normally, only one switch in each float is used and the contact closes when it is in the horizontal position.

The pressure-diaphragm type requires a 9-inch head to close and a 3-inch head to open. A rubber diaphragm deflects and closes the switch. These switches had problems, so ships were recommended to request an Alternation (AER) Kit Mercury Float 2-S4320-LL-HAL-218. NAVSEA recommends that all sensors be changed to the mercury-float type.

Sewage Transfer Hoses

The sewage transfer hose is used to transfer sewage from the ship's deck riser to the shore connection. The hose is 4 inches in diameter. Two types of hose are available: collapsible and noncollapsible.

The collapsible hose is the most common of the two. Public works centers (PWCs) have trucks with hose reels mounted in the truck beds. The collapsible hoses lie flat, and several hoses may be stored on a single hose reel. When the ship enters port, PWC will furnish the hose and make the connections on shore. The ship's personnel will make the connection on board the ship.

A noncollapsible hose is also available. It is a full bore hose that is wire reinforced and has a rigid body. This hose is superior to the collapsible hose in one respect-it does not kink up and restrict the flow of sewage.

Both types of hoses have cam-locking couplings with male and female end fittings. Both types of hoses are interchangeable with each other. Before any hose is disconnected, it must be flushed for 10 minutes to eliminate any sewage.

CHT System Labeling

All CHT system components are labeled and marked according to *General Specifications for Ships of the United States Navy,* NAVSEA 0902-001-5000. Piping that passes through unmanned spaces, such as tanks, voids, and cofferdams, is marked at least once in each space. Piping in machinery spaces is marked at least twice; at its point of entry and exit. The pipes should be stenciled to identify the system and the direction of flow. Valves and remote operating devices are labeled by service and position for system operating modes. The damage control classifications are to be plainly marked. Handwheel of valves in sewage piping systems are to be painted gold. (See *NSTM*, chapter 505.) The drains are marked to show the type of service, such as soil, waste, and garbage grinder drains.

Washup Facilities

Washup facilities, including a sink with hot and cold water, soap, disinfectant, and hand drying facilities are located in or near the pump room. The sink drains into the sump in the pump room. The sump is emptied by either an installed saltwater eductor or by a sump pump. The water is discharged into the CHT pump discharge line.

The pump room and deck discharge stations have a source of saltwater to wash up a sewage spill.

Further information on washup procedures and materials was provided earlier in this chapter under the heading Sanitation.

Fire Fighting

Fire-fighting equipment must be provided at or near CHT spaces in case of an emergency. The CHT tank may contain toxic and/or combustible gases which can be hazardous.

Communications

A telephone connection to the ship's internal communication system is located in the pump room. Another is located at the continuously manned remote location where the high-level alarm is monitored. In addition, telephone communication at each deck discharge connection is required whenever the operating mode of the CHT system is changed. The X52J sound-powered phone circuit is used at these locations.

CHT SYSTEM OPERATIONAL MODES

There are three operating modes for the CHT system: at-sea, transit, and in-port. The at-sea mode is used when the ship is outside the 3-mile limit, known as the contiguous zone. In this mode, the valve alignment allows both the soil and the waste drains to be diverted directly overboard. The transit mode is used just before the sewage transfer hoses are disconnected and while the ship is underway within the 3-mile limit, known as the restricted zone. The valve alignment for the transit mode requires the soil drains to be diverted to the holding tank and the waste drains to be diverted overboard. The in-port mode is used whenever the ship is pierside. In this mode, the valve alignment diverts both the soil and the waste drains to the holding tank. The discharge piping is aligned to the deck risers where the sewage transfer hoses are connected to the ship's system and the pier's system. The pumps are set in the automatic mode to discharge the sewage off the ship to the pier. When ships are on extended cruises, the CHT system should be exercised in all modes at least once each week. This will allow you to flush the tank weekly as required and, by doing so, keep toxic gases to a minimum. You should check each mode of operation weekly. This will ensure that the valves operate smoothly and do not leak. Any leaks must be corrected immediately.

The Sewage Disposal Operational Sequencing System (SDOSS) was designed using the Engineering Operational Sequencing System (EOSS) as a guideline. The SDOSS gives step-by-step procedures for changing the valve alignment when changing the operational mode of the system. It also gives step-by-step procedures for other operations of the system, such as cleaning the tank. Refer to the foldouts of figures 17-1, 17-2, and 17-3 for the location of drains, valves, and other components as we continue the discussion on the various modes of operation.

At-Sea Mode

Once the ship is beyond the 3-mile limit, and in the area known as the contiguous zone, the CHT system may be placed in the at-sea mode by following these procedures:

1. Place the soil drain diverter valve (H) and the waste drain diverter valve (J) in the overboard discharge position. Ensure that the gagged scupper valves near the overboard discharge are open.

2. Open the pump suction valves (A) and the pump discharge valves (B).

3. Shift the pump discharge diverter valve (C) to the overboard discharge position.

4. Set the discharge pump controller selector switches to the MAN 1 position.

5. After the pumps lose suction, set both controller selector switches to the AUTO position.

6. Open the tank washdown supply valve (L) and wash the tank for 30 minutes.

7. Close the tank washdown supply valve (L).

8. Set the controller selector switches to the MAN 1 position.

9. After loss of pump suction, set the controller switches in the OFF position.

10. Close the pump suction valves (A) and the pump discharge valves (B).

11. For the strainer-type CHT system, close the inflow stop valves (G). For the comminutor-type CHT system, secure the comminutor isolationvalves (D) right after shifting the soil drain diverter valves (H) to the overboard position. For comminutor systems with the aeration system, close the air blower discharge valve (M) and secure the air blower. Or, secure the ship's service air system supply valves (N) once the tank washdown procedures have been completed and the pump has lost suction. If an air aspirator system is installed, shut down the system and secure the aspiration pump.

After you have placed the valve alignment in the at-sea mode, place the electrical components in the at-sea mode as follows:

1. De-energize the controller at the local power panel by placing the pump controller selector switches in the OFF position.

2. Place the local CHT holding tank high-level alarm cutout switch in the ON position. You can then monitor the tank level for overfilling.

3. Energize the high-level alarm circuit at the IC switchboard to continuously monitor the tank level.

4. Secure both the air blower and the comminutor power supply switches at the local power panel.

During the at-sea mode, you must flush the holding tank for 30 minutes each week, and pump it down even when the tank is not in use. Keep the pump rooms clean and dry. Make sure that the pump-room sumps are clean and pumped down. De-energize the pump-room power panels at the main switchboards.

Transit Mode

The OOD should inform the engineer officer 1 hour before the ship enters restricted waters. (Restricted waters are the waters within 3 miles of land.) The engineer officer will then have personnel in charge of the CHT system start switching the system over from the at-sea mode to the transit mode.

To change the system over to the transit mode, follow these preliminary procedures first:

1. Make sure the tanks are pumped down.

2. Check the pump-room power panels to ensure that all switches are in the OFF position, including the pump selector switches.

3. Verify that these valves are in their proper positions:

a. The pump suction valves (A) should be open.

b. The pump discharge valves (B) should be closed.

c. The tank washdown supply valve (L) should be closed.

d. The air blower discharge valve (M) should be open.

e. The ship's service air supply valves (N) should be open.

f. For strainer-type systems, the inflow stop valves (G) should be open.

4. Call main control and request that the CHT pump-room power panels be energized.

5. Check the comminutor belt tension.

6. For comminutor-type systems, once the power panels are energized, open the comminutor isolation valves (D) and start up the comminutor. Observe the comminutor to ensure that it is operating properly.

7. Notify DC central (or main control) that the CHT system is ready to be shifted to the transit mode.

The engineering officer of the watch (EOOW) will report to the OOD that the CHT system is ready to be shifted.

When the ship is 4 miles out from land, the OOD will direct the EOOW to have the CHT system shifted. The EOOW will, in turn, direct the CHT personnel to make the shift. The EOOW will also inform DC central when the shift is to be made.

When you are notified to shift the CHT system to the transit mode, follow these procedures:

1. Shift the soil drain diverter valves (H) to the CHT collection position.

2. Check the waste drain diverter valves (J) to ensure that they are still in the overboard position.

3. Inform DC central that the system is in the transit mode.

DC central will then inform the EOOW that the switch has been completed. DC central will then update the valve positions on the valve status board.

When the ship is going into anchorage, arrangements for a sewage barge will be required. The sewage barge is normally furnished by the host activity or by a civilian contract.

In-Port Mode

While the ship is entering port, the CHT system stays in the transit mode. Once the ship moors to the pier, it will need to be shifted to the in-port mode. The CHT personnel should stand by their assigned positions in the pump room and the deck discharge valves on the side of the ship that will be pierside. Phone communications are to be set up between the pump room, deck discharge valve stations, and DC central.

Once all hands concerned are at their assigned positions and phone communications are set up, these procedures should be used to shift the system to the in-port mode.

1. The deck discharge valve station and pier personnel will connect the sewage transfer hoses to the ship and the shore receiving riser. The hoses normally come from the pier to the ship. Therefore, a working party may be needed to haul the hoses on board.

2. The deck phone talker performs the following actions:

a. Verifies that the connections have been made on the ship and on the pier.

b. Notifies the pump-room personnel when the connections are made.

c. Notifies the pier personnel to stand by to receive sewage.

3. The pump-room personnel will now take the following actions:

a. Make sure that the pump suction valves (A) are open.

b. Open the pump discharge valves (B).

c. Shift the pump discharge diverter valve (C) to the deck discharge position.

d. Notify the deck discharge valve station personnel that the system is ready to commence pumping. (**NOTE:** The tank must be aerated continuously when it is in use. The report should be, "Pump room No.1 ready to commence pumping.")

4. The deck discharge valve station personnel open the deck discharge valve (F). The valve may be on the portside or the starboard side, depending on what side of the ship is pierside.

5. The pump-room personnel will now energize the system in the following manner:

a. Energize the pump controller.

b. Set the sewage pump selector switch in the AUTO position.

C. Depress the start button.

d. Notify the deck discharge valve station personnel that the pumps are running.

e. Shift the waste drain diverter valves (J) to the CHT collection position.

f. Verify that the soil drain diverter valves (H) are still in the CHT collection position.

g. When the tank has been pumped down and the pump stops, open the tank washdown supply valve (L). The tank should be washed down for 30 minutes.

h. Close the tank washdown supply valve (L) upon completion of washing down the tank. (**NOTE:** The comminutor and the aeration systems should be operated continuously while in the in-port mode. During extended in-port periods, the CHT tank is to be washed down a minimum of 30 minutes per week.)

6. The deck discharge valve and pier personnel must check their sewage transfer hose connections for leaks.

a. If a leak is discovered, the deck phone talker should order the pump-room personnel to stop pumping immediately.

b. The deck discharge valve station personnel are to ensure that the hoses are connected and supported properly to prevent the hose from rupturing.

c. All personnel should stay on station until it is evident that the system is operating properly without any leaks or possible problems.

7. The pump-room personnel will observe and verify that the pumps in the automatic mode are operating properly. Two cycles of operation are required to verify that the pumps alternated. To accomplish this, the pump-room personnel will take the following actions:

a. Open the tank washdown supply valve (L) to raise the level of the tank to be pumped down.

b. Check the pump-room fittings and components for leaks. Immediate action is required to correct any leaks discovered.

c. Pump down the pump-room sump.

d. Upon completion of these actions, stow the phones in the stowage box in a clean condition.

e. Clean the pump room and themselves. Personnel hygiene is important to protect everyone's health.

f. Notify DC central that the tank has been pumped down and that the system is in the automatic mode for that pump room.

DC central will then update the CHT system status board to show that the valves are in the in-port mode. DC central will inform the OOD, who will, in turn, inform the CDO that the CHT system is in the in-port auto mode.

The petty officer of the watch will log the time that the CHT system was shifted to the shore connection. If the sewage offload barge is alongside at anchorage, the petty officer of the watch will log the times that the pumping started and finished. The log entry is required to protect the ship in the event of a sewage spill in the vicinity by another ship. Furthermore, each ship should set its own procedures to ensure that the CHT connections at the deck discharge valve, the shore connection, and any hose connections in between are checked for leakage. These checks should be conducted at least once each hour.

If a leak goes unnoticed and releases sewage into the water, the ship will be in violation of the pollution control law. If a leak should occur topside, all of the pump selector switches should be placed in the OFF position. The system will need to be placed in the transit mode and the waste drain diverter valves (J) diverted overboard. Immediate action is required to repair the leak.

When the ship joins a nest of ships alongside a pier, the nesting procedures are used. (See fig. 17-4.) These procedures are basically the same as if the ship were to go alongside the pier by itself. The ship's force personnel will be required to rig and connect the hoses to their ship and to the

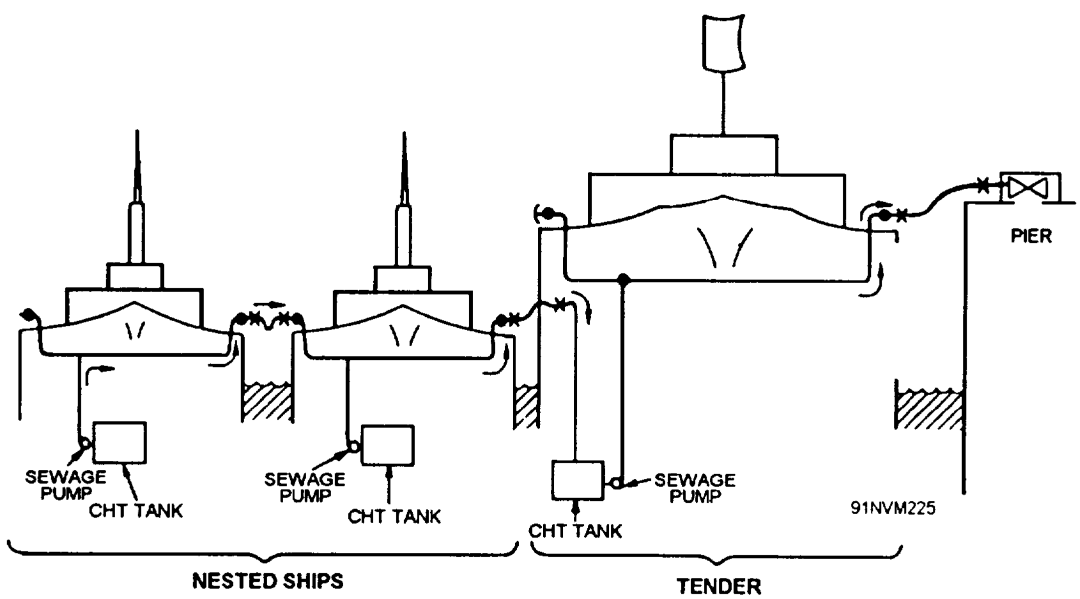


Figure 17-4.—Nested ship sewage transfer.

receiving ship. PWC, however, will normally provide the hoses. All ships in the nest must be notified before pumping. There will not be any high-level alarm conditions set on the inboard ships.

When leaving a nest, the ship follows basically the same procedures as leaving the pier. However, if your ship is inboard, all the ships outboard of yours must stop pumping and shift to the transit mode also. Once your ship has broken away, the other ships can commence reconnecting and shifting to the in-port mode.

SAFETY PRECAUTIONS FOR IN-PORT MODE.— The following precautions are applicable to operation in the in-port mode:

—In the event of a high-level alarm, you, as the operator, should recognize that a problem exists with the pumps, the discharge piping, or both. If the tank completely fills while the system malfunction is being checked out, the waste will overflow overboard and flow through any heads or fixtures located below the overflow discharge lines. These fixtures should be identified and marked before initial use of the system.

—Whenever a high-level alarm sounds, immediately close the isolation valves on the marked drains below the overflow overboard discharge and/or divert the upper deck drains overboard to prevent flooding and fouling of spaces.

—In the event of leakage or snagging of the transfer hoses, close valve (F) (see figs. 17-1 and 17-3) at the deck connection. (Closing the pier valve may cause the discharge hose to rupture.) Line up the pump discharge diverter valve (C) in the overboard discharge position to prevent overflow or backup of drains located below the tank overflow. Once the problem has been corrected, return the system to the operational alignment.

PROCEDURES FOR GETTING UNDERWAY.— When in the in-port mode, follow the following procedures to prepare the CHT system for getting underway (see figs. 17-1 and 17-3).

1. Set the waste drain diverter valve (J) to the overboard discharge position.
2. Set the sewage discharge pump controller switch to MAN 1 for emptying the tank. The aeration system should remain in operation.
3. When the discharge pump loses suction, place the controller selector switch in the OFF position.
4. Close the pump discharge valves (B).
5. Open the flushing/eductor supply valve (E) and flush the discharge piping and hose for 10 minutes.
6. Close the flushing/eductor valve (E).
7. Open the pump discharge valves (B).
8. Operate the manual hold-open device on the pump discharge check valves (K) to drain the discharge lines back into the tank.
9. Try raising the hose to remove fluid from the drooping portion.
10. Close the deck discharge valve (F) and the receiving station valve.
11. Break the highest hose connection first to ensure proper drainage of the hose. This allows air into the line and breaks any vacuum or pressure seal.

NOTE: Personnel engaged in sewage transfer hose operations must observe all applicable safety, sanitary, and hygienic practices.

12. Cap or seal the ends of the transfer hose.
13. Reset (close) the pump discharge check valves (K).
14. Wash down the deck connection area with a solution of hot water, stock detergents, and bleach.
15. Close the pump discharge valves (B).

The ship should now be prepared for transit. Follow the procedures listed in the SDOSS to switch the system from the in-port mode to the transit mode and then to the at-sea mode. This operation is basically just the opposite of going from the at-sea mode and working down to the in-port mode.

Sewage Transfer During Tender Operations

During all tender operations, sewage is transferred from the ships being serviced to receiving stations in the tender. Typical receiving stations in submarine tenders and surface ship tenders are shown in figures 17-5 and 17-6. The tender then transfers the sewage to the receiving facility.

Layouts for submarine sewage transfer hose connections differ from those of surface ships in that each submarine always uses independent hoses for direct transfer to a tender or receiving facility. That is, when nested, submarines do NOT discharge sewage through inboard ships to the receiving facility as in the case of nested surface ships.

Tenders furnish 4-inch sewage transfer hoses with quick-disconnect fittings for surface ships and 2 l/2-inch hoses with quick-disconnect fittings for submarines. In the following paragraphs, we will discuss shipboardsewage transfer procedures unique to tender operations.

TENDER RECEIVING SEWAGE FROM SURFACE SHIPS.—Before sewage can be

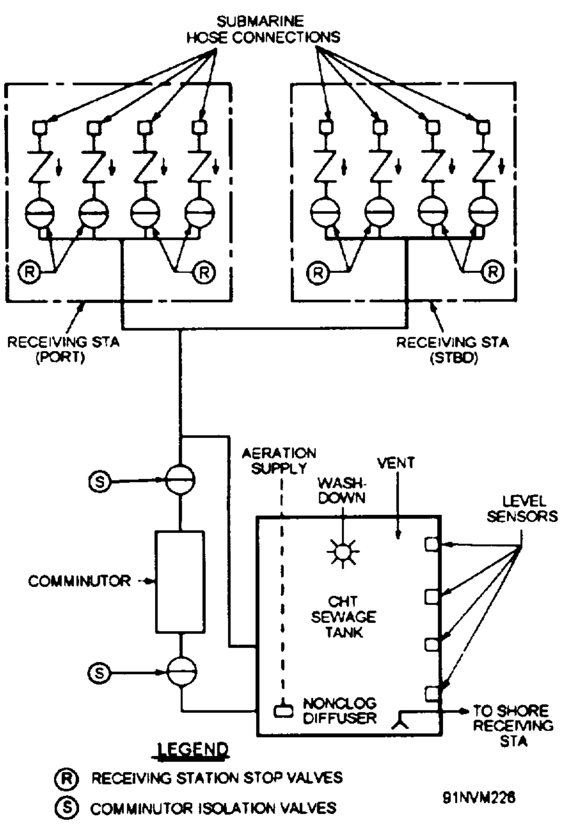


Figure 17-5.—Submarine tender receiving system.

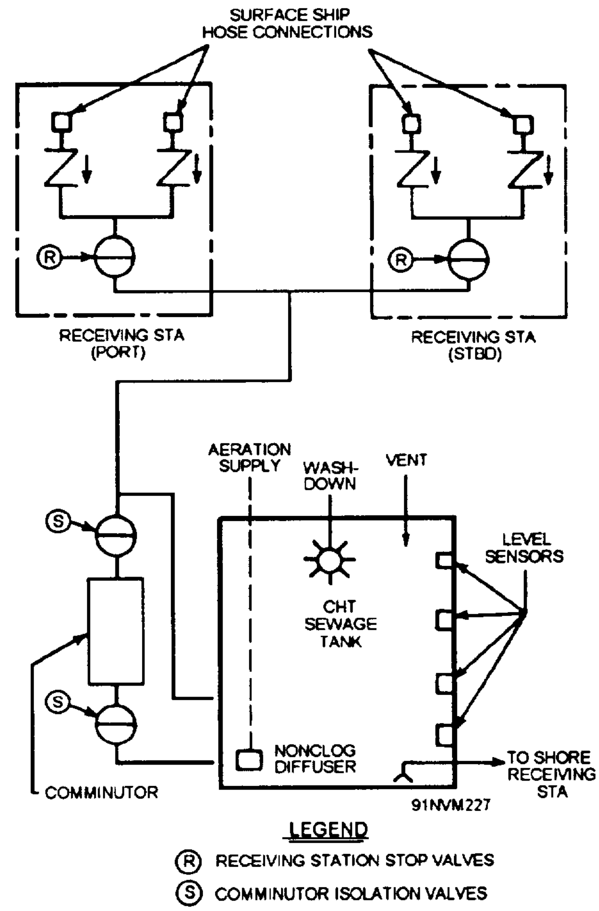


Figure 17-6.—Surface ship receiving system.

transferred from tended ships, sewage hoses must be connected to the tender sewage-receiving station according to the procedures previously discussed. Then, open tender receiving station stop valves (R) and comminutor isolation valves (S) (see fig. 17-6). The surface ship should then be advised that transfer operations may begin.

> **CAUTION**
>
> When hoses are connected during nesting operations, no valves are to be opened until after all connections are made. If the high-level alarm sounds on the tender while a tended ship's tank is being emptied, notify the ship to stop transferring, and then close the receiving station's stop valves. Investigate and take corrective action before restarting transfer operations.

SECURING TENDER RECEIVING OPERATIONS.—When the tended ship has transferred its sewage, close the tender receiving station stop valves (R), and disconnect sewage hoses from the receiving stations following previously discussed procedures.

> **CAUTION**
>
> Before any hose is disconnected, open all valves in the lines to the CHT tanks on the tended ships to depressurize the lines. Also assure that all pump selector switches on the tended ships are in the OFF position.

SUBMARINE SEWAGE TRANSFER TO TENDER.—Submarine transfer procedures are similar to surface ship transfer procedures. The exception is that the receiving station stop valves (R) (fig. 17-5) are opened and remain open only during receiving. Submarines must obtain permission from the tender before discharging sewage. When receiving operations have been secured, the tender gives a complete air blow of the hose and piping to minimize hose spillage during disconnect.

> **CAUTION**
>
> If the high-level alarm sounds on the tender while it is receiving sewage from the submarine, notify the submarine to stop transfer. Investigate and take corrective action before resuming transfer. Ensure that sewage transfer hoses are not pressurized before they are disconnected.

CHT TANK WORK PROCEDURES AND MAINTENANCE

The hygienic practices discussed under sewage transfer operations must be observed by all personnel who perform maintenance or troubleshoot the CHT system.

CHT tanks should be cleaned and inspected at least every 3 years. This inspection should be conducted only at a maintenance facility where proper industrial assistance is available. Furthermore, no work procedure or maintenance should be performed without proper equipment, safety precautions, and supervision.

Work Procedures

Advance facility arrangements should be made for a qualified gas-free engineer and for the design and installation of the necessary temporary ventilation. These arrangements should be made with the production engineering, gas-free engineering, and industrial hygiene departments, or similar operating units. Before opening the tank, these specialists should ensure that the pump room is properly ventilated and under positive pressure. The following procedures should then be followed:

1. Divert all drains overboard.

2. Isolate all heads, fountains, or drains located below the level of the overflow discharge.

3. Ensure that the valve in the overflow discharge line is open.

4. Operate the aeration system, if available.

5. Pump out the tank completely. When pump suction is lost, turn off the pump.

6. Open the tank washdown valve and fill the tank until water comes from the overflow overboard discharge. Secure the washdown system.

7. Repeat steps 5 and 6.

8. Repeat step 5.

9. Secure the air supply.

> **WARNING**
>
> TOXIC HAZARD: Toxic gases may exist in the tank and associated piping in and adjacent to the pump room. Do not open the system until it has been certified gas-free.

10. Have the gas-free engineer inspect the tank and issue a gas-free certificate as required in *NSTM*, chapter 074. Pay particular attention to the presence of hydrogen sulfide, methane, carbon dioxide, and oxygen. If the tank is not gas-free, reseal the tank and repeat the washdown procedure outlined previously (steps 1 through 9) until the tank can be certified gas-free and safe. The tanks must be recertified periodically. In any event, the recertification must be performed at least every 4 hours while the tank is open.

11. Even though a tank may be certified gas-free, toxic gases may remain in the sludge blanket and may be released when the blanket is disturbed. Before opening the tank in any manner (for example, by removal of manhole access covers or liquid-level sensor flanges), wear either an OBA or an air-line mask as described in *NSTM*, chapter 079, volume 4. You must have a second person on hand to lend assistance as required. A spare OBA or air-line mask (preferably OBA) must be immediately available.

12. After the tank is opened, ventilate it continuously by taking suction from the tank and exhausting directly to the atmosphere. Ventilation should provide a change of air in the tank every 3 minutes. The number and types of blowers needed, ducting path and arrangement, and position of suction in the tank are to be determined by the production engineering and industrial hygiene departments.

13. Once forced ventilation of the tank has begun (step 12), you can continue work around the tank without using OBAs or air-line masks.

14. Before entering the tank, force ventilate it for 30 minutes and then clean it thoroughly with a firehose or manually controlled high-pressure water cleaning nozzle. Continue ventilation during this washdown. Be careful not to get water into the blower inlet line or to damage internal tank equipment (level sensors). Pump out the tank as necessary during cleaning.

15. Have the gas-free engineer repeat gas level measurements. When the tank is designated gas-free and safe, you may enter using an OBA or air-line mask. Personnel entering the tank must wear overalls, boots, gloves, and head covering. If the tank is found to be unsafe, continue ventilation until it can be certified gas-free and safe. If you enter the tank alone, you must use a safety harness and tending line. If more than one person enters the tank, they should not use the tending line. However, the OBA or air-line mask wearers should keep in constant sight or touch with one another. Personnel should always be on hand outside the tank to lend assistance if required.

16. After the tank is entered, remove the remaining sludge and wash down.

17. Have the tank recertified as gas-free and safe by the gas-free engineer. If the tank is found unsafe, continue ventilation until the tank can be recertified gas-free and safe.

18. Personnel may now continue work in the tank without air-line masks or OBAs, provided ventilation is continued.

19. Inspect the tank coating, level sensors, aeration, and washdown systems. If recoating is necessary, it should be done with the four-coat tank-coating system, MIL-P-24441. The cement used to fill voids and pockets should be replaced with latex cement, MIL-D-21631.

WARNING

TOXIC/EXPLOSIVE HAZARD: The tank must be assumed to contain toxic/explosive gases until otherwise determined. Observe all NO-SMOKING regulations. Do not allow open flame, ordinary electric lights, flashlights, or sparking electrical apparatus in or near the open tank until safety is certified by

20. Do not perform any welding or hot work on the tank until the gas-free engineer first determines that the tank is safe for hot work. After the welding is completed, inspect the coating for heat damage and repair as necessary.

Toxic Gases

Toxic gases are generated at various rates depending upon the sewage temperature, pH, oxygen, and the amount of sewage in the tank. Toxic gases are likely to form in tanks where sewage is allowed to remain for long periods of time.

Therefore, the tank is to be flushed and pumped out at least weekly whether in the in-port mode or the at-sea mode.

Hydrogen sulfide (H_2S) is the most common gas you will find in the CHT system, and it can be produced within 6 to 12 hours. It can also exist as a liquid at low temperatures and high pressures. H_2S is a colorless gas that has a strong odor of rotten eggs. It can affect an individual's sense of smell and cause an irritation to the eyes, nose, and throat. A headache, dizziness, and an upset stomach are caused by inhaling low concentrations of H_2S. At higher concentrations of 1,000 to 2,000 ppm, you can go into a coma or meet sudden death after just one single breath. It is also possible that you may be completely unaware of the presence of H_2S.

H_2S is also a flammable gas. It has a lower flammable limit by volume of 4.3 percent and an upper limit of 46 percent. The au toignition temperature is 260°C (500°F). When H_2S burns, it has a pale blue flame. This type of fire may be extinguished by using either CO, or water in the fog form. The gas can travel a considerable distance to a source of ignition. Once ignited, it will flash back to the source.

The toxicity level for H_2S is currently set at 20 ppm by the Occupational Safety and Health Administration (OSHA). The National Institute for Occupational Safety and Health (NIOSH) has recommended that the permissible exposure limit be reduced to IO ppm averaged over a lo-minute period. At the time of this printing, the acceptable safe limits are set at 10 ppm averaged over an 8-hour period.

An aeration system must be provided for each CHT collection tank. The aeration system is to be operated continuously while in the in-port mode. The tank is to be pumped down each 6- to 12-hour period when in the in-port mode to reduce the amount of H_2S that may be produced.

Fresh sewage contains a mixture of bacteria, normally aerobic bacteria. The aerobic bacteria survive and grow in the presence of oxygen. If the sewage is not provided with additional oxygen (use of the aeration system), and the sewage is allowed to remain in the tank in excess of 6 to 12 hours, the bacteria will consume all the oxygen and die off. As the aerobic bacteria die off, the anaerobic bacteria begin to take over. Anaerobic bacteria require no oxygen to survive. The anaerobic bacteria produce hydrogen sulfide, methane, and other toxic and flammable gases. H_2S is not limited to the CHT system. If drainage water from refrigeration boxes gets into a confined space and is overlooked for long periods of time, it too can produce H_2S.

Other gases of concern are as follows:

—Methane (CH_4) is a colorless, odorless, nontoxic gas that is highly flammable. Flammable vapors may spread from a spill. The heat of a fire can cause a container of CH_4 to explode. Its flashpoint is -188°C and ignition temperature is 538°C. The lower flammable limit by volume is 5.53 percent.

CH_4 itself has no effect on humans. However, it does reduce the oxygen concentration of the air. If the oxygen concentration is dropped below 20 percent, an individual without an OBA, or similar device, will suffocate.

—Carbon dioxide (CO,) is primarily a colorless and odorless gas. However, CO, is also available as a liquid and as a solid. The maximum allowable dose of CO, authorized by OSHA is 5,000 ppm averaged during an 8-hour period. NIOSH has recommended that the amount be changed to 10,000 ppm averaged over a period of up to 10 hours per day. For our purposes, and keeping these figures in mind, an acceptable limit of less than 0.5 percent is authorized.

CO_2 is nonflammable, but it is an asphyxiant and a potent respiratory stimulant. It is also a stimulant and a depressant to the central nervous system. CO_2 displaces the oxygen in the compartment into which it is discharged. When you enter a space where carbon dioxide has been discharged, you must wear an approved respirator or similar breathing device.

—Hydrogen (H) is a colorless and odorless gas. It is flammable with an ignition point of 585°C and has a wide range of explosive limits. H is harmless in itself, but it can lower the amount of oxygen in the air if a leak occurs. You will suffocate if the percentage of oxygen is reduced below 20 percent.

—Ammonia (NH_3) is a colorless gas with a sharp and intensely irritating odor. It liquifies readily under pressure. It is flammable with an ignition temperature of 651°C. The flammable limits are 16 to 25 percent by volume.

NH_3 has a maximum safe level of 50 ppm. However, the acceptable safe limit is 25 ppm. Ammonia is toxic, and inhaling it in a high concentration can cause swelling of the respiratory tract. It can also cause headaches, nausea, vomiting, breathing difficulties, and coughing. If ammonia gets into your eyes, it can cause a visual disorder. If NH, gets into your eyes, wash your eyes with large quantities of water and seek medical help.

CHT TANK MAINTENANCE NOT REQUIRING TANK ENTRY

Tank maintenance sometimes calls for equipment to be removed from the outside of the tank so that an opening will be left in the tank. Some examples are the removal of level sensors, washdown nozzles, or valves adjacent to the tank and below the level of the tank overflow in the pump room. If this is done but the tank is not to be entered, observe steps 1 through 9 of the preceding discussion under Work Procedures with this exception: The ship's gas-free engineer can determine the space ventilation requirements and ensure that the atmosphere in the tank is at 10 percent or less than the lower explosive limit (LEL). Equipment can then be removed using an air-line mask or other approved respirator. Openings should then be sealed using either blank flanges or a suitable sealing device. Air-line masks or OBAs can then be removed and work can be continued on the equipment.

SUMMARY

In this chapter, you were introduced to the CHT sewage system. There are other marine sanitation devices in use. If your ship has a system that was not discussed here, refer to the manufacturer's technical manual for that system. Keep in mind that there are regulations that govern the discharge of sewage in navigable waters within 3 miles of the coastline. For your health and the safety of others, follow the prescribed sanitation procedures. Courses, PQS, and schools are available for sewage systems maintenance and operation. See your educational services officer or career counselor for more information and class convening dates for these schools.

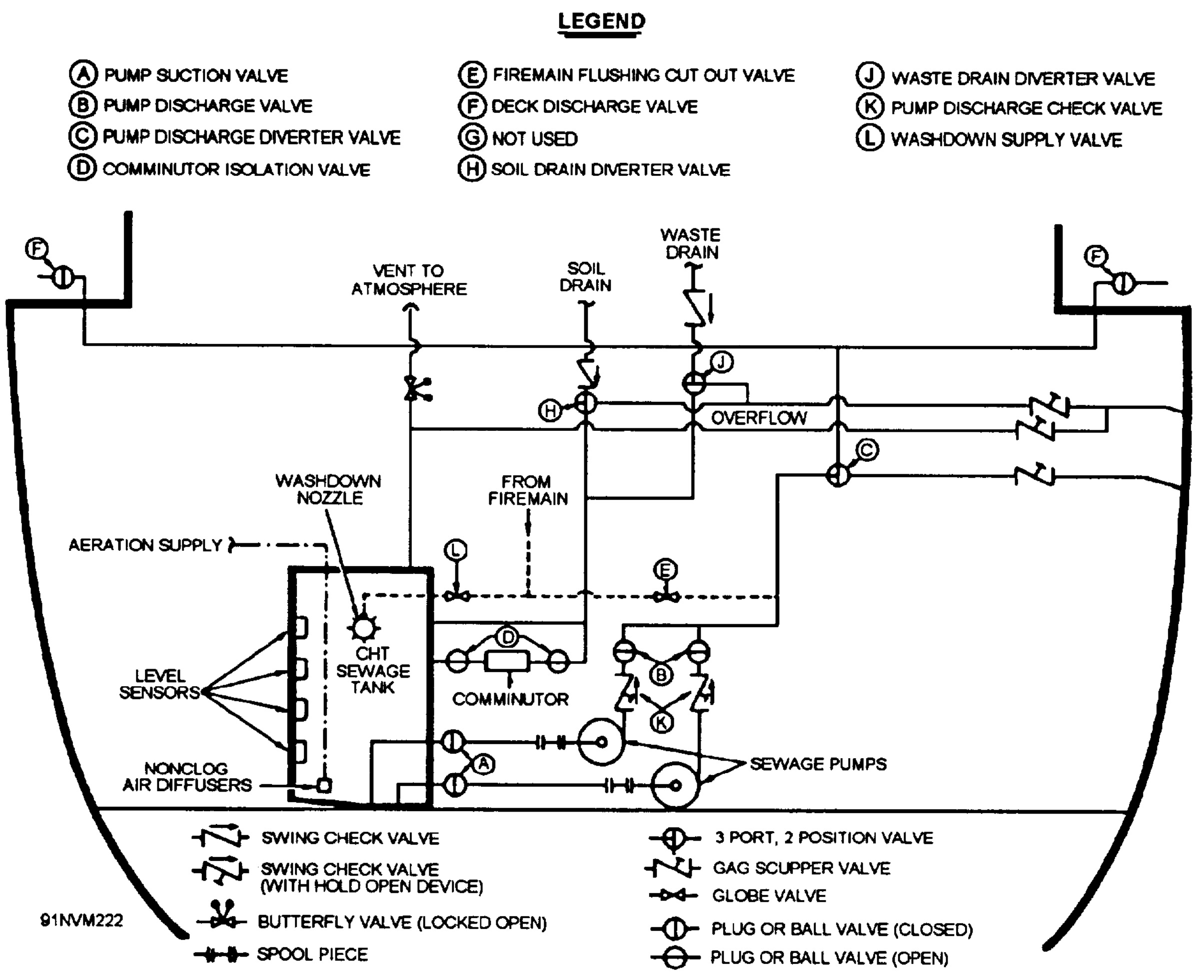


Figure 17-1.—Comminutor-type CHT system.

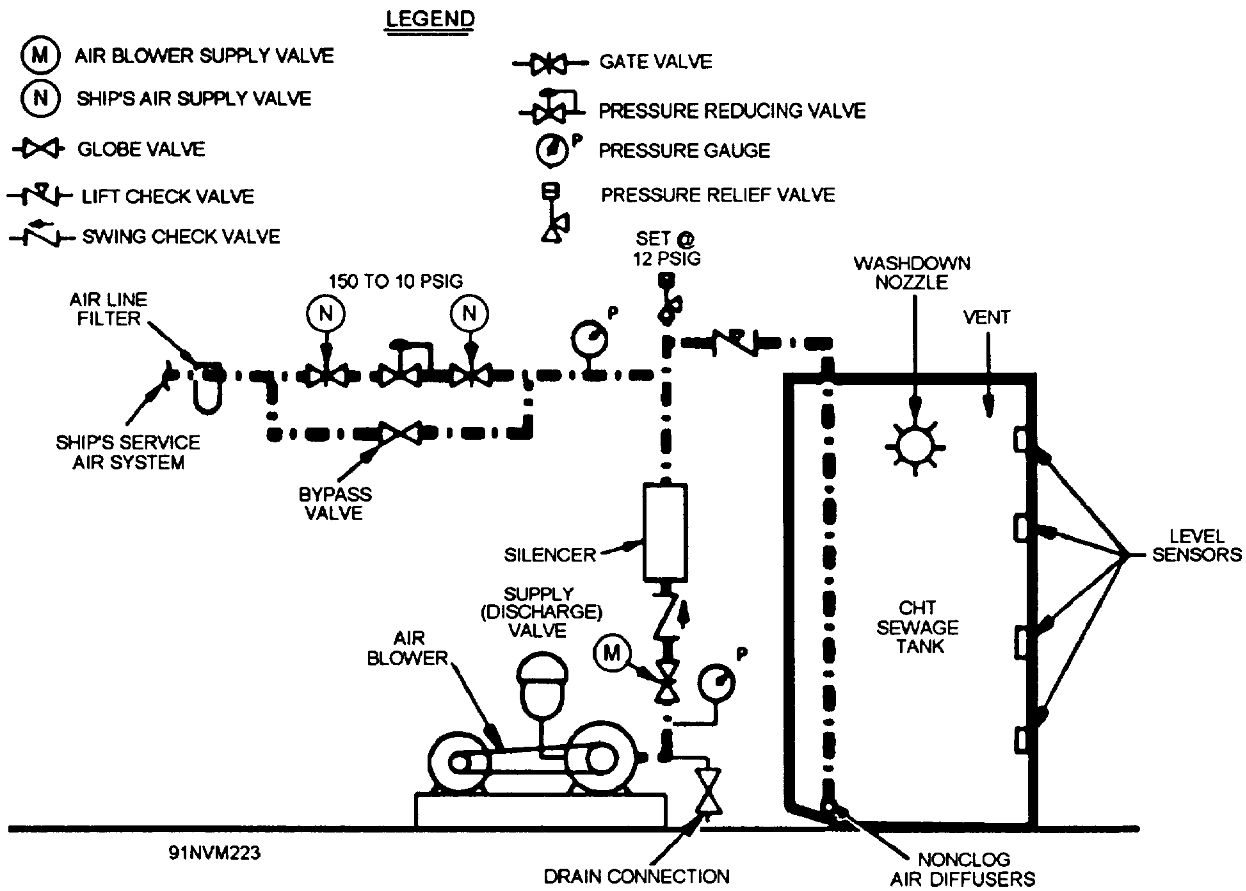


Figure 17-2.—Aeration subsystem.

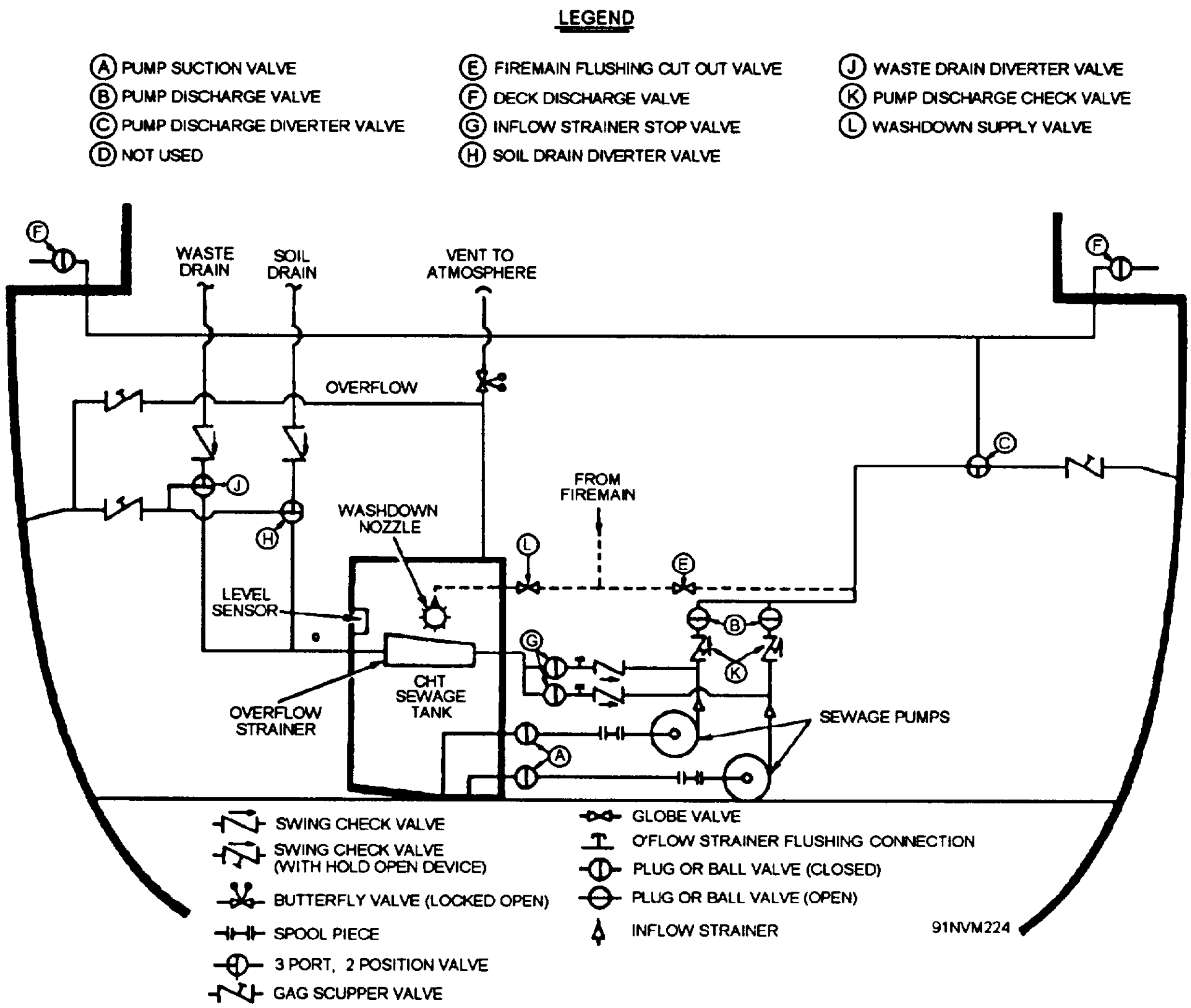


Figure 17-3.—Strainer-type CHT system.

APPENDIX II

GLOSSARY

ADAPTER— A coupling or similar device that permits fittings with different-sized openings (apertures) to be joined together.

AIR-DRIED LUMBER—Lumbered seasoned by being permitted to dry naturally.

AISI—American Iron and Steel Institute. Produces a numerical index for the classification and identification of the chemical composition of structural steel.

ALLOY—Any composite metal produced by the mixing of two or more metals.

ALLOYING— A procedure used to add elements, other than those that usually make up a metal or alloy, to change the characteristics and properties of the base metal.

ALLOYING ELEMENTS—Elements added to nonferrous and ferrous metals and alloys to change their characteristics and properties.

ANGLE VALVE—A stop valve is actually a combination valve and elbow, since its outlet branch is at right angles to its inlet branch.

ANNEALING—The softening of metal by heating and slow cooling.

ASTM—American Society for Testing Materials.

AWR—Automated Work Request. A computer-produced 3-M form that displays the information found on the 4790/2K and the planning information found on the 4790/2P and that is used by the IMA for advanced planning and work completed.

BACK-GOUGE— A term used in welding for the removal of the root and first layer of weld beads before welding the opposite side of a weld joint.

BACK-PRESSURE VALVE—A valve that is similar in design to a low-pressure valve, but which is capable of opening independently of the pressure, thereby giving free exhaust.

BACKING STRAP—A term used in welding where the root of the weld joint is closed by the application of a backer plate. This backer plate is used as a base for depositing weld metal and preventing the introduction of oxygen contamination of the root weld bead while in the molten state. The backing strap may or may not be removed after welding is complete.

BARNACLES— Small shellfish that are found attached to the bottoms of vessels and to pilings and other submerged structures.

BELL—The recessed or enlarged female end of a pipe into which the male end of the next pipe fits.

BEND—A curved length of pipe bent to a radius larger than that of an elbow. The term l/8 bend represents a 45-degree bend, l/4 represents a 90-degree bend, and l/2 represents a 180-degree bend.

BEND ALLOWANCE—An additional amount of metal used in a bend in metal fabrication.

BENDING ROLLS—A large machine used to give curvature to plates by passing them through and in contact with the three rolls.

BENDING SLAB—Heavy cast-iron blocks with square or round holes used for "dogging down." The blocks are arranged to form a large solid floor on which frames and structural members are bent and formed.

BEVEL—A term for a plane having any angle other than 90 degrees to a given reference plane. Also, a small tool similar to a try square except that the blade is adjustable for taking bevels.

BILL OF MATERIAL—A list of standard parts or materials needed to fabricate an item.

BISECT—To divide into two equal parts.

BLANK FLANGE—A flange that is complete except for drilling.

BOLT—A metal rod used as a fastening. With a few exceptions, such as drift bolts, a head or shoulder is made on one end and a screw thread to carry a nut is cut on the other.

BOLTING UP—Securing, by means of bolts and nuts, parts of a structure in proper position for permanent attachment by riveting or welding.

BONNET— A cover used to guide and enclose the tail end of a valve spindle.

BORDER LINES—Dark lines defining the inside edge of the margin on a drawing.

BOSS—A socket, with a heavy wall, that is welded or brazed onto pipe to provide connections for gauges and related fittings.

BRACKET—A steel plate, commonly of triangular shape, with a reinforcing flange on its free edges. It is used to connect two parts, such as a deck beam to a frame, or a frame to a margin plate. It is also used to stiffen or tie items, such as beam angles to bulkheads and frames to longitudinals.

BRANCH—The outlet or inlet of a fitting not in line with the axis of the system, but making an angle with it.

BRASS—An alloy composed chiefly of copper and zinc.

BRITTLENESS—That property of a material that causes it to break or snap suddenly with little or no prior sign of deformation.

BRONZE—An alloy composed chiefly of copper and tin.

BUCKLE—(l) A distortion, such as a bulge. (2) To become distorted. (3) To be bent out of its own plane.

BULKHEAD FLANGE—A flange with two bolt circles; the larger circle is to secure the flange to the bulkhead, the smaller is to secure the pipe to the flange. This type of flange is used where piping must pass through a watertight bulkhead.

BULKHEAD SLEEVE—A sleeve welded into a bulkhead with piping butted together and welded onto each end of the sleeve. If a section of pipe can be slipped through the sleeve, there is no need of butted ends inside the sleeve. However, the pipe must be welded to the sleeve at each end to make a watertight joint at the bulkhead.

BURR—The rough, uneven edge of a sheared or burned plate, or the area around a punched or burned hole. Also, a washer-shaped piece of metal through which the rivet is inserted and against which the rivet point is riveted over.

BUSHING—A hollow plug with internal and external threads, used to connect a pipe with a fitting of a different diameter.

BUTT—The end or edge of a plate or timber that comes squarely against another piece, or the joint thus formed. The long edge of a plate is called the edge and the short edge is called the end.

BUTT WELD—A welding along a seam that is not scarfed or beveled, but is joined by the edges coming together.

BYPASS—A small passage that will permit the passage of fluid in a system around a larger valve. In this way, pressure can be equalized on both sides of the larger valve so that it may be readily opened or closed as required.

BYPASS VALVE—A small pilot valve used in connection with a larger valve to equalize pressure on both sides of the disk of the larger valve before the latter is opened.

CALKING—The operation of jamming material into the contact area to make a joint watertight or oiltight.

CALKING TOOL—A blunt-ended chisel used in calking.

CAP—A fitting placed over a pipe to make a dead end.

CENTERLINES— (l) Lines that indicate the center of a circle, arc, or any symmetrical object; consisting of alternate long and short dashes evenly spaced. (2) The middle line of the ship from stem to stem as shown in any waterline view. (3) Well-defined knife or gauge lines placed upon the work to serve as a point from which dimensions will be measured.

CHAMFER—A bevel surface formed by cutting away the angle of two intersecting faces of a piece of material.

CHECK VALVE—An automatic nonreturn valve, or a valve that permits a fluid to flow in one direction but automatically closes if the fluid begins to flow in the opposite direction.

CLAMP—A metal fitting used to grip and hold wire ropes. Two or more may be used to connect two ropes in lieu of a short splice or turning in an eye. Also, a device generally operated by hand to hold two or more pieces of material together, usually called a "C" clamp.

CLEAN-OUT FITTING—One that is equipped with a cover and handhole to provide access for cleaning the pipes.

CLOSE NIPPLE—One whose length is about twice the length of a standard pipe thread and is without any shoulder.

CLOSE RETURN BEND—A short U-shaped fitting made of cast or malleable iron and used to unite two parallel pipes. It differs from the open return bend in having the arms joined.

COLD SHUT—The imperfect junction where two streams of molten metal meet but do not fuse together.

COLLAR—A threaded pipe coupling, or the sleeve in back of a riveting flange. Certain types of flanges that can be attached by peening and beading are also called collar flanges.

COMBUSTIBLE—A material that can bum, or the capability of burning.

COMMON THREAD—In machinery, an ordinary standard machine thread as distinguished from a pipe thread.

CONTRACTION—The amount that the metal will decrease in size from the time it is poured to the time the temperature has fallen to the normal temperature of the metal.

CONTRACTION RULE (ALSO CALLED SHRINKAGE RULE)—A rule having the graduations enlarged to compensate for the lessening in the size of a casting caused by the decreasing size of the cooling metal.

COUNTERSINK—(l) A tool used to chamfer the lips of a hole. (2) An operation that requires use of a countersink tool.

COUNTERSUNK—As applied to fittings, this indicates that the edges of a tapped opening are chammered to a 45-degree angle.

COUPLING—A threaded sleeve used to connect two pipes. As a joining device, it may be either straight or reducing.

CRADLE—A support of wood or metal shaped to fit the object that is stowed upon it.

CUP JOINT—A lead joint in which one pipe has a flared cup and the other pipe is tapered to fit this cup. The joint is then soldered.

CUPPING—The tendency of sawed boards to curl away from the heart of the tree.

CUTOUT VALVE—A valve that is intended normally to be fully open or fully closed.

CYLINDER—Any tank, drum, retort, receiver, or reservoir made of pipe and closed at each end, except for a required test hole.

DECK—A deck in a ship corresponds to a floor in a building. It is the plating, planking, or covering of any tier of beams above the inner bottom forming a floor either in the hull or superstructure of a ship. Decks are designated by their locations. Examples are upper deck, main deck, forward lower deck, and after superstructure deck. The after portion of a weather deck was formerly known as the quarterdeck and on warships is allotted to the use of the officers.

DECK PLATING—A term applied to the steel plating of a deck.

DEFORMATION—Permanent alteration of form or shape.

DEVELOPMENT—The process of making a flat pattern from the dimensions of a drawing. Used to fabricate sheet metal objects.

DIE—A tool for cutting threads with the cutting usually accomplished in one pass. It differs from a chasing or threading tool in that the latter has one or just a few cutting edges, whereas the die has many cutting edges.

DRIFTED—This term means that a drift or short mandrel has been passed through a pipe to remove any irregularities on the inside surface of the pipe.

DRIFT PIN—A conical-shaped pin gradually tapered from a blunt point to a diameter a little larger than the rivet holes in which it is to be used. The point is inserted in rivet holes that are not fair, and the other end is hammered until the holes are forced into line.

DRILLED—Used in connection with flanges, it means that the flange bolt holes have been made by a drill, and not by cores.

DUCTILITY—The property permitting the permanent deformation by stress or tension without rupture.

DUMMY SPOOL—A substitute piece of pipe with flanges that can be temporarily substituted for valves if the latter are not available when the piping is installed.

EDGE—An abrupt border or margin, a bounding or dividing line, the part along the boundary.

ELBOW or ELL—A fitting that makes an angle between adjacent pipes. Unless the angle is specifically stated, the elbow is a 90-degree angle.

EXPANSION JOINT—A device for connecting up long lines of pipe to permit linear expansion and contraction. The usual pattern of an expansion joint is a sleeve attached to one length of pipe and passing through a stuffing gland attached to a second length of pipe.

EXPANSION LOOP—Either a U-shaped bend or a "pigtail" coil.

EXPANSION PIPES—pipes in refrigerated spaces that lower temperature when the refrigerant flowing through the pipes changes to a gas under release of pressure, and in the process of changing from the liquid to the gaseous state, draws heat from the surrounding space.

EXTRA STRONG—The correct term for pipe that is thicker than standard pipe, but not as heavy as double extra strong pipe.

FABRICATE—To shape and assemble the component parts and to secure them in place to form a complete whole. To manufacture.

FACED—A term used to indicate that flanges are faced after they are attached to pipe, and that the pipe ends are faced flush with the flange, with flange and pipe ends at right angles to the long axis of the pipe.

FACEPLATE— A flat plate fitted perpendicular to the web and welded to the web plate; or welded or riveted to the flange or flanges of a frame, beam stiffener, or girder to balance the continuous plating attached to the opposite flange of the member.

FATIGUE—The tendency of a material to break under repeated strain.

FERROUS—Refers to metals having iron as the base metal.

FILE-FINISH—Finishing a metal surface with a file.

FILLET—A term applied to the metal filling in the bosom or concave comers where abrupt changes in direction occur in the surface of a casting, forging, or weldment.

FITTINGS—A term used to denote all bends, unions, flanges, and related parts except couplings and valves that are attached to a piping system to provide connections or outlets.

FLAMMABLE—A combustible material that bums easily, intensely, or quickly.

FLANGE—The turned edge of a plate or girder that acts to resist bending. The turned edge of a plate or shape for tying in intersecting structural members. A casting or forging attached to, or worked integrally with, a pipe to form a disk, normal to the axis of an exterior to the pipe, for connecting lengths of pipe.

FLANGED JOINT—A joint in a pipe made by bolting flanges together.

FLUX—A fusible material or gas used to dissolve or prevent the formation of oxides, nitrides, or other undesirable inclusions formed in welding and brazing. Flux also aids fusion.

FOLLOWER— A half coupling or locknut used on a long screw.

FRAME—(l) A term generally used to designate one of the transverse ribs that make up the skeleton of a ship. The frames act as stiffeners, holding the outside plating in shape and maintaining the transverse form of the ship. (2) The athwartship strength member of a ship's hull.

GAUGE—Devices for testing threaded, plug, and ringed pieces.

GAUGE LENGTH—The distance that a gauge will go on the threaded end of a pipe by hand.

GAUGE RING—A ring used for gauging the thread on a pipe.

GALVANIZING—The process by which a layer of zinc is applied to iron or steel surfaces.

GASKET—A thin sheet of composition or metal used in making a joint.

GATE VALVE—A sluice with two inclined seats between which the valve wedges down in closing. The passage through the valve is in an uninterrupted line, and when the valve is opened, the sluice is drawn up into a dome or recess, leaving an unobstructed passage the full diameter of the pipe.

GLOBE VALVE—A valve with a round, ball-like shell, and much in use for regulating or controlling the flow of gases or steam.

GRIND—Truing up the surface of a casting with an abrasive wheel or belt.

GROMMET—A ring of lampwick or hemp, soaked in red lead or linseed oil, and placed under washers. When drawn tight, this forms a watertight seal at deck, bulkhead, or shell connections.

HAND TIGHT—The effort used to hand tighten should be only that amount that the average person can continuously exert, not the forcing that could be done by a person picked for his/her strength. Standard gauges should be put on hand tight.

HARDNESS—The ability of a material to resist penetration.

HULL—(l) The framework of a vessel, together with all decks, deck houses, and the inside and outside plating or planking, but exclusive of masts, yards, rigging, and all outfit or equipment. (2) The shell, or plating, of a ship from keel to gunwale.

INCLUDED BEVEL ANGLE—A term used in the preparation of a weld joint where the total degree of bevel is determined by the addition of the bevel angles applied to both pieces of metal to be welded.

INLET—The side of a fixture in which a substance enters.

ISOTOPE—Atoms of an element having the same atomic number of different mass numbers.

JOB ORDER—An order issued by a repair activity to its own subdivision to perform a repair job in response to a work request.

JOINT, BUTT—A connection between two pieces of material that is made by bringing their ends or edges together (no overlap) and joined by welding alone, or by welding, riveting, or bolting each to a strip or strap that overlaps both pieces.

JOINT, LAPPED—A connection between two pieces of material that is made by bringing their ends together by overlapping each other and fastening, welding, riveting, or bolting the ends together.

KILN-DRIED—Lumber artificially dried in a kiln under controlled conditions.

LAYING OUT—Placing the necessary instructions on plates and shapes for shearing, planing, punching, bending, flanging, beveling, or rolling from templates made from drawings.

LAYOUT—A full-size drawing of a pattern with the appropriate shrink rule and showing pattern construction and core arrangement.

LIFT TEMPLATE—A template the same size and shape as the part of the ship involved that may be used to lay out material for fabrication.

LIFTING—The act of transferring marks and measurements from an item or model to a plate or other object by templates or other means.

MACHINABILITY—The capability of being cut, turned, sheared, and so forth, by machine tools.

MALE AND FEMALE FLANGES—The female flange of a pair has a flat, recessed face extending from inside the pipe nearly to the bolt holes. The male flange is faced with a corresponding raised portion, and a slightly smaller diameter. The object of facing the flanges in this way is to prevent a blowout of the gasket.

MALLEABLE CAST IRON—Cast iron that is heat treated or annealed so that its strength is greater than cast iron. It can be bent or hammered to a limited extent, without breaking.

MANIFOLD—A fitting with numerous branches for conveying fluids between a large pipe and several smaller pipes.

MEDIUM PRESSURE—This term applied to valves and fittings means that they are capable of withstanding a working pressure of from 125 to 175 pounds per square inch.

METALLURGY—The science dealing with the structure and properties of metals and alloys and the process by which they are obtained from ore and adapted to human use.

MIL-STD—Military standards—a formalized set of standards for supplies, equipment, and design work purchased by the United States Armed Forces.

MILL THICKNESS—Thickness of lumber as it is sawed from the log.

NIPPLE—A tubular fitting usually threaded on both ends, and not more than 12 inches long. A length greater than 12 inches is called cut pipe. A nipple is also a button or pop that is welded to the inside or outside of a pipe as a reinforcement where a hole is to be tapped.

NONFERROUS— Refers to metals not having iron as the base metal.

NORMALIZING—The act of heating iron-base alloys to approximately 100$F above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

OCCUPATIONAL STANDARDS—Requirements that are directly related to the work of each rating.

OFFSET PIPE—A pipe that is bent to move the line to a position parallel to and in alignment with the balance of the pipe. It may also be used to signify a fitting that accomplishes this purpose.

OLD MAN—A heavy bar of iron or steel bent in the form of a Z and used to hold a portable drill. One leg is bolted or clamped to the work to be drilled and the drill head is placed under the other leg, which holds the drill to its work

OPERATING GEAR—A system of rods with universal joints and couplings connecting to valves, which may be set at particular angles to fit conditions. The system extends to points above the deck and provides a means of operating the valves by remote control.

PACKING—A yielding material employed to effect a tight joint or to pack the stuffing boxes of valves. The material may be sheet rubber or braided hemp. For joints that must allow considerable or incessant motion, metallic rings are used as packing.

PAD EYE—A fitting having one or more eyes integral with a plate or base to provide ample means of securing and to distribute the strain over a wide area. The eyes may be either “worked” or "shackled". They are also known as lug pads or hoisting pads.

PEEN—(l) The lesser head of a hammer. This part is called “ball” when it is spherical, “cross” when it is in the form of a ridge at right angles to the axis of the handle, and “straight” when it is like a ridge in the plane of the handle. (2) To round off or shape an object, smoothing out burrs and rough edges.

PEENED FLANGE JOINT—A term used to indicate that the flanges are attached to the pipe by peening, rather than by screwing, riveting, or welding.

PEENING—The act or process of hammering sheet metal with the peen of a hammer, either to straighten or to impart a required curvature.

PERFORATED—A term used to describe a surface in which holes have been bored, drilled, punched, or otherwise pierced.

PERPENDICULAR—Vertical lines extending through the outlines of the hull ends and the designer's waterline.

PET COCK—A small cock used to drain a cylinder, fitting, and related parts.

PIPE—A hollow cylinder made of metal, plastic, or other materials, used for the conveyance of fluids or gases.

PIPE BEND—A bent pipe, as distinguished from a bend in a piping system where the bend is made by means of a fitting.

PIPE BENDING MACHINE—A device for coiling or bending pipe of any ductile metal. The bending is done by the use of formers and saddles. However, where the pipe wall is relatively thin, it may be necessary to use internal mandrels to prevent buckling or collapse of the pipe wall.

PIPE CLAMP—A joint support fitted with a clamp on each end, connected laterally with four short pieces of flat bar. These clamps are used for holding butt-welded and sleeve-welded joints together until they have been tacked.

PIPE COUPLING—A cylindrical sleeve or socket with female threads designed to receive the ends of two adjacent pipe lengths.

PIPE COVERING—A jacket of nonconducting material placed around the piping of a steam or other hot system to prevent the loss of heat.

PIPE CUTTER—A device for cutting pipe. The common type consists of a hook-shaped frame with a movable slide upon a stem, and another slide upon which cutting disks are mounted. As the appliance is rotated about the pipe, the cutting edges are forced into the metal.

PIPE DIE—A tool for cutting external threads on pipe. (Internal threads are cut with a tap.)

PIPE DOPE—Materials used on the threads of screwed pipe joints. There are many such compounds available under a variety of trade names.

PIPE FITTINGS—Connections, appliances, and various designs of adjuncts used in connection with pipes. Examples are elbows and bends that alter directing of flow, tees and crosses to connect branches with a main, plugs and caps to close an end, and bushings and reducers to couple pipes of different diameters.

PIPE HANGER—A suspension link or band used to support a pipe without interfering with its expansion and contraction.

PIPELINE—A run of pipe used for transporting liquids and gases.

PIPE THREAD—A thread employed in connection with pipe. The standard thread has an included angle of 60 degrees between sides, is slightly rounded at top and bottom, and is tapered. Threads may be either tapered or straight, depending upon the requirements of the specific job.

PIPE VISE—A special type of vise with three serrated jaws, one of which moves against the other two, and may be forced against the pipe by means of a screw or toggle.

PIPE WRENCH—A wrench arranged to grip with increasing pressure as force is exerted on the handle; the jaws of the wrench are usually serrated.

PIPING—The whole system of piping aboard ship. The term is also applied to a section of a system.

PITCH—Distance measured on a line parallel to the axis, and between two adjacent threads or two convolutions of a screw.

PLASTICITY—That property that enables a material to be excessively and permanently deformed without breaking.

PLUG—Without a qualifying adjective, this term is used to designate an ordinary plug or pipe plug with an exterior thread and a projecting head by which it is screwed into the opening of a fitting.

PLUG COCK—Usually called simply a cock. All cocks are essentially plug cocks.

PLUG TAP—A tap with the threaded portions straight or without lead, and designed for bottoming.

POROSITY—State of being full of pores or holes, like a sponge. A defect commonly found in weld metal.

PREHEATING—The application of heat to base metal before it is welded or cut to bring it to a minimum temperature or working temperature.

PROTECTOR—A ring threaded on its inside and used to protect the threaded end of pipe during transit.

PUNCH—A machine for punching holes in plates and shapes.

PUNCH, PRICK—A small punch used to transfer holes from a template to a plate. Also called a center punch.

PLYWOOD—A building material consisting usually of an odd number of veneers glued over each other at right angles.

PYROMETER—An instrument used to measure the temperature of metal and used in the welding process to determine preheat and interpass temperature.

RADIATOR—A coil in a steam or hot water system, or some similar device, that radiates or sends forth heat.

RADIATOR VALVE—An angle valve fitted to a steam or hot water heating radiator.

RADIUS OF BEND—The distance from the center line of a pipe or fitting to the center of curvature.

RAISED FACE FLANGE—A type of flange that has a raised face, to a height of l/l6 to l/4 inch, inside the bolt circle of the flange. The gasket is fitted to this raised portion.

REAMED—A term meaning that burrs left by the action of cutting-off tools have been removed.

REAMING—Enlarging a hole by revolving in the hole a cylindrical, slightly tapered tool with cutting edges running along its sides.

RECESSED—As applied to couplings, this term means that they are counterbored for a short distance; as applied to flanges, it means that they are provided with a calking recess at the back.

REDUCER—A fitting larger at one end than at the other, and designed to conduct flow from one size pipe to another of different diameter. Reducers have inside threading unless specified for a flange or for some special joint. The threaded type is made with abrupt reduction. The flanged type has a tapered body.

REDUCING TEE—A tee with two different sized openings. It may reduce on a branch or on the main run.

REDUCING VALVE—A spring-loaded or lever-loaded valve similar to a safety valve, designed to maintain a lower end constant pressure beyond the valve.

RETURN BEND—In general, this term signifies a fitting with inside threads that changes the direction of piping by 180 degrees.

RISER—A pipe extending vertically with side branches.

RIVET—A metal pin used to connect two or more pieces of material. The rivet is inserted into holes punched or drilled in the pieces and upset at one or both ends. The end that bears a finished shape is called the head and the end upon which some operation is performed after its insertion is called the point. Small rivets are “driven cold,” that is, without heating, and large ones are heated so that points may be formed by hammering.

RUN—A section made of more than one length of pipe; the portion of a fitting having its ends "in line," contrasted with the branch or side opening of a tee.

SAE—Society of Automotive Engineers.

SAFETY TREADS—A special nonslipping metal plate fitted to the deck at the foot of a ladder *or* stairway and often fitted on the upper surface of the steps of ladders and stairs. Steps made of safety threads are called safety steps.

SCARF—An end connection made between two pieces of material. The ends of the two pieces are tapered so that they fit together in a joint of the same breadth and depth as the pieces.

SCARF WELD—A joint made by overlapping and welding together the scarfed or beveled edges of metal plate.

SCUPPER CASTINGS—An opening cut through the waterway and bulwarks of a ship so that water falling on the deck may flow overboard. The casting is secured under the opening that is cut in the waterway.

SEAM—A term applied to an edge joint.

SEAMLESS— This term means that a pipe is without seam, especially without a welded seam. Seamless pipe is produced by a cupping or mandrel process.

SEQUENTIALLY—Done in a predesigned sequence, not necessarily in numerical order.

SET, PERMANENT—The permanent deformation caused by stressing an elastic material beyond its elastic limit.

SHEET STEEL—Flat steel weighing less than 5 pounds per square foot.

SHORT NIPPLE—A nipple with a length that is somewhat longer than the length of a close nipple, but is only a little greater than that of two threaded lengths. There is always some unthreaded shoulder between the two threads.

SHOULDER NIPPLE—A nipple that has a shoulder of pipe between the two pipe threads. This nipple may be any length, but is usually about halfway between a close nipple and a short nipple.

SLEEVE—This term is used generally to designate a tubular piece of metal that slips over a metal rod, pipe, or other tubular form.

SLIP JOINT—An inserted joint in which the end of one pipe is slipped into the flared or swaged end of an adjacent pipe.

SOCKET—A recess, or piece furnished with a recess, into which some other piece may be inserted and secured. For example, the enlarged and recessed end of a cast—iron pipe into which the end of a second pipe is inserted.

SOCKET PLUG—A device for stopping the ends of pipes or openings in pipe fittings. It differs from an ordinary plug in that it has a recess into which a wrench fits.

SOFT PATCH—A temporary plate put on over a break or hole and secured. It is made watertight with a gasket such as canvas saturated in red lead.

SOFT SOLDER—An alloy of tin and lead that melts at a lower temperature than either tin or lead.

SOLDER—An alloy used to connect two metals that are less easily heated.

SOLDER JOINT—A joint soldered by feeding solder through a hole in a valve or fitting. The piping is inserted in the valve, the connection is heated, and the solder is liquified by the heat and flows between the contacting surfaces.

SOUND—To determine the depth of water.

SPECIFICATION—A detailed description or identification relating to quality, strength, or similar performance requirements.

STANDARD PRESSURE—This term applies to all valves and fittings that support a working pressure of 125 pounds per square inch.

STIFFENER—An angle bar, T-bar, channel, or related parts used to stiffen the plating of a bulkhead or similar areas.

STRAIGHT EDGE—A relatively long piece of material having one or both edges a true plane.

STRENGTH—The ability of a material to resist strain.

STRESS RELIEVING—Heat treatment to remove stresses or casting strains.

STUD—A bolt threaded on both ends, one of which is driven into but not through a hole that has been bottom drilled and tapped, and the other end secured by the stud.

STUD BOLT—A bolt threaded on both ends, but larger than a stud, driven into a hole that has been drilled and tapped. This permits connections to the bolts on both sides of the metal while the bolt is secured in the structure.

STUFFING TUBE—A packed tube that makes a watertight fitting for a cable or small pipe passing through a bulkhead.

SWEATED—A surface coated with soft solder or tin. In making a sweated joint, the pipe and the fitting are sweated separately and then sweated again after they have been assembled.

SWIVEL JOINT—A joint that rotates about an axis without any loss in its efficiency.

SYSTEM—A grouping of components or equipment joined to serve a common purpose.

TAP—A tool used to cut internal threads. Small sizes are usually solid, but larger sizes are often made with inserted cutters so that they may be withdrawn from the work, without stopping, when the desired threads have been cut.

TEE—A fitting with a side outlet at right angles to the run; a single outlet branch pipe.

TEE BAR—A rolled or extruded structural shape having a cross section shaped like the letter *T*.

TEMPERING—The heating and controlled cooling of a metal to produce the desired hardness.

TEMPLATE—A piece of thin material used as a true-scale guide or as a model to reproduce various shapes.

TOE—The edge of a flange on a bar.

TRIANGULATION—A technique used to develop complex sheet metal forms by using geometrical constructions to translate dimensions from the drawing to the pattern.

UNDERCUT—A defect in the toe of a weld bead where the base metal is washed away by the welding process, leaving a crater.

UNITED STATES STANDARD THREAD—The standard screw thread with an inclined angle of 60 degrees between threads and one-eighth flattened at top and bottom. It is also known as Sellers Thread and Franklin Institute Standard Thread.

UNION—A term used to describe almost any device used to connect pipes. A union ordinarily consists of three pieces: thread end fitted with exterior and exterior threads, bottom end fitted with interior threads and a small exterior shoulder, and a ring with an inside flange at one end and inside threads similar to that on the exterior of the thread end on the other. A gasket is placed between the thread and bottom ends, which are then drawn together by the ring. The use of unions permits connections with a minimum disturbance of pipe positions.

VALVE—A device for regulating, stopping, or starting flow in a system, and for controlling the direction of flow.

VALVE SEAT—A flat or conical fixed surface on which a valve rests, or against which it presses.

VALVE STEM—A rod or spindle attached to a valve and used to move the valve.

VENT—A valve or pipe in a tank or compartment used to permit air to escape.

WARPING—The distortion, twisting, or bending of metal from its normal form caused by the absorption and loss of heat.

WATER HAMMER—A shock or blow on metal piping that results when flow is suddenly arrested. An example is steam condensing into water and rushed against elbows, or valves, by the force of following steam rushing into cold and partially empty pipe. The remedy is easy bends in pipe, slow admission of fluid until all piping in the system is brought to the required temperature, and slow closure of valves.

WELDED FLANGE JOINT—A joint made by flanges attached to a pipe by welding. The material of the flange must be capable of being welded. The end of the pipe is slipped through the flange ring forgings, and then the assembly is brought to welding heat and hammered or pressed together.

WELDING LEAD—The conductor through which electrical current is transmitted from the power source to the electrode holder and welding rod.

WHEEL VALVE—A stop or gate valve that can be opened by means of a handwheel and screw rather than by the lever, which is a feature of some gate valves, and of some butterfly and other throttle valves.

WIRE—The term applied to pipefitting means a template that has been bent for a piece of pipe.

WYE or Y—A fitting, cast or wrought, that has one side outlet at any angle other than 90 degrees. If no angle is specified, a Y is set at a 45-degree angle.

Y BRANCH—The same as a Y, although the term is also used at times todesignate a fitting whose shape is nearly like that of a single sweep tee.

YIELD POINT—The stress at which a piece of material under strain yields markedly, becoming permanently distorted without increase of load.

YOKE—In a rising stem valve, this is the portion of the bonnet that supports the nut or handwheel. As applied to pipe, the term indicates two branches-for example, hot and cold water uniting to form one stream.

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