NONRESIDENT
TRAINING
COURSE

Electrician's Mate

NAVEDTRA 14344

PREFACE

About this course:

This is a self-study course. By studying this course, you can improve your professional/military knowledge, as well as prepare for the Navywide advancement-in-rate examination. It contains subject matter about day-to-day occupational knowledge and skill requirements and includes text, tables, and illustrations to help you understand the information. An additional important feature of this course is its reference to useful information in other publications. The well-prepared Sailor will take the time to look up the additional information.

History of the course:

- *Apr 1996: Original edition released. Authored by EMC(SW) Scottie Harris.*
- *Sep 2003: Administrative update released. Errata incorporated. Reviewed by EMC(SW) Marcelito Sangalang and EMC(SW) Darryl Woodall. No change in technical content.*

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ASSIGNMENT QUESTIONS follow Index.

CREDITS

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CHAPTER 1

RATING INFORMATION, GENERAL SAFETY PRACTICES, AND ADMINISTRATION

Your knowledge and skill make our modem Navy possible. Navy training manuals (TRAMANs) help you develop your technical skills. By learning the information in this manual and gaining practical experience on the job, you will prepare yourself for a successful and rewarding Navy career. The Navy's training system helps you learn the duties of the next higher grade in your rating. To advance in rate, you must demonstrate your performance on the job. You must master the required skills and compete in Navywide advancement exams for the next higher paygrade.

LEARNING OBJECTIVES

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

1. *Identify various NECs of the EM rating.*
2. *Recognize the purpose of blueprints and drawings.*
3. *Recognize the basic safety requirements for working with electricity.*
4. *Identify the safety procedures to follow when working on or with various tools, equipment, and machinery.*
5. *Identify various sources of information about safety.*
6. *Identify basic first-aid procedures to use on electrical shock victims.*
7. *Recognize the purpose of the Navy's Hearing Conservation and Noise Abatement, Heat Stress, and Hazardous Material programs.*
8. *Identify various warning tags, signs, and plates.*
9. *Recognize the purpose for equipment tag-out procedures.*
10. *Identify the standard organization of engineering departments aboard ship.*
11. *Recognize the responsibilities of various personnel in the engineering department.*
12. *Identify the use and stages of a counseling session.*
13. *Recognize the need for training within the division, the department and the command.*
14. *Recognize the purpose of training forms and records and identify their use to track and monitor training.*

THE ELECTRICIAN'S MATE RATING

As an Electrician's Mate (EM) you work with motors, generators, power and lighting distribution systems, and a wide variety of test equipment. Your training for the EM rates includes electronics and electrical theory, fundamentals of motor and generator operation, alarms, sensors, and other electrical equipment. To do your job, you use handtools and electrical measuring equipment to troubleshoot electrical systems. Also, you use blueprints and schematic diagrams to understand the performance of an electrical circuit.

The EM rating is a general rating and is not divided into service ratings. An example of a service rating is the Gas Turbine Systems Technician (GS). The rating is divided into two service ratings-the GSE, who maintains the electrical support equipment, and the GSM, who maintains the mechanical or turbine portion of the system.

The EM rating is geared to shipboard duties; therefore, there are EMs on most naval vessels. Ashore, EMs may work in their rating in a repair facility or as an instructor. Sometimes, EMs work outside their rating in a duty such as shore patrol or recruiting.

The requirements for advancement are outlined in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068. By meeting these requirements, an EM assigned to any ship in the fleet is qualified to perform all assigned duties. Some ships have special equipment, such as complex degaussing systems on minesweepers. On this type of equipment, EMs require special training. A Navy Enlisted Classification (NEC) coding system identifies the personnel who have this special training.

NAVY ENLISTED CLASSIFICATION CODES (NECs)

What you can do is indicated by your rate. However, it does not show any of your special skills within or outside your rating. NECs show specific qualifications that are not shown by the rate designation. The NEC identifies special qualifications by using a four-digit number. The qualification considered the most important is identified by the first code number. The qualification of secondary importance is shown by the second code number. You get NECs by completing special on-the-job training (OJT) or through the successful completion of a class "C" school.

Some of the NECs that maybe assigned to qualified EMs are as follows:

EM— 4613 IMA Outside Electrical Journeyman

EM— 4615 Electric Motor Rewinder

EM— 4632 Auxiliaries Electrical System Technician

EM— 4666 Minesweeping Electrician

EM— 4668 and 4669 Unrep Electrical Component Maintenanceman

EM— 4671 Shipboard Elevator Electronic/Electrical System Maintenance Technician

EM— 4672 Steam Catapult Electrician

EM— 4673 Lamps Mk III Rast/Hrs Electrical Maintenanceman

EM— 4707 Machinery Systems Console Maintenance Technician

QUALIFICATIONS FOR ADVANCEMENT

Advancement is important. Many rewards of Navy life come through the advancement system. Some rewards are easy to see-more pay, more interesting and challenging job assignments, and greater respect from officers and enlisted personnel. Also, you enjoy the satisfaction of getting ahead in your chosen Navy career.

As an EM, you perform both military and professional duties. The military requirements and professional qualifications for all ratings of the Navy are listed in NAVPERS 18068.

SOURCES OF INFORMATION

No single publication can give you all the information you need to perform the duties of your rate. You should learn where to look for accurate, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some of the publications described here change from time to time. When using any publication that is subject to change or revision, be sure you have the latest edition.

You cannot depend on printed material alone. Much of your learning comes from watching experienced personnel and practicing your skills.

Naval Education and Training Publications

The Naval Education and Training Program Management Support Activity (NETPMSA) produces TRAMANS and NRTCs. These are used as references and for advancement purposes. NETPMSA also produces the *Bibliography for Advancement Study,* NAVEDTRA 12052.

Navy Training Manuals

The TRAMANs will help you gain the knowledge you need to do your job and to advance. Some TRAMANs share general information, and personnel in many ratings use them. Others, such as the EM, are specific to a particular rating.

You can tell whether a TRAMAN is the latest edition by checking the NAVEDTRA number. The letter following the number is the most recent edition of the TRAMAN, and it is listed in the *Catalog of Nonresident Training Courses,* NAVEDTRA 12061.

Navy Electricity and Electronics Training Series

Personnel in many electrical- and electronic-related Navy ratings use the Navy Electricity and Electronics Training series (NEWS). NEETS gives beginners fundamental electrical and electronic concepts through a self-study method NEETS material is not oriented to any specific rating structure.

The NEETS series is divided into modules that contain related information organized in traditional paths of instruction. Modules 1 through 20 provide a training package within the broad fields of electricity and electronics. Module 21 presents general information on the fundamental concepts of test methods and practices. Module 22 gives an introduction into microcomputers.

DEPARTMENT OF THE NAVY INFORMATION PROGRAM REGULATION

The *Department of the Navy Information and Personnel Security Program Regulation,* OPNAVINST 5510.1, is the basic directive for administering the Information Security Program throughout the Department of the Navy (DON). The program ensures the protection of official DON information that relates to national security. It also provides the necessary instructions and policy guidance for the DON. The *Standard Organization and Regulations of the U.S. Navy* also contains basic information for the ship's security practices.

TECHNICAL MANUALS

Much of your work is routine; however, you always face new problems and need to lookup information to solve them. The engineering legroom on your ship should contain a comprehensive technical library. The books in this library are primarily for the engineer officer's use, but you will have occasion to use them. You can find manufacturers' technical manuals for most of the equipment in the ship in the legroom library. These technical manuals are a valuable source of information on maintenance instructions, overhaul instructions, inspection procedures, parts lists, illustrations, and diagrams.

The "encyclopedia" of Navy engineering, *Naval Ships' Technical Manual (NSTM),* contains the latest accepted engineering practices. The *NSTM* is a publication of the Naval Sea Systems Command (NAVSEA). The *NSTM* provides technical information that helps fleet personnel manage ships, shipboard machinery, and equipment to achieve optimum performance and readiness for any assigned mission.

PERIODICALS

Periodicals are publications such as magazines and newsletters published at stated intervals. In the Navy, most periodicals serve as training and public relations media; that is, they instruct and build morale. Periodicals explain policy, outline the functions of various units, discuss current happenings, and frequently respond to questions and complaints. In the following paragraphs, you will learn about periodicals that should be of interest to you.

The periodical *Deckplate* is published by NAVSEA. It has useful articles on all aspects of shipboard engineering. It supplements and clarifies information contained in the *Naval Ship's Technical Manual* and presents information on new developments.

The periodical *Fathom* (surface ship and submarine safety review), published quarterly by the Naval Safety Center, provides accurate and current information on nautical accident prevention

The *Electronics information Bulletin* (EIB) is published biweekly by NAVSEA. Articles in the EIB contain advance information on field changes, installation techniques, maintenance notes, beneficial suggestions, and technical manual distribution. Articles of lasting interest are included in the *Electronics Installation and Maintenance Book* (EIMB). The EIMB is a single-source reference document of maintenance and repair policies, installation practices, and overall electronics equipment and material-handling procedures. The EIMB is used to implement the major policies found in the *NSTM,* chapter 400.

BLUEPRINTS AND DRAWINGS

Blueprints are reproduced copies of mechanical, electrical, or other types of technical drawings. Navy electrical prints are used by the EM to install, maintain, and repair shipboard electrical equipment and systems.

To interpret shipboard electrical prints, you must be able to recognize the graphic symbols for electrical diagrams and the equipment symbols for electrical wiring. For information on blueprint reading and drawings, refer to *Blueprint Reading and Sketching,* NAVEDTRA 10077-F1.

SAFETY AND THE ELECTRICIAN'S MATE RATING

The material discussed next stresses the importance of electrical and general safety precautions. The two main purposes of safety are to protect personnel and to ensure that unwanted equipment operations do not occur. You have the responsibility to recognize unsafe conditions and to take appropriate actions to correct any discrepancies. You must always follow safety precautions when working on equipment or operating machinery. Preventing accidents that are avoidable will help you in the Navy and possibly determine whether or not you survive.

Besides studying the information on safety described throughout this manual, you should read and have knowledge of the information on safety in the following publications:

- *Naval Ships' Technical Manual,* chapters 300, 330, 400, and 491
- *Standard Organization and Regulations of the U. S. Navy,* OPNAVINST 3120.32
- *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat,* OPNAVINST 5100.19
- *Hearing and Noise Abatement,* chapter 18, "Hearing Conservation and Noise Abatement," OPNAVINST 5100.23
- *Standard First Aid Training Course,* NAVEDTRA 12081

SAFETY RESPONSIBILITIES

Safety standards and regulations are for the prevention of injury and damage to equipment. You are responsible for understanding and following safety standards and regulations. As an individual, you have a responsibility to yourself and to your shipmates to do your part in preventing mishaps. As a petty officer, you need to set a good example. You cannot ignore safety regulations and expect others to follow them.

Personnel should always obey the following safety practices:

- Obey all posted operating instructions and safety precautions.
- Report any unsafe condition or any equipment or material you think might be unsafe.
- Warn others of hazards or of their failure to follow 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 if an emergency or other unforseen hazardous condition occurs.
- Inspect equipment and associated attachments for damage before using the equipment. Be sure the equipment is right for the job.

Personnel working around energized electric circuits and equipment must obey safety precautions. Injury may result from electric shock. Short circuits can occur by accidentally placing or dropping a metal tool, flashlight case, or other conducting article across an energized line. These short circuits can cause an arc or fire, even on low-voltage circuits. Extensive damage to equipment and serious injury to personnel may result.

ELECTRIC SHOCK HAZARDS AND PRECAUTIONS

If you don't recognize hazardous conditions or take precautions, you could get an electric shock. You must recognize hazardous conditions and take immediate action to correct any discrepancy noted Plates, posters, signs, or instructions (fig. 1-1), placed in conspicuous areas, guide personnel in the safe operation or handling of equipment, components, systems, or material. Warning signs (red) and caution signs (yellow) are placed in areas where known hazardous conditions exist, or could exist. Hazardous areas include those that are wet, oily, or electrical spaces.

The resistance of the human body is low. Therefore, it can't be relied on to prevent fatal shock if a person comes into contact with voltages of 115 volts or even lower. When the skin is damp, body resistance can be as low as 300 ohms. If the skin is broken, body resistance can be as low as 100 ohms.

The following are general guidelines for the effect of shocks from 60-Hz ac systems:

- 1 milliampere (0.001 A)-Shock is felt.
- 10 milliamperes (0.01 A)—A person may be unable to let go.
- 100 milliamperes (0.1 A)-Shock may be fatal if it lasts for one second or more.

The danger of shock from 450-volt ac ship's service systems is recognized by shipboard personnel. Yet, there are reports of personnel receiving a serious shock from this voltage source. Most shipboard fatalities caused by electrocution are caused by contact with 115-volt circuits. **Regard all electrical energy as dangerous.** Shipboard conditions are particularly favorable to severe shock because the body may contact the ship's metal structure and body resistance maybe low because of perspiration or damp clothing.

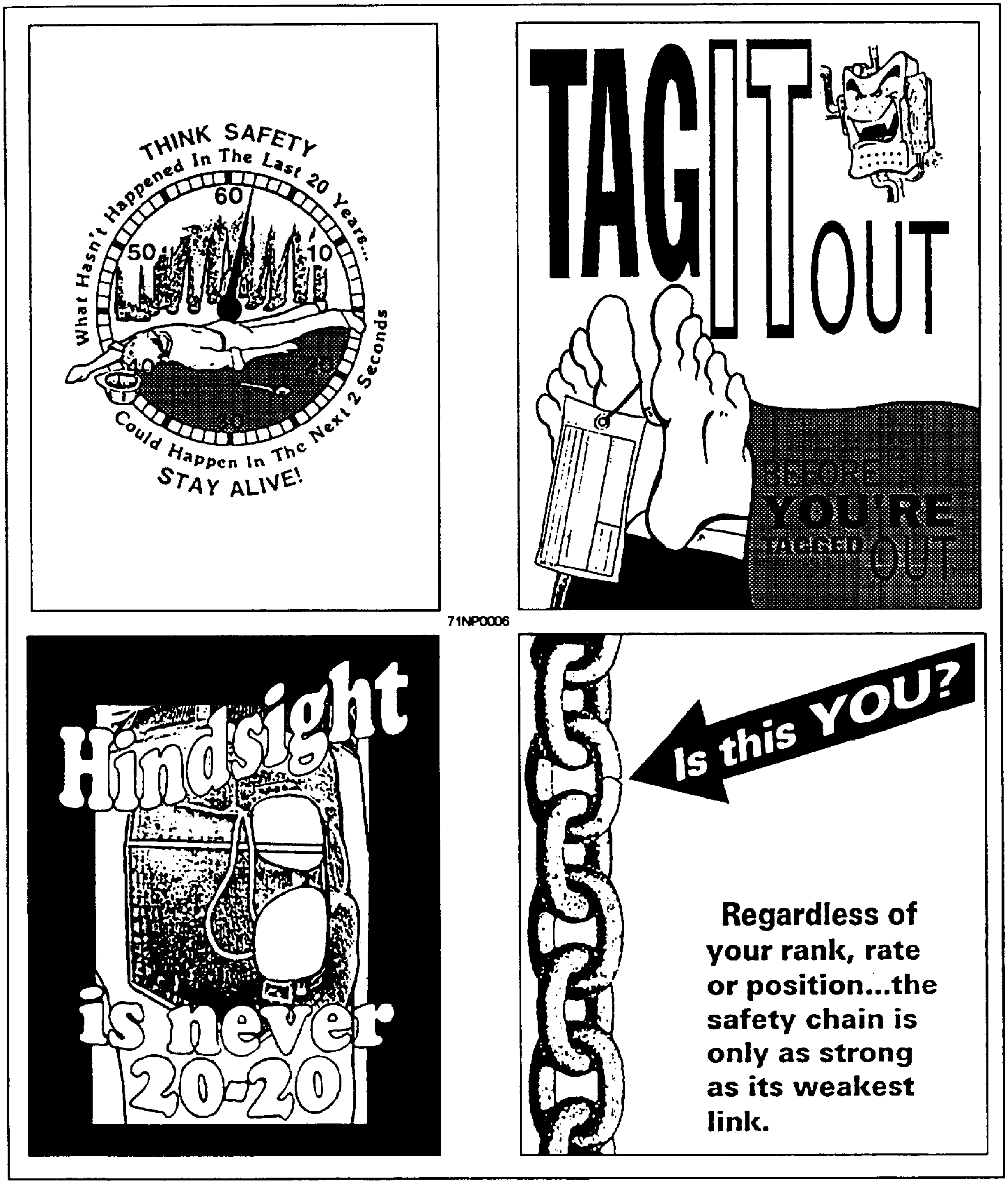


Figure 1-1.—Safety posters.

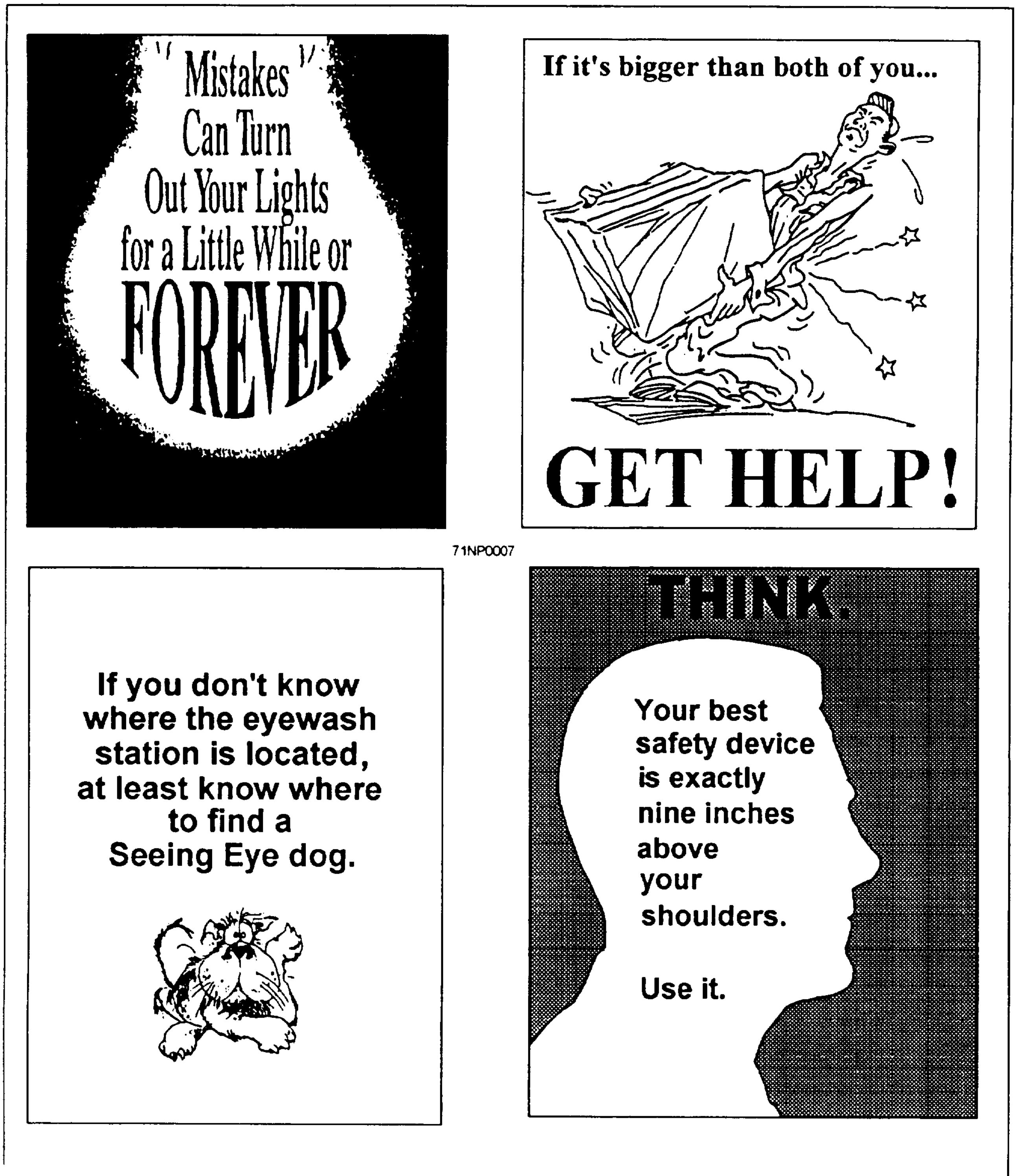


Figure 1-1.—Safety posters—Continued.

The following safety practices will help you avoid receiving an electric shock

- Keep your clothing, hands, and feet dry if possible.
- When you work in a wet or damp location, use a dry, wooden platform to sit or stand on.
- Place rubber matting or other nonconductive material between you and the wood surface.
- When you work on exposed electrical equipment, use insulated tools and a nonmetallic flashlight.

LIVE CIRCUITS

The safest practice to follow when you maintain or repair electrical and electronic equipment is to de-energized all power supplies. However, there are times when you can't do this because de-energizing the circuits isn't desirable or possible. For example, in an emergency (damage control) condition or when de-energizing one or more circuits would seriously affect the operating of vital equipment or jeopardize the safety of personnel, circuits aren't de-energized. **No work may be done on energized circuits before obtaining the approval of the commanding officer.** When working on live or hot circuits, you must be supervised and aware of the danger involved. The precautions you must take to insulate yourself from ground and to ensure your safety include the following actions:

Provide insulating barriers between the work and the live metal parts.

- Provide ample lighting in the immediate area.
- Cover the surrounding grounded metal with a dry insulating material, such as wood, rubber matting, canvas, or phenolic. his material must be dry, free of holes and imbedded metal, and large enough to give you enough working room.
- Coat metallic hand tools with plastisol or cover them with two layers of rubber or vinyl plastic tape, half-lapped. Insulate the tool handle and other exposed parts as practical.

NOTE: Refer to *Naval Ships' Technical Manual,* chapter 631, for instructions on the use of plastisol. If you don't have enough time to apply plastisol or tape, cover the tool handles and their exposed parts with cambric sleeving, synthetic resin flexible tubing, or suitable insulation from scraps of electric cables; however, do this only in an emergency situation.

- Do not wear a wristwatch, rings, other metal objects, or loose clothing that could become caught in live circuits or metal parts.
- Wear dry shoes and clothing, and ALWAYS wear a face shield.
- Tighten the connections of removable test leads on portable meters. When checking live circuits, NEVER allow the adjacent end of an energized test lead to become unplugged from the meter.
- Ensure a person qualified to give mouth-to-mouth resuscitation and cardiac massage for electric shock is in the immediate area.
- Ensure a person who is knowledgeable of the system is standing by to de-energize the equipment.
- Tie a rope around the worker's waist to pull him or her free if he or she comes in contact with a live circuit.
- Work with one hand only; wear a rubber glove on the other hand. (Where work permits, wear gloves on both hands.)

LEAKAGE CURRENTS

The ungrounded electrical distribution system used aboard ship differs from the grounded system used in shore installations. **Never touch one conductor of the ungrounded shipboard system, because each conductor and the electrical equipment connected to it have an effective capacitance to ground.** If you touch the conductor, you will be the electrical current path between the conductor and the ship's hull. The higher the capacitance, the greater the current flow will be for your fixed body resistance. This situation occurs when one conductor of the ungrounded system is touched while your body is in contact with the ship's hull or other metal enclosures. If your hands are wet or sweaty, your body resistance is low. When your body resistance is low, the inherent capacitance is enough to cause a FATAL electrical current to pass through your body.

As you read the following sections on ungrounded systems, look at figure 1-2.

A Perfect Ungrounded System

A perfect ungrounded system (fig. 1-2, view A) exists under the following conditions:

- The insulation is perfect on all cables, switchboards, circuit breakers, generators, and load equipment.
- There aren't any filter capacitors connected between ground and the conductors.
- The system equipment or cables don't have any inherent capacitance to ground.

If these conditions are met, there would be no path for electrical current to flow from any of the system conductors to ground.

Look at figure 1-2, view A. Here you can see that if a person touches a live conductor while standing on the deck, no completed path exists for current to flow from the conductor through the person's body. No electric shock would occur.

However, shipboard electrical power distribution systems **don't** and **can't** meet the definition of a PERFECT ungrounded system.

Real Ungrounded Systems

In a shipboard real ungrounded system (fig. 1-2, view B) additional factors (resistance [R] and capacitance [C]) must be considered. Some of these are not visible.

When combined in parallel, the resistances form the insulation resistance of the system that is periodically measured with a 500-volt dc Megger. Look at figure 1-2, view B. Here, you can see that there's a generator insulation resistance, an electric cable insulation resistance, and a load insulation resistance. The resistors cannot be seen as physical parts, but represent small current paths through equipment and cable electrical insulation. The higher the resists.rw, the better the system is insulated; therefore, less current will flow between the conductor and ground. Representative values of a large operating system can vary widely, depending on the size of the ship and the number of electrical circuits connected.

Figure 1-2, view B, also shows the capacitance of the generator to ground, the capacitance of the distribution cable to ground, and the capacitance of the load equipment to ground. As before, these capacitances cannot be seen, since they are not actually physical parts, but are an inherent part of the design of electrical equipment and cable.

Several factors determine the value of the capacitance generated between the conductor and ground: the radius of the conductor, the distance between the conductor and the bulkhead, the dielectric constant of the material between the two, and the length of the cable. Similar capacitance exists between the generator winding and ground and between various load equipment and ground.

Ideally, capacitors have an infinite impedance to direct current; therefore, their presence can't be detected by a Megger or insulation resistance test. In addition to the nonvisible system capacitance, typical shipboard electrical systems contain radio frequency interference (RFI) filters that contain capacitors connected from the conductors to ground. These falters may be apart of the load equipment, or they may mount separately. To reduce interference to communications equipment, filters are used.

Look at figure 1-2, view C. If physical contact is made between cable B and ground current will flow from the generator through the person's body to ground and back through the system resistances and capacitances to cable A. This current flow completes the electrical circuit back to the generator and presents a serious shock hazard.

Suppose you are using a Megger to check for ground in this system, and you get a reading of 50,000 ohms resistance. You can conclude that no low-resistance ground exists. However, don't assume that the system is a perfect ungrounded system without checking the circuit further. Don't forget the system capacitance that exists in parallel with the resistance.

Remember, never touch a live conductor of any electrical system, grounded or ungrounded. Make insulation resistance tests to ensure the system will operate properly, not to make the system safe. High insulation readings in a Megger test do not make the system safe-nothing does.

SHOCK-MOUNTED EQUIPMENT

Normally on steel-hulled vessels, grounds are provided because the metal cases or frames of the equipment are in contact with one another and the vessel's hull. In some installations grounds are not provided by the mounting arrangements, such as insulated shock mounts. In this case, a suitable ground connection must be provided.

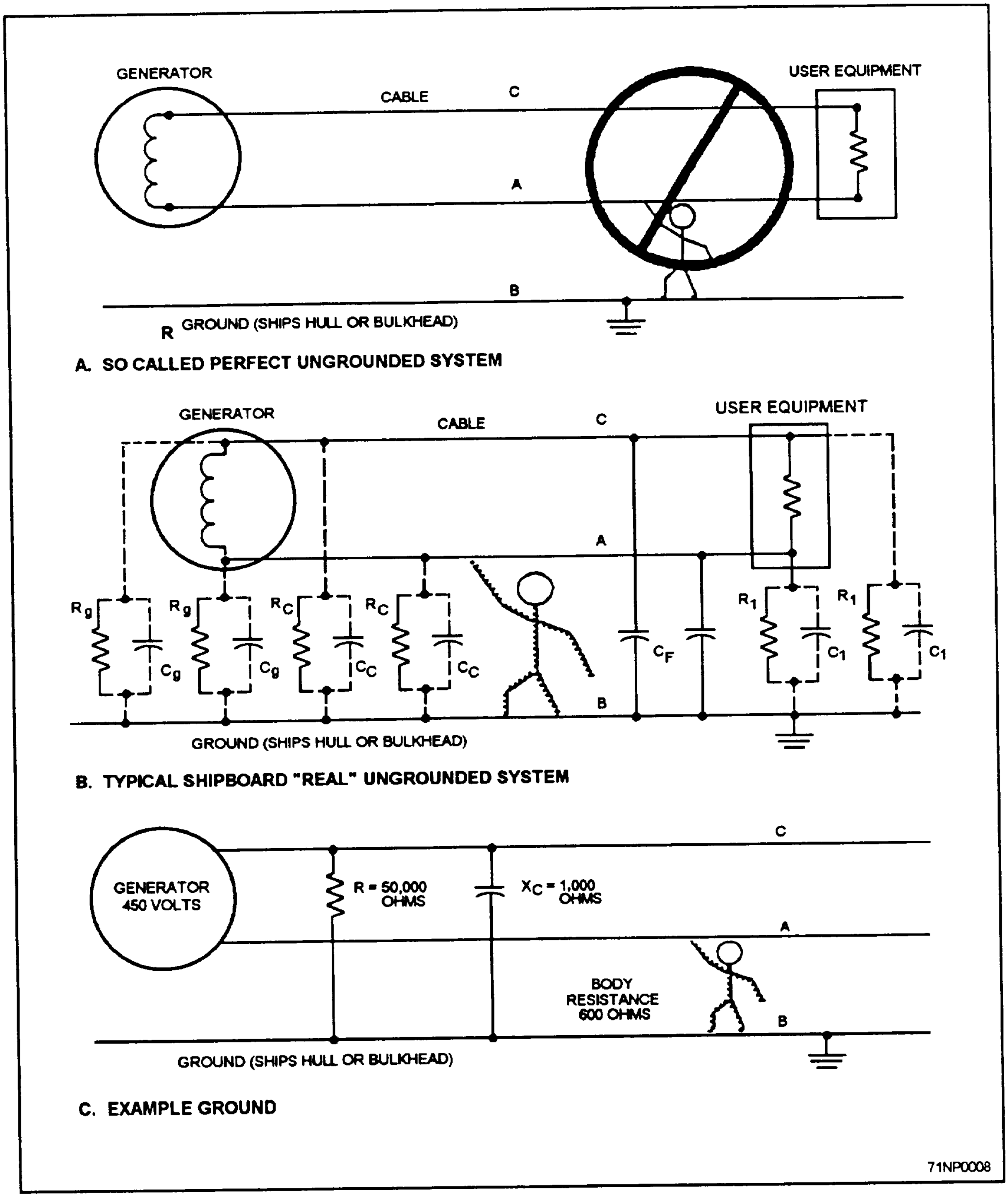


Figure 1-2.—DANGEROUS! BEWARE! Shipboard ungrounded electrical distribution systems are DEADLY.

CAUTION

Before disconnecting a ground strap on equipment supported by shock mounts, ensure the equipment is DE-ENERGIZED and a DANGER/RED tag is installed

If the grounding strap is broken and the equipment cannot be de-energized, use a voltmeter from the equipment to ground to ensure that no voltage is present.

Maintenance of grounding cables or straps consists of the following preventive procedures:

- Clean all strap-and-clamp type of connectors periodically to ensure that all direct metal-to-metal contacts are free from foreign matter.
- Replace any faulty, rusted, or otherwise unfit grounding straps, clamps, connections, or parts between the equipment and the ship's hull.
- When replacing a grounding strap, clean the metallic contact surfaces and establish electrical continuity between the equipment and the ship's hull. Check continuity with an ohmmeter (the reading must be 1 ohm or less).
- Recheck to ensure the connection is securely fastened with the correct mounting hardware.
- If a voltage is present, and the equipment cannot be de-energized, you must wear electrical rubber gloves and use a rubber mat while replacing the grounding strap.

SWITCHBOARDS AND SWITCHGEARS

Safety precautions, operating instructions, wiring diagrams, and artificial respiration/ventilation instructions must be posted near the switchboards and switchgears. DANGER HIGH VOLTAGE signs must be posted on and/or near switchboards, switchgears, and their access doors.

SWITCHBOARD METERS AND INSTRUMENT TRANSFORMERS

When removing or installing switchboard and control panel meters and instrument transformers, you need to be extremely careful to avoid electric shock to yourself and damage to the transformers and meters. Some of the precautions you should follow when working around switchboard meters and instrument transformers include the following:

- Short-circuit the secondary of a current transformer **before** you disconnect the meter. An extremely high voltage buildup could be fatal to unwary maintenance personnel.
- Open the primary of a potential transformer before you remove the meter to prevent damage to the primary circuit due to high circulating currents.
- In most installations potential transformer primaries are fused, and the transformer and associated meter can be removed after you pull the fuses for the transformer. When disconnecting the transformer and meter leads, avoid contact with nearby energized leads and terminals.

SAFETY SHORTING PROBE

Before you start working on de-energized circuits that have capacitors installed, you must discharge the capacitors with a safety shorting probe (fig. 1-3). When using a safety shorting probe, first connect the test clip to a good ground to make contact. If necessary, scrape the paint off the metal surface. Then hold the safety shorting probe by the handle and touch the probe end of the shorting rod to the points to be shorted. The probe end can be hooked over the part or terminal to provide for a constant connection to ground. **Never touch any metal parts of the shorting probe while grounding circuits or components.**

It pays to be safe—use the safety shorting probe with care

NOTE: Capacitors not electrically connected to the chassis ground must have their terminals shorted together to discharge them by the use of a shorting probe.

HAND TOOLS

Hand tools include all electric-, electronic-, pneumatic-, and hydraulic-powered equipment used in the repair, maintenance, calibration, or testing of other shipboard equipment. Handtools can either be installed in a fixed location or portable. You probably have seen some dangerous practices in the use of hand tools that could have been avoided One unsafe practice involves the use of handtools with plastic or wooden handles that are cracked, chipped, splintered, broken, or unserviceable. Do not use these tools.

PORTABLE ELECTRIC-POWERED TOOLS

Portable, electric-powered tools should be clean, properly oiled, and in good operating condition. Before

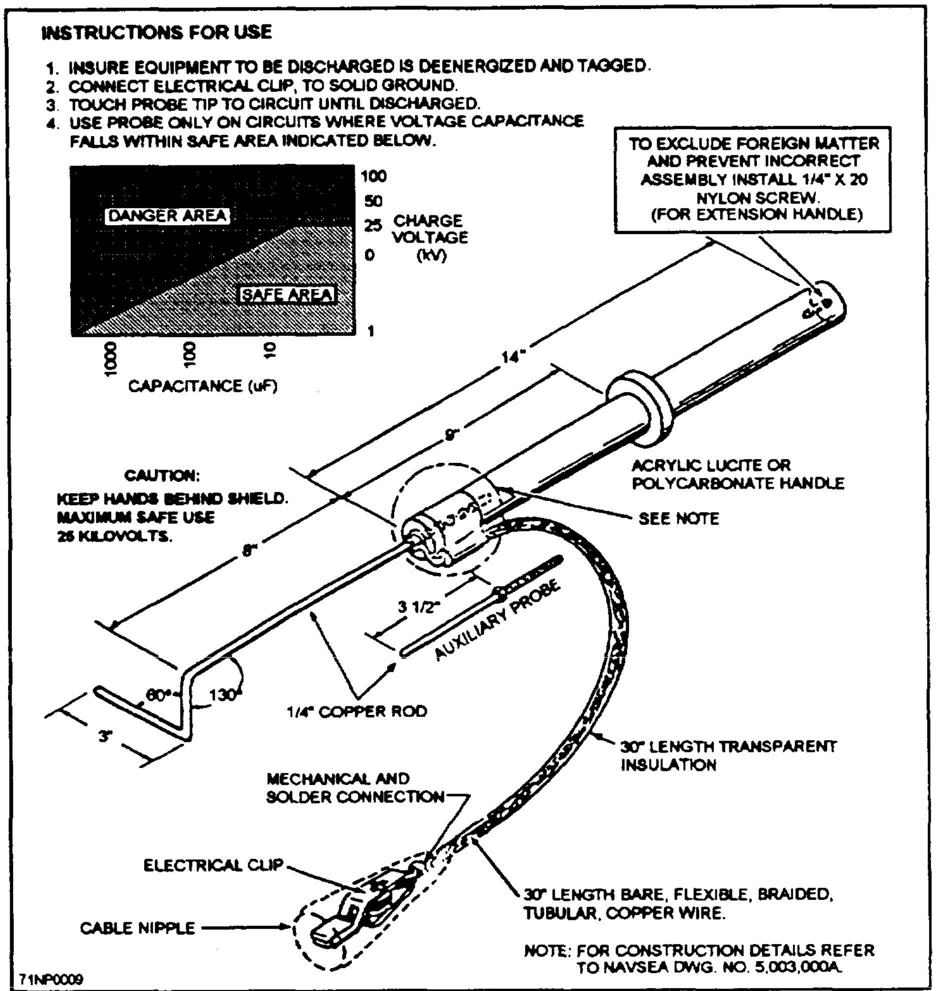


Figure 1-3.—Approved safety shorting probe.

portable electric equipment is issued, it should be visually examined. The parts to be looked at include the attached cable with plug (including extension cords), making sure it is in satisfactory condition according to prescribed PMS instructions. Any cable that has tears, chafing, or exposed conductors, and any plug that has damage should be promptly replaced.

You should use an approved tool tester or multimeter to test portable electrical equipment with its associated extension cord connected. When using the multimeter to check continuity of the ground conductor from the tool case to the dummy receptacle, you should make sure the meter reading is less than 1 ohm. With the multimeter still connected between the tool case and ground, bend or flex the cable. The resistance must be 1 ohm or less. If the resistance varies, you might have broken conductors in the cord or loose connections.

Other safe practices in the use of portable electric-power tools include the following:

- Before you use a tool, inspect the tool cord and plug. Don't use a tool with a frayed cord or with a damaged or broken plug. Never use spliced cables, except in an emergency.
- Before using a tool, arrange the portable cables so you and others will not trip over them. The length of extension cords used with portable tools should not exceed 25 feet. Extension cords of 100 feet are authorized on flight and hangar decks. Extension cords of 100 feet are also found in damage control lockers, and labeled FOR EMERGENCY USE ONLY.
- Don't use jury-rigged extension cords that have metal handy boxes on the receptacle ends of the cord. All extension cords must have nonconductive plugs and receptacle housings.
- When using an extension cord with a portable electric tool, always plug the tool into the

extension cord before you insert the extension cord plug into a live receptacle.

- After using the tool, unplug the extension cord from the live receptacle before you unplug the tool cord from the extension cord. Do not unplug the cords by yanking on them. Always remove the plug by grasping the plug body.
- When using portable electric tools, always wear rubber gloves and eye protection.
- If you notice a defect, return the tool to the ship's tool issue room (TIR).
- When tools produce hazardous noise levels, wear hearing protection.

Another good practice to establish (at the discretion of the commanding officer) is to list the portable equipment that requires testing more or less often than once a month, depending on conditions in the ship. Where PMS is installed, tests should be conducted following the maintenance requirement cards (MRCs).

ELECTRIC SOLDERING IRONS

When using and handling an electric soldering iron, you can avoid burns or electric shock by taking the following precautions:

- Grasp and hold the iron by its handle. Always assume a soldering iron is hot, whether it is plugged in or not. **Never use an iron that has a frayed cord, damaged plug, or no safety inspection tag.**
- Hold small soldering workplaces with pliers or a suitable clamping device. **Never hold the work in your hand.**
- Always place the heated iron in its stand or on a metal surface to prevent fires or equipment damage.
- Clean the iron by wiping it across a piece of canvas placed on a suitable surface. **Don't hold the cloth in your hand. Don't swing the iron to remove excess hot solder.** Swinging the iron could cause a fire in combustible materials or burn other personnel in the area.
- Before soldering electrical or electronic equipment, make sure it is disconnected from its power supply.
- After soldering, disconnect the iron from its power supply. Let it cool before you store it.

ISOLATED RECEPTACLE CIRCUITS

Isolated receptacle circuits are installed on all new construction ships. These circuits are individually isolated from the main power distribution system by isolation transformers. Each circuit is limited to 1,500 feet in length to reduce the capacitance to an acceptable level. This design is intended to limit ground leakage currents to 10 mA, which would produce a nonlethal shock. These receptacles are located where personnel usually plug in electric-power tools or appliances. To maintain a safe level of leakage currents, make sure the isolated receptacle circuits are free of all resistance grounds.

TEST EQUIPMENT

Test equipment is precision equipment that must be handled with care if it is to perform its designed functions accurately. Some hazards to avoid when using test equipment include rough handling, moisture, and dust.

Rough handling includes bumping or dropping equipment. Bumping or dropping test instruments may distort the calibration of the meter or short-circuit the elements of an electron tube within the instrument.

Moisture effects are minimized in some types of electronic test equipment, such as signal generators and oscilloscopes, by built-in heaters. Operate these heaters for several minutes before applying the high voltage to the equipment.

The meter is the most delicate part of test equipment. You should protect a meter by making sure the amplitude of the input signal being tested is within the range of the meter.

Since the moving coils of the meter in electric test equipment are of the limited-current type, they can be permanently damaged by excessive current. When using test equipment, you should observe the following safety precautions and procedures:

- Never place a meter near a strong magnetic field.
- Whenever possible, make the connections when the circuit is de-energized.
- When connecting an ammeter, current coil of a wattmeter, or other current-measuring device, always connect the coils in series with the load-never across the line.
- To measure a circuit, the potential coil of a wattmeter, or other instrument, connect the voltmeter across the line.

- Extend wires attached to an instrument over the back of the workbench or worktable on which the instrument is placed, and away from observers **—never over the front of the workbench.**

- Place a mat or folded cloth under the test instrument when used in high-vibration areas.

- Remember that interlocks aren't always provided and, even when provided, they don't always work. Removing the case or rear cover of an instrument not equipped with an interlock allows access to circuits carrying voltages dangerous to human life.

- **Don't change tubes or adjust inside equipment with the high-voltage supply energized.**

- Under certain conditions, dangerous potentials may exist in circuits. With the power controls in the off position, capacitors can still keep their charge. To avoid electric shock, always de-energize the circuit, discharge the capacitors, and ground the circuit before working on it.

- Only authorized maintenance personnel having proper approval should be permitted to gain access to enclosures, connect test equipment, or test energized circuits or equipment.

- Circuits should be de-energized and checked for continuity or resistance, rather than energized and checked for voltage at various points.

- **When a circuit or a piece of equipment is energized, never service, adjust, or work on it alone.**

INSULATING AND PROTECTIVE EQUIPMENT

Insulated workbenches and decks and the use of rubber gloves are just a few of the requirements for personnel protection. The amount and type of personal protective equipment used is dictated by the type of work being performed and the area in which it is located.

WORKBENCHES

As an EM, you test and repair equipment on a workbench in the electric shop. You must make sure your workbench is properly insulated. Figure 1-4 shows

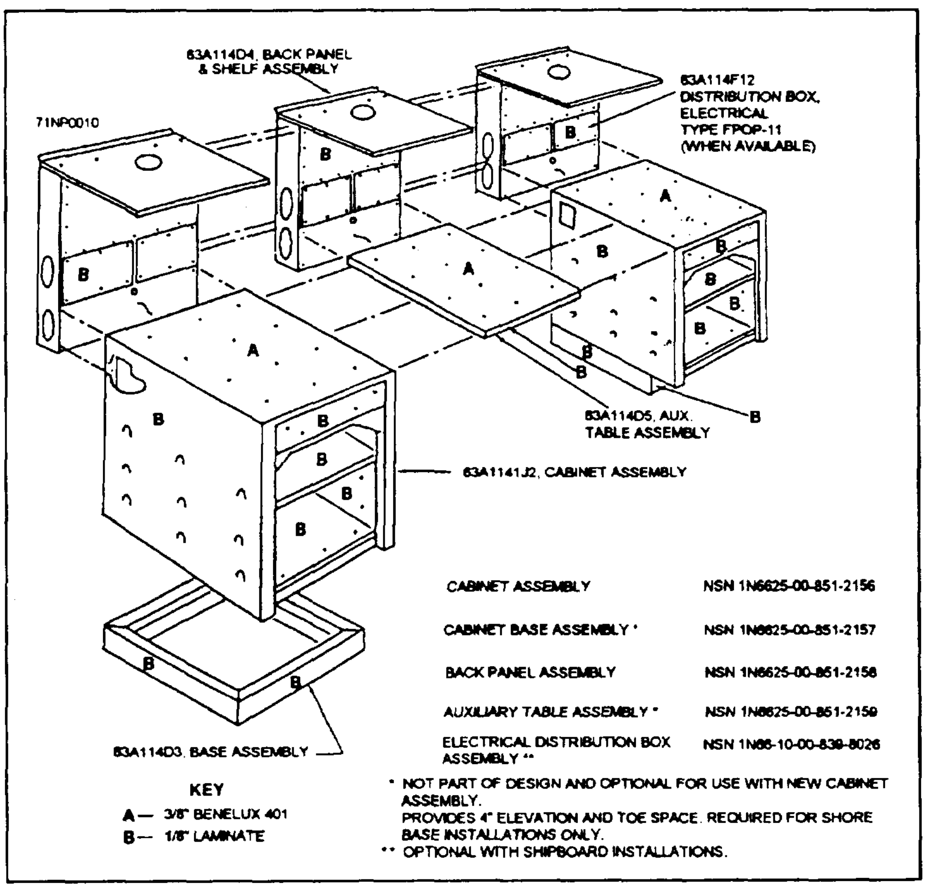


Figure 1-4.—A typical electric workbench.

the construction features of a safe electric or electronic workbench. The work surface, or top, is usually 30 inches wide and 4 feet long. The bench must be secured to the deck.

Where electrical vinyl sheet deck covering is not used, matting is installed over the minimum area (not less than 3 feet wide) to prevent electric shock. Additionally, a rubber matting 3 feet wide is installed to insulate the walkway in front of insulated workbenches where electrical grade vinyl sheet is not specified.

The top of the working surface of an electric or electronic workbench must be insulated with 3/8-inch Benelex 401. All other surfaces should be covered with 1/8-inch laminate, including kneeholes under auxiliary worktables and bulkheads or other hull structures or equipment attached to the hull that are within 3 feet of the workbench. The inside of drawers and cabinets need not be insulated as they should be left closed while working on energized circuits or equipment. Don't defeat the purpose of the insulation by attaching vises, locks, hasps, hinges, or other hardware with metal through bolts to the metal parts of the workbench. When mounting hardware items, insulate them from the workbench.

The workbench must have type D, size 10 grounding leads that are at least 54 inches in length according to MIL-W-16878 (fig. 1-5). The ground leads must be secured to the ship's structure or at the back of the workbench and must be equipped at the free end with a So-ampere power clip (type PC) and insulated sleeving (both conforming to Federal Specification W-C-440). One grounding lead should be installed for every 4 feet of workbench length to ensure positive grounding of the

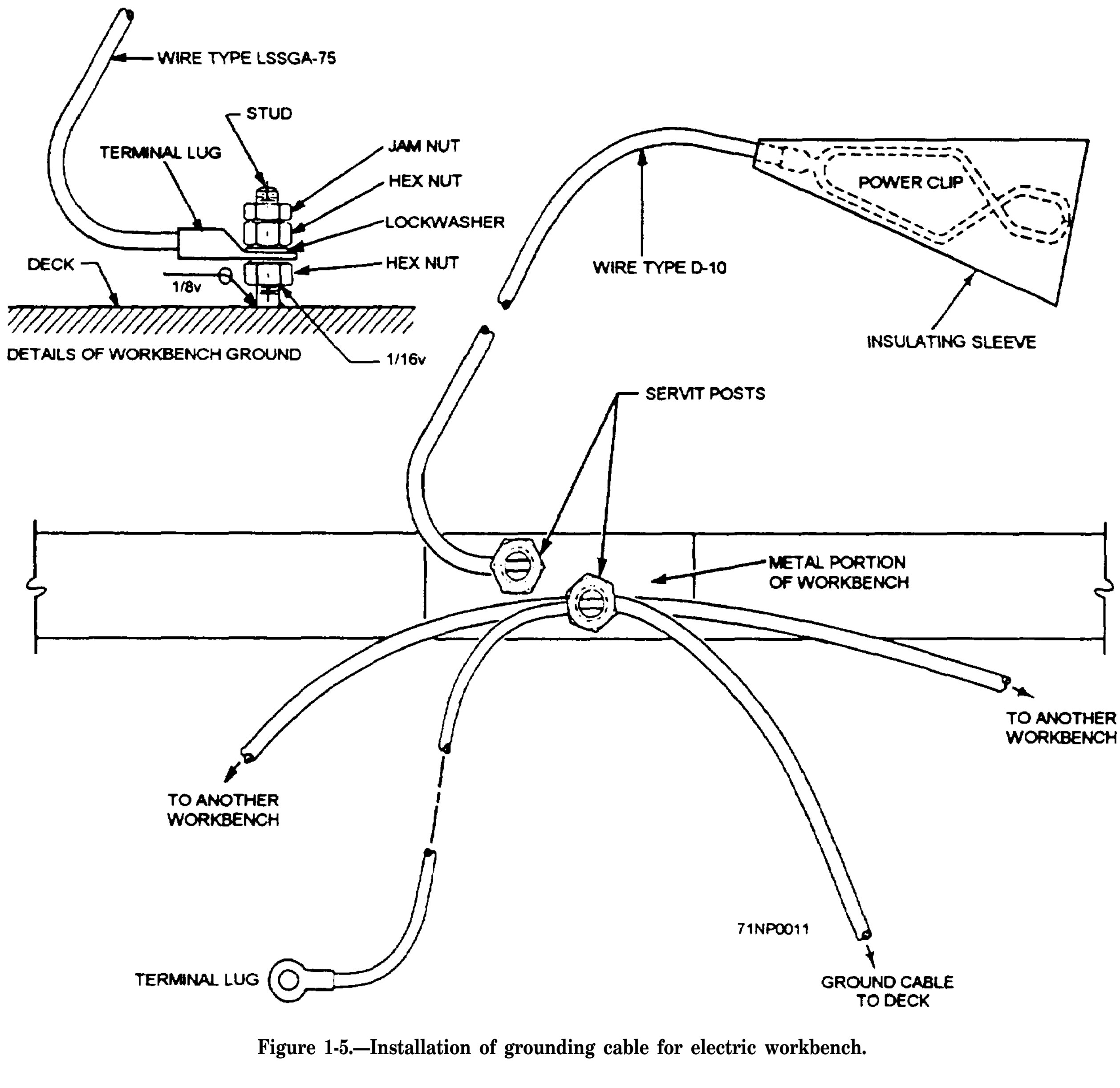


Figure 1-5.—Installation of grounding cable for electric workbench.

equipment being tested. The grounding leads installed in ships with wooden hulls should be the same as those installed in ships with steel hulls except that the leads should be secured to the ship's electrical grounding system. A bare, solid-copper conductor, not less than 83,690 circular roils, must be used for the main internal grounding wire.

Test bench receptacle panels should be installed on test benches where power at various voltages and frequencies (other than ship's service) are needed for testing equipment.

The illumination requirements vary between those for general-purpose workbenches and workbenches for the repair of instruments, such as typewriters and meters.

A dummy outlet is installed near the workbench to check the grounding conductor on portable tools before they are issued

Workbench receptacle connectors should not supply other types of loads. AU receptacles on the workbench must be connected to a common or an individual isolation transformer. The transformer must be either 450/120-volt supplied from a 450-volt load center or a 120/120-volt supplied from a 120-volt distribution point.

General Specifications for the Overhaul of Surface Ships (1991), Section 320, requires that a means of disconnecting power be provided in the compartment in which the workbenches are installed. Distribution panels, when installed in the same compartment as the

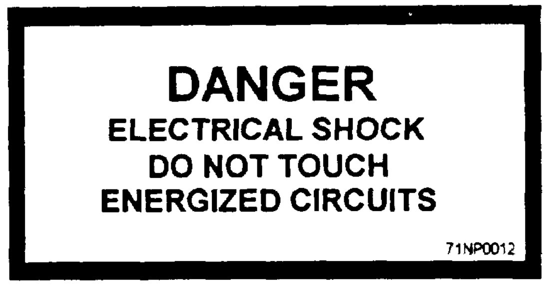


Figure 1-6.—Danger sign to he posted near electric workbench.

workbenches, satisfy this requirement. The disconnect switch must not be located on the workbench. The safe place to install the disconnect switch is away from the bench, between the entrance to the space and the bench.

The required safety signs for a workbench must conform with General Specifications for the Overhaul of Surface Ships (GSO), Section 665. Signs that must be posted include the following:

- The sign shown in figure 1-6 must be posted near each workbench. This sign must be reproduced locally on 0.05-inch aluminum engraved with red enamel letters.
- A sign giving artificial respiration instructions (NSN 0177-LF-226-3400) must also be posted.
- A sign showing an approved method to rescue personnel (fig. 1-7) in contact with energized circuits. This sign is locally produced.

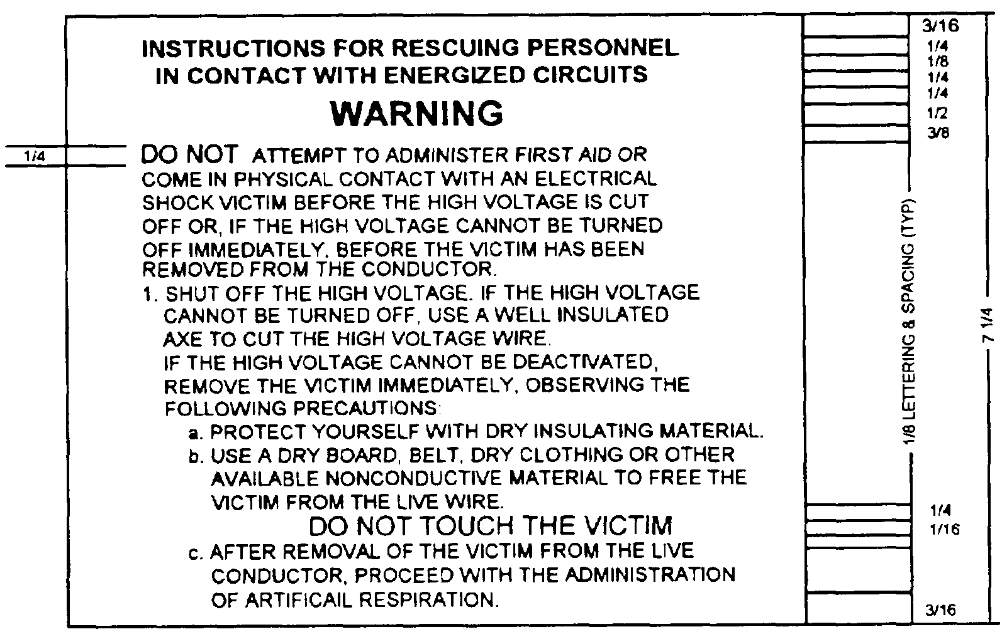


Figure 1-7.—Instructions for rescuing personnel in contact with energized circuits.

DECK MATTING

An insulating deck covering prevents electric shock to anyone who may touch bare, energized, ungrounded circuits. You must use approved rubber floor matting in electrical and electronic spaces to eliminate accidents and afford maximum protection from electric shock. *NSTM,* chapter 634, table 634-1, gives approved deck coverings for every space in your ship. Accident investigations often show that the floors around electrical and electronic equipment had been covered only with general-purpose black rubber matting. The electrical characteristics of this type of matting do not provide adequate insulation to protect against electric shock. There are various types of electrical grade mats or sheet coverings conforming to Military Specification Mil-M-15562 that meet the requirements.

To ensure that the matting is completely safe, you must promptly remove from the matting surfaces all foreign substances that could contaminate or impair its dielectric properties.

Th dielectric properties of matting can be impaired or destroyed by oil, imbedded metal chips, cracks, holes, or other defects. If the matting is defective, cover the affected area with a new piece of matting. Cementing the matting to the deck is not required, but is strongly recommended This prevents removal of the mat for inspection and cleaning, which would leave the area unprotected. If the mat is not cemented, stencil an outline of the proposed mat on the deck. Inside the mat outline, stencil "ELECTRIC-GRADE MAT REQUIRED WITHIN MARKED LINES." Use 3/4-inch or larger letters.

Electrical insulating deck covering should be installed so there are no seams within 3 feet of an electrical hazard. Where this is not possible, thermoplastic deck coverings, such as vinyl sheet manufactured by Lonseal, Inc., should be fused chemically, heat welded, or heat fused with a special hot air gun. With rubber deck coverings, fusing with heat is not possible. A 3- or 4-inch wide strip of #51 Scotchrap 20-mil thick Polyvinyl Chloride (PVC) tape (manufactured by Minnesota Mining and Manufacturing Company) should be installed beneath the seam. You also may use a 1-foot wide strip of electrical grade deck covering under either rubber- or vinyl-type coverings (instead of heat welding vinyl).

RUBBER GLOVES

There are four classes of rubber insulating gloves. The primary feature being the wall thickness of the gloves and their maximum safe voltage, which is identified by a color label on the glove sleeve. Use only rubber insulating gloves marked with a color label. Table 1-1 contains the maximum safe use voltage and label colors for insulating gloves approved for Navy use.

Before using rubber gloves, carefully inspect them for damage or deterioration. To inspect robber gloves for tears, snags, punctures, or leaks that are not obvious, hold the glove downward, grasp the glove cuff, and flip the glove upward to trap air inside the glove. Roll or fold the cuff to seal the trapped air inside. Then squeeze the inflated glove and inspect it for damage. For additional information on rubber gloves, refer to *Naval Ships' Technical Manual,* chapter 300.

ELECTRICAL FIRES

When at sea, fire aboard a Navy vessel is more fatal and damaging to both personnel and the ship itself than damage from battle. The time to learn this is as soon as you report aboard. The Navy requires that all hands must be damage control qualified within 6 months after reporting aboard. You must learn the types of fire-fighting equipment, their location, and their operating procedures. It is too late after the fire has started.

FIGHTING AN ELECTRICAL FIRE

Use the following general procedures for fighting an electrical fire:

1. Promptly de-energize the circuit or equipment affected. Shift the operation to a standby circuit or equipment, if possible.
2. Sound an alarm according to station regulations or the ship's fire bill. When ashore, inform the

Table 1-1.—Rubber Gloves

Class	Maximum Safe Voltage	Label Color
0	1,000 Volts	Red
I	7,500 Volts	White
II	17,500 Volts	Yellow
III	26,500 Volts	Green

fire department; if afloat, inform the officer of the deck. Give the location of the fire and state what is burning. If possible, report the extent of the fire; that is, what its effects are upon the surrounding area.

3. Secure all ventilation by closing compartment air vents or windows.

4. Attack the fire with portable CO_2 extinguishers (or a CO_2 hose reel system, if available) as follows:

   - Remove the locking pin from the release valve.
   - Grasp the horn handle by the insulated (thermal) grip (the grip is insulated against possible frostbite of the hand).
   - Squeeze the release lever (or turn the wheel) to open the valve and release the carbon dioxide. At the same time, direct the discharge flow of the carbon dioxide toward the base of the fire.
   - Aim and move the horn of the extinguisher slowly from side to side.
   - Don't stop the discharge from the extinguisher too soon. When the fire has been extinguished, coat the critical surface areas involved with carbon dioxide "snow" to cool the substances (fuels) involved and prevent a rekindling of the fire.
   - Don't lose positive control of the CO_2 bottle.

EXTINGUISHERS

Fire extinguishers of the proper type must be conveniently located near all equipment that is subject to fire danger, especially high-voltage equipment. **Be extremely careful when using fire-extinguishing agents around electrical circuits.** A stream of salt water or foam directed against an energized circuit can conduct current and shock the fire fighters. The same danger is present, but to a lesser degree, when using fresh water. Avoid prolonged exposure to high concentrations of CO_2 in confined spaces since there is danger of suffocation unless an oxygen breathing apparatus (OBA) is used.

Look at table 1-2, which contains a list of the types of fire extinguishers that are normally available for use.

Table 1-2.—Types of Fire Extinguishers

EXTINGUISHER	USE
CO_2 Gas	Effective on any type of fire, particularly electrical fires.
Potassium Bicarbonate (PKP)	Very effective on Class B fires. Not recommended for electrical fires because it causes corrosion of electrical and electronics components.
Soda-Acid	Effective only on Class A fires. Not recommended for electrical fires, as the compound is a good conductor of electricity. Not effective on burning compounds, such as oil and the likes.
Foam	Very effective on burning compounds, such as oil and similar materials. Not satisfactory for electrical fires, as the compound is a good conductor of electricity.
Halon 1301	Effective on all classes of fire except Class D. It is a colorless, odorless gas that does not conduct electricity or leave a residue.

REPAIR PARTY ELECTRICIAN

As a repair party electrician, you maybe directed to perform various tasks if battle damage occurs. These tasks could range from donning an OBA to being a stretcher bearer. Your primary responsibilities, however, will be those tasks in your rating.

You must be familiar with all electrical power sources and distribution panels in your assigned repair party area. In the event of a free, the on-scene leader will decide whether or not to secure the power. If the word is passed to you to secure the power to a specific compartment or piece of equipment, do so quickly so the task of putting out the fire can be expedited.

When general quarters (GQ) sounds, the crew will proceed to GQ stations and set material condition Zebra. After Zebra is set, you must report to your repair party leader for muster and wait for further instructions. By this time the repair locker should be opened, and you should take an inventory of all the electrical equipment in the locker. This equipment will usually consist of items such as an electrical repair kit, floodlights, flashlights with spare batteries, a submersible pump, casualty power cables and wrenches, extension cords, rubber gloves, and rubber boots. After testing all the electrical equipment to ensure it is functional and safe, stow it in an easily accessible area.

All members of the repair party are responsible for rigging casualty power and tying it to the overhead. The repair party electrician is responsible for proper connection to the biscuits (from load to source) and energizing the system. Follow standard safety precautions, wear rubber gloves and rubber boots, and stand on a section of rubber matting while making these connections.

Tag the casualty power cable at various locations. Remember, you need to warn all hands of the potential danger that exists. A typical warning sign is shown in figure 1-8.

RESCUE AND FIRST AID

The EM's job is risky even under the best working conditions. Although accidents are preventable, you run a good chance of getting shocked, burned, and being exposed to one or more of the hazards described earlier. If you are at the scene of an accident, you will be expected to help the victim as quickly as possible.

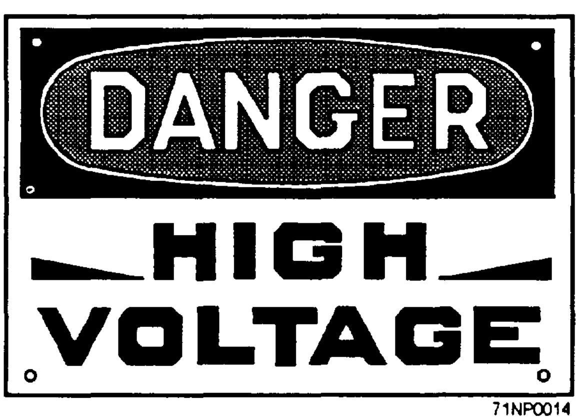


Figure 1-8.—DANGER HIGH VOLTAGE sign.

RESCUE

When a victim is unconscious because of an electric shock, you should start artificial resuscitation as soon as possible. Statistics show that 7 out of 10 victims are revived when artificial resuscitation is started in less than 3 minutes after the shock. Beyond 3 minutes, the chances of revival decrease rapidly. The person nearest the victim should start artificial resuscitation without delay, and call or send others for help and medical aid.

Before starting artificial resuscitation, free the victim from contact with electricity y in the quickest, safest way. (NOTE: This step must be done with extreme care; otherwise, there may be two victims instead of one.)

- If the contact is with a portable electric tool, light, appliance, equipment, or portable extension cord, turn off the bulkhead supply switch or remove the plug from its bulkhead receptacle.
- If the switch or bulkhead receptacle cannot be quickly located, the suspected electric device may be pulled free of the victim by grasping the insulated flexible cable to the device and carefully withdrawing it clear of its contact with the victim. Other persons arriving on the scene must be clearly warned not to touch the suspected equipment until it is unplugged. Aid should be enlisted to unplug the device as soon as possible.
- If the victim is in contact with stationary equipment (fig. 1-9), such as a bus bar or electrical connections, pull the victim free if the equipment cannot be quickly de-energized or the ship's operations or survival prevent immediate securing of the circuits. To save time in pulling the victim free, improvise a protective insulation for the rescuer. For example, instead of hunting for a pair of rubber gloves to use in grasping the victim, you can safely pull the victim free (if conditions are dry) by grasping the victim's slack clothing, leather shoes, or by using your belt. Instead of trying to locate a rubber mat to stand on, use nonconducting materials, such as deck linoleum, a pillow, a blanket, a mattress, dry wood, or a coil of rope.

NOTE: During the rescue, never let any part of your body directly touch the hull, metal structure, furniture, or victim's skin.

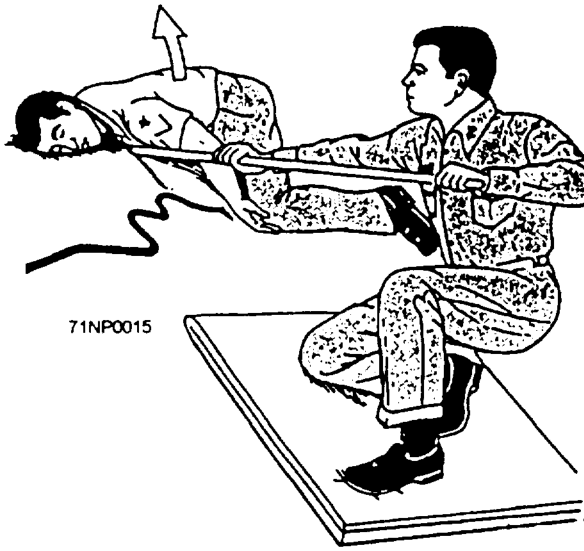


Figure 1-9.—Pushing a victim away from a power line.

RESUSCITATION

Methods of resuscitating or reviving an electric shock victim include artificial respiration/ventilation (to reestablish breathing) and external heart massage (to reestablish heart beat and blood circulation).

Artificial Ventilation

A person who 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 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 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 maybe 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.

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 giving artificial ventilation: mouth-to-mouth and mouth-to-nose.

For additional information on performing artificial ventilation, refer to *Standard First Aid Training Course,* NAVEDTRA 12081.

Cardiopulmonary Resuscitation

A rescuer who knows how to give cardiopulmonary resuscitation (CPR) increases the chances of a victim's survival. CPR consists of artificial ventilations and external heart compressions. The lungs are ventilated by the mouth-to-mouth or mouth-to-nose techniques; the compressions are performed by pressing the chest with the heel of your hands. 'he victim should be lying face upon a firm surface. The procedure forgiving CPR is given in figure 1-10.

WARNING

CPR should not be attempted by a rescuer who has not been properly trained.

One-Rescuer Technique

The rescuer must not assume that an arrest has occurred solely because the victim is lying on the deck and looks unconscious. First, try to arouse the victim by gently shaking the shoulders and try to get a response; loudly ask, "Are you OK?" If there is no response, place the victim face upon a firm surface. Kneel at a right angle to the victim, and open the airway, using the head tilt-neck lift or the jaw thrust methods previously discussed. Look for chest movements. Listen and feel for air coming from the nose or mouth for at least 5 seconds. If the pulse is absent, call for help and begin CPR.

Locate the lower margin of the victim's rib cage on the side closest to you by using your middle and index fingers. Then move your fingers up along the edge of the rib cage to the notch (xiphoid process) where the ribs meet the sternum in the center of the lower chest. Place the middle finger on the notch, and place the index finger next to it. Place the heel of the other hand along the midline of the sternum, next to the index finger. You must keep the heel of your hand off the xiphoid process

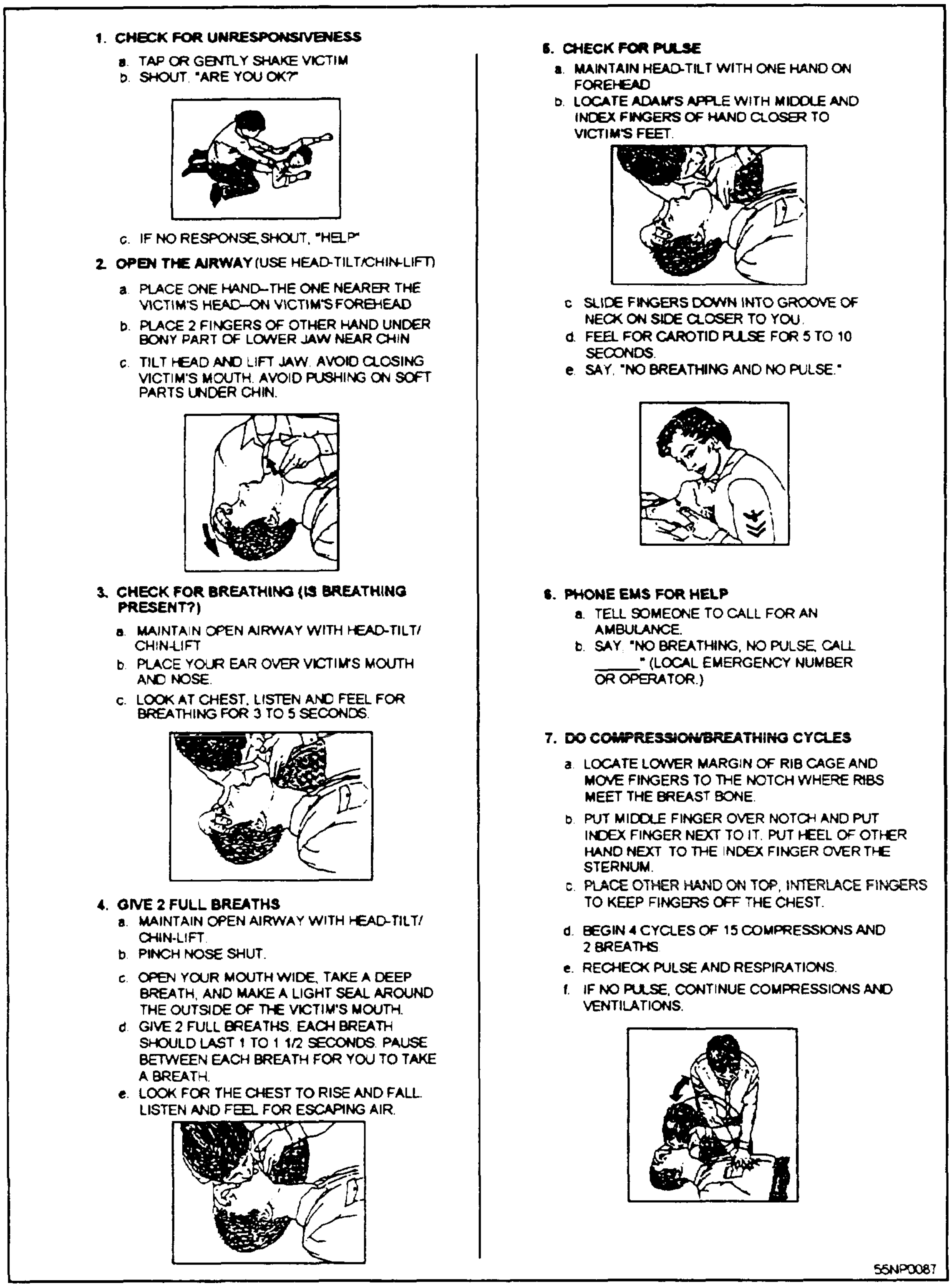


Figure 1-10.—Instructions for administering CPR.

(fig. 1-11). A fracture in this area could lacerate the liver.

Place the heel of one hand directly on the lower half of the sternum, two fingers up from the notch, and the heel of the other on top of the first hand. Interlock your fingers or extend them straight out, and KEEP THEM OFF THE VICTIM'S CHEST! See figure 1-12.

With the elbows locked, apply vertical pressure straight down to depress the sternum (adult) from 1 1/2 to 2 inches. Then release the pressure, keeping the heels

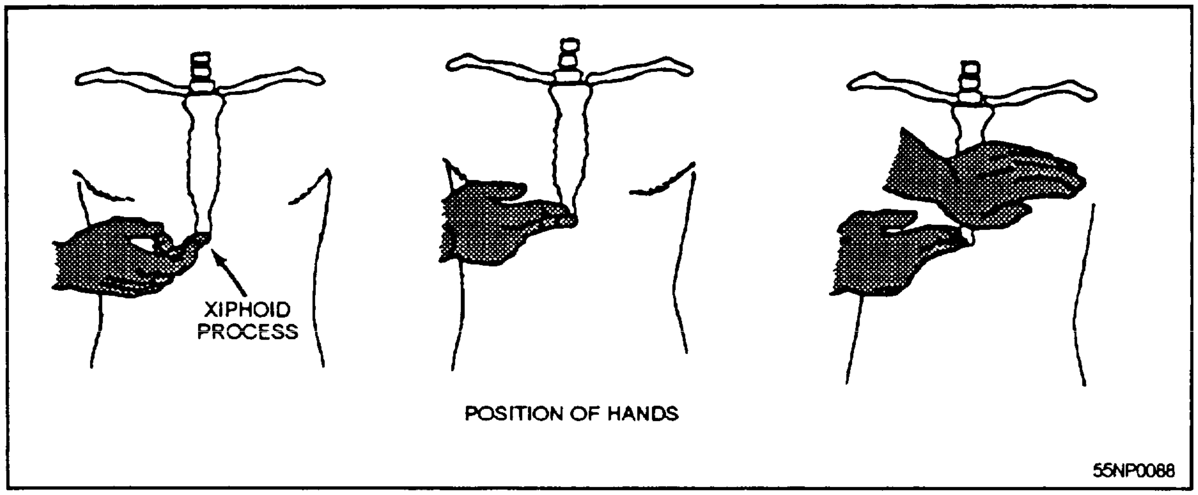


Figure 1-11.—Xiphoid process.

of the hands in place on the chest. This process compresses the heart between the sternum and the victim's back, thus pumping blood to the vital parts of the body.

If you use the proper technique, a more effective compression will result, and you will feel less fatigue. Ineffective compression occurs when the elbows are not locked, the rescuer is not directly over the sternum, or the hands are improperly placed on the sternum.

When one rescuer performs CPR, the ratio of compressions to ventilations is 15 to 2. It is performed at a rate of 80 to 100 compressions per minute. Vocalize "one, and two, and three," and so on, until you reach 15.

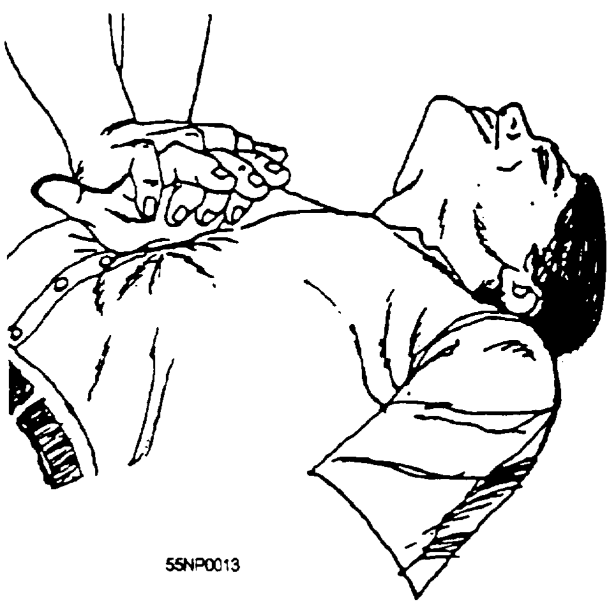


Figure 1-12.—Interlocking fingers to help keep fingers ON the chest Wall.

After 15 compressions, you must give the victim 2 ventilations. Continue for four full cycles of 15 compressions and 2 ventilations. Then take 5 seconds to check for the carotid pulse and spontaneous breathing. If there are still no signs of recovery, continue CPR. If a periodic check reveals a return of puke and respiration, stop CPR. Closely watch the victim's puke and respirations, and be prepared to start CPR again if required If a pulse is present but no respiration, continue to give the victim one ventilation every 5 seconds and check the pulse frequently.

Let's review the steps for one-rescuer CPR:

1. Determine whether the victim is conscious.
2. Open the airway (it may be necessary to remove the airway obstruction).
3. Link, listen, and feel.
4. Ventilate two times.
5. Check the pulse—if none, call for help.
6. Begin the compression-ventilation ratio of 15 to 2 for four complete cycles.
7. Check again for a pulse and breathing. If no change, continue the compression-ventilation ratio of 15 to 2 until the victim is responsive, until you are properly relieved, until you can no longer continue because of exhaustion or until the victim is pronounced dead by a medical officer. For additional information refer to *Standard First Aid Training Course,* NAVEDTRA 12081.

WOUNDS

A wound or breaking of the skin, is another problem that could arise, and in some instances, could be the result of an electric shock. An EM could accidentally come in contact with an energized circuit, causing 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 and the control of bleeding.

There are many classifications of wounds, but we will discuss only the three common types.

Abrasions. Abrasions are made when the skin is rubbed or scraped off. Rope burns, 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 sharp instruments such as knives,

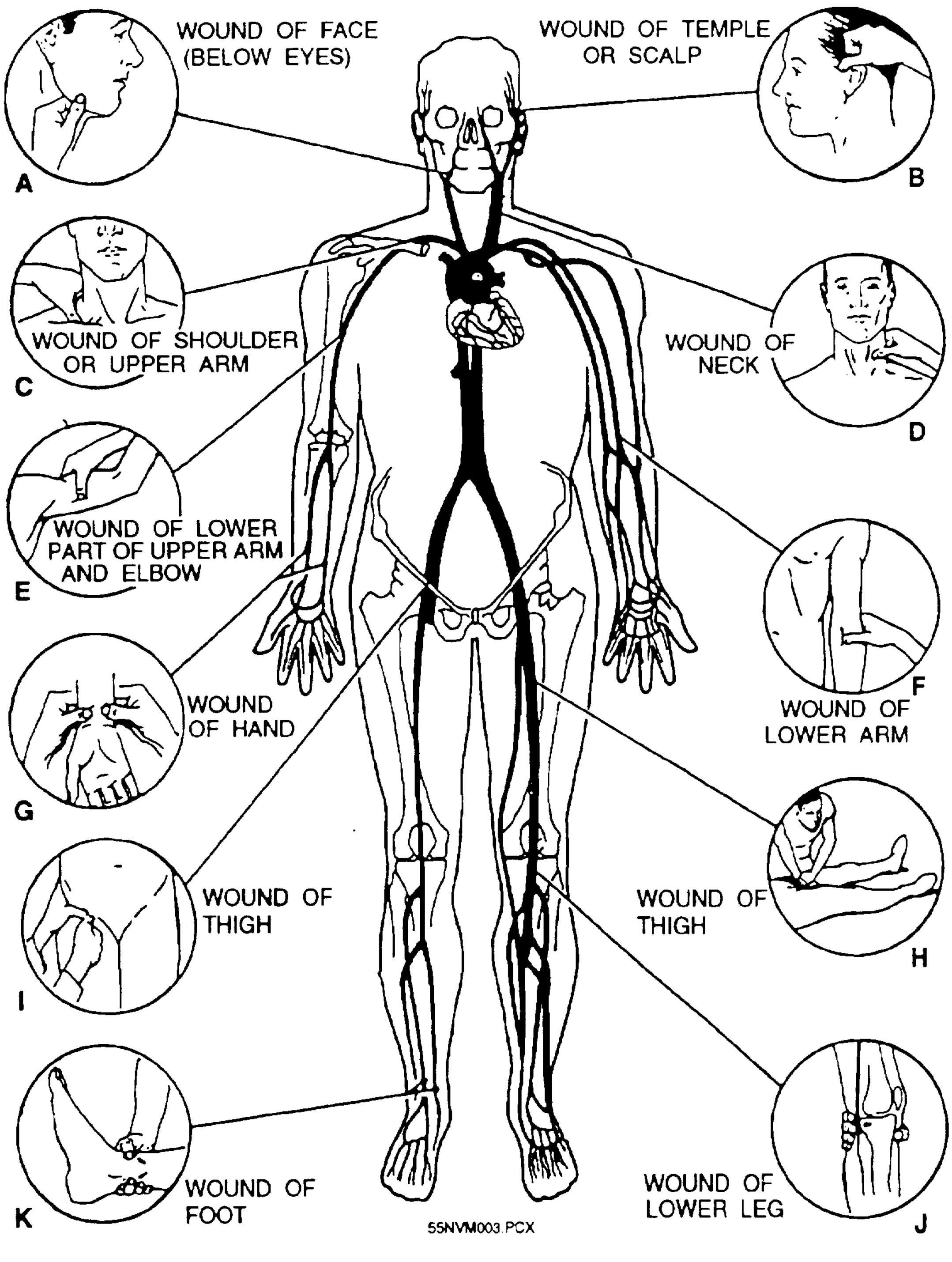


Figure 1-13.—Pressure points for control of bleeding.

razors, or broken glass. Incisions tend to bleed very freely because the blood vessels are cut straight across.

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

For additional information on first aid, refer to the *Standard First Aid Training Course,* NAVEDTRA 12081.

BLEEDING

You should use the direct-pressure method to control bleeding. Use a compress made with a clean rag, handkerchief, or towel to apply direct pressure to the wound. If the direct-pressure method does not stop the bleeding, use the pressure point (fig. 1-1 3) nearest the wound.

Use a tourniquet on an injured limb only as a last resort; for example, if the control of hemorrhaging cannot be stopped by other means. Apply a tourniquet above the wound (towards the trunk) and as close to the wound as practical.

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 pencil, crayon, or blood and mark a large T on the victim's forehead to alert medical personnel that the patient has a tourniquet.

WARNING

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

BURNS

The principal dangers from burns are shock and infection. Direct all casualty care measures toward combating shock, relieving pain, and preventing infection.

Classification of Burns

Burns may be classified according to their cause as thermal, chemical, or electrical.

Thermal burns. A thermal burn is the direct result of heat caused by fire, scalding, sun, or an explosion.

Chemical burns. A chemical burn is caused by chemical action, such as battery acid on the skin.

Electrical burns. An electrical burn is caused by electrical current passing through tissue or the superficial wound caused by electrical flash.

Bums are also classified as first, second, or third degree, based on the depth of skin damage (fig. 1-14).

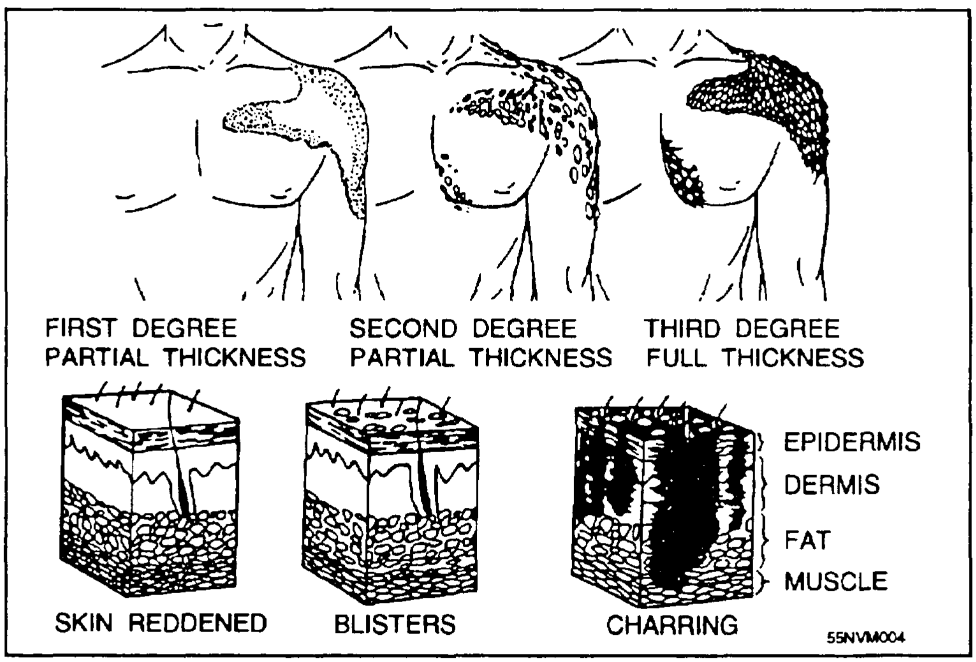


Figure 1-14.—First-, second-, and third-degree burns.

First-degree burns. A first-degree burn is the mildest. Symptoms are reddening of the skin and mild pain.

Second-degree burns. A second-degree burn is more serious. Symptoms include blistering of the skin, severe pain, some dehydration, and possible shock.

Third-degree burns. A third-degree burn is characterized by complete destruction of the skin with charring and cooking of the deeper tissues. **This is the most serious type of burn.** It produces a deep state of shock and causes more permanent damage. It is usually not as painful as a second-degree burn because the sensory nerve endings are destroyed.

Burn Emergency Treatment

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, use the rule of nines (fig. 1-15).

As a guideline, burns exceeding 20 percent of the body surface endanger life. Burns covering more than 30 percent of the body surface are usually fatal.

If time and facilities permit caring for patients with supeficial burns, clean the burned area with soap and

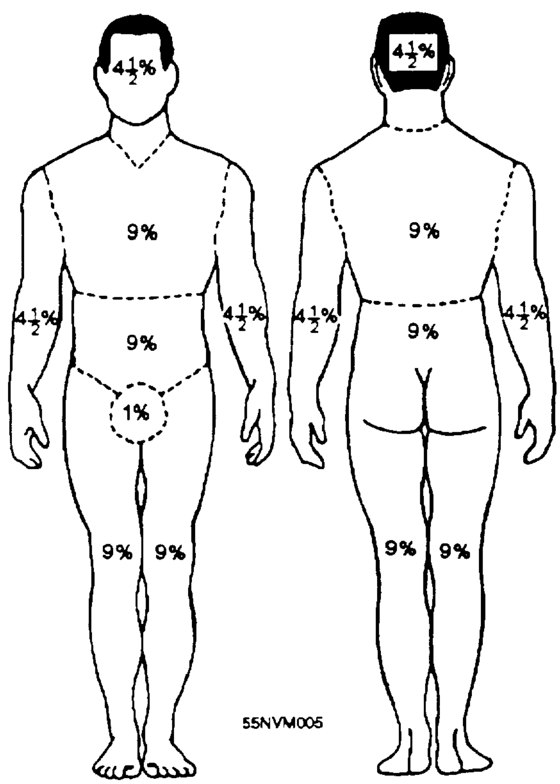


Figure 1-15.—Rule of nines.

water. Apply a simple sterile dressing of fine-mesh, dry gauze over the area to protect it from infection. Casualty treatment for first-degree burns needs little attention beyond self-care.

When emergency treatment of the more serious second-degree burns and third-degree burns is required, treat the patient for shock first. Make the patient as comfortable as possible, and protect the person from cold, excessive heat, and rough handling.

The loss of body fluids is the main factor in burn shock. If the patient is conscious, able to swallow, and has no internal injuries, you can give the patient frequent small amounts of coffee, tea, fruit juice, or sugar water.

To enable trained personnel to determine the kind of treatment required, no not apply medication to burns during emergency treatment. Pain is closely associated with the degree of shock and should be relieved as soon as possible. When available, ice water is an effective pain reducer. Flooding with lots of clean, cool fresh water also helps if not too much force is used. In electric shock cases, burns may have to be ignored temporarily while the patient is being revived.

After treating the patient for pain and shock, apply a compress and bandage to protect the burned area. If a universal protective dressing is not available, use a fine-mesh gauze. Remove constricting articles of clothing and ornaments, and immobilize and elevate the burned area.

Evacuate patients with extensive deep burns to a medical facility for treatment as rapidly as possible. Pain should be alleviated and shock must be controlled before and during evacuation.

Clothing that sticks to a burn maybe cut around the burn and the adhering cloth allowed to remain until removed by medical personnel. The area of the burn is usually sterile; therefore, be careful not to contaminate it.

HEARING CONSERVATION AND NOISE ABATEMENT

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

Hearing loss has been and continues to be a source of concern within the Navy. Hearing loss attributed to 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 and Noise Abatement Program is to prevent occupational noise-related hearing loss among Navy personnel. The program includes the following elements:

- Work environments are surveyed to identify potentially hazardous noise levels and personnel at risk.
- If environments contain or equipment produces potentially hazardous noises, they should be modified to reduce the noise to acceptable levels. Where engineering controls are not feasible, administrative controls and/or the use of hearing protection devices are employed.
- Periodic hearing testing is conducted to monitor the program.
- Educating Navy personnel in hearing conservation programs is vital to the overall success.

HEARING TESTING

All personnel required to work in designated noise hazard areas or with equipment that produces sound levels greater than 84 decibels (dB) or 140 dB sound/pressure levels are entered in the hearing testing program. The hearing testing program includes a reference hearing test and monitored hearing tests.

Reference (Base Line) Hearing Test

All military personnel should receive a reference hearing test upon entry into naval service. his test is called the *base line.*

Monitored Hearing Tests

If a person works in a noise hazard area, a hearing test is conducted within 90 days of reporting and repeated at least annually. Hearing tests are conducted when there are individual complaints or difficulties in understanding conversational speech or a sensation of ringing in the ears. The 90-day or annual audiogram is compared to the reference (base line) to determine if a hearing threshold shift has occurred.

HEARING PROTECTIVE DEVICES

All personnel must wear hearing protective devices when they must enter or work in an area with noise levels greater than 84 dB. There are many types of hearing protection—inserts of numerous styles (earplugs) and circumaurals (earmuffs).

Single hearing protection. Single hearing protection is required when in areas where the noise level is above 84 dB.

Double hearing protection. Double hearing protection is required when the noise level is 104 dB or higher.

IDENTIFYING AND LABELING OF NOISE AREAS

Industrial hygienists use a noise level meter to identify noise hazardous areas. All noise hazardous areas are labeled using a HAZARDOUS NOISE WARNING decal (fig. 1-16). Post this decal at all accesses.

You will find further information on hearing conservation in OPNAVINST 5100.23.

HEAT STRESS PROGRAM

Heat stress is any combination of air temperature, thermal radiation, humidity, airflow, and workload that

Figure 1-16.—Hazardous noise warning decal.

may stress the human body as it attempts to regulate its temperature. Heat stress becomes excessive when your body's capability to adjust to heat is exceeded. This condition produces fatigue, severe headaches, nausea, and poor physical and/or mental performance. Prolonged exposure to heat stress could cause you to have heatstroke or heat exhaustion.

Primary factors that increase heat stress conditions include the following:

- Excessive steam and water leaks
- Boiler air casing leaks
- Missing or deteriorated lagging on steam piping and machinery
- Ventilation systems ductwork clogged or an inoperative fan motor
- Ships operating in hot or humid climates

Dry-bulb thermometers are used to determine the heat stress conditions in areas of concern. Permanently mounted dry-bulb thermometers are installed at watch stations. Readings should be taken and recorded at least once a watch period. When the reading exceeds 100°F, a heat survey must be ordered to determine the safe stay time for personnel.

The heat survey is taken with a wet-bulb globe temperature (WBGT) meter. Then, these readings are compared to the physiological heat exposure limits (PHEL) chart. After comparing the readings with the PHEL chart, the safe stay time for personnel can be determined.

Refer to OPNAVINST 5100.19 for further information on the heat stress program and procedures.

HAZARDOUS MATERIALS

Hazardous materials include anything that may pose a substantial hazard to human health or to the environment because of their quantity, concentration, or physical or chemical characteristics when purposefully or accidentally spilled. Hazardous materials include flammable and combustible materials, toxic materials, corrosives, oxidizers, aerosols, and compressed gases. his section covers aerosols, paints and varnishes, cleaning solvents, steel wool and emery paper, cathode-ray tubes, and radioactive electron tubes.

Hazardous Material Control and Management, OPNAVINST 4110.2, and *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat,* OPNAVINST 5100.19, provide requirements for handling, storage, and disposal of hazardous materials.

AEROSOL DISPENSERS

If personnel deviate from or ignore procedures prescribed for selecting, applying, storing, or disposing of aerosol dispensers, they have been poisoned, burned, or have suffered other physical injury. Material Safety Data Sheets (MSDSs) contain specific precautions and safe practices for handling aerosol dispensers. You can get MSDSs from your supervisor. However, you can guard against poisoning, fire, explosion, pressure, and other hazards associated with aerosols by regarding all aerosols as flammable. You can prevent an injury or hazard by the following basic rules:

<u>Poisoning</u>. All areas where people use aerosols require adequate ventilation. Ventilation is critical if the aerosol is toxic or flammable. Exhaust ventilation is needed to remove harmful vapors, or additional supply ventilation to dilute vapors to a safe level. When ventilation is inadequate or absent, you must wear respiratory protection.

<u>Chemical Burns</u>. Avoid spraying your hands, arms, face, or other exposed parts of the body. Some liquid sprays are strong enough to burn the skin, while milder sprays may cause rashes.

<u>Fire.</u> Keep aerosol dispensers away from direct sunlight, heaters, and other sources of heat. Do not store dispensers in an area where the temperature can exceed the limit printed on the container. Do not spray volatile substances on warm or energized equipment.

<u>Explosion.</u> Do not puncture an aerosol dispenser. Discard used dispensers in approved waste receptacles that will not be emptied into an incinerator.

PAINTS AND VARNISHES

You must take special precautions when removing paint from or repainting electrical equipment. In general, avoid removing paint from electrical equipment. If scraping or chipping tools are used on electrical equipment, insulation and delicate parts can be damaged. Furthermore, paint dust is composed of abrasive and semiconducting materials that impair the insulation. When paint must be scraped, cover all electrical equipment, such as generators, switchboards, motors, and controllers to prevent entrance of the paint dust. After removing paint from electrical equipment, thoroughly clean it, preferably with a vacuum cleaner.

Repaint electrical equipment only when necessary to prevent corrosion due to lack of paint. Paint only the affected areas. General repainting of electrical equipment or enclosures for electrical equipment only to improve their appearance is not desirable. Never apply paint to any insulating surfaces in electrical equipment. DO NOT PAINT OVER IDENTIFICATION PLATES.

Apply electrical insulating varnish to equipment only as necessary. Frequent applications of insulating varnish build up a heavy coating that may interfere with heat dissipation and develop surface cracks. Do not apply insulating varnish to dirty or moist insulation; the varnish will seal in the dirt and moisture and make future cleaning impossible.

The two types of insulating varnishes commonly used in the Navy are clear baking varnish (grade CB) and clear air-drying varnish (grade CA). Grade CB is the preferred grade. If it is not possible to bake the part to be insulated, use grade CA.

NOTE: Shellac and lacquer are forms of varnish, but **don't** use them for insulating purposes.

CLEANING SOLVENTS

Cleaning electrical and electronic equipment with water-based and nonvolatile solvents is an approved practice. These solvents do not vaporize readily. Some cleaning solvents are discussed in this section.

When it is not possible to clean with a water-based solvent, use inhibited methyl chloroform (1,1,1—trichloroethane). Methyl chloroform is a safe effective cleaner when used in an adequately ventilated area, and not inhaled Do not use it on warm or hot equipment.

WARNING

Wear an organic vapor cartridge respirator when using 1,1,1—trichloromethane or make sure the work area has good local exhaust ventilation.

When using cleaning solvents in a compartment, always make sure the ventilation is working properly. Rig an exhaust trunk for local exhaust ventilation if you expect a high vapor concentration. Keep a ready-to-use fire extinguisher close by. Never work alone in a compartment.

Avoid coming in contact with cleaning solvents. Always wear gloves and goggles, but especially when equipment is being sprayed. When spraying, hold the nozzle close to the equipment. Do not spray cleaning solvents on electrical windings or insulation.

NOTE: Never use carbon tetrachloride as a cleaning agent. It is a highly toxic (poisonous) compound that is a suspected carcinogen. Its threshold is 20 times lower than that of methyl chloroform, making it more dangerous. (Threshold is the point above which the concentration of vapor in the air becomes dangerous.)

NOTE: Never use volatile substances, such as gasoline, benzene, alcohol, or ether as cleaning agents. Besides being fire hazards, they readily give off vapors that injure the human respiratory system if inhaled directly for along time.

STEEL WOOL AND EMERY CLOTH/PAPER

Steel wool and emery cloth/paper is harmful to the normal operation of electric and electronic equipment. The *Naval Ships' Technical Manual* and other technical publications warn you against using steel wool and emery cloth/paper on or near equipment. When these items are used, they shed metal particles. These particles are scattered by ventilation currents and attracted by the magnetic devices in electrical equipment. This could cause short circuits, grounds, and excessive equipment wear.

Clean the contacts with silver polish, sandpaper, or burnishing tools. After cleaning, use a vacuum to remove the excessive dust.

NOTE: Never use emery cloth/paper and steel wool for cleaning contacts.

CATHODE-RAY TUBES

Handle cathode-ray tubes (CRTs) with extreme caution. The glass encloses a high vacuum. Because of its large surface area, it is subject to considerable force caused by atmospheric pressure. (The total force on the surface of a lo-inch CRT is 3,750 pounds, or nearly 2 tons; more than 1,000 pounds is exerted on its face alone.)

The chemical phosphor coating of the CRT face is extremely toxic. When disposing of broken tubes, be careful not to come into contact with this compound. Certain hazardous materials are released if the glass envelope of a CRT is broken. These hazardous materials are:

- <u>Thorium oxide—</u> The radioactive decay of thorium (thorium daughter products) and thorium oxide are considered carcinogenic agents.
- <u>Barium acetate—</u> A small residual remains after manufacture, TLV 0.5 mg/m^3.
- <u>Barium getters—</u> Composition unknown, 10-12 grams.

Several manufacturers will dispose of returned tubes. Instructions for the return of tubes are available from the manufacturer. If unable to return the CRT to the manufacturer for disposal, make it harmless by breaking the vacuum glass seal. The safest method of making a CRT harmless is to place the tube in an empty carton, with its face down. Then, carefully break off the locating pin from its base (fig. 1-17). Complete disposal instructions may be found in Navy Electricity and Electronics Training Series (NEETS), NAVEDTRA 172-06-00-82, Module 6.

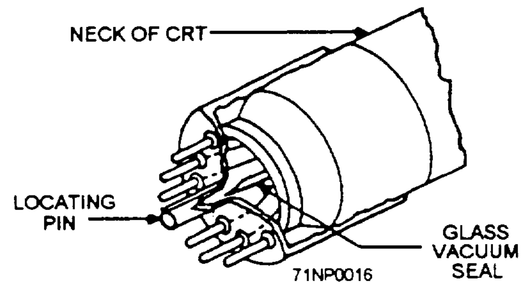


Figure 1-17.—Cathode-ray tube base structure.

RADIOACTIVE ELECTRON TUBES

Electron tubes containing radioactive material are now commonly used. Some tubes containing radioactive material contain dangerous intensity levels. These tubes are marked according to military specifications. Most tubes contain radioactive cobalt (Co-60), radium (Ra-226), or carbon (C-14); several contain nickel (Ni-63). Some tubes contain cesium barium (CsBa-137).

No hazard exists when an electron tube containing radioactive material remains intact. However, a potential hazard exists when the electron tube is broken

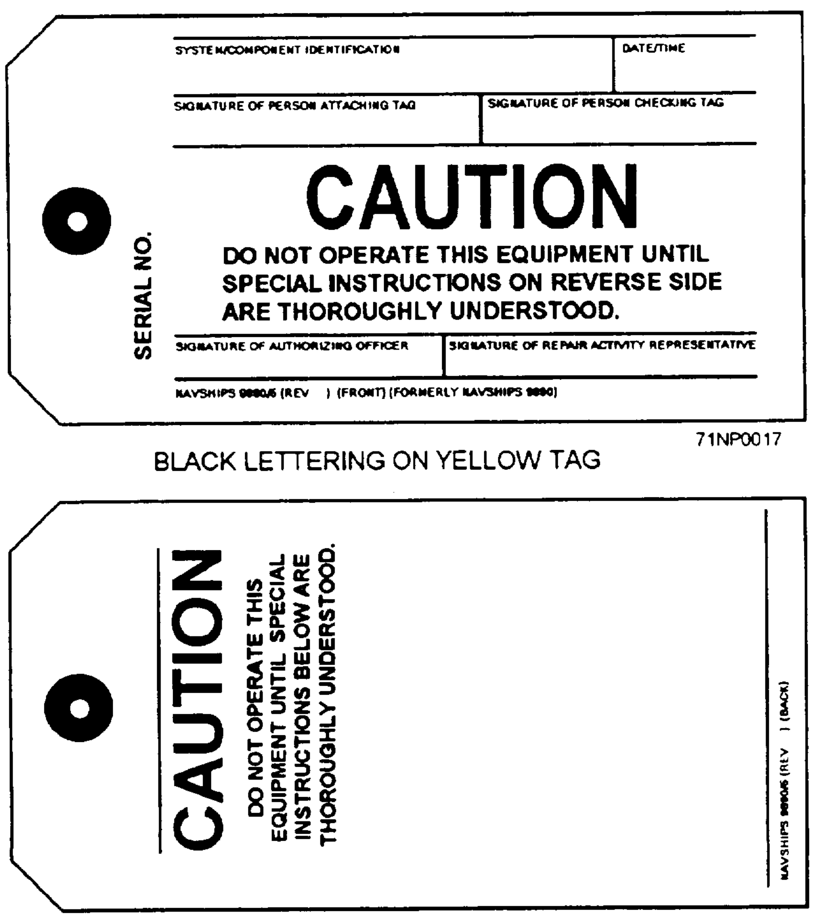


Figure 1-18.—CAUTION tag (colored YELLOW).

and the radioactive material escapes. The concentration of radioactivity in a normal collection of electron tubes at a maintenance shop does not approach a dangerous level, and the dangers of injury from exposure are slight. However, at major supply points, the storage of large quantities of radioactive electron tubes in a small area may create a hazard. For this reason, personnel working with equipment that contains radioactive electron tubes or in areas where many radioactive tubes are stored should read and become thoroughly familiar with the safety precautions and safe-handling practices outlined in Section 1, *Radiac EIMB HandBook,* NAVSEA SE000-00-EIM-050.

TAG OUT

Equipment needing repair must be de-energized and tagged out by use of either a CAUTION or DANGER tag.

CAUTION TAG

A CAUTION tag (fig. 1-18) is a YELLOW tag. It is used as a precautionary measure to provide temporary special instructions or to show that unusual caution must be exercised to operate equipment. These instructions must state the specific reason that the tag is installed. Use of phrases such as DO NOT OPERATE WITHOUT EOOW PERMISSION is not appropriate since equipment or systems are not operated unless permission from the responsible supervisor has been obtained. A CAUTION tag cannot be used if personnel or equipment could be endangered while performing evolutions using normal operating procedures; a DANGER tag is used in this case.

DANGER TAG

Safety must always be practiced by persons working around electric circuits and equipment. Practicing safety prevents injury from electric shock and from short circuits caused by accidentally placing or dropping a conductor of electricity across an energized line. The arc and fire started by these short circuits, may cause extensive damage to equipment and serious injury to personnel.

No work will be done on electrical circuits or equipment without permission from the proper authority and until all safety precautions are taken. One of the most important precautions is the proper use of DANGER tags, commonly called RED tags (fig. 1-19).

Danger tags are used to prevent the operation of equipment that could jeopardize your safety or endanger the equipment systems or components. When equipment is red tagged, under no circumstances will it be operated. When a major system is being repaired or when PMS is being performed by two or more repair

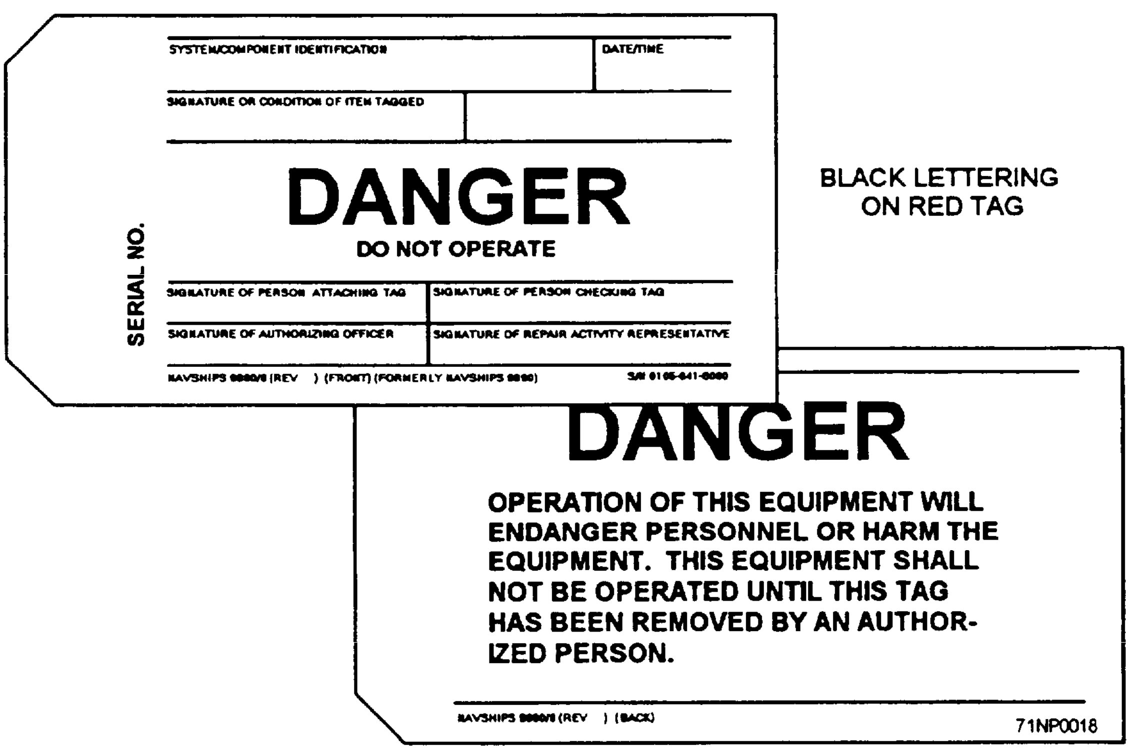


Figure 1-19.—DANGER tag (colored RED).

groups, such as ENs and EMs, both parties will hang their own tags. This prevents one group from operating or testing circuits that could jeopardize the safety of personnel from the other group.

No work is done on energized or de-energized switchboards before approval of the commanding officer, engineer officer, and electrical officer. Because of the continuous use of the tag-out system by EMs in their day-to-day activities, they are expected to be the experts in the interpretation of the *Equipment Tag-Out Bill,* OPNAVINST 3120.32B, chapter 6, paragraph 630.17.

All supply switches or cutout switches from which power could be fed should be secured in the off or open (safety) position, and red tagged. Circuit breakers are required to have a handle locking device installed as shown in figure 1-20. The proper use of red tags cannot be overstressed. When possible, double red tags should be used, such as tagging open the main power supply breaker and removing and tagging the removal of fuses of the same power supply.

ADMINISTRATION, SUPERVISION, AND TRAINING

The higher you go in the Navy, the more administrative, supervisory, and training tasks you will be required to perform. This section addresses some of your responsibilities as a senior petty officer for supervising and training others.

When a shop is assigned a motor overhaul job, the senior petty officers duties involve administration, supervision, and training all at the same time.

As an administrator, your job includes the following:

- Scheduling the job
- Checking on the history of the motor
- Making sure that the required forms and reports are submitted

As a supervisor, your job involves the following:

- Overseeing the actual work
- Making sure it is done correctly

As a trainer, your job involves the following:

- Providing information and instruction on repair parts
- Providing information on rewind procedures
- Providing information on safety precautions and other matters

Administrative, supervisory, and training tasks have a direct relationship to the job—overhauling the electric motor.

The only way to keep things running smoothly is to take your administrative supervisory and training responsibilities seriously. Repair jobs cannot get started unless a variety of administrative, supervisory, and training functions are performed on a continuing basis.

- Materials, repair parts, and tools must be available when they are needed.
- Jobs must be scheduled with regard to the urgency of other work.
- Records must be kept and required reports submitted.
- Personnel must be in a continuous state of training to assume increasingly important duties and responsibilities.

ADMINISTRATION

The engineering department administrative organization is setup to provide for proper assignment of duties and for proper supervision of personnel. However, no organization can run itself. Senior EMs should ensure that all pertinent instructions are carried out and that all machinery, equipment, and electrical systems are operated following good engineering practices. Other responsibilities include the posting of instructions and safety precautions next to operational equipment and ensuring that they are followed by all personnel. Watch standers must be properly supervised to ensure that the entire engineering plant is operated with maximum reliability, efficiency, and safety.

To monitor your plant's status and performance, you need to know which engineering records and reports are required. Reports regarding administration, maintenance, and repair of naval ships are prescribed by directives from such authorities as the Type Commander, Naval Ship Systems Command (NAVSEA), and Chief of Naval Operations (CNO). These records must be accurate and up to date.

As an EM1 or EMC, your supervisory duties will require a greater knowledge of engineering records and administrative procedures than you needed at the EM2 or EM3 level. Your supervisory duties and responsibilities require a knowledge of the following:

- Engineering records

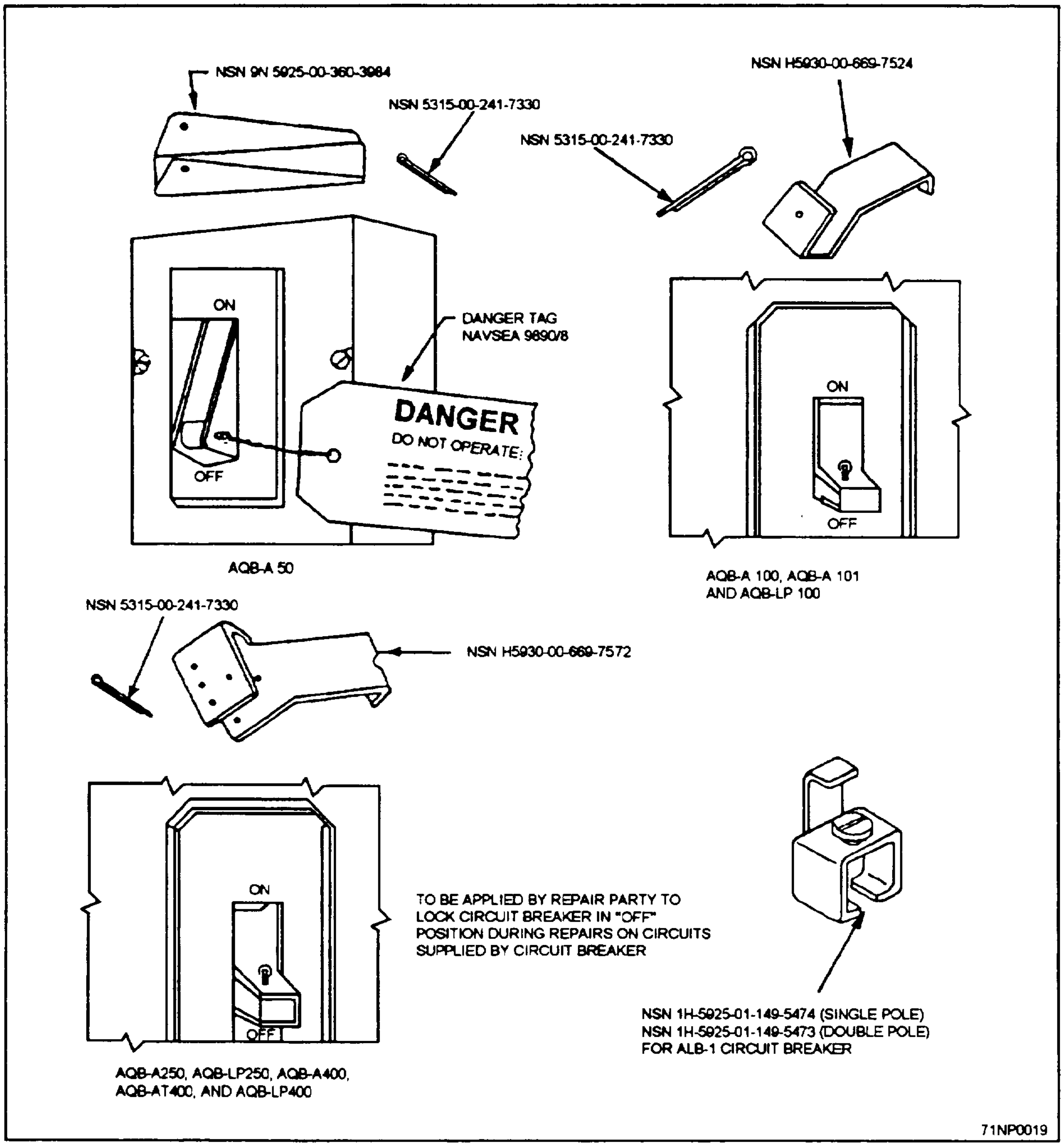


Figure 1-20.—Handle-locking devices for circuit breakers.

- Infections
- Administrative procedures
- Training procedures
- Preventive maintenance
- Repair procedures

Information on the most common engineering records and reports is given in this section. These standard forms are prepared by the various systems commands and CNO. The forms are for issue to forces afloat and can be obtained as indicated in the *Navy Stock List of Publications and Forms,* NAVSUP 2002. Since these forms are revised periodical y, personnel must be sure that the most current are obtained. When complementary forms are necessary for local use, make sure that an existing standard form will serve the purpose.

STANDARD SHIP ORGANIZATION

The responsibility for organization of a ship's crew is assigned to the commanding officer by U.S. Navy regulations. The executive officer is responsible, under

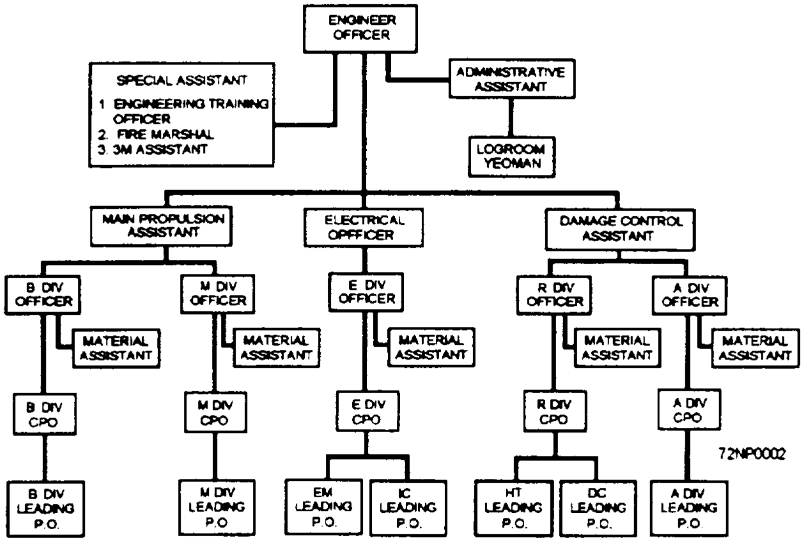


Figure 1-21.—Typical engineering departments.

the commanding officer, for the organization of the command. The department heads are responsible for the organization of their departments for readiness in battle and for assigning individuals to stations and duties within their respective departments. *The Standard Organization and Regulations of the U.S. Navy,* OPNAVINST 3120.32B, prescribes this administrative organization for all types of ships. For more information on standard ship organization, refer to Engineering Administration, NAVEDTRA 12147.

THE ENGINEER OFFICER

The engineering officer (chief engineer) is the head of the engineering department on naval ships. As a department head, the chief engineer represents the commanding officer in all matters pertaining to the department. All personnel in the engineering department are subordinate to the chief engineer, and all orders issued by him or her must be obeyed A structural organization chart for the department is shown in figure 1-21.

The chief engineer must conform to the policies and comply with the orders of the commanding officer. Besides general duties that are applicable to all department heads on naval ships, the engineering officer has certain duties peculiar to his or her position.

The engineer may confer directly with the commanding officer in matters relating to the engineering department when he or she believes such action is necessary. The engineering officer will report to the executive officer for the administration of the engineering department.

Duties of the engineering officer	
Keep the CO informed about the following:	• Operational readiness and actual operation of the main propulsion and electrical plants • Damage control organizations and systems
Obtain the permission of the CO before the following actions are taken:	• Disable any machinery or equipment in the engineering department if such action will adversely affect the safety or operation of the ship • When such disablement of machinery will adversely affect the ship's ability to accomplish its mission, permission is also required from the type or fleet commander
Follows good engineering practices by doing the following:	• Keeping performance of routine maintenance on major items of machinery to a minimum during operating periods

ASSISTANTS TO THE ENGINEER OFFICER

The engineering officer is assigned assistants for damage control, main propulsion, electrical, and other specific duties as may be required for the proper performance of the engineering department. The engineering officer is responsible for ensuring that his or her assistants perform their assigned duties.

Electrical officer Under the engineer officer, the electrical officer is responsible for:	The operation, care, and maintenance of the following: • The ship's electric power generators and distribution systems • Interior communications equipment and systems • Degaussing equipment and systems • Gyrocompass equipment and associated systems • Dead reckoning analyzer and associated equipment • Small boat electrical systems • All other electrical and electronic equipment, machinery, and systems not specifically assigned to another division or department • The preparation, maintenance, and submission of logs, records, and reports required in connection with assigned duties The electrical officer is usually assigned collateral duty as motion picture officer. As such, the electrical officer is responsible for the following: • The procurement, stowage, scheduling, and showing of entertainment motion picture programs; for the training and assignment of motion picture projectionists • The operation, care, and maintenance of motion picture projectors, video and closed-circuit television systems, and associated equipment • The preparation, maintenance, and submission of the required logs, records, and reports concerning motion picture progr programs and equipment
Electrical (E) division officer The E division officer heads the electrical division. Personnel of the EM and IC ratings are assigned to this division.	The E division is responsible for: • the cleanliness and maintenance of the electrical shop, gyro room, IC room, IC shop, storage battery room, battery locker, underwater log compartment, winch controller rooms, wiring trunks, and switchboard rooms The E division is assigned preventive and corrective maintenance of: • all electrical motors, generators, and controllers not specifically assigned to another department E division personnel are responsibile for the following equipment: • Degaussing systems • Electrical distribution systems, including cabling, switching, and protective equipment • Gyrocompass and related equipment such as the dead reckoning analyzer and the dead reckoning tracer • Battery charging equipment • The underwater log equipment • Small boat electrical systems • Automatic and sound-powered telephone systems • Sound motion picture equipment • Lighting systems • Closed-circuit television systems • IC systems including ship control and indicating systems • Portable announcing systems • Portable electric tools

Electrical division chief petty officer The division chief petty officer (CPO) assists the division officer in coordinating and administering the division. The duties, responsibilities, and authority of the division CPO depends on the division organization.	The division CPO may be required to perform the following tasks: 1. Supervise the preparation and maintenance of the watch, quarter, and station bills and such other bills as may be necessary for the operation of the division. 2. Formulate and implement policies and procedures for the operation of the division. 3. Supervise the division in the performance of its daily routine, and conduct inspections to ensure that division functions are properly executed. 4. Administer discipline within the division. 5. Fill out the annual Enlisted Performance Evaluation Report (NAVPERS 1616/24) by evaluating individual performances of division personnel, with the assistance of the leading division petty officer. These reports will be turned into the division officer. 6. Provide counsel and guidance to division personnel. 7. Ensure the correct maintenance of routine logs and records and the proper preparation of reports required of the division. 8. Act as the division officer in the absence of the division officer. 9. Perform other duties as may be assigned by the division officer.
Division leading petty officer The division leading petty officer (LPO) designated by the division officer or chief will usually be the senior petty officer within the division.	The LPO will assist in the administration, supervision, and training of division personnel, and in the qualifying of the switchboard watchstanders.

ACCOUNTABILITY

The outlook of the young sailor today indicates that the degree of leadership success depends less on the position of the leader than upon the leader's ability to gain the full commitment of those under him or her. This has come about because todays' sailor is more intelligent, better educated. They are asking more probing questions—they will not follow blindly. Their personal commitments will not be given just because of a leader's position; it has to be generated by the leader as a competent individual. In developing this competency, accountability for one's actions and for those under him or her cannot be ignored.

The relationship between responsibility, authority, and accountability has never been better expressed than by Admiral George Anderson, when he was Chief of Naval Operations. He stated, "We cannot evade any of our own responsibilities; while it is perfectly appropriate to single out a junior as having been responsible for a success, the responsibility for failure must always be retained by the senior officer."

COUNSELING

It is the responsibility of every senior petty officer in the navy to help those under him or her solve their problems. Senior petty officers have the ability and know-how to solve the vast majority of their subordinate's problems within their own command's resources, and it their duty to do so.

In meeting this responsibility, counseling is a valuable tool. Whether conducted formally in the work center office or informally on the flight deck, counseling is intended to reward a person for a job well done or to point out some deficiency to the sailor before it becomes a problem. When counseling a person for a deficiency, the outcome goal should be pointed out to the person—that is for the person to act to correct the deficiency before it becomes a problem. If the person being counseled should require help to attain the goal, it must be made available.

The act of counseling is something that takes practice and experience. Broken down into its basics, counseling for deficiencies consists of six steps:

1. Reinforce relationships. Set the relationship between the person being counseled and the counselor at the beginning of the session. The person counseled (junior) should be aware that the deficiency is not approved by the command or the counselor (senior).

2. Identify the problem. The person being counseled may not have been aware that the action/inaction was a problem. In identifying the problem the person must be made aware why the deficiency is a problem.

3. Acknowledgement. In order to expect positive change, the person being counseled must agree that the deficiency pointed out is in fact a deficiency and requires change.

4. Goal identification. Once the deficiency is identified, it is the counselor's job to help the subordinate identify the means by which the deficiency will be corrected In setting the goal for correction, the time allowed for the correction to take place must be defined.

5. Termination of the counseling session. In terminating the session, the counselor reinforces that the subordinate is a worthwhile member of the team and his or her welfare is a valid concern of the command and the counselor.

6. Follow up. At the preset time setup in the goal identification, the counselor must see that the deficiency has been corrected. Periodic monitoring after that should prevent further problems.

Used correctly, counseling will prevent most problems from becoming serious or out-of-hand. Counseling records, both good and bad, are valuable sources of information when writing performance evaluations.

TRAINING PROGRAMS

As an EM1 or EMC, you are required to establish and/or maintain a training program for your work center personnel. On smaller ships you might be the division officer, responsible for a number of work centers. In these programs you are required to teach the proper methods of equipment operation, repair, and safety. You should use all the materials available to you, including teaching aids such as manufacturer's technical manuals, instructions, or training manuals. In addition you should know what schools are available to your workers and try to get quotas for eligible and deserving personnel (for example, EM A or C).

Apprenticeship Training

The Apprenticeship Program for Electrical Repairers (DOT Code 829.28 1-014) was started in 1976. It was established under the authority of the Secretary of the Navy and Secretary of Labor as the National Apprentice Standards for the United States Navy. The purpose of establishing the National Apprenticeship Standards for the United States Navy was to provide general policy and guidance to commanding officers responsible for normal and on-the-job rating training. It was also designed to develop and register with the National Office of the Bureau of Apprenticeship and Training, U.S. Department of Labor, programs of apprenticeship for active-duty naval personnel in occupations closely related and applicable to the needs and requirements of private industry. In many instances, current Navy training and on-the-job experience will, if properly documented, satisfy the requirements of private industry for the training of apprentices in nationally recognized occupations.

The objectives of the National Apprenticeship Standards of the United States Navy are the following:

1. Provide registered certification of the rate training of Navy personnel

2. Achieve recognition of the Navy person equal to his or her civilian counterpart.

Registration with the Bureau of Apprenticeship and Training (BAT), U.S. Department of Labor, for naval occupational specialties is mutually beneficial to the Navy, to the individual, and to private industry. You should ensure that your personnel are familiar with this program. Processing of applications for registration is administered by the Branch Head, EM A School SSC, NTC, Great Lakes.

Personnel Qualification Standards (PQS)

The PQS Program (OPNANINST 3500.34B) is a method of qualifying officer and enlisted personnel to perform assigned duties. PQS is a written compilation of knowledge and skills required to qualify for a specific watch station, maintain a specific equipment or system, or perform as a team member within the assigned unit. PQS is in the format of a qualification guide, which asks the questions a trainee must answer to verify readiness to perform a given task. It also provides a record of the progress and final certification. The PQS approach to training is based on individual learning. The learner has the complete written program in hand. The operational supervisor serves as both a source for specific assistance and as quality control over the learning process through certification of completion of each step. NAVEDTRA 43100-1, *Handbook on Personnel Qualification Standards,* provides information on the PQS concept and describes its implementation into the training program of operational units of the Navy.

SUMMARY

This chapter contains general information that should familiarize you with the EM rating, means of reducing accidents and preventing many hazardous conditions in engineering spaces and workshops, and the various administrative duties to which you may be assigned. For additional information, refer to *Naval Ship's Technical Manual,* chapters 079, volume 2,090, and 300, OPNAVINSTs 4110.2, 5100.19, and 5100.23, and NAVEDTRA 12081.

CHAPTER 2

ELECTRICAL INSTALLATIONS

The proper installation and maintenance of the various electrical systems aboard ship are the Electrician's Mate (EM) job. The repair of battle damage, alterations, and some electrical repairs may require changes or additions to the ship's cables and control and protective devices. You may be required to inspect, test, and approve new installations during shipyard overhaul or tender availabilities.

LEARNING OBJECTIVES

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

1. *ldentify electrical cables by classification, type and size designation, ratings, and characteristics.*
2. *Recognize the different types of deck risers, wireways, cable supports, and installations.*
3. *Identify the various protective devices that include relays and circuit breakers.*
4. *Recognize the purpose of and identify control devices, to include manually and electrically operated contacts, limit and float switches, and pilot control devices.*
5. *Recognize the purpose for ground cables and identify their requirements.*
6. *Identify various plugs and cords and their safe usage.*

ELECTRICAL CABLES

Shipboard electrical and electronic systems require a large variety of electrical cables. Some circuits require only a few conductors having a high current-carrying capacity. Other circuits require many conductors having a low current-carrying capacity. Other types of circuits may require cables with a special type of insulation; for example, the conductors may have to be shielded, or, in some cases, the conductors may have to be of a metal other than copper.

As an EM, you will work on electric cables. To do this, you must be able to recognize the purpose and identify various types, sizes, capacities, and uses of shipboard electrical cables. Also, you must be able to select, install, and maintain cables so they will be functional. To maintain an electrical system in proper operating condition, you must know the purpose, construction, installation, and required testing procedures for electrical cables.

An important reference for you is the *Cable Comparison Handbook,* MIL-HDBK-299 (SH). It contains information and current data for the new family of low-smoke (LS) cables authorized for shipboard use. This handbook provides information to supply and installation activities on the procurement and use of electrical shipboard cables, particular y the selection of suitable substitute cables for use if the specified types and sizes aren't immediately available. [t also contains information so you can select currently available items suitable for replacement of obsolete items.

For many years most of the shipboard power and lighting cables for fixed installation had silicone-glass insulation, a polyvinyl chloride jacket, and aluminum armor. The construction was watertight. The determination was made that cables with all these features were not necessary for many applications, especially within watertight compartments and noncritical areas above the watertightness level.

Cables jacketed with polyvinyl chloride give off toxic fumes and dense, impenetrable smoke when on fire. These hazards were noticed when an electrical fire smoldered through the cable ways aboard a naval ship. Because of the overwhelming amount of smoke and fumes, fire fighters were unable to effectively control the fire, which caused a lot of damage.

A new family of cable was designed to replace the silicone-glass insulation with polyvinyl chloride jacket. The new cable is constructed with a polyolefin jacket.

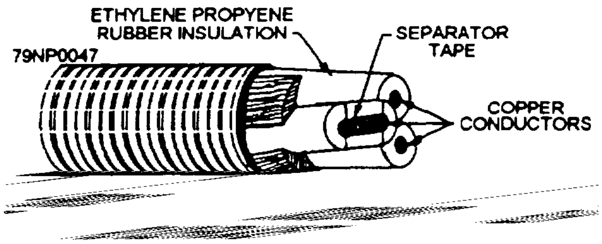


Figure 2-1.—Construction of low-smoke cable (typical).

The new design conforms to rigid toxic and smoke (fig. 2-1) indexes to effectively reduce the hazards associated with the old design. This new family of cables is electrically and dimensionally interchangeable with silicone-glass insulated cables of equivalent sizes. This cable is covered by Military Specification MIL-C-24643.

A family of lightweight cables has been introduced to help eliminate excessive weight from the fleet. Considering the substantial amount of cable present on a ship or submarine, a reduction in cable weight will impact on the overall load and improve performance and increase efficiency. This new family of lightweight cables is constructed from cross-linked polyalkene and micapolmide insulation and a cross-linked polyolefin jacket. The lightweight cable is covered by Military Specification MIL-C-24640.

TYPES AND SIZE DESIGNATIONS OF CABLES

Shipboard electrical cables are identified according tot type and size. Type designations consist of letters to indicate construction and/or use. Size designations consist of a number or numbers to indicate the size of the conductor(s) in circular mil area, number of conductors, or number of pairs of conductors, depending upon the type of cable.

The first part of the cable designation is the type letters, such as LS for low smoke. In most cases, the number of conductors in a cable identification includes up to four conductors; for example, S—single conductor, D—double conductor, T—three conductor, and F—four conductor. For cables with more than four conductors, the number of conductors is usually indicated by a number following the type letters. In this latter case, the letter M is used to indicate multiple conductor.

The new LS cable identification is shown in table 2-1. Two examples of common shipboard cable designations are as follows:

LSTSGU/A-9

LS — Low smoke

T — Three conductors

SG — Extruded silicone rubber and glass insulation, cross-linked polyolefin jacket

U — Unarmored

A — Armored

9 — Cross-sectional area in circular mils (column 5)

LSTHOF-42

LS — Low smoke

T — Three conductors

HO — Heat and oil-resistant

F — Flexible: ethylene propylene rubber insulation, cross-linked polyolefin jacket

42 — Cross-sectional area in circular mils (column 5)

Table 2-1.—Low-Smoke Cable Identification

MIL-C-	Cable type designation	Conductor size: AWG or MCM	Number of conductors in cable	Area of each conductor (MCM)	Cable overall diameter max. (inches)	Cable weight per ft approx (lbs)	Radius of bend min. (inches)	CDR ID	Rated voltage, max. (RMS)	Ampacity, each conductor (amps, max) dc or 60 Hz 40° C Ambient	Ampacity, each conductor (amps, max) dc or 60 Hz 50° C Ambient	Ampacity, each conductor (amps, max) 400Hz 40° C Ambient	Ampacity, each conductor (amps, max) 400Hz 50° C Ambient	NSN 6145-01
24643/1	LSCVSF- 4	3	3	52.620	1.450	1.328	9.0	STD-3	600	100	75	100	75	202-9490
		5	1	33.090	—	—	.	—	—	—	—	—	—	—
24643/3	LSDHOF- 3	16	2	2.580	0.425	0.101	3.0	STD-3[1/]	600	23	21	23	21	201-9494
	LSDHOF- 4	14	2	4.110	.460	.117	3.5	STD-3[1/]	600	30	28	30	28	202-7745
	LSDHOF- 6	12	2	6.530	.510	.150	4.0	STD-3[1/]	600	41	37	41	37	202-2036
	LSDHOF- 9	9	2	9.045	.570	.172	4.5	STD-3[1/]	600	50	45	50	45	202-2037
	LSDHOF- 14	14	2	14.070	.705	.293	5.0	STD-3[1/]	600	60	54	60	54	203-0365
	LSDHOF- 23	7	2	22.910	.860	.395	6.5	STD-3[1/]	600	80	72	80	72	202-2038
	LSDHOF- 30	5	2	33.090	.960	.690	7.5	STD-3[1/]	600	90	83	90	83	202-2039
	LSDHOF- 83	83	2	84.230	1.450	1.359	11.0	STD-3[1/]	600	169	152	169	152	202-0661
	LSDHOF- 250	250	2	252.700	2.100	2.811	17.0	STD-3[1/]	600	322	287	285	254	202-0662
	LSDHOF- 400	400	2	413.500	2.500	4.532	20.0	STD-3[1/]	600	422	382	290	262	202-0663
24643/3	LSFHOF- 3	16	4	2.580	0.480	0.130	4.0	STD-3[1/]	600	17	16	17	16	201-9495
	LSFHOF- 4	14	4	4.110	.550	.165	4.5	STD-3[1/]	600	23	21	23	21	202-0672
	LSFHOF- 9	9	4	9.045	.660	.281	5.5	STD-3[1/]	600	36	34	36	34	202-0673
	LSFHOF- 42	42	4	42.110	1.380	1.210	11.0	STD-3[1/]	600	79	73	79	73	202-0674
	LSFHOF- 60	60	4	61.260	1.510	1.550	12.0	STD-3[1/]	600	95	80	95	80	202-9491
	LSFHOF- 133	133	4	137.800	2.000	2.863	16.0	STD-3[1/]	600	163	148	155	140	202-0675
24643/3	LSSHOF- 3	16	1	2.580	0.210	0.027	1.5	STD-3[1/]	600	20	18	20	18	201-9530
	LSSHOF- 23	7	1	20.820	.460	.143	3.5	STD-3[1/]	600	88	80	88	80	201-9531
	LSSHOF- 60	60	1	61.260	.600	.341	5.0	STD-3[1/]	600	162	153	162	153	201-9532
	LSSHOF- 150	150	1	153.100	.870	.769	7.0	STD-3[1/]	600	285	263	285	263	210-4000
	LSSHOF- 200	200	1	199.100	.980	.966	8.0	STD-3[1/]	600	323	306	—	—	201-9533
	LSSHOF- 250	250	1	252.700	1.085	1.318	8.5	STD-3[1/]	600	397	362	—	—	202-2051
	LSSHOF- 500	500	1	500.000	1.450	2.585	11.5	STD-3[1/]	600	602	578	—	—	202-2052
	LSSHOF- 650	650	1	650.000	1.610	3.090	13.0	STD-3[1/]	600	698	658	—	—	202-2053
	LSSHOF- 800	800	1	812.700	1.670	3.306	13.5	STD-3[1/]	600	803	732	—	—	201-9534
24643/11	LSSSF- 300	300	1	300.000	1.100	1.287	6.6	--	600	—	—	—	—	204-5529
24643/3	LSTHOF- 3	16	3	2.580	0.450	0.094	3.5	STD-3[1/]	600	19	17	19	17	202-0664
	LSTHOF- 4	14	3	4.110	.480	.136	4.0	STD-3[1/]	600	25	23	25	23	205-3626
	LSTHOF- 6	12	3	6.530	.550	.179	4.5	STD-3[1/]	600	33	31	33	31	202-0665
	LSTHOF- 9	9	3	9.045	.600	.201	5.0	STD-3[1/]	600	38	34	36	34	202-0666
	LSTHOF- 14	14	3	14.070	.750	.346	6.0	STD-3[1/]	600	50	46	50	46	202-0667

79NPT048

You should note that there are only two changes to the cable designation, the LS and U/A additions to the cable identification.

Most cables and cords contain a continuous, thin, moisture-resistant marker tape directly under the cable or cord binder tape or jacket at less than 1-foot intervals. This tape contains the following information

1. The name and location of the manufacturer
2. The year of manufacture; the military specification number of the cable
3. The progressive serial number. The serial number is not necessarily a footage marker. A serial number is not repeated by a manufacturer in anyone year for anyone type and size of cable or cord.

CLASSIFICATIONS OF CABLES

Cables must have the ability to withstand heat, cold, dampness, dryness, bending crushing, vibration, twisting, and shock because of the varied service conditions aboard ship. No one type of cable has been designed to meet all of these requirements; therefore, a variety of types are used in a shipboard cable installation.

Cables are classified as watertight or nonwatertight, watertight or nonwatertight with circuit integrity construction, and armored or unarmored. They are further classified as being nonflexing service, flexing service, and special purpose.

Look at table 2-2, which shows the various classifications for cables used in power, lighting, control, electronic, and communication and instrumentation applications.

Watertight Cable

The term *watertight cable* indicates standard cable in which all spaces under the impervious sheath are filled with material. This eliminates voids and prevents the flow of water through the cable by hose action if an open end of cable is exposed to water under pressure.

Circuit Integrity

The term *circuit integrity* indicates the cable has been constructed in such a way as to provide added protection that will allow it to function for a longer period of time while under fire conditions. Because it has circuit integrity, vital circuits remain energized longer, allowing you to setup alternate sources of power.

Armored Cable

The term *armored cable* refers to a cable that has an outer shield of weaved braid. The braid is made of aluminum or steel and applied around the impervious sheath of the cable. This weaved braid serves only as physical protection for the vinyl cable jacket during the initial installation of the cable. Thereafter, it serves no useful purpose.

Nonflexing Service Cable

Nonflexing service cable, designed for use aboard ship, is intended for permanent installation, Cables used with lighting and power circuits are intended for nonflexing service. Nonflexing service can be further

Table 2-2.—Cable Classifications

MIL-C-24640	MIL-C-915	MIL-C-24643
Watertight (with circuit integrity), nonflexing service:	Watertight, flexing service:	Watertight, flexing service:
Power	Power	Power
Control	Control	Control
Electronic, communication, and instrumentation	Electronic, communication, and instrumentation	Electronic, communication, and instrumentation
		Nonwatertight, flexing service:
Watertight, nonflexing service:	Nonwatertight, flexing service:	Power and lighting
Electronic, communication, and instrumentation	Power and lighting	Electronic, communication, and instrumentation
	Electronic, communication, and instrumentation	Nonwatertight, nonflexing service:
Nonwatertight, nonflexing service:		Electronic, communication, and instrumentation
Power		Watertight, non-flexing service:
Electronic, communication, and instrumentation		Electronic, communication, and instrumentation

classified according to its application and is of two types—general use and special use.

GENERAL USE.— Nonflexing service cable can be used in nearly all parts of electric distribution systems, including the common telephone circuits and most propulsion circuits. Special cases occur in dc propulsion circuits for surface ships. In those cases where the impressed voltage is less than 1,000 volts, an exception is permitted.

LSDSGA (low-smoke, two-conductor, silicone rubber and glass-braided insulation, cross-linked polyolefin jacket, armored)is one type of cable usually found in this general use, nonflexing service. Also in this classification is LSMSCA (low-smoke, multiconductor, silicone rubber insulated-glass braided conductors, cross-linked polyolefin jacket, armored). This cable is nothing more than watertight cable used in interior communications, as well as in fire control circuits.

SPECIAL USE.— There are many shipboard electrical circuits that have special requirements for voltage, current, frequency, and service. These requirements must be met in cable installation. There are also other circuits where general-use, nonflexing service cable may meet the necessary requirements but be economical y impracticable. For these reasons, there are many different types of nonflexing service cable for specialized use, such as degaussing, telephone, radio, and casualty power. For example, LSMDU cable is a multiconductor cable used in degaussing circuits. LSTCJA cable consists of one conductor of constantan (red) and one conductor of iron (gray), and is used for pyrometer base leads.

Flexing Service Cable

Flexing service cable designed for use aboard ship is commonly referred to as being portable. It is principally used as leads to portable electric equipment. There are two types of flexing service cable—general use and special use.

GENERAL USE.— Repeated flexing service cable is used as leads to portable electric equipment and permanently installed equipment in places where cables are subjected to repeated bending, twisting, mechanical abrasion, oil, sunlight, or where maximum resistance to moisture is required. Its letter designation is LSHOF (low smoke, heat and oil resistant, flexible).

Repeated flexing service cable designed for general use is of four different types, depending on the number of conductors. This type cable is available in various conductor sizes and designated:

- LSSHOF (single conductor)
- LSDHOF (two conductor)
- LSTHOF (three conductor)
- LSFHOF (four conductor)

SPECIAL USE.— There are many different types of flexing service cable designed for special requirements of certain installations, including those used in communications lines (LSTTOP) and casualty power cables (LSTHOF). TRF cable is used for arc-welding circuits.

RADIO-FREQUENCY COAXIAL CABLES

Radio-frequency (RF) cables may look like power cables, but they require special handling and careful installation. RF cables are vital to the proper operation of all electronic equipment. They must be installed and maintained with the greatest care. The following is an example of a common RF cable having the properties shown below:

LSTTRSU/A The following is an example of the properties of a common radio-frequency cable:

LS — Low smoke

TT — Twisted pairs

R — Radio

S — Shielded flexible, cross-linked polyethylene insulation, braided shield for each pair, cross-linked polyolefin jacket

U — Unarmored

A — Armored

Flexible RF transmission lines (coax) are two-conductor cables. One conductor is concentrically contained within the other as shown in figure 2-2. Both

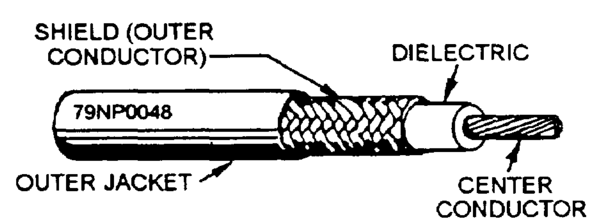


Figure 2-2—Construction of flexible RF transmission line.

conductors are essential for efficient operation of the transmission line. The proper connectors and terminations are also necessary for efficient operation of the line.

The inner conductor maybe either solid or stranded. It may be made of unplated copper, timed copper, or silver-plated copper. Special alloys may be used for special cables.

The dielectric insulating material is usually polyethylene or Teflon™.

- Polyethylene is a gray, translucent material. Although it is tough under general usage, it will flow when subjected to heavy pressure for a period of time.
- Teflon™ is a white opaque plastic material that withstands high temperatures and remains flexible at relatively low temperatures. It has a peculiar quality in that nothing will stick to it. Also, it is unaffected by the usual solvents.

Braided copper is usually used for the outer conductor, and it may be tinned, silver plated, or bare. The outer conductor is chosen to give the best electrical qualities consistent with maximum flexibility.

The protective insulating jacket is usually a synthetic plastic material (vinyl resin). Neoprene rubber is generally used on pulse cable; silicone rubber jackets are used for high-temperature applications.

Armor is needed for protection. It may be braided aluminum, or sometimes galvanized steel, similar to that used on power cables.

SELECTING CABLE

When selecting cable, use all reference data available. Electrical cables installed aboard Navy vessels must meet certain requirements determined by the Naval Sea Systems Command These requirements, published in the *General Specifications for Ships of the U.S. Navy* (NAVSEA S9AA0-AA-SPN-010/ GEN.SPEC), are too numerous to cover in detail in this TRAMAN; therefore, only the more basic requirements are included.

Two-conductor cable should be installed for two-wire, dc and single-phase, ac circuits. Three-conductor cable should be installed for three-wire, dc, or three-phase, ac circuits. Four-conductor cable should be installed where two two-wire lighting circuits are run in the same cable. Four-conductor and multi-conductor cable should be installed for control circuits and communications circuits as necessary.

To select the proper size cable for a particular installation, you must know the following:

- The total connected load current
- The demand factor
- The allowable voltage drop

To compute the total connected load current for dc power circuits, you add the sum of the rated current of the connected loads as listed on the identification plates of connected motors and appliances. Add an additional 100 watts for each receptacle not specifically indicated. To compute the total connected load current for ac power circuits, add the connected load current of the connected motors and appliances vectorially.

The demand factor of a circuit is the ratio of the maximum load averaged for a 15-minute period to the total connected load on the cable. If you cannot determine the feeder demand factor for a group of loads, you may assume a value of 0.9. For power systems supplying a single-phase load or for a lighting system branch, submain, and main circuits, the demand factor is unity.

The voltage drop (difference in voltage between any two points in a circuit) is expressed as a percentage of the rated switchboard (or switchgear group) bus voltage or the transformer nominal voltage. The maximum percentage of voltage drop allowed for a circuit is specified by the Naval Sea Systems Command and varies according to the intended service of the circuit.

CABLE INSTALLATION

EMs install cable whenever necessary to repair damage or to accomplish authorized ship alterations

(SHIPALTs). Before work is begun on a new cable installation, cableway plans should be available. If repairs to a damaged section of installed cable are to be made, information on the original installation can be obtained from the plans of the ship's electrical system. These plans are normally on file in the engineering department office (legroom) aboard ship. If a ship alteration is to be accomplished, applicable plans not already on board can be obtained from the naval shipyard listed on the authorization for the SHIPALT at the planning yard for the ship.

Installing the Cables

Before installing new cable, you should survey the area to see if there are spare cables in existing wireways and spare stuffing tubes that can be used in the new installation. The following considerations should be made when planning the cable run:

- Locate the cable so damage from battle will be minimized, to include running cables along different well-separated paths to reduce the probability of battle damage to several cables simultaneously.
- Locate the cable run so physical and electrical interference with other equipment and cables will be avoided
- Locate the cable so maximum dissipation of internally generated heat will occur.
- Do not run cables on the exterior of the deckhouse or similar structures above the main deck, except where necessary because of the location of the equipment served, structural interferences, or to avoid hazardous conditions or locations.
- Where practicable, route vital cables along the inboard side of beams or other structural members. This location will give maximum protection against damage by flying splinters or machine-gun strafing.
- When running cables, avoid possible high-temperature locations, if possible.
- Run pulse cables separately, when possible, to reduce coupling and interference.
- Because attenuation (power loss) in a line increases with its length, keep cables as short as practicable. With the use of short lengths of cable, high-temperature locations, sharp bends, and strain on the cable can be avoided.
- Keep the number of connectors to a minimum to reduce line losses and maintenance problems.

Flexible cables are flexible only in the sense that they will assume a relatively long bend radius. They are not intended to be stretched, compressed, or twisted; they are to be installed with this in mind. The flexibility of cables can be expressed by their minimum bend radius.

The measurement point for minimum radius of bend should be that surface of the cable that is on the innermost portion of the cable bend. Dimensions listed in the *Cable Comparison Handbook* (MIL-HDBK-299(SH)) are approximately 8 times the overall diameter of the cable or cord. During the installation process, the minimum radius should be about 12 times the cable diameter for conduit bends, sheaves, and other curved surfaces around which the cable or cord may be pulled under tension.

Fabricated straps are used for holding the cables. They are snug, but not too tight. Back straps (used to keep the cable away from a surface) are used for cable runs along masts or in compartments that are subject to sweating. In more recent installations, semicontour straps and cable bands are used for certain applications.

The exact methods that you should use to install cables are included in the *Electronics Installation and Maintenance Book,* NAVSEA 0967-000-0110. The *Cable Comparison Guide,* NAVSEA 0981-052-8090, contains information about all types of electrical shipboard cable that was installed before 1986.

For elementary and isometric blueprints of ship's electrical cable wiring diagrams, their care and stowage, and the correction of blueprints after modification of their circuits, refer to *Blueprint Reading and Sketching,* NAVEDTRA 12014.

Cable Ends

When connecting a newly installed cable to a unit of electrical equipment, the first thing you should determine is the proper length of the cable. Then, you remove the armor (if installed) and impervious sheath, trim the cable, and finish the end.

1. Determine the correct length by using the following procedure:

- Form the cable run from the last cable support to the equipment by hand. Allow sufficient slack and bend radius to permit repairs without renewal of the cable.

- Carefully estimate where the armor, if applicable, on the cable will have to be cut to fit the stuffing tube (or connector) and mark the location with apiece of friction tape. Besides serving as a marker, the tape will prevent unraveling and hold the armor in place during cutting operations.

- Determine the length of the cable inside the equipment, using the friction tape as a starting point. Whether the conductors go directly to a connection or form a laced cable with breakoffs, carefully estimate the length of the longest conductor. Then add approximately 2 1/2 times its length, and mark this position with friction tape. The extra cable length will allow for mistakes in attaching terminal lugs and possible rerouting of the conductors inside the equipment. You now know the length of the cable and can cut it.

2. Next the armor, if installed, must be removed. Use a cable stripper of the type shown in figure 2-3. Be careful not to cut or puncture the cable sheath where the sheath will contact the rubber grommet of the nylon stuffing tube (fig. 2-4). The uses and construction of stuffing tubes will be described later in this chapter.

3. Remove the impervious sheath, starting a distance of at least 1 1/4 inches (or as necessary to fit the requirements of the nylon stuffing tube) from where

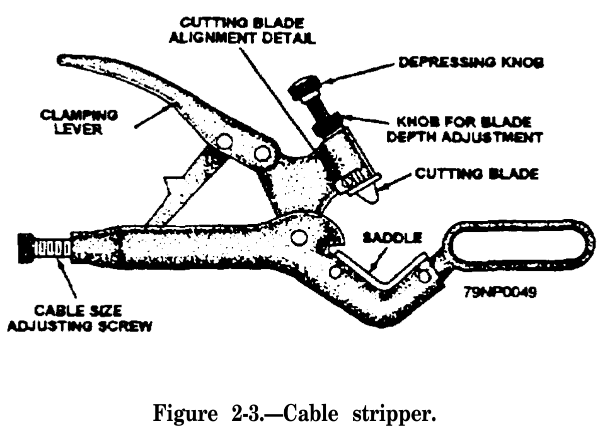


Figure 2-3.—Cable stripper.

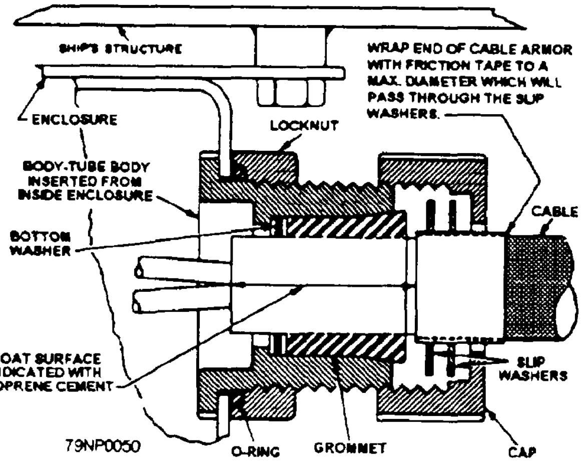


Figure 24.—Representative nylon stuffing tube installations.

the armor terminates. Use the cable stripper for this job. Do not take a deep cut because the conductor insulation can be easily damaged. Flexing the cable will help separate the sheath after the cut has been made. Clean any paint from the surface of the remaining impervious sheath exposed by the removal of the armor (this paint will conduct electricity).

4. Once the sheath has been removed, trim the cable filler with a pair of diagonal cutters.

5. There are several methods for finishing and protecting cable.

- The proper method for finishing and protecting cable ends not requiring end sealing is shown in figure 2-5. For cables entering enclosed equipment (such as connection boxes, outlet boxes, fixtures, etc.), use the method shown in figure 2-5, view A.

- An alternate method (when synthetic resin tubing is not readily obtainable) is to apply a coat of air-drying insulation varnish to the insulation of each conductor as well as to the crotch of the cable. The end of the insulation on each conductor is reinforced and served with treated glass cord, colored to indicate proper phase marking.

- For watertight cables entering open equipment (such as switchboards), use the method shown in figure 2-5, view B. An alternate method is shown in figure 2-5, view C.

- For nonwatertight cables entering open equipment, use the methods as shown in figure 2-5, views D and E.

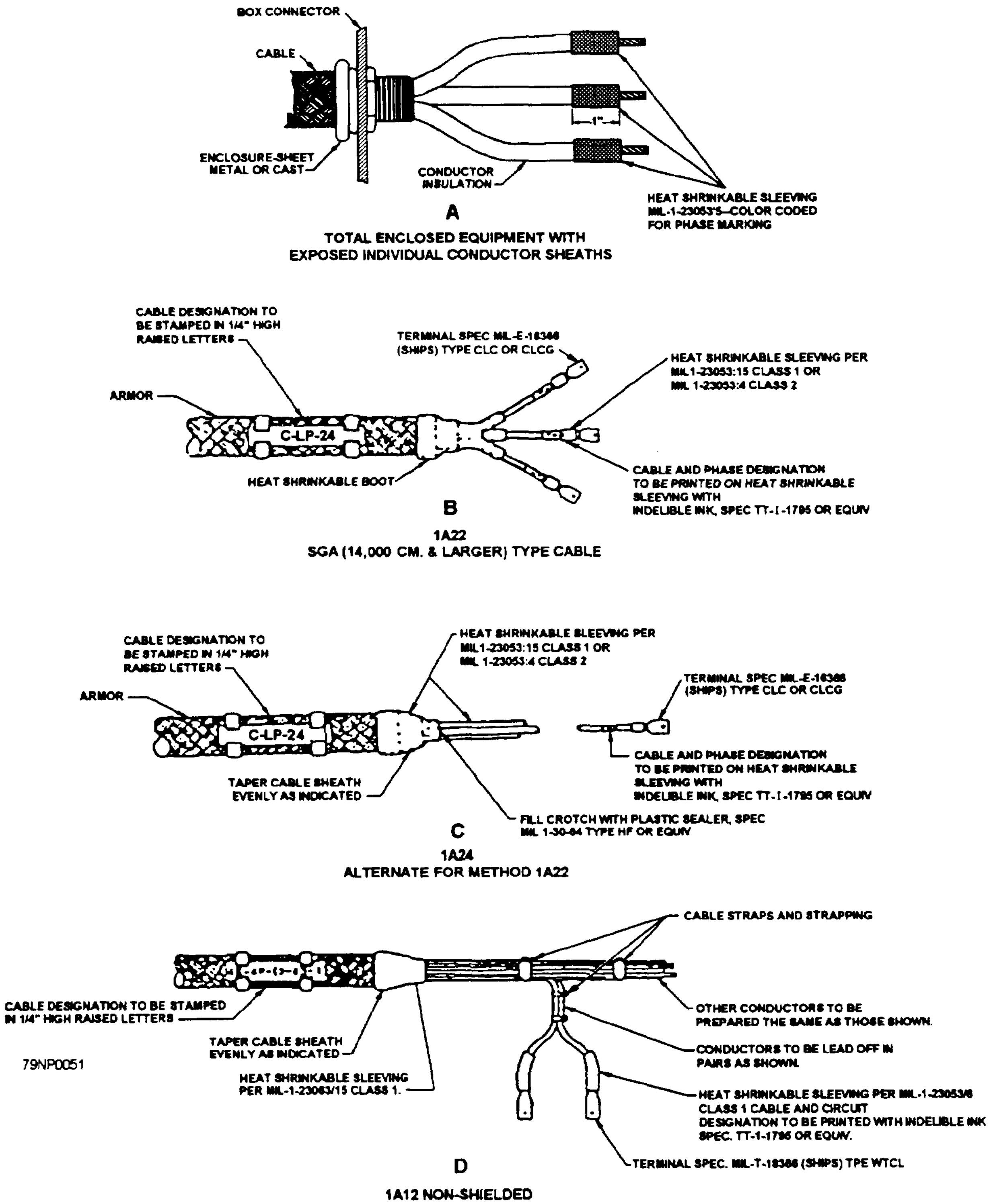
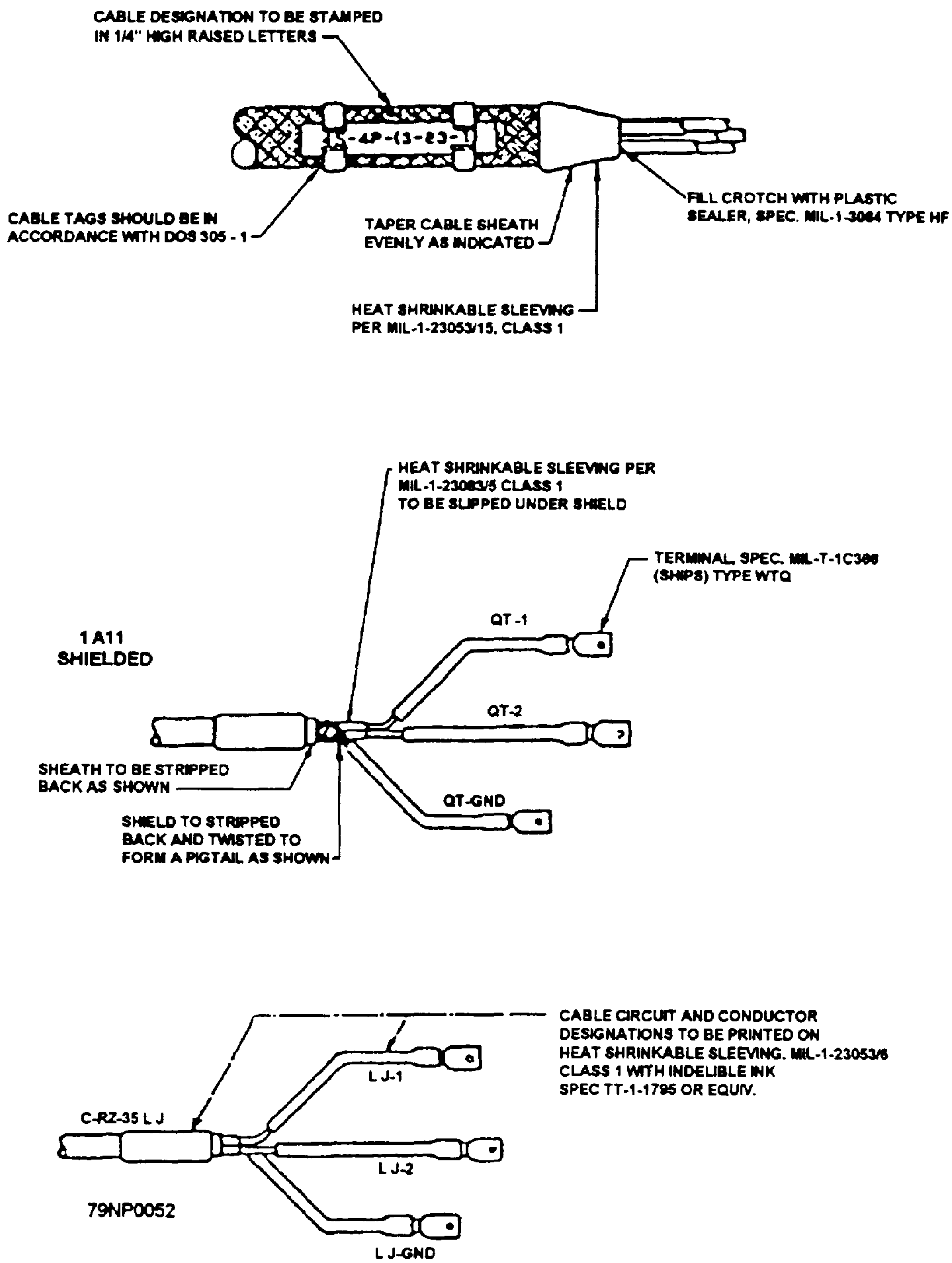
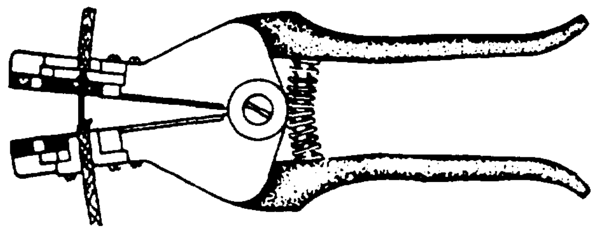


Figure 2-5.—Protecting cable ends.



E

Figure 2-5.—Protecting cable ends—Continued.



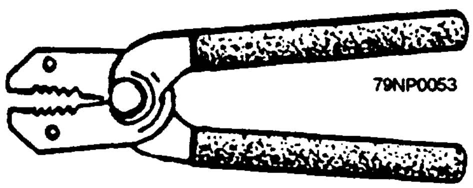


Figure 2-6.—Wire strippers.

Conductor Ends

Wire strippers (fig. 2-6) are used to strip insulation from the conductors. You must be careful not to nick the conductor stranding while removing the insulation. Do not use side or diagonal cutters for stripping insulation from conductors.

Thoroughly clean conductor surfaces before applying the terminals. After baring the conductor end for a length equal to the length of the terminal barrel, clean the individual strands thoroughly and twist them tightly together. Solder them to form a neat, solid terminal for fitting either approved clamp lugs or solder terminals. If the solder terminal is used, tin the terminal barrel and clamp it tightly over the prepared conductor (before soldering) to provide a solid mechanical joint. You do not need to solder conductor ends for use with solderless terminals applied with a crimping tool. Don't use a side or diagonal cutter for crimping solderless terminals.

Solderless terminals may be used for lighting, power, interior communications, and fire control applications. However, equipment provided with solder terminals by the manufacturer and wiring boxes or equipment in which electrical clearances would be reduced below minimum standards require solder terminals.

For connection under a screwhead where a standard terminal is not practicable, you can use an alternate method. Bare the conductor for the required distance and thoroughly clean the strands. Then twist the strands tightly together, bend them around a mandrel to form a suitable size loop (or hook where the screw is not removable), and dip the prepared end into solder. Remove the end, remove the excess solder, and allow it to cool before connecting it.

After the wiring installation has been completed, measure the insulation resistance of the wiring circuit with a Megger or similar (0- to 100-megohm, 500-volt dc) insulation resistance measuring instrument. Do not energize a newly installed, repaired, or modified wiring circuit without making sure (by insulation tests) that the circuit is free of short circuits and grounds.

Small refrigerators, drinking fountains, and coffee makers are plugged into receptacles connected directly to the ship's wiring. To remove stress from the equipment terminal block and its connected wiring, rigidly clamp the cable to the frame of the equipment close to the point where the cable enters the equipment.

Conductor Identification

Each terminal and connection of rotating ac and dc equipment, controllers, and transformers is marked with standard designations. This is done with synthetic resin tubing or fiber wire markers located as close as practicable to equipment terminals, with fiber tags near the end of each conductor, or with a stamp on the terminals.

Individual conductors may also be identified by a system of color coding. Color coding of individual conductors in multi conductor cable is done according to the color coding tables contained in *Naval Ships' Technical Manual,* Chapter 320.

The color coding of conductors in power and light cables is shown in table 2-3. Neutral polarity,(±), where it exists, is always identified by the white conductor.

Cable Markings

Metal tags embossed with the cable designation are used to identify all permanently installed shipboard electrical cables. These tags, when properly applied, make it easy to identify cables for maintenance and replacement purposes.

The marking system for power and lighting cables consists of three parts in sequence: source, voltage, and service. Where practical, the destination of the cable is shown as well. Each of the parts are separated by hyphens.

Table 2-3.—Color Code for Power and Lighting Cable Conductor

System	No. of Conductors in Cable	Phase or Polarity	Color Code
Three-phase ac	3	A	Black
		B	White
		C	Red
	2	AB	A, black
			B, white
	2	BC	B, white
			C, black
	2	AC	A, black
			C, white
Three-wire dc	3	+	Black
		±	White
		–	Red
	2	+ and ±	+, black
			±, white
	2	± and –	±, white
			–, black
	2	+ and –	+, black
			–, white
Two-wire dc	2	+	Black
		–	White

Letters used to designate the different services are shown in table 2-4.

Voltages below 100 volts are designated by the actual voltage, for example, 24 for a 24-volt circuit. The number "1" is used to indicate voltages between 100 and 199; "2" for voltages between 200 and 299; "4" for voltages between 400 and 499; and so on. For a three wire (120/240), dc system or a three-wire, three-phase system, the number used indicates the higher voltage.

The destination of cables beyond panels and switchboards is not designated except that each circuit alternately receives a letter, a number, a letter, and so on progressively, each time it is fused. The destination of power cables to power consuming equipment is not

Table 2-4.—Cable service designation letters

SERVICES	DESIGNATIONS
Cathodic protection	CPS
Control, power plant & ship	K
Degaussing	D
Electronics	R
Fire control	G
Interior communications	C
Lighting, emergency	EL
Lighting, navigational	N
Lighting, ship service	L
Minesweeping	MS
Night flight lights	FL
Power, casualty	CP
Power, emergency	EP
Power, propulsion	PP
Power, ship service	P
Power, shore connections	PS
Power, special frequency	SF
Power, weapon system	WP
Power, weapon system, 400 Hz	WSF

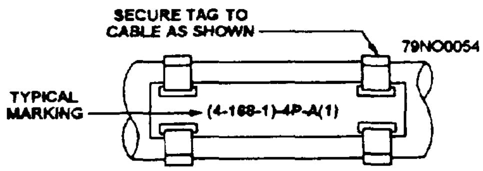


Figure 2-7.—Cable tag.

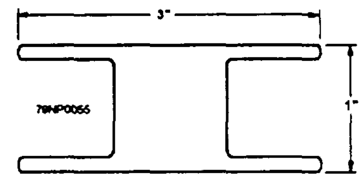


Figure 2-8.—A lacing shuttle.

designated except that each cable receives a single-letter alphabetical designation, beginning with the letter A.

Where two cables of the same power or lighting circuit are connected in a distribution panel or terminal box, the circuit classification is not changed. However, the cable markings have a suffix number (in parentheses) indicating the cable section. For example, (4-168-1)4P-A(1) (fig. 2-7) identifies a 450 volt power cable supplied from a distribution panel on the fourth deck at frame 168 starboard. The letter A indicates that this is the first cable from the panel, and the (1) indicates that it is the first section of a power main with more than one section.

The power cables between generators and switchboards are labeled according to the generator designation. When only one generator supplies power to a switchboard, the generator will have the same number as the switchboard plus the letter G. Therefore, you know that 1SG denotes one ship service generator that supplies power to 1S switchboard. When more than one generator supplies power to a switchboard, the first generator (determined by the general rule for numbering machinery) will have the letter A immediately following the designation; the second generator that supplies power will have the letter B following the designation; and so on. Therefore, 1SGA and 1SGB denote two ship service generators that supply ship service switchboard 1S.

Lacing Conductors

Conductors within equipment must be kept in place to present a neat appearance and to make it easier to trace conductors when alterations or repairs are required. When conductors are properly laced, they support each other and form a neat, single cable.

The most common lacing material is waxed cord. The amount of cord required to single lace a group of conductors is approximately 2 1/2 times the length of the longest conductor in the group. Twice this amount is required if the conductors are to be double laced.

Normally, conductors are laid out straight and parallel to each other before to lacing since this makes conductor lacing and tracing easier. However, some installations require the use of twisted wires. One example of a twisted wire installation is the use of twisted pairs for the ac filament leads of certain electron tube amplifiers. This reduces the effect of radiation of their magnetic field and helps to prevent annoying hums in the amplifier output. When you replace any wiring harness, duplicate the original layout.

A shuttle on which the cord can be wound will keep the cord from fouling during the lacing operations. A shuttle similar to the one shown in figure 2-8 may easily be fashioned from aluminum, brass, fiber, or plastic scrap. The edges of the material used for the shuttle should be smoothed to prevent injury to the operator and damage to the cord. To fill the shuttle for single lace, measure the cord, cut it, and wind it on the shuttle. Double lacing is done like single lacing, except that the length of the cord before winding it on the shuttle is doubled. Also, start the ends on the shuttle to leave a loop for starting the lace.

Before starting, terminating, and splicing knots, apply a binder such as GLYPTOL to the knots.

Start the single lacing procedure by using a clove hitch, with an overhand knot tied over the clove hitch (fig. 2-9, view A). Lockstitch lacing is shown in (fig. 2-9, view B). The cable is laced its entire length using

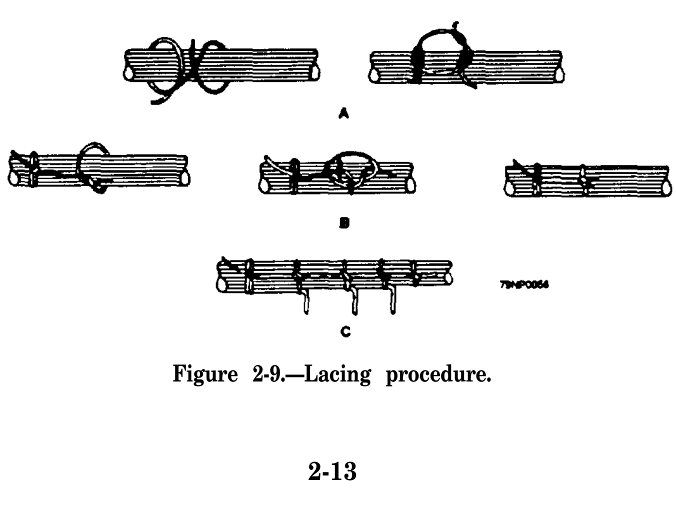


Figure 2-9.—Lacing procedure.

the lockstitch as shown in (fig. 2-9, view C). The lacing is terminated with two lockstitches. Use the same procedure when using a double wrap of lacing twine.

Place lockstitching immediately next to and on both sides of breakouts that are to be laced. Anchor the lacing of auxiliary lines and final breakouts to the main section by passing the lacing twine through the two lockstitches on the main section and then using the starting hitch and knot (fig. 2-9, view A).

On cable sections 5/8 inch or smaller in diameter, the space between the lockstiches must be 1/2 inch to 3/4 inch On cable sections larger than 5/8 inch in diameter, the spacing must be 1/2 inch to 1 inch. On cable sections larger than 5/8 inch in diameter, use a double wrap of lacing.

Double lace is applied in a reamer similar to single lace, except that it is started with the telephone hitch and is double throughout the length of the lacing (fig. 2-10). You can terminate double as well as single lace by forming a loop from a separate length of cord and using it to pull the end of the lacing back underneath a seining of about eight turns (fig. 2-11).

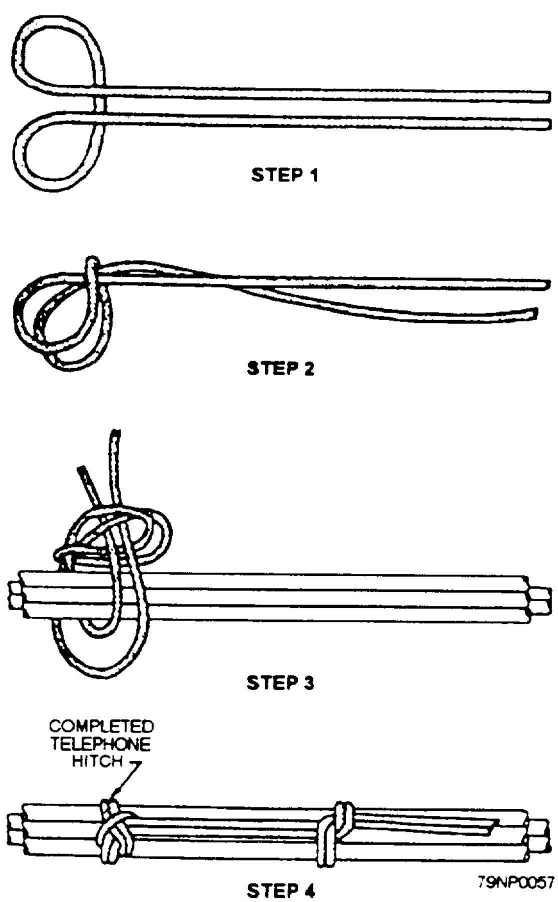


Figure 2-10.—Starting double lace with the telephone hitch.

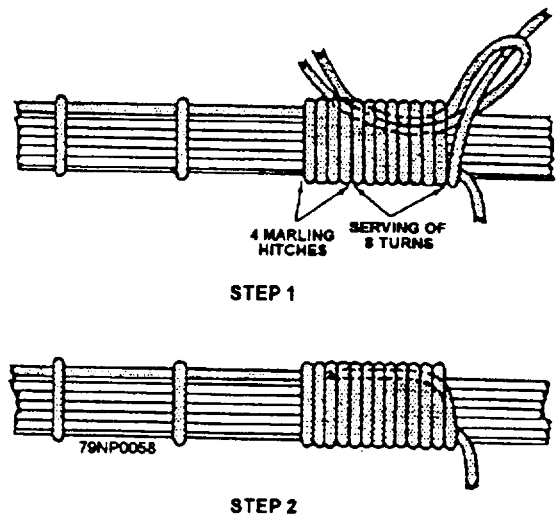


Figure 2-11.—The loop method of terminating the lace.

Lace the spare conductors of a multiconductor cable separately. Then secure them to active conductors of the cable with a few telephone hitches. When two or more cables enter an enclosure, lace each cable group separately. When groups parallel each other, bind them together at intervals with telephone hitches (fig. 2-12).

You should serve conductor ends (3,000 cm or larger) with cord to prevent fraying of the insulation (fig. 2-13). When conductor ends are served with glass cord colored for phase marking, make sure that the color of the cord matches the color of the conductor insulation

CABLE MAINTENANCE

The primary purpose of electrical cable maintenance is to preserve the insulation resistance. To preserve the insulation resistance, you must know the characteristics of the insulating materials used in naval shipboard electrical equipment. You must also know the factors that affect insulation resistance.

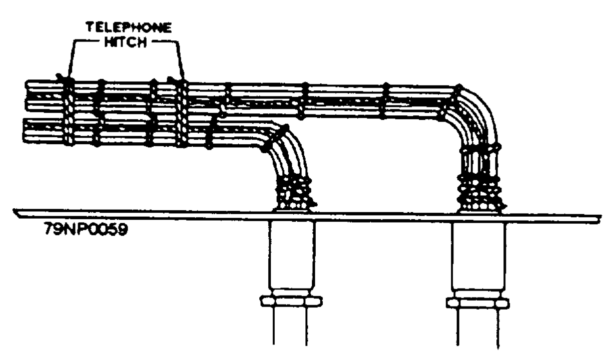


Figure 2-12.—Binding cable groups with the telephone hitch.

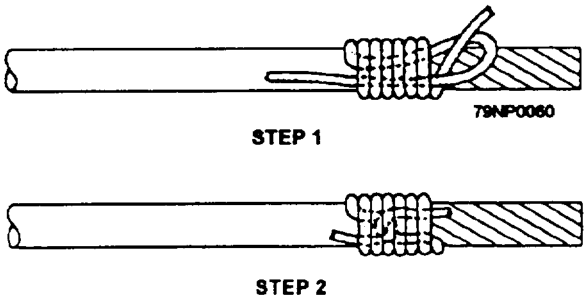


Figure 2-13.—Serving conductor ends.

Insulation

Their are two purposes of insulation on electric cables and equipment:

1. To isolate current-carrying conductors from electrically conductive structural parts
2. To insulate points of unequal potential on conductors from each other.

Normally, the conductivity of the insulation should be sufficient y low to result in negligible current flow through or over the surface of the insulation.

Electrical insulating materials used in naval shipboard electrical equipment (including cables) are classified according to their temperature indexes. The temperature index of a material is related to the temperature at which the material will provide a specified life as determined by test, or as estimated from service experience. To provide continuity with past procedures, the preferred temperature indexes given in table 2-5 are used for insulating materials that, by test or experience, fall within the temperature ranges indicated.

Table 2-5.—Temperature Indexes of Insulating Materials

Temperature Range (°C)	Temperature Index
105 through 129	105
130 through 154	130
155 through 179	155
180 through 199	180
200 through 219	200
220 through 249	220
250 and above	None established

The purpose of assigning each material a definite temperature index is to make it easier to compare materials and to provide a single designation of temperature capability for purposes of standardization. Some of the classes of insulation are discussed in this section.

Class O insulation. Class O insulation consists of cotton, silk, paper, and similar organic materials that are not impregnated or immersed in a liquid dielectric. Class O insulation is seldom used by itself in electrical equipment.

Class A insulation. Class A insulation consists of the following:

1. Cotton, paper, and similar organic materials when they are impregnated or immersed in a liquid dielectric
2. Molded and laminated materials with cellulose filler, phenolic resins, and other resins of similar properties
3. Films and sheets of cellulose acetate and other cellulose derivatives of similar properties
4. Varnish (enamel), as applied to conductors.

Class B insulation. Class B insulation consists of mica, asbestos, fiber glass, and similar inorganic materials in built-up form with organic binding substances.

Class H insulation. Class H insulation consists the following:

1. Mica, asbestos, fiberglass, and similar inorganic materials in built-up form with binding substances composed of silicone compounds or materials with equivalent properties; and
2. Silicone compounds in the rubbery or resinous forms, or materials with equivalent properties.

Class C insulation. Class C insulation consists entirely of tics, glass, quartz, and similar inorganic material. Class C materials, like class O, are seldom used alone in electrical equipment.

Class E insulation. Class E insulations an extruded silicone rubber dielectric used in reduced-diameter electric cables in sizes 3, 4, and 9. Special care should be exercised in handling the cables to avoid sharp bends and kinks that can damage the silicone rubber insulation on the old types that did not employ a nylon jacket over each insulated conductor.

Class T insulation. Class T insulation is a silicone rubber treated glass tape. It is also used in reduced-diameter cables in sizes 14 through 2000.

For an idea of some insulation uses, look at the table shown below:

INSULATION USE	INSULATION CLASS
Propulsion generators and motors	Class B
Ship's service and emergency generators	Either class A, B, or H materials; however, the trend is away from class A
Auxiliary motors	Usually class A, although the trend is toward class B and class H materials
Lighting transformers for 60-hertz service	Class B insulated
Lighting transformers for 400-hertz service	Class H
Miscellaneous coils for control purposes	Class A, B, or H; however, the majority of such coils are class A insulated

Temperature Effects on Insulation.

Very high temperatures that produce actual burning or charring may destroy insulation in a few seconds. It is important to maintain operating temperatures of electrical equipment within their designed values to avoid premature failure of insulation Temperatures only slightly in excess of designed values may produce gradual deterioration, which, though not immediately apparent, shortens the life of the insulation. As a rule of thumb, thermal aging will cause the life of insulation will decrease by 1/2 for every 10° to 15°C increase in the operating temperature above the rated temperature for the insulation class.

Insulation system classes are designated by letters, numbers, or other symbols and may be defined as assemblies of insulation materials in association with equipment parts. Table 2-6 shows the insulation system classification used for Navy electrical equipment based on limiting temperatures. The limiting temperatures of an insulation system may be established by test or by service, and depend on an observable temperature rise of the equipment, design ambient temperature, and hot-spot temperature. The difference between the insulation limiting temperature and the sum of the ambient and temperature rise temperatures is the additional temperature allowed for the hot-spot temperature.

The ultimate temperature rise of electrical equipment is reached when the rate at which heat is developed equals the rate at which heat is transferred to the surrounding atmosphere. The heat developed by electrical equipment can usually be accurately measured. However, the temperature of the immediate surrounding area (ambient temperature) can become critical to the equipment if proper ventilation is not maintained.

The maximum allowable temperature rise and the design ambient temperature allowed for electrical equipment are usually shown on equipment nameplates, on equipment drawings, and in technical manuals for specific equipment. When information is not available from these sources, refer to *NSTM,* chapter 300, for information on the maximum permissible temperature rises.

The engineering design of ships takes into account the relationship of cable sizes and resistances with the cable load currents and temperatures.

Insulation Resistance Measurements.

The insulation resistance of shipboard electrical cable must be measured periodically with an insulation-resistance-measuring instrument (Megger) to determine the condition of the cable. Measurements

Table 2-6.—Limiting Temperature of Insulation systems

Limiting Temperature (°C)	Insulation System Letter Class	Insulation System Number Class
105	A	105
130	B	130
155	F	155
180	H	180
200	N	200
220	R	220
240	S	240

should be made on each individual leg of dc circuits and each individual phase lead of three-phase ac circuits.

For lighting circuits, the legs or phase leads should include all panel wiring, terminals, connection boxes, fittings, fixtures, and outlets normally connected. The lights should be turned off at their switches and all plugs removed from the outlets (fig. 2-14). If local lighting switches are double pole, the insulation resistance of the local branch circuit will not be measured when the switch is open. In such cases, making an insulation test from one leg or phase lead to ground with the local switches closed will determine whether grounds exist on the circuits and fixtures.

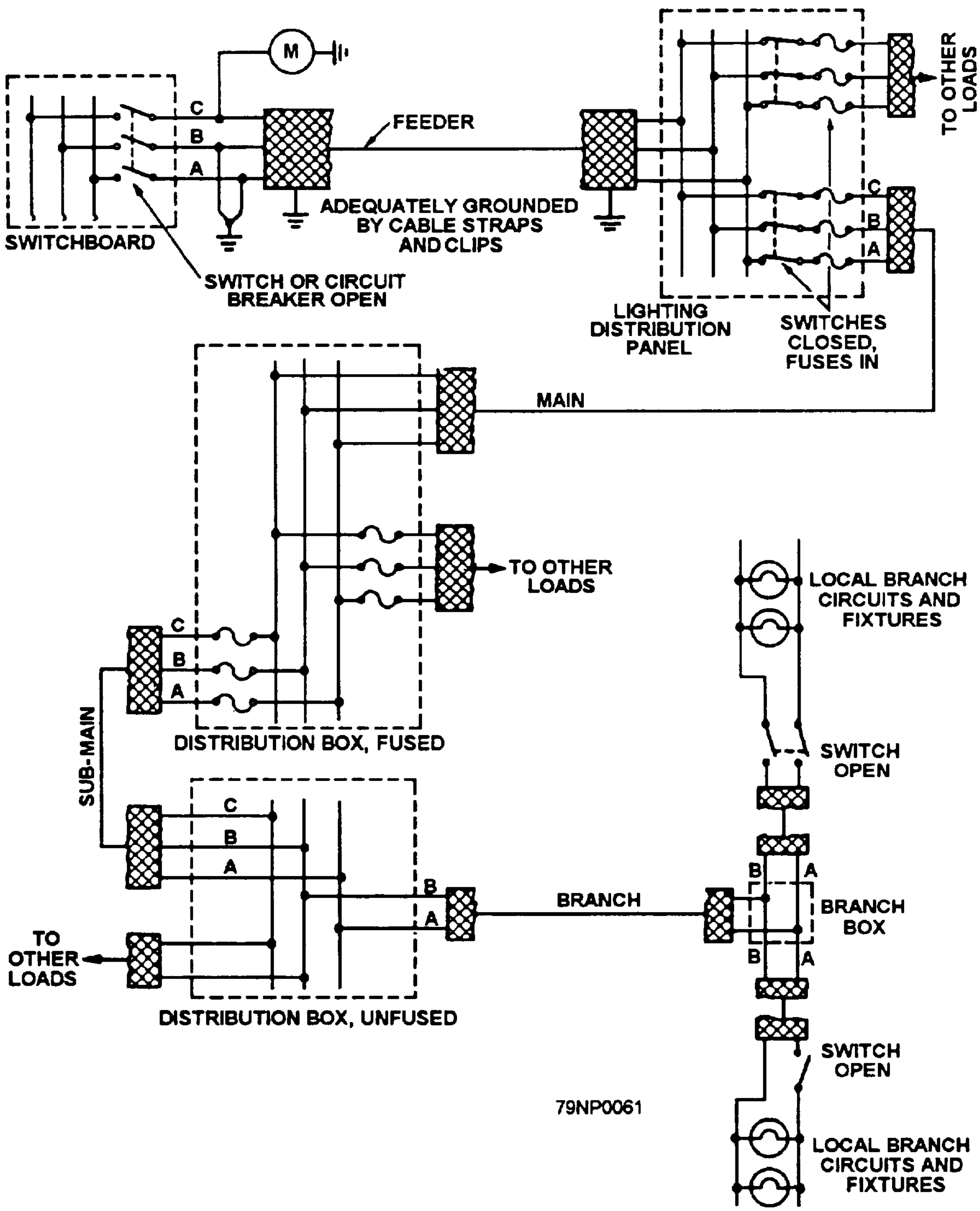


Figure 2-14.—Measuring insulation resistance of a lighting circuit.

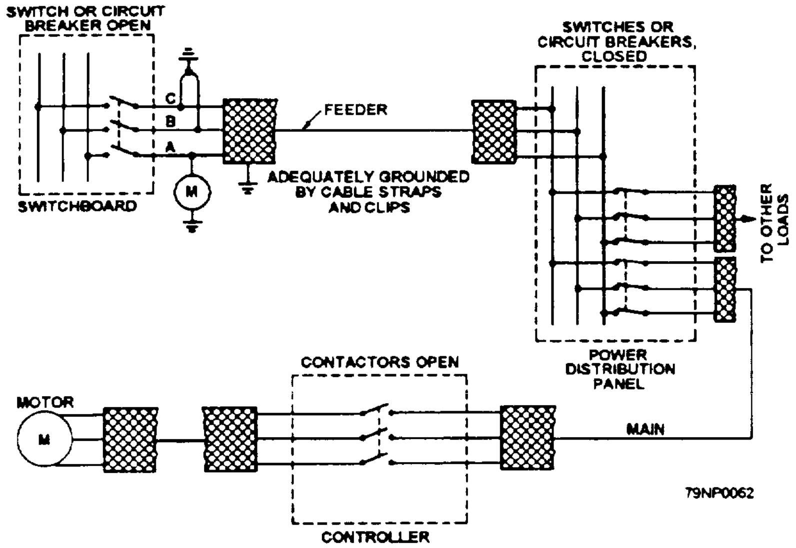


Figure 2-15.—Measuring insulation resistance of a power circuit.

In power circuits (fig. 2-15), include the legs or phase leads, panel wiring terminals, connection boxes, fittings, and outlets (plugs removed).

For degaussing circuits, you should take measurements at a degaussing coil connection box; include in the legs measured the coil cables, through boxes, and feeder cables. Disconnect the supply and control equipment by opening the circuit on the coil side of the control equipment. Measure the compass-compensating coil feeder cable with all control equipment disconnected. Additional information on tests of degaussing installations is obtained in *NSTM,* chapter 475, and in the degaussing folder furnished with each degaussing installation.

As you use the table, refer to figure 2-16. You should make measurements of the lighting, power, and degaussing circuits as shown in table 2-7.

These resistance measurements are considered satisfactory if they are not less than 1 megohm for each complete power circuit or at least 0.5 megohm for each complete lighting circuit. Circuits that have been de-energized for at least 4 hours are classed as either warm ambient or cold ambient.

NOTE: A *warm ambient* is defined as a warm climate or a condition in which the entire cable is in a heated space and not in contact with the ship's hull. A *cold ambient* is defined as a cold climate or a condition in which most of the cable is in an unheated space or is against the ship's hull in cold waters.

The cable temperature should be considered to be 104°F if the cable has been energized for 4 hours, 70°F if it is de-energized in a warm ambient, and 40°F if it is de-energized in a cold ambient.

Look at figure 2-17, which shows a nonograph for obtaining resistance per foot. Select the point of allowable resistance per foot based on the ambient condition and the type of cable. Using the nomograph, draw a straight line from the measured insulation resistance to the length of cable. The line should cross the resistance per foot line above the selected minimum resistance per foot point. Corrective action is required if the resistance per foot is less than the selected point.

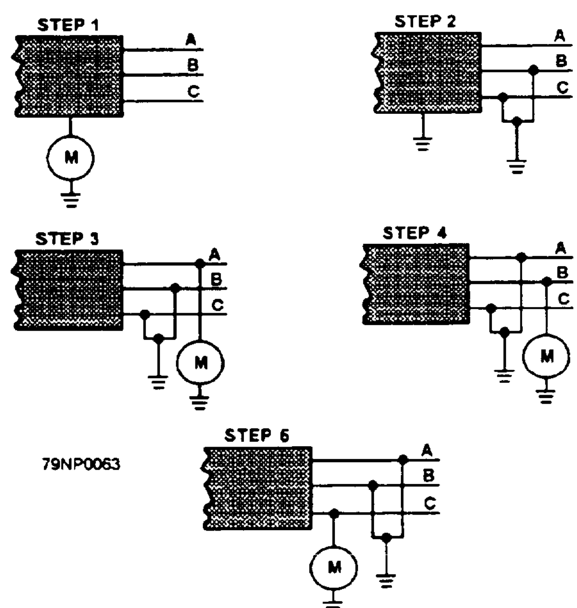


Figure 2-16.—Measuring circuit insulation resistance.

Table 2-7.—Measuring Circuit Insulation Resistance

STEP NUMBER	ACTION
Step 1	Check to see that the cable armor is adequately grounded by measuring between the cable armor and the metal structure of the vessel (fig. 2-16, step 1). Normally, grounding has been accomplished with cable straps. If a zero reading is not obtained, ground the cable armor.
Step 2	Select one lead to be measured, and connect all the other leads in the cable together. Ground them with temporary wires (fig. 2-16, step 2).
Step 3	Measure the resistance of the lead being tested to ground (fig. 2-16, step 3). Apply the test voltage until a constant reading is obtained. Crank the hand-driven generator instruments (Meggers) for at least 30 seconds to ensure a steady reading.
Steps 4	Repeat steps 2 and 3, as necessary, to measure each leg or phase lead to ground (fig. 2-16, steps 4 and 5). When circuits contain permanently connected paths between legs or phases, such as transformers, indicator lights, or control relays, take measure- ments only between one lead and ground. However, low readings may require further tests.

You need to remember mind that you cannot use a 400-volt dc Megger to check insulation resistance on circuits where semiconductor control devices are involved. You should use an electron tube megohmmeter to check insulation resistance on circuits and components where the insulation resistance must be checked at a much lower potential. The megohmmeter operates on internal batteries. When circuits or components under test contain a large electrical capacity, the megohmmeter READ button must be depressed for a sufficient time to allow its capacitor to charge before a steady reading is obtained. The test voltage applied by the megohmmeter to an unknown resistance is approximately 50 volts when resistances of approximately 10 megohms are measured and slightly greater than this when higher resistances are measured.

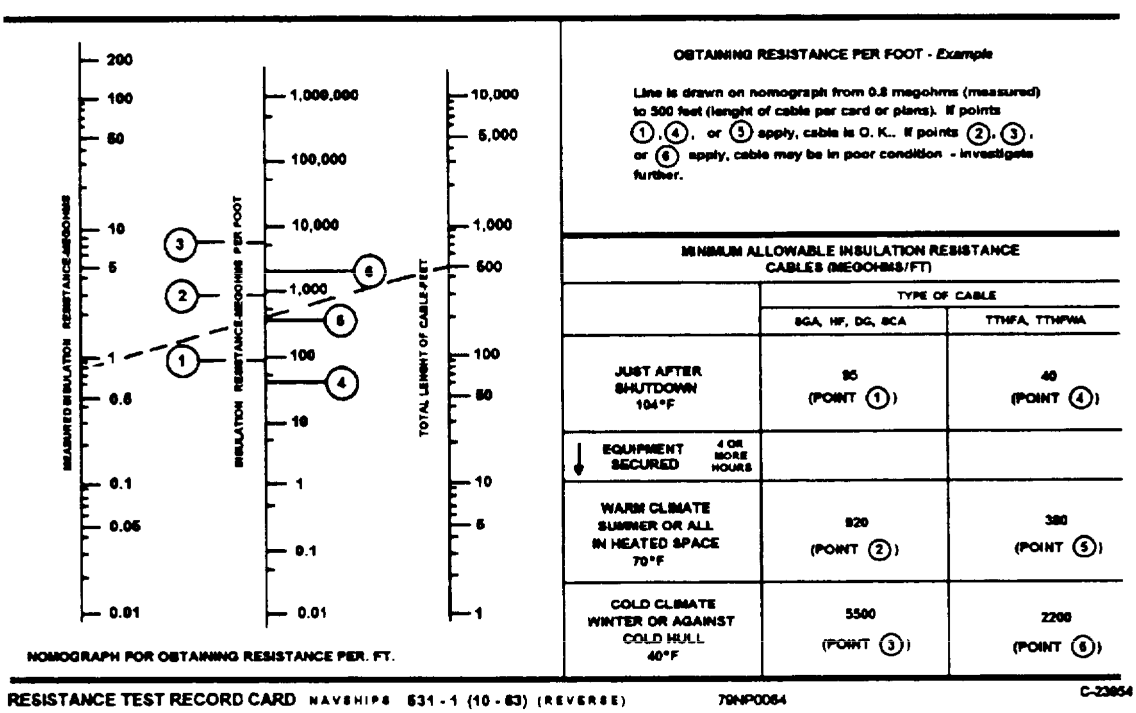


Figure 2-17.—Nomograph for obtaining resistance per foot.

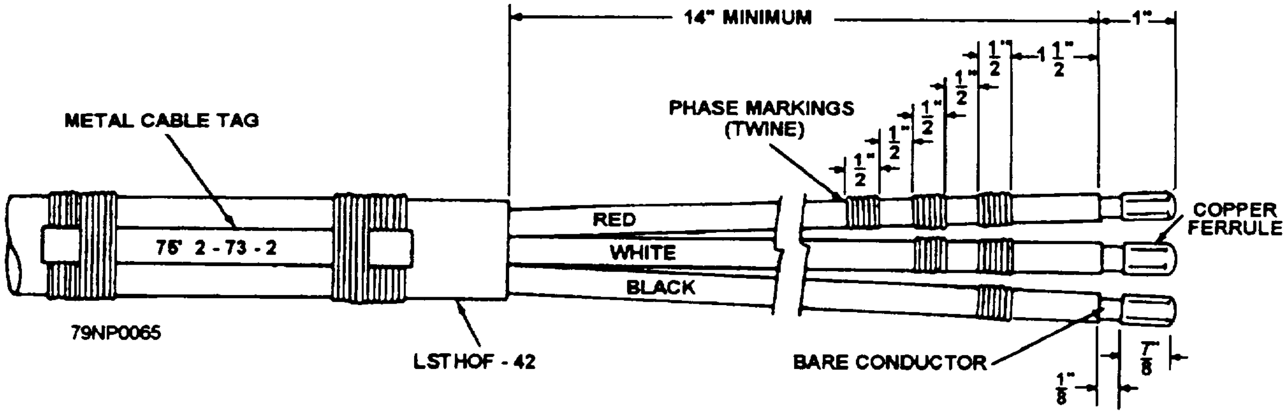


Figure 2-18.—Casualty power cable—old method of serving.

Cable Repairs

A cable repair is the restoration of the cable armor or the outermost sheath or both. Cable repair may be made by ship's force. However, cable repair should be made according to DOD-STD-2003(NAVY), unless standard methods cannot be applied.

Cable Splicing

A cable splice is the restoration on any part of a cable that cannot be restored by a cable repair. Cable splices should be made according to methods described in DOD-STD-2003(NAVY), unless standard methods cannot be applied. Cable splices should not be made by ship's force except in an emergency. When such splices are made, the y should be replaced at the earliest opportunity by a continuous length of cable or by an approved splice installed by a repair activity.

CASUALTY POWER CABLE

Suitable lengths of portable casualty power cables are stowed close to the locations where they may be needed for making temporary connections. They are of suitable lengths (normally no more than 75 feet) and distributed throughout the ship according to the *Ship lnformation Book.* These portable cables are used to connect one fixed terminal to another to energize vital equipment if the installed distribution system is damaged.

Portable casualty power cables are type LSTHOF-42. They are capable of carrying 93 A at 40°C and 86 A at 50°C indefinitely. They have a casualty power application of 200 A. Metal tags installed on the cables designate their proper lengths and locations.

On older ships, the portable cable ends are marked to identify the A, B, and C phases visually or by touch when illumination is insufficient for visual identification. Phase A is color-coded black and has one serving on the conductor end; phase B is color-coded white and has two servings; and phase C is red with three servings (fig. 2-18).

The insulation of the individual conductors is exposed to shipboard ambient temperatures and perhaps oil or oil fumes and accidental damage. After an exposure period of 5 years or more, the conductor insulation may lose elasticity and crack when bent while being handled. This could happen when the casualty power system is rigged for emergency use. The exposed ends of the individual conductors of the casualty power cables should be inspected following PMS. The best method for determining acceptable insulation is to sharply bend all conductors by hand. If no cracks develop, the insulation is satisfactory. Refer to figures 2-19 and 2-20 as you read the following steps you should use to repair a defective cable:

STEP NUMBER	ACTION
Step 1	Cut off the protruding ends and prepare new terminals as shown in figure 2-18. To avoid inserting a bare conductor into bulkhead terminals, do not strip more than 1 inch of the insulation from the conductor.
Step 2	Apply one heavy coat of clear air-drying varnish, grade CA, to the cut ends of the insulation. Varnishing makes the cut ends watertight.
Step 3	Place a round copper ferrule on the conductor and secure it by forming as shown in figure 2-19.
Step 4	Use either of the following methods to identify the phase by touch and color: • Old method (fig. 2-18)—Apply close wrappings of cotton twine approximately 3/64 inch in diameter, knot securely, and coat with grade CA varnish: Black wire (A phase) 1 wrapping White wire (B phase) 2 wrappings Red wire (C phase) 3 wrappings • New method (fig. 2-20)—Instead of cotton twine, O-rings and heat-shrinkable colored tubing are used. The number of O-rings correspond to the number of wrappings in this method. If colored tubing is not available, transparent tubing may be used: Black wire (A phase) 1 O-ring, black tubing White wire (B phase) 2 O-ring, white tubing Red wire (C phase) 3 O-ring, red tubing
Step 5	Measure the individual conductors for proper placement of the O-rings and roll the rings on the conductors. Then cut the tubing to proper lengths, slide them over the O-rings, and apply heat with a heat gun. The tubing will shrink around the conductors and rings, making clear and distinctive markings for proper identification of the casualty power cable. The O-rings, tubing, and heat gun used in this method are readily available in the Navy supply system.

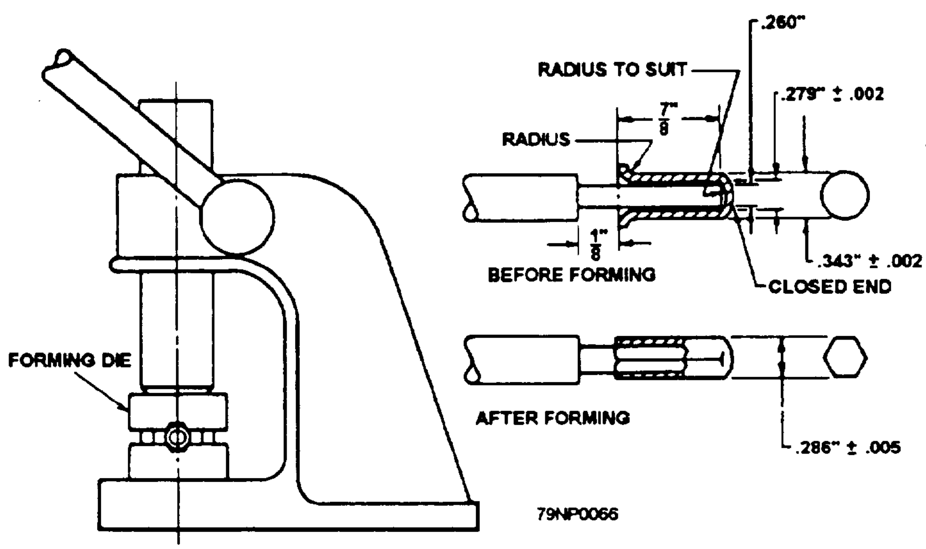
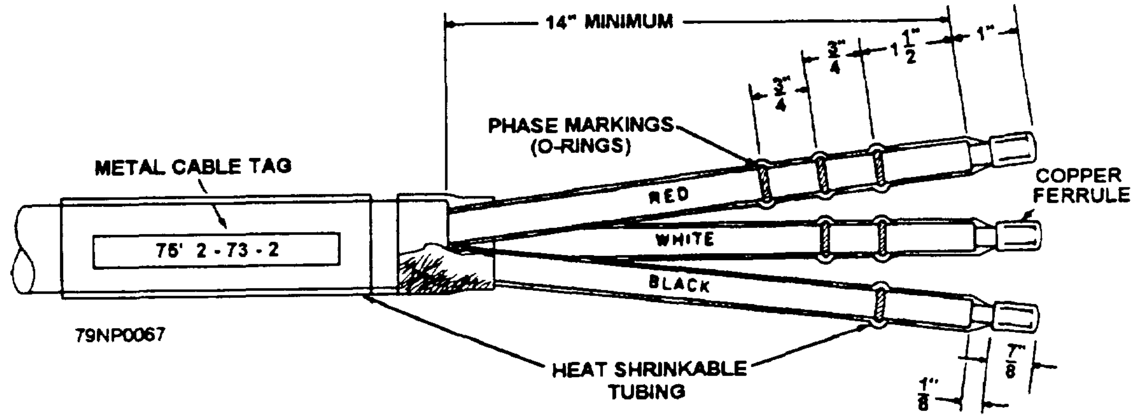


Figure 2-19.—Method of securing a copper ferrule to a conductor.



TUBING 3/4" I.D.	FSN
BLACK	5970 - 914 - 3118
WHITE	5970 - 812 - 1360
RED	5970 - 914 - 3117
CLEAR	5970 - 767 - 0611
CLEAR (2" I.D.)	5970 - 089 - 1454
O-RING (3/8" I.D.)	5330 - 060 - 1211
HEAT GUN	4940 - 561 - 1002

Figure 2-20.—Casualty power cable ends.

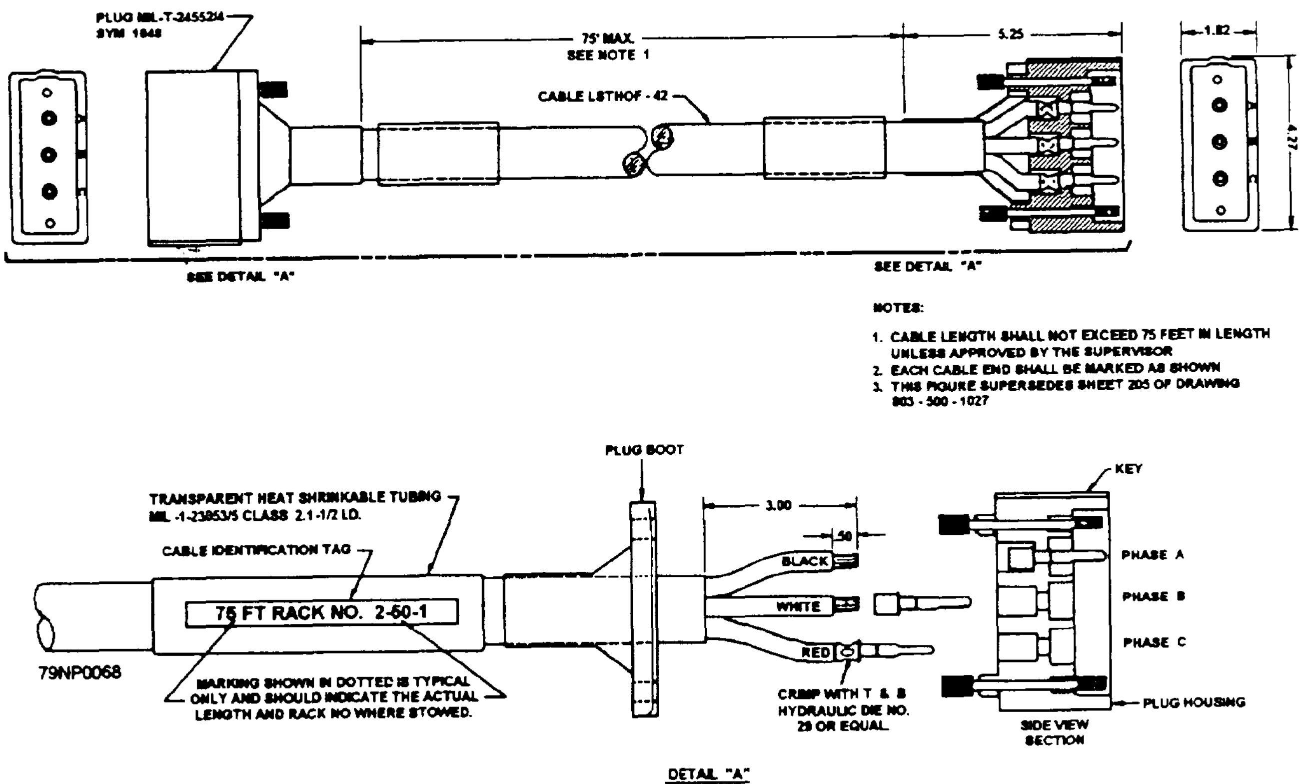


Figure 2-21.—New method of preparing casualty power cable ends.

Another method being used on newer ships to prepare casualty power cable ends is shown in figure 2-21. The use of the plug (SYM 1049) makes marking of the individual phases unnecessary since the keyed segment prevents improper connections.

Fixed terminals are connected to cables which penetrate watertight decks (riser terminals) and bulkheads (bulkhead terminals). These cables are of type LSTSGU-75. They are capable of carrying 148 A at 40°C and 136 A at 50°C. These fixed terminals are marked by nameplates (fig. 2-22) indicating the terminal location and the location of the other end.

Portable casualty power cables should be rigged only when required for use or for practice in rigging the casualty power system. At all other times, they should be stowed in the cable rack indicated on the cable tag. When portable casualty power cables are rigged, connections should be made from the load to the supply to avoid handling energized cables.

Casualty power cables are a very important part of the ship's equipment. Each year the cables and terminal connections should be closely inspected and tested. If you are assigned to inspect casualty power cables, follow the step-by-step procedures listed on the appropriate maintenance requirement card. It tells what tools and material the job will require, safety precautions to observe, and procedures to follow.

Refer to chapter 3 of this manual for a description of the casualty power distribution system.

SHORE POWER

A means of supplying electrical power to a ship from an external source is known as *shore power.* This installation requires a shore-power station, plugs, and connecting cables.

Shore Power Station

Ashore-power station (fig. 2-23, view A) is located at or near a suitable weather deck location. Portable cables can be attached to the weather deck location from shore or a ship alongside. The same station can be used to supply power from the ship to a ship alongside. The shore-power station has a receptacle assembly arrangement as shown in figure 2-23, view B. The shore-power system is designed to handle only enough power to operate necessary machinery and provide illumination for habitability.

SHORE POWER PLUG.— A shore-power plug is installed on the end of shore-power cables for ease of making the shore-power connection. A shore-power

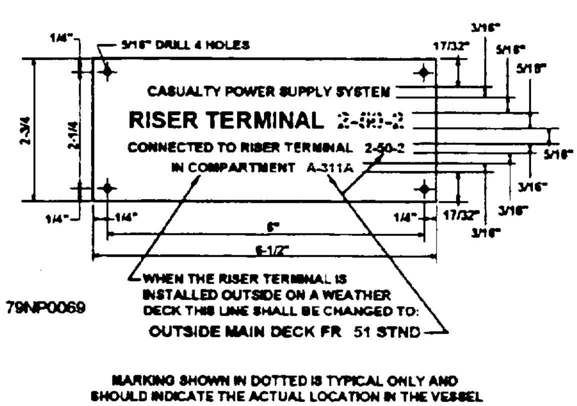


Figure 2-22.—Casualty power fixed terminal cable tag.

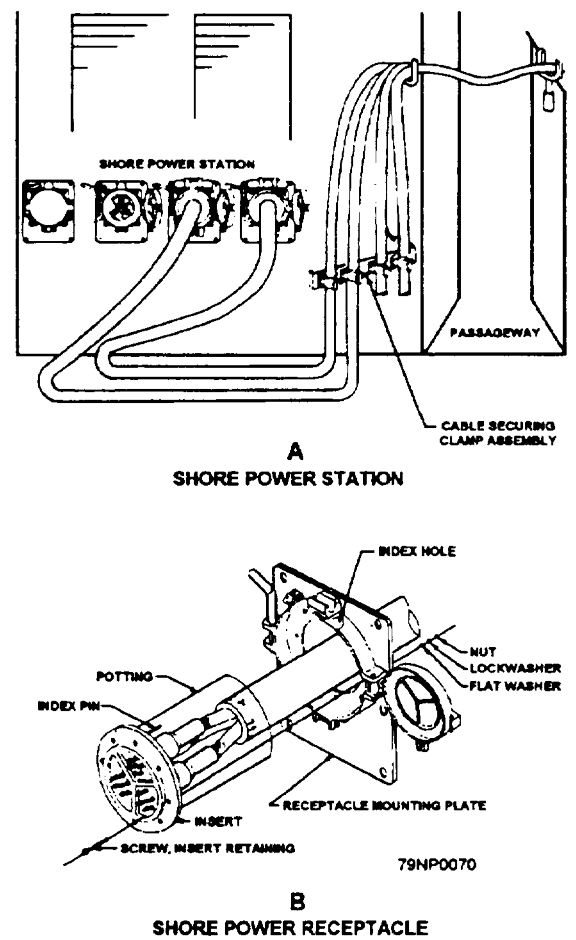


Figure 2-23.—Shore-power station and receptacle assembly.

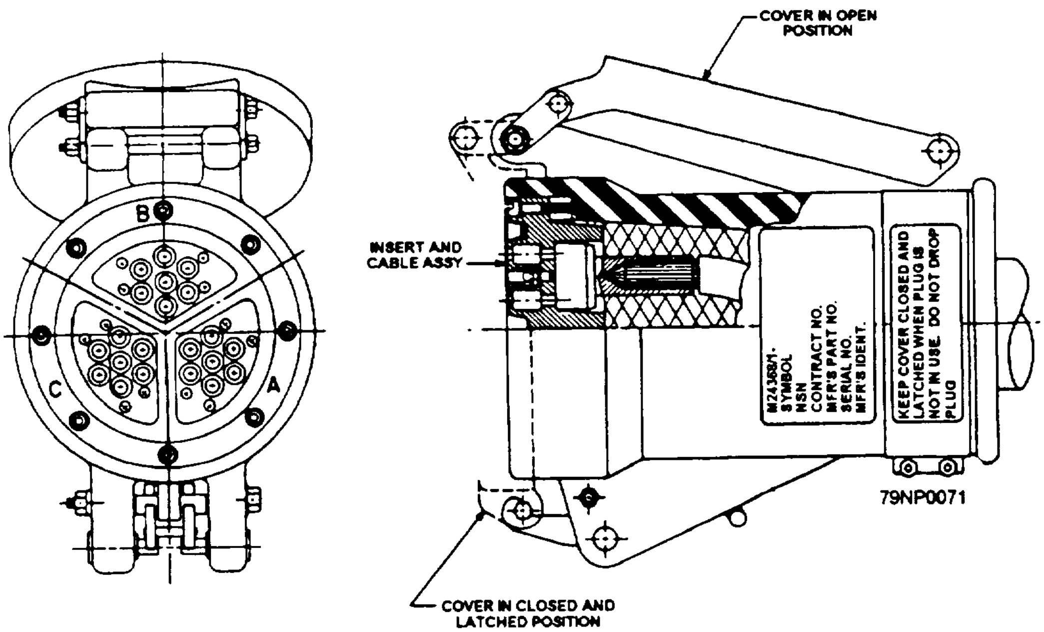


Figure 2-24.—Shore-power plug.

plug is shown in figure 2-24. To avoid personnel injury and equipment damage, carefully inspect shore-power cables and fittings before making shore-power connections. When completing the shore-power connections, follow installation instructions, maintenance requirement card (MRC) procedures, and checkoff lists cautiously.

SHORE POWER CABLES.— Shore power is supplied to the ship through 150-foot lengths of portable cables of type THOF-400. These cables are rated at 400 amperes each. They are constructed according to DOD-STD-2003-2(NAVY).

Be careful when connecting or disconnecting the shore power cables to ensure your personal safety. Procedures for connecting and disconnecting the cables are discussed in greater detail in chapter 3.

CABLE REELS.— To protect cables when they aren't being use, they are stowed in reels located near the shore power station. The reels are maintained according to PMS procedures. In addition to being kept clean and dry, they must be periodically lubricated in order to turn freely while removing or stowing cables.

Phase-Sequence Indicator

A phase-sequence indicator is used when connecting shore power to your ship to verify proper

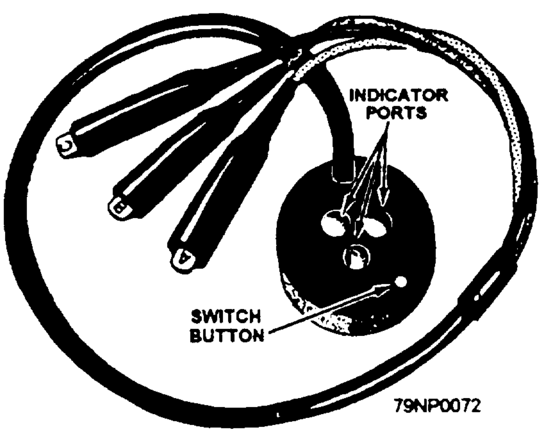


Figure 2-25.—Phase-squence indicator.

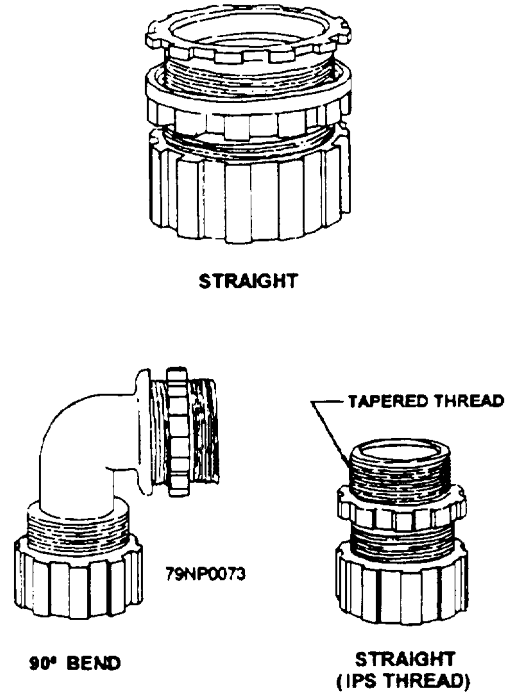


Figure 2-26.—Nylon Stuffing tubes.

phase relationship between your ship and shore power. An approved type of phase-sequence indicator (fig. 2-25) has a miniature, three-phase induction motor and three leads with insulated clips attached to the ends. The leads are labeled A, B, and C. The miniature motor can be started through a momentary contact switch. This switch is mounted in the insulated case with a switch button protruding out the front of the case to close the switch. When the motor starts turning, you can tell its direction of rotation through the three ports on the front of the case. Clockwise rotation indicates a correct phase sequence. You can stop the motor by releasing the momentary contact switch.

STUFFING TUBES

Stuffing tubes (fig. 2-26) are used to provide for the entry of electrical cable into splashproof, spraytight, submersible, and explosion proof equipment enclosures. Cable clamps, commonly called *box connectors* (fig. 2-27), may be used for cable entry into all other types

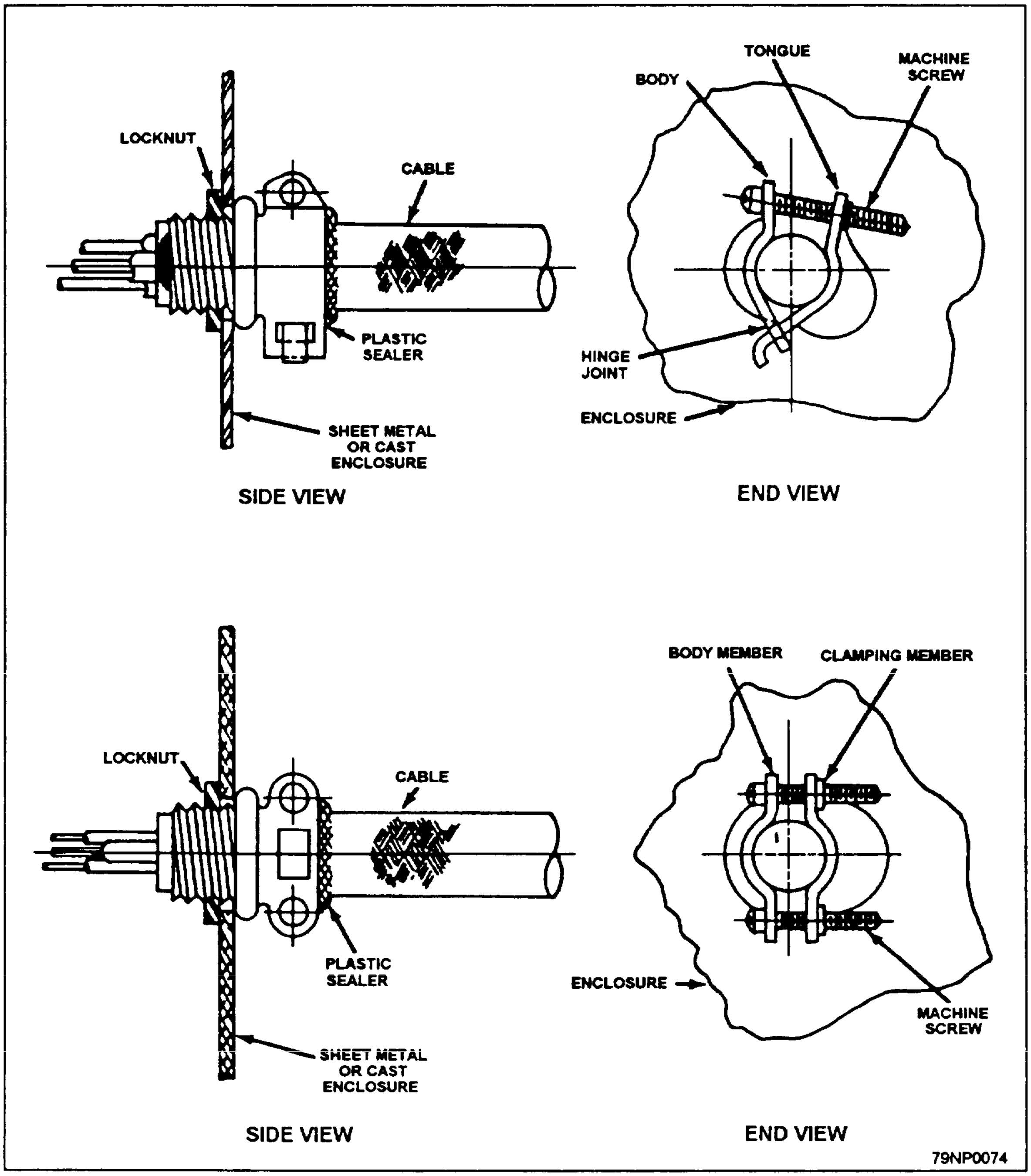


Figure 2-27.—Cable clamps.

of equipment enclosures. However, top entry into these enclosures should be made dripproof through stuffing tubes or cable clamps sealed with plastic sealer.

Uses below and above the Main Deck

Below the main deck, stuffing tubes are used to penetrate the following areas:

- Watertight decks
- Watertight bulkheads
- Watertight portions of bulkheads that are watertight only to a certain height

Above the main deck, stuffing tubes have the following uses for cable penetrations:

- Watertight or airtight boundaries
- Bulkheads designed to withstand a waterhead
- Portions of the bulkhead below the height of the sill or coaming of compartment accesses
- Flametight or gastight or watertight bulkheads, decks, or wiring trunks within turrets or gun mounts
- Structures subject to sprinkling

Construction

Stuffing tubes are made of nylon, steel, brass, or aluminum alloys. Nylon tubes have very nearly replaced metal tubes for cable entry to equipment enclosures. Cable penetration of bulkheads and decks are normally of metal because of their integrity during fires. Stuffing tubes made of metal are normally used for cable penetration of bulkheads and decks. Nylon stuffing tubes melt and fail to act as a barrier during a fire.

The nylon stuffing tube is lightweight, positive-sealing, and noncorrosive. It requires only minimum maintenance for the preservation of watertight integrity. The watertight seal between the entrance to the enclosure and the nylon body of the stuffing tube is made with a neoprene O-ring, which is compressed by a nylon locknut. A grommet-type, neoprene packing is compressed by a nylon cap to accomplish a watertight seal between the body of the tube and the cable. Two slip washers act as compression washers on the grommet as the nylon cap of the stuffing tube is tightened. Grommets of the same external size, but with different sized holes for the cable, are available. This allows a single-size stuffing tube to be used for a variety of cable sizes, and makes it possible for nine sizes of nylon tubes to replace 23 sizes of aluminum, steel, and brass tubes.

The nylon stuffing tube is available in two parts. The body, O-ring, locknut, and cap comprise the tube; and the rubber grommet, two slip washers, and one bottom washer comprise the packing kit.

A nylon stuffing tube that provides cable entry into an equipment enclosure is applicable to both watertight and nonwatertight enclosures (fig. 2-28, view A). Note that the tube body is inserted from inside the enclosure. The end of the cable armor, which will pass through the slip washers, is wrapped with friction tape to a maximum diameter. To ensure a watertight seal, one coat of neoprene cement is applied to the inner surface of the rubber grommet and to the cable sheath where it will contact the grommet. After the cement is applied, the grommet is immediate y slipped onto the cable. You must clean the paint from the surface of the cable sheath before applying the cement.

Sealing plugs are available for sealing nylon stuffing tubes from which the cables have been

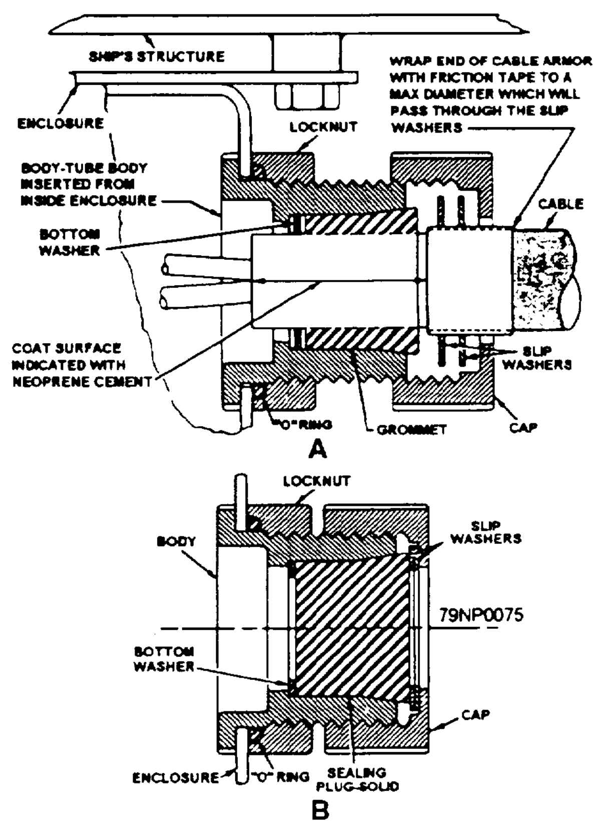


Figure 2-28.—Representative nylon stuffing tube installations.

removed. The solid plug is inserted in place of the grommet, but the slip washers are left in the tube (fig. 2-28, view B).

A grounded installation that provides for cable entry into an enclosure equipped with a nylon stuffing tube is shown in figure 2-29. This type of installation is required only when radio interference tests indicate that additional grounding is necessary within electronic spaces. In this case, the cable armor is flared and trimmed to the outside diameter of the slip washers. One end of the ground strap, inserted through the cap and one washer, is flared and trimmed to the outside diameter of the washers. Contact between the armor and the strap is maintained by pressure of the capon the slip washers and the rubber grommet.

Aboard ship, watertight integrity is vital. Just one improper cable installation could endanger the entire ship. For example, if one THFA-4 cable (0.812 inch in diameter) were to be replaced by the newer LSTSGA-4 cable (0.449 inch in diameter), but the fittings passing through a watertight bulkhead were not changed to the proper size, the result might be two flooded spaces if a collision or enemy hit occurs.

Deck Risers

Where one or two cables pass through a deck in a single group, kickpipes are provided to protect the cables against mechanical damage. Steel pipes are used with steel decks, and aluminum pipes with aluminum and wooden decks. Inside edges on the ends of the pipe and the inside wall of the pipe must be free of burrs to prevent chafing of the cable. Kickpipes, including the

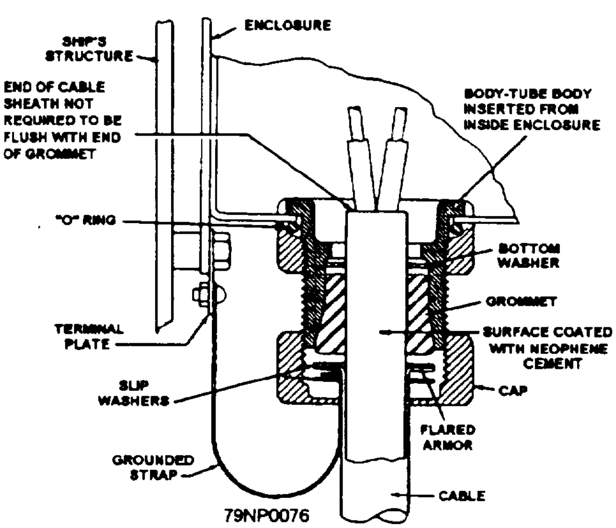


Figure 2-29.—Nylon stuffing tube grounded installation.

stuffing tube, should have a minimum height of 9 inches and a maximum height of 18 inches. If the height exceeds 12 inches, a brace is necessary to ensure rigid support. If the installation of kickpipes is required in nonwatertight decks, a conduit bushing may be used in place of the stuffing tube.

When three or more cables pass through a deck in a single group, riser boxes must be used to provide protection against mechanical damage. Stuffing tubes are mounted in the top of riser boxes required for topside weather-deck applications. For cable passage through watertight decks inside a vessel, the riser box may cover the stuffing tubes if it is fitted with an access plate of expanded metal or perforated sheet metal.

Wireways

Before you install new cable, survey the area to see if there are spare cables in existing wireways and spare stuffing tubes that can be used in the new installation. The cable run must meet the following criteria:

- Be located so that damage from battle will be minimized
- Be located so physical and electrical interference with other equipment and cables will be avoided
- Be located so that maximum dissipation of internally generated heat will occur.

Where practical, you should route vital cables along the inboard side of beams or other structural members to afford maximum protection against damage by flying splinters or machine gun straffing. Only when necessary, should cables be run on the exterior of the deckhouse or similar structures above the main deck.

Avoid installing cable in locations subject to excessive heat, if possible. Never install cables adjacent to machinery, piping, or other hot surfaces having an exposed surface temperature greater than 150°F. In general, cables should not be installed where they may be subjected to excessive moisture.

CABLE SUPPORTS

To prevent unnecessary stress and strain on cables, cable supports or straps are used. Types of cable supports are the single cable strap, cable rack, and modular cable supports.

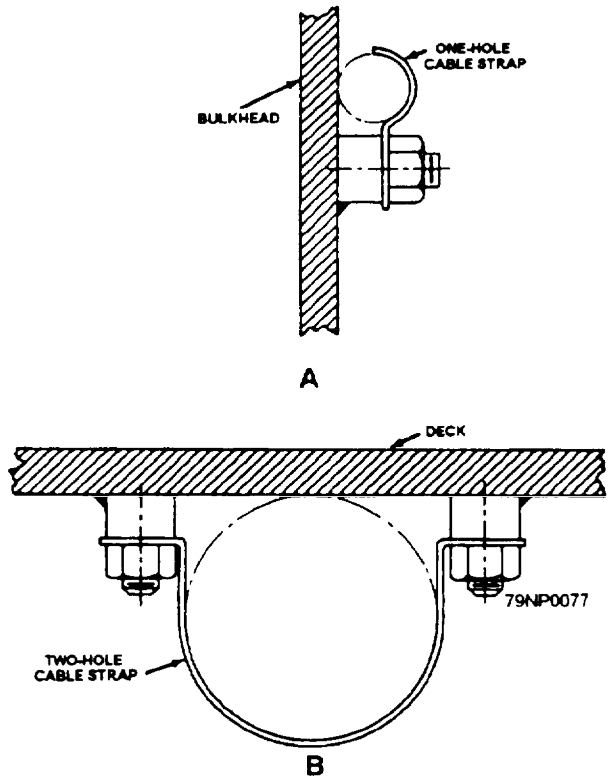


Figure 2-30.—Single cable strap application.

Single Cable Strap

The single cable strap (fig. 2-30) is the simplest form of cable support. The cable strap is used to secure cables to bulkheads, decks, cable hangers, fixtures, and so forth. The one-hole cable strap (fig. 2-30, view A) may be used for cables not exceeding five-eighths inch in diameter. The two-hole strap (fig. 2-30, view B) may be used for cables over five-eighths inch in diameter. The spacing of simple cable supports, such as those shown in figure 2-30, must not exceed 32 inches, center to center.

Cable Rack

The cable rack is more complex than the single cable strap. The cable rack consists of the cable hanger, cable strap, and hanger support (fig. 2-31).

The banding material of the cable rack is 5/8 inch wide. It may be made from zinc-coated steel, corrosion-resistant steel, or aluminum, depending on the requirements of the installation. For weather deck installations, use corrosion-resistant steel with copper-armored cables, zinc-coated steel with steel armor, and aluminum with aluminum armor.

When applying banding material to the cable rack, you should apply one turn of banding for a single cable of less than 1 inch in diameter. Apply two turns of banding for single cables of 1 inch or more in diameter and for a row of cables. Apply three turns of banding for partially loaded hangers where hanger width exceeds the width of a single cable or a single row of cable by more than 1/2 inch.

Cables must be supported so that the sag between supports, when practical, will not exceed 1 inch. Five

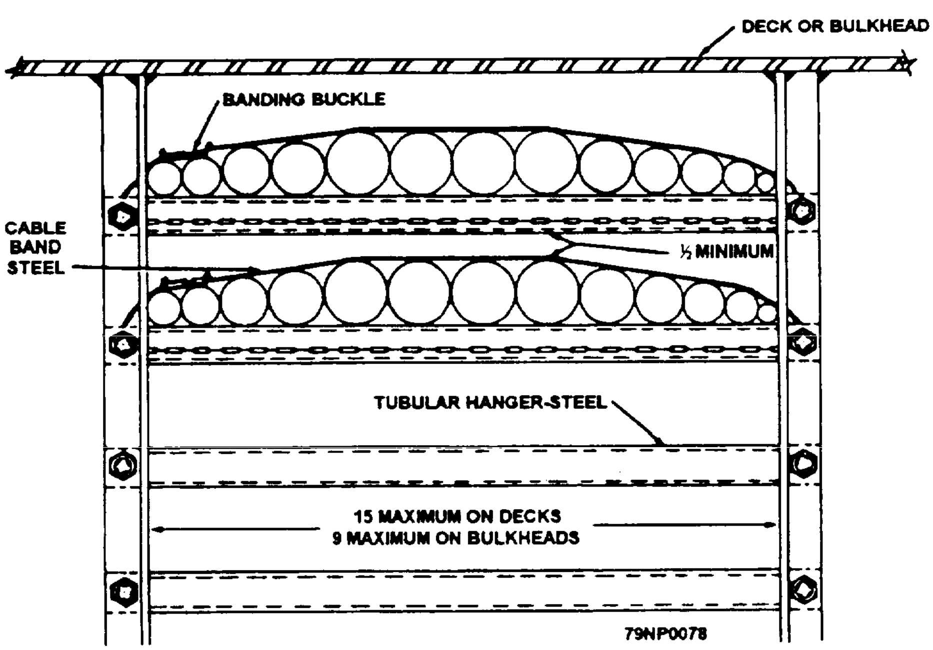


Figure 2-31.—Cables installed in a cable rack.

rows of cables may be supported from an overhead in one cable rack; two rows of cables may be supported from a bulkhead in one cable rack. As many as 16 rows of cables may be supported in main cableways, in machinery spaces, and boiler rooms. However, not more than one row of cables should be installed on a single hanger.

Modular Cable Supports

Modular cable supports (fig. 2-32) are installed on a number of naval ships. The modular method saves over 50 percent in cable-pulling time and labor. Groups of cables are passed through wide opened frames instead of inserted individually in stuffing tubes. The times are then welded into the metal bulkheads and decks for cable runs. The modular method of supporting electrical cables from one compartment to another is designed to be tireproof and water- and airtight.

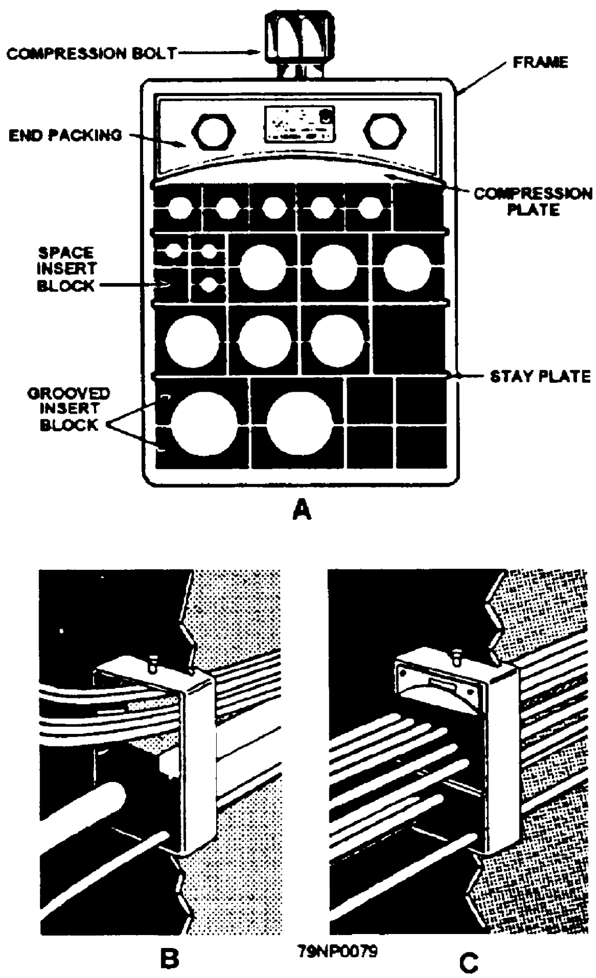


Figure 2-32.—Modular cable supports.

Modular insert, semicircular, grooved twin half-blocks are matched around each cable to form a single block. These grooved insert blocks, which hold the cables (along with the spare insert solid blocks), fill up a cable support frame.

During modular armored cable installation (fig. 2-32, view B), a sealer is applied in the grooves of each block to seal the space between the armor and cable sheath, The sealer penetrates the braid and prevents air passage under the braid. A lubricant is used when the blocks are installed to allow the blocks to slide easily over each other when the y are packed and compressed over the cable. Stay plates are normally inserted between every completed row to keep the blocks positioned and help distribute compression evenly through the frame. When a frame has been built up, a compression plate is inserted and tightened until there is sufficient room to insert the end packing.

To complete the sealing of the blocks and cables, the two bolts in the end packing are tightened evenly until there is a slight roll of the insert material around the end packing metal washers. This roll indicates the insert blocks and cables are sufficiently compressed to form a complete seal. The compression bolt is then backed off about one-eighth of a turn.

When removing cable from modular supports, first tighten down the compression bolt. Tightening this bolt pushes the compression plate further into the frame to free the split end packing. Then, remove the end packing by loosening the two bolts that separate the metal washers and the end packing pieces. Back off the compression bolt, loosening the compression plate. Then remove this plate, permitting full access to the insert blocks and cables.

CONTROL DEVICES

A control device, in its simplest form, is an electrical switching device that applies voltage to or removes it from a single load. In more complex control systems, the initial switch may set into action other control devices that govern motor speeds, compartment temperatures, water depth, aiming and firing guns, or guided missile direction. In fact, all electrical systems and equipment are controlled in some manner by one or more controls.

MANUALLY OPERATED CONTACTS

Manually operated switches are those familiar electrical items that can be conveniently operated with the hand. (NOTE: As you read this paragraph, look at

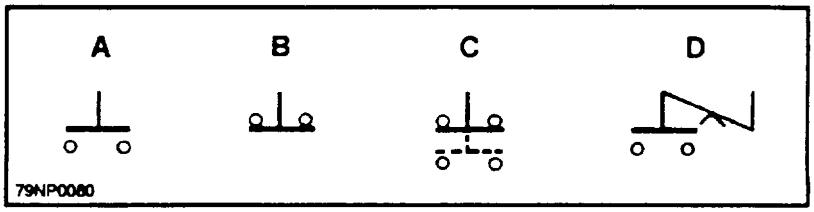


Figure 2-33.—Manually operated contacts.

figure 2-33.) The push button (fig. 2-33) is the simplest form of electrical control. When the button is pushed down (view A), contact is made across the two circles representing wire connections. When pressure is released a spring (not shown) opens the contact. View B shows a normally closed contact. When it is pressed, contact at the two terminals is broken. When it is relased, a spring-loaded feature (not shown) closes the switch again. The switch in view C is designed to make one contact and break another when it is pressed. The upper contact is opened when the lower is closed; again, the spring arrangement (not shown) resets the switch to the position shown. The switch in view D is a maintained contact switch. When it is pressed, it hinges about the center point and will stay in that position until the other part of the button is pressed.

ELECTRICALLY OPERATED CONTACTS

Schematic wiring diagrams have both push-button and electrically operated contacts. Two different methods of control contacts are shown in figure 2-34. View A shows the normally open (NO) position that closes when operated. View B shows the normally close (NC) position that opens when energized. Views C, D, E, and F show timer contacts. After being energized, these contacts will take some time to close or open. This time element is controlled by a timer motor, a dashpot, pneumatically, or by magnetic flux. Those devices that are timed closed or open have the following indications at the lower contacts: TC (timed closed), TO (timed open), and TO ENERGIZE (while this contact is already shown open, before it can be timed open, it must close). In operation, this switch might be closed by a clutch in a timer assembly. After the timer motor operates through a given number of revolutions, a clutch in the timer will release the contact, causing the switch to reopen. The timed switches may also be shown with an arrow that indicates whether the contact is timed to open or close. The direction of the arrow indicates what condition exists.

LIMIT SWITCHES

In certain applications, the ON-OFF switch does not give enough to ensure safety of equipment or personnel. A limit switch is incorporated in the circuit so that operating limits are not exceeded

The limit switch is installed in series with the master switch and the voltage supply. Any action causing the limit switch to operate will open the supply circuit.

One application of limit switches is in equipment that moves over a track. It is possible to apply power so that operation will continue until the carriage hits an obstruction or runs off the end of the track.

If limit switches are installed near the end of travel, an arm or projection placed on the moving section will trip a lever (fig. 2-35) on the limit switch. The switch then opens the circuit and stops the travel of the carriage. This type of control is a direct-acting, lever-controlled limit switch. Another type, an intermittent gear drive limit switch, may be coupled to a motor shaft to stop action when a definite number of shaft revolutions is completed.

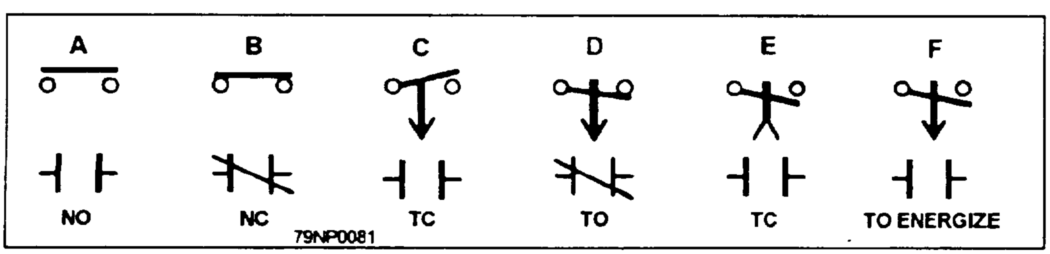


Figure 2-34.—Electrically operated contacts.

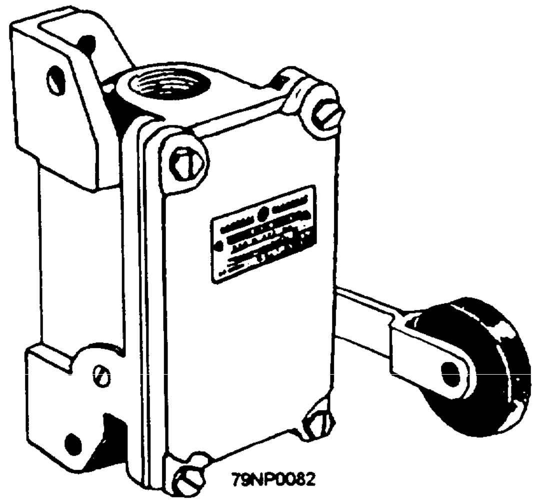


Figure 2-35.—A limit switch, roller actuator arm operated.

FLOAT SWITCHES

Float switches are used to control electrically driven pumps and regulate liquid levels in tanks.

Construction

In a tank installation (fig. 2-36), the deck and overhead flanges are welded to the deck and overhead of the tank. The float guide rod, E, fits into the bottom flange and extends through the top flange. The float guide rod then passes through an opening in the switch operating arm. Collars A and B on the guide rod exert upward or downward pressure on the operating arm as the float approaches minimum or maximum depth positions. The switch operating arm is fastened to the shaft, which is coupled to the switch contact mechanism

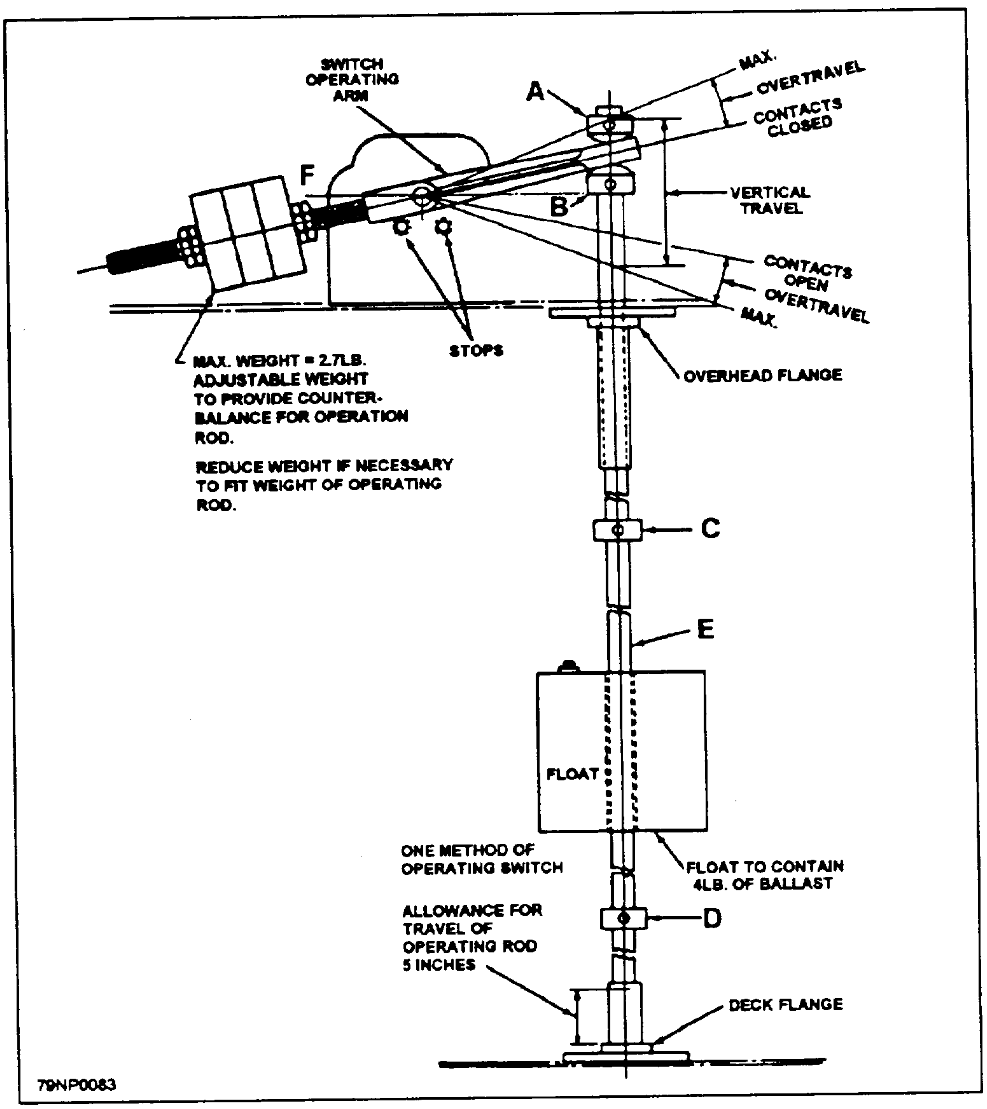


Figure 2-36.—A float switch tank installation.

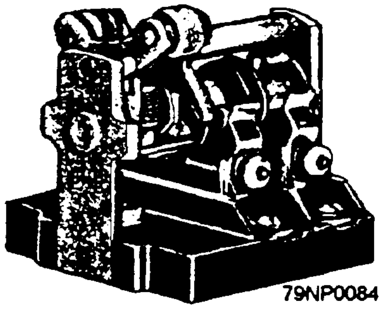


Figure 2-37.—A float switch mechanism.

(fig. 2-37). Collars C and D on the guide rod are held in position by setscrews so that their positions can be changed to set the operating levels to the desired positions.

As the float goes up and down, corresponding to the liquid level, it does not move the operating red, E, until contact is made with either collar. When the float comes in contact with either collar, the external operating arm of the switch is moved and the switch is operated.

Although the switch assembly is of rugged construction, it must be checked regularly for proper performance.

Maintenance

You should ensure that the switch contacts are kept in good electrical condition. Determine the kind of metal used for the contacts, whether copper or silver, and apply the maintenance procedures outlined in *Naval Ship's technical Manual,* chapter 300. While power is applied to the circuit, never clean the contacts or apply lubricants to the contact surfaces.

PRESSURE AND TEMPERATURE SWITCHES

Pressure and temperature controls have been grouped together because the switching mechanism is the same for both controls; the difference is in the operation.

Pressure-controlled switches (fig. 2-38) are operated by changes in pressure in an enclosure such as a tank. On the other hand, temperature-controlled switches operate from changes in temperature that take place in an enclosure or the air surrounding the temperature-sensing element. Actually, both switches are operated by changes in pressure. The temperature element is arranged so that changes in temperature cause a change in the internal pressure of a sealed-gas or air-filled bulb or helix, which is connected to the actuating device by a small tube or pipe. Temperature changes cause a change in the volume of the sealed-in gas, which causes movement of a diaphragm. The movement is transmitted by a plunger to the switch arm. The moving contact is on the arm. A fixed contact may be arranged so that the switch will open or close on a temperature rise.

When the switch is used to control pressure, the temperature element is replaced by a tube that leads to the pressure tank. The pressure inside the tank then operates the switch mechanism.

Pressure or temperature controls may be used as a pilot device (fig. 2-39). The circuit operation is exactly

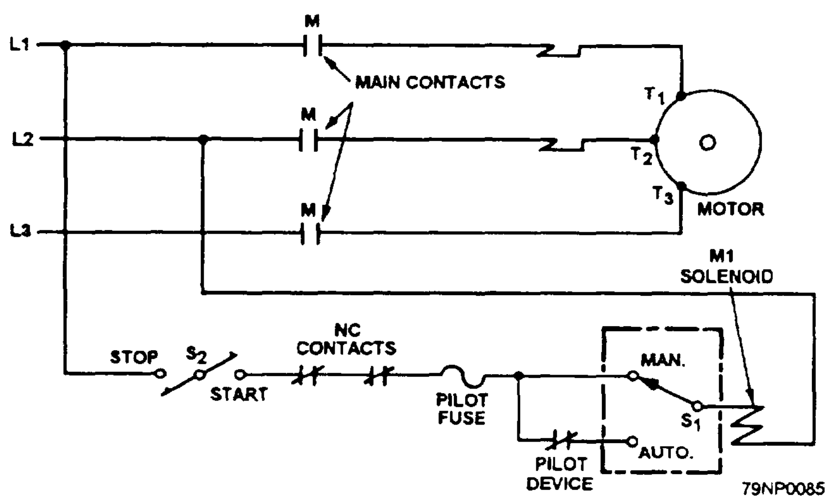


Figure 2-38.—A representative pilot device control circuit.

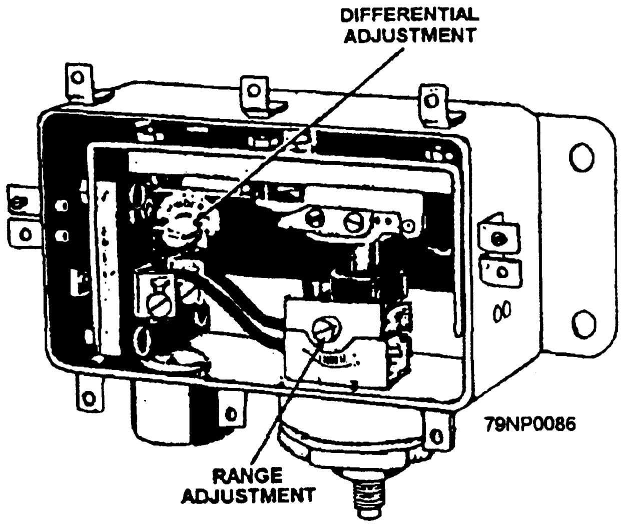


Figure 2-39.—A pressure-operated switch.

the same regardless of the kind of pilot device used to control the circuit. To maintain more or less constant temperature or pressure, switch contacts are arranged to close when the pressure or temperature drops to a predetermined value and to open when the pressure or temperature rises to the desired value. The reverse action can be obtained by a change in the contact positions.

The difference in pressure for contact opening and closing is the differential. The switch mechanism has a built-in differential adjustment so that the differential can be varied over a small range. Once set, the differential remains essential y constant at all pressure settings.

Each switch has a range adjustment that sets the point at which the circuit is closed. Changing the range adjustment raises or lowers both the closing and opening points without changing the differential.

Adjustments

The following table describes the steps in adjusting pressure operated switches (table 2-8);

Table 2-8.—Steps to adjust pressure operated switches

STEP	ACTION	
1	Turn the differential adjustment screw (fig. 2-39) counterclockwise against the stop for minimum differential.	
2	Bring the system pressure to that at which you wish the switch to close.	
3	**IF**	**THEN**
	Contacts are open when the desired temperature is reached.	Turn the range screw slowly clockwise until the contacts just close.
	Contacts are closed when the desired temperature is reached.	Turn the range screw slowly counterclockwise until the contacts open; then clockwise until they just close.
4	Bring the system to the pressure at which you wish the switch to open.	
5	Turn the differential adjustment screw slowly clockwise to widen the differential until the desired opening pressure is obtained.	

Thermal Unit Type

The bulb and helix units can be connected to the switch section (fig. 2-40). The bulb unit (fig. 2-40, view

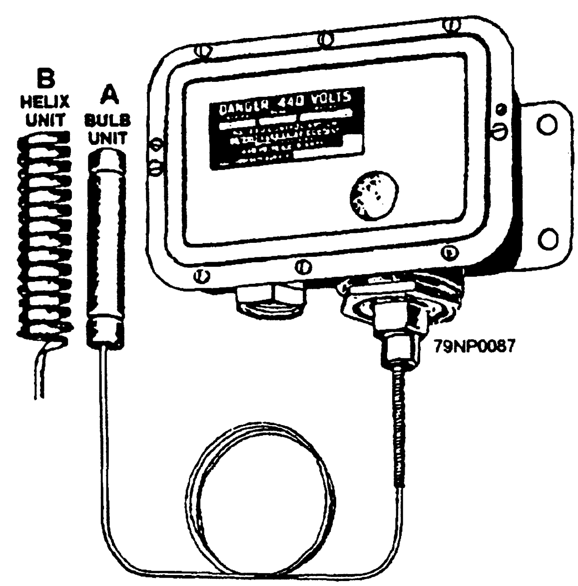


Figure 2-40.—Thermal units.

A) is normally used when liquid temperatures are to be controlled. However, it may control air or gas temperatures, provided the circulation around it is rapid and the temperature changes at a slow rate.

The helical unit (fig. 2-40, view B) has been specifically y designed for air and gas temperature control circuits. To be most effective, the thermal unit must be located at a point of unrestricted circulation so it can "feel" the average temperature of the substance that is to be controlled.

Some switches are stamped WIDE DIFFERENTIAL. They are adjusted in the same manner described for the regular controls. However, because of slight design changes, it is possible to get wider variation in differential settings.

Maintenance

When adjusting temperature controls, allow several minutes for the thermal unit to reach the temperatures of the surrounding air, gas, or liquid before setting the operating adjustments. After adjusting the operating range of pressure or temperature controls, check the operation through at least one complete cycle. If you find variation from the desired operating values, go through the entire procedure again and observe operation through a complete cycle.

PILOT CONTROL DEVICES

A pilot is defined as a director or guide of another thing (or person). You may be familiar with ship pilots, pilot rudders, and pilot flames. In this text, a pilot is a small device that controls a relative] y larger device or mechanism, usually doing so by electrical means. The previously described float switch and pressure-operated switches are representative examples of such pilot devices. Pilot devices are limited in their ability to handle large currents and voltage required to operate shipboard motors or power-handling units. Therefore, it is customary for a pilot device to actuate only a magnetic switch. The magnetic switch can be chosen with characteristics suitable for handling the desired amount of power in the motor circuit.

Float switches used as pilot devices control the pump operation through other controls. A typical control circuit is shown in figure 2-38.

Switch S 1 makes it possible to have either manual or automatic operation of the motor-driven device. Table 2-9 describes the sequence of events when operating the pilot device control circuit (table 2-10) manually.

Table 2-9.—Manual Operation of Pilot Control Circuit

STEP	ACTION
1	Switch S_1 is placed in the Manual position
2	The circuit is closed by start/stop switch S_2
3	Current flows through holding coil M_1
4	Line contacts M close to energize the motor
5	The motor operates until stopped manually

The following table describes the sequence of events during the automatic operation of the circuit in table 2-10.

Table 2-10.—Automatic Operation of Pilot Control Circuit

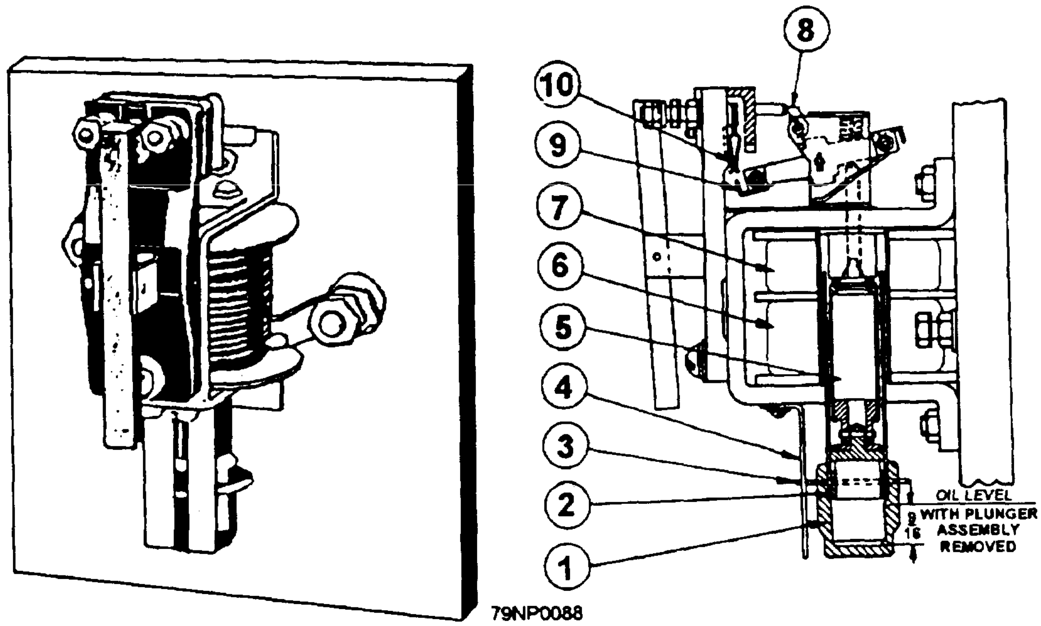
<table>
<tr><th>STEP</th><th colspan="2">ACTION</th></tr>
<tr><td>1</td><td colspan="2">Switch S_1 is placed in the Automatic position</td></tr>
<tr><td>2</td><td colspan="2">Start/stop switch S_2 is closed</td></tr>
<tr><td rowspan="3">3</td><td>When</td><td>Then</td></tr>
<tr><td>The pilot device closes its contacts</td><td>The M_1 solenoid will be energized and the motor will run</td></tr>
<tr><td>The pilot device opens its contacts</td><td>The M_1 solenoid will be de-energized and the motor will stop</td></tr>
<tr><td>4</td><td colspan="2">The operation will continue until:
1. The position of S_1 is changed, or
2. The position of S_2 is changed</td></tr>
</table>

PROTECTIVE DEVICES

Protective devices allow normal operation of circuits to continue unhampered. Once something goes wrong in the circuit, protective devices will de-energize the circuit to minimize of prevent damage to equipment and ensure the safety of personnel. A thorough knowledge of protective devices will help you isolate troubles in circuits, find the cause of interruption, clear the trouble, and restore operation with minimum loss of time.

MAGNETIC OVERLOAD RELAY

A magnetic type of overload relay for a dc system is shown in figure 2-41. A pictorial view and a diagram



1. Dashpot
2. Piston
3. Indicating plate
4. Calibration plate
5. Plunger
6. Series coil
7. Shunt coil (when used)
8. Latch
9. Movable contact
10. Stationary contacts

Figure 2-41.—A magnetic overload relay.

identifying the various parts are shown in views A and B, respectively.

In an installation, the operating (series) coil (6) is connected in series with the protected circuit. Normal current through the coil will have no effect on relay operation. If an overload occurs, increased current will flow through the coil and cause an increase in the magnetic flux around the coil. When the flux becomes great enough, the iron plunger (5) will be lifted into the center of the coil, opening the contacts (9 and 10). This action opens the control circuit to the main contactor in series with the motor terminals, which disconnects the motor from the line.

To keep the relay from operating when the motor is drawing a heavy but normal starting current, an oil dashpot mechanism (1 and 2) is built in. This gives a time delay action that is inversely proportional to the amount of overload.

Overload relays may use either single or double coils. In addition, the single-coil overload relay maybe obtained with or without a manual latching control (8). Relays with manual latching are used on three-wire controls and reset automatically after an overload has occurred. Double-coil overload relays are used for two-wire control. They have a series coil (6) carrying the load current and a shunt holding coil (7) mounted above the series coil. These two coils are connected so that their respective fields aid each other. Then, when an overload occurs, the plunger moves up into the shunt-connected field coil. It is held in the tripped position until the shunt coil is de-energized, which can be accomplished when a reset button or some other form of contact (switch) device is pressed.

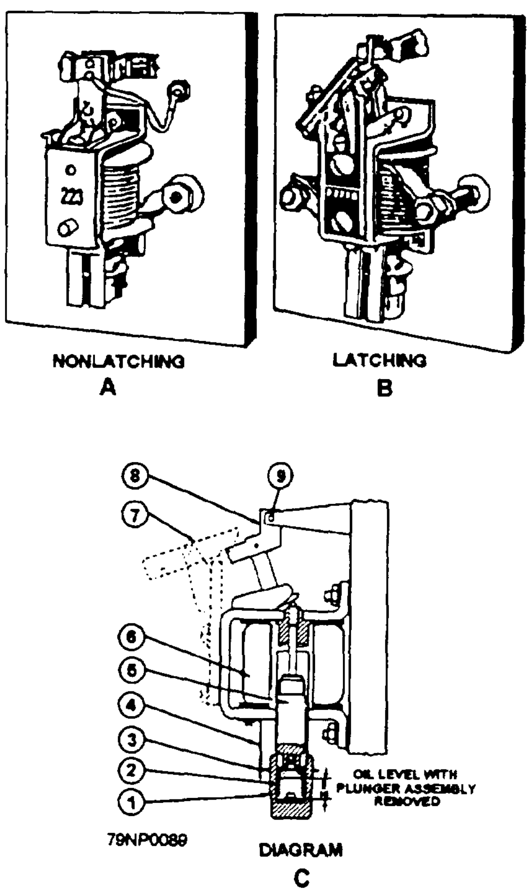
Before placing the overload relay in service, raise the indicating plate (3) to allow the dashpot (1) to be unscrewed from the relay. Lift out the plunger (5) and make certain all of the internal parts are clean. Place about nine-sixteenths of an inch of dashpot oil (furnished with the relay) in the dashpot. Replace the plunger and indicating plate, and then screw the dashpot on the relay to the desired setting.

The relay is calibrated at the factory for the individual application. The current values for which it is calibrated are stamped on the calibration plate (4). The marked values are minimum, maximum, and midpoint currents.

You can set the operating points by first raising the indicating plate (3), which allows the dashpot to be turned Then, to lower the tripping current, raise the dashpot by turning it. This action raises the plunger further into the magnetic circuit of the relay so that a lower current will trip the relay.

You can increase the current at which the relay trips by turning the dashpot in a reverse direction. This action reduces the magnetic pull on the plunger and requires more current to trip the relay. After the desired settings have been obtained, lower the indicating plate over the hexagonal portion of the dashpot to again indicate the tripping current and lock the dashpot in position.

Figure 2-42 shows two magnetic types of ac overload relays. View A is the nonlatching type, and view B is the latching type. In view C the various components are identified



1. Dashpot
2. Piston
3. Indicating plate
4. Calibration plate
5. Plunger
6. Series coil
7. Latch (when used)
8. Insulating splitter
9. Contacts

Figure 2-42.—Two ac overload relays.

The operating (series) coil (6) is connected in series with the protected circuit. Therefore, the load current flows through the coil. If the circuit current rises above normal because of overload conditions, it will cause an increase in the magnetic lines of flux about the coil. The increased flux lifts the iron plunger (5) into the center of the coil and opens the contactor/contacts (9). This, in turn, causes the main contactor (not shown) to open, and disconnects the motor or other device from the line. An oil dashpot mechanism (1 and 2) is used to prevent the operation of the relay on motor starting current surges.

If the relay does not have manual latching, a three-wire control is provided to give automatic reset after an overload occurs. The manual-latch relay is generally used with two-wire control. The latch (7) holds the contacts in the open position after an overload has occurred and the circuits have been de-energized. The operator must manually reset the overload relay at the controller.

THERMAL OVERLOAD RELAY

The thermal type of overload relay (ac and dc) is designed to open a circuit when excessive current causes the heater coils to reach the temperature at which the ratchet mechanism releases. The heater coils are rated so that normal circuit current will not produce enough heat to release the ratchet mechanism.

The essential operating parts of a de thermal overload relay (fig. 2-43) are the two heater coils (4), two solder tube assemblies (5), and control contacts (8). Under normal conditions the splitter arm (7) (so called because it splits the overload contacts) completes a circuit with the contacts. The spring is then under compression, and the operating arm (3) tends to rotate the splitter arm out of the circuit. This action is prevented by the ratchet assembly, which is held by the solder film between the outer and inner part of the solder tubes.

When current flows through the heater coils and produces enough heat to melt the solder film, the inner part of the solder tube assembly rotates and releases the ratchet mechanism to open the control circuits. When this happens, the circuit to the coil handling the power contacts (not shown in fig. 2-43) opens and disconnects the load. As soon as the load is disconnected, the heaters cool, and the solder film hardens. When the hardening is complete, the relay is ready to be reset with the reset button.

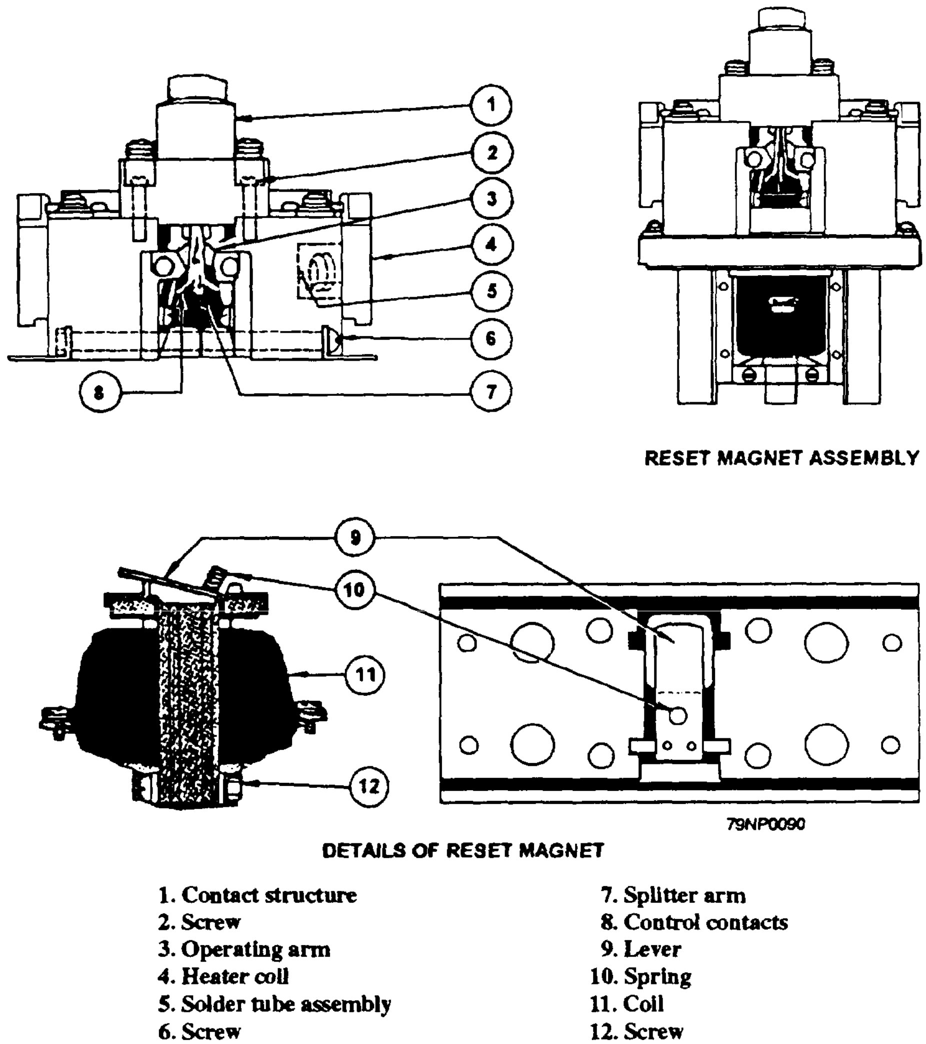


Figure 2-43.—An adjustable thermal overload relay and a reset magnet assembly.

The adjustable thermal relay may be adjusted to trip at a value between 90 to 110 percent of the rated coil current. To change the operating point, loosen the binding screws that hold the relay heater coil (4) so that the coil position may be changed. Moving the coil away from the relay will increase the amount of current needed to trip the relay. Moving the coil closer to the relay will decrease the current needed to trip the relay. This range of adjustment is available only within the range of 90 to 110 percent of coil rating. Each rating has a different manufacture part number. The correct rating is installed when the controller is installed in the ship. Do not use another rating. Make sure both heater coils in each overload relay are the same rating.

The terminal plates and the underside of the slotted brackets of the heater coil assembly are serrated so that the coil is securely held in position when the binding screws are tightened. Some thermal overload relays have reset magnet assemblies attached. You may have to replace the heater coils from the relay. If so, remove the four screws that hold the overload relay to the mounting plate. When removing the relay from the mounting plate, use care not to lose the phenolic pin and bearing block located between the thermal blocks on the underside of the relay.

Next, remove the four large countersunk screws that hold the mounting plate and the reset magnet assembly to the square posts. Remove the four screws in the mounting plate, which support the reset magnet. Take care not to loosen the lever and spring (9 and 10). Remove the two screws (12) and pull the plunger guides. Remove the old coil (11) and install the new coil. Then insert the plunger guides and replace the screws (12). Reassemble the magnet, spring, and lever to the mounting plate. Mount the plate on the posts, and then mount the overload relay on the mounting plate. Replace the heater coils as the last operat.ion.

Overload relays are PROTECTIVE DEVICES. After an overload relay has performed its safeguarding function, you must reset it before running the system again with overload protection.

REVERSE-POWER RELAY

On all ships with ac ship's service power systems where the generators are operated in parallel, each generator control unit has a reverse-power relay. The relay should trip the generator circuit breaker in approximate] y 10 seconds with reverse power equal to 5 percent of the generator rating.

Reverse-power relays trip the generator circuit breaker to prevent motoring the generator. This protection is provided primarily for the prime mover or system, rather than for the generator. Motoring results from a deficiency in the prime mover input to the ac generator. This deficiency can be caused by loss of or low steam to the turbine, lack of fuel to the diesel engine or gas turbine, or other factors that affect the operation of the prime mover. In the absence of reverse-power protection, when the input to the generator falls below that needed to maintain synchronous generator speed, real power is taken from the ship's service power system. The generator acts as a motor driving the prime mover. Reverse-power protection prevents damage to the prime mover if a reverse-power condition should occur.

The reverse-power relay consists of two induction disk-type elements. The upper element is the timer, and the lower one is the direction element. Figure 2-44 shows the coil and induction disk arrangement in the induction-type relay timer element. The disk is 4 inches in diameter and is mounted on a vertical shaft. The shaft is mounted on bearings for minimum friction.

An arm is clamped to an insulated shaft, which is geared to the disk shaft. The moving contact, a small silver hemisphere, is fastened on the end of the arm. The electrical connection to the contact is made through the arm and a spiral spring. One end of the spring is fastened to the arm and the other end to a slotted spring-adjusted disk fastened to a molded block mounted on the element frame. The stationary contact is attached to the free end of a leaf spring. The spring is fastened to the molded block, and a setscrew makes it possible to adjust the stationary contact position.

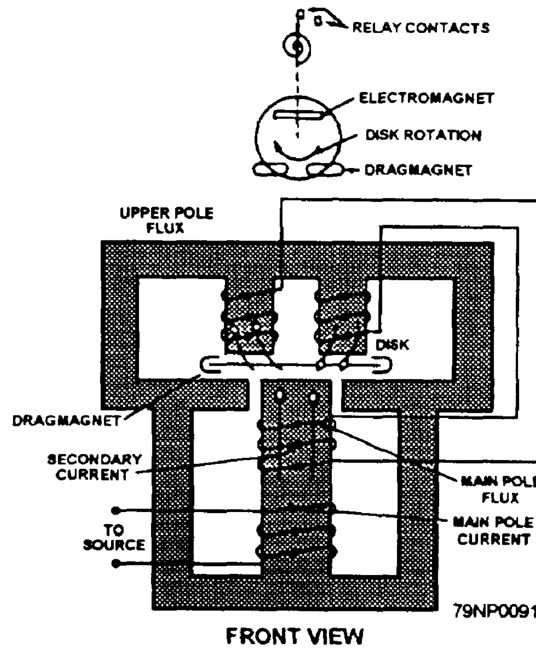


Figure 2-44.—A coil and disk arrangement of an ac reverse-power relay.

The main relay contacts (not shown in fig. 244) will safely handle 30 amperes at 250 volts dc and will carry the current long enough to trip a breaker.

The induction disk is rotated by an electromagnet in the rear of the assembly. Movement of the disk is damped by a permanent magnet in front of the assembly.

The operating torque of the timer element is obtained from the electromagnets (fig. 2-44). The main-pole coil is energized by the line voltage. This coil then acts as the primary of a transformer and induces a voltage in the secondary coil. Current then flows through the upper pole coils. This produces a torque on the disk because of the reaction between the fluxes of the upper and lower poles.

The timer element cannot be energized unless the power flow is in the direction that will cause tripping. This interlocking action is accomplished by connection of the timer potential coil in series with the contacts of the directional element. Thus, the direction of power flow controls the timer relay.

The directional element is similar to the timing element, except that different quantities are used to produce rotation of the disk. There is also a different contact assembly. The two upper poles of the electromagnet are energized by a current that is proportional to the line current, and the lower pole is energized by a polarizing voltage. The fluxes produced by these two quantities cause rotation of the disk in a direction depending upon the phase angle between the current and voltage. If the line power reverses, the current through the relay current coils will reverse with respect to the polarizing voltage and provide a directional torque.

The contact assembly and permanent magnet construction are the same as that used for the timer element. The timer element is rated at 115 volts, 60 hertz. The minimum timer element trip voltage is 65 volts, and its continuous rating is 127 volts.

The direction element has a power characteristic such that, when the current and voltage are in phase, maximum torque is developed. The potential coil is rated at 70 volts, 60 hertz.

The current coil rating is 5 amperes, and the minimum pickup current is 0.1 ampere through the coil. This current is in phase with 65 volts (minimum) across the potential coil. These are minimum trip values, and the timing characteristic of the timing relay may be erratic with low values.

For maximum protection and correct operation, connect the relay so that maximum torque occurs for unity power factor on the system. Because the directional element has power characteristics, make the connection by using line to neutral voltage for the directional element potential coil (polarizing voltage) and the corresponding line current in the series coils. If a neutral is not available, you can obtain a dummy neutral by connecting two reactors, as shown in figure 2-45. When connected in this manner, the directional element voltage coil forms one leg of a wye connection, and the reactors form the other two legs of the wye. Connect the voltage-operated timer element across the outside legs of the transformer secondaries.

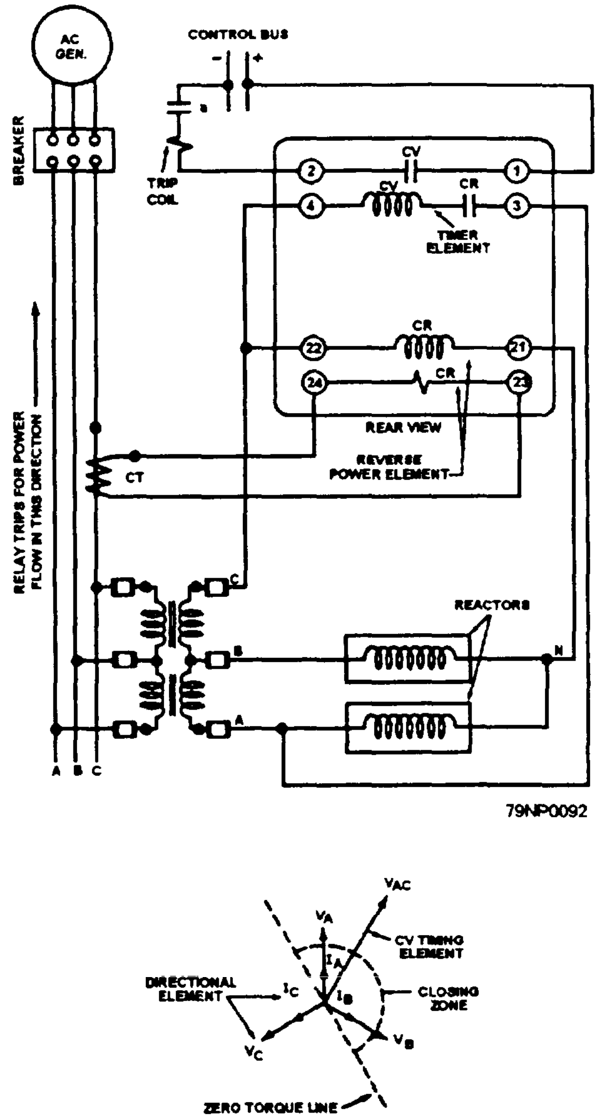


Figure 2-45.—Schematic wiring diagram of an ac reverse-power relay.

REVERSE-CURRENT RELAY

Two or more dc generators may be connected in parallel to supply sufficient power to a circuit. Each dc generator is driven by its own prime mover. If one prime mover fails, its generator will slow down and draw power from the line. The generator will then operate as a motor, and instead of furnishing power to the line, it will draw power from the line. This can result in damage to the prime mover and overloading of the generator. To guard against this possibility, use reverse-current relays.

The reverse-current relay connections are such that when the reverse power reaches a definite percentage of the rated power output, it will trip the generator circuit breaker, disconnecting the generator from the line. Normally, the reverse-current settings for dc relays are about 5 percent of rated generator capacity for dc generators.

The reverse-current relay (one for each generator) is located on the generator switchboard and is an integral part of the circuit breaker. The mechanical construction of a dc relay designed to limit reverse-current flow is

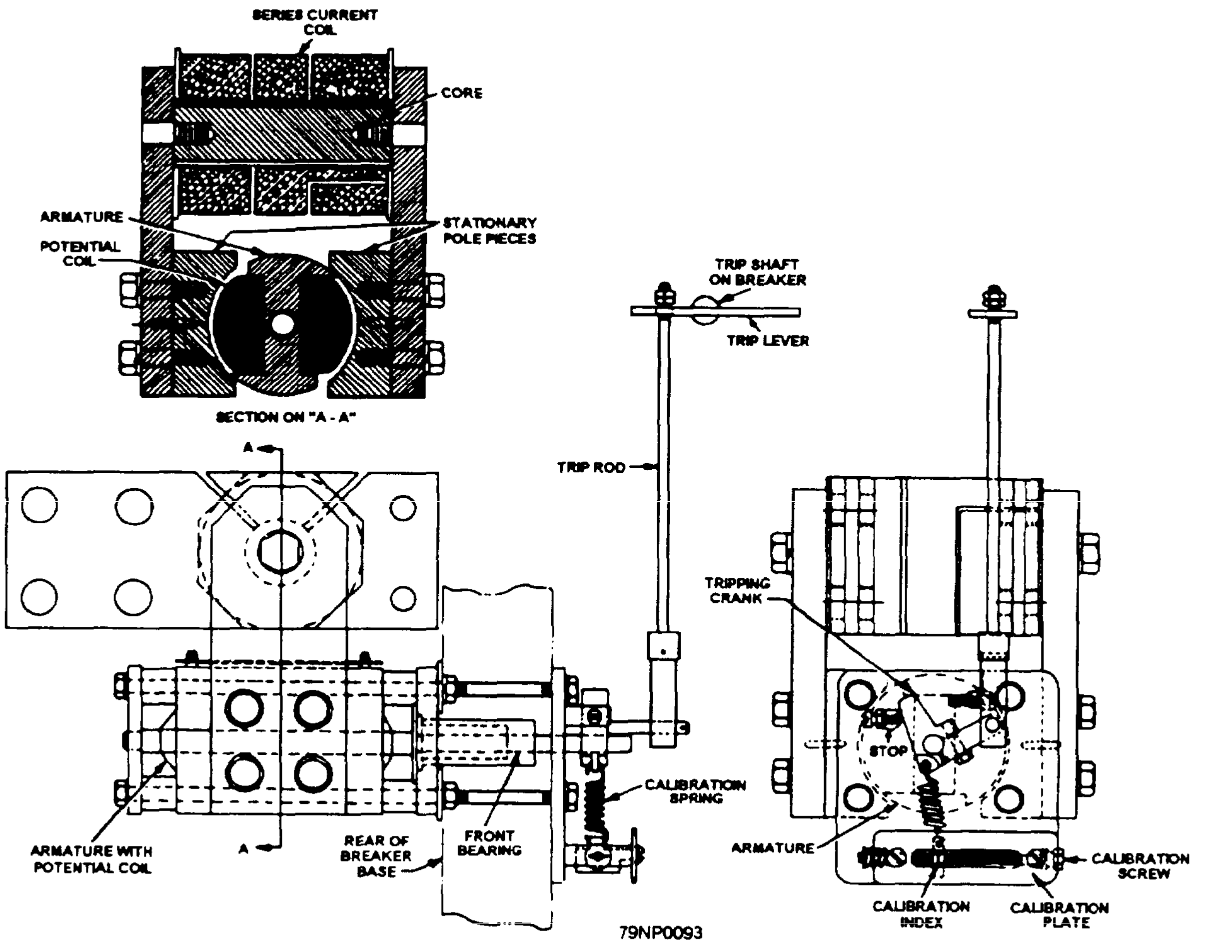


Figure 2-46.—Mechanical construction of an dc reverse-current relay.

shown in figure 2-46. Note that the construction is similar to that of a bipolar motor with stationary pole pieces and a rotating armature.

Figure 2-47 shows the connections of a dc reverse-current relay. The potential coil is wound on the armature, and a current coil is wound on the stationary pole pieces. When used as a protective device, the current coil is in series with the load, and the potential coil is connected across the line. If the line voltage exceeds the value for which the potential coil is designed, connect a dropping resistor at point X in the circuit.

When the line is energized, current flowing through the series coil produces a magnetic field across the air gap. Voltage applied to the armature winding produces a current in the armature coil, which interacts with the magnetic field. A torque is developed that tends to rotate the armature in a given direction. The construction of the relay is such that the armature cannot turn through 360 degrees as in a motor. Instead, the torque produced by the two fields plus the force from the calibrated spring tends to hold the tripping crank on the armature shaft against a fixed stop. This pressure is maintained as long as current flows through the line in the right direction.

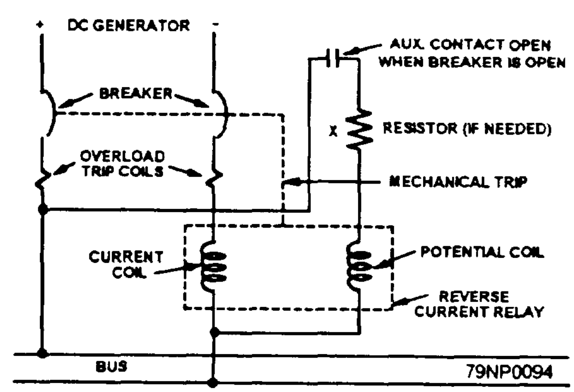


Figure 2-47.—A dc reverse-current connection.

If one generator fails, the voltage output of that generator will drop. When the voltage drops below the terminal voltage of the bus to which it is connected, the generator terminal current (through the relay series coil) will reverse. However, the polarity of the voltage applied to the potential coil remains the same. When the reversed current exceeds the calibration setting of the relays, the armature rotates, and through a mechanical linkage, trips the circuit breaker that opens the bus. This action disconnects the generator from the line.

PHASE-FAILURE RELAY

Because the propulsion type of ac motors require full voltage and current from all three phases supplied by the generator, phase-failure protection is a requirement for this type of shipboard propulsion.

This type of relay is used to detect short circuits on alternating current propulsion systems for ships. Ordinary instantaneous trip relays cannot be used because, under certain conditions, when the motor is plugged, the momentary current may be as great as the short-circuit current.

The relay in use operates when there is a current unbalance. It is connected in the control circuit so that it will shutdown the system fault. However, operation of the relay is not limited to short-circuit detection. The relay may be used as a phase-failure relay. Figure 2-48 shows a phase-failure relay. View A is the arrangement of the parts in the complete assembly, and view B is a closeup of the contact assembly. The entire unit is enclosed in a cover to prevent dirt and dust from interfering with its operation.

The moving contact is the only moving element in the complete relay. There are two stationary contacts that make it possible to have the relay open or close a circuit when it operates.

Two coils are built into the relay. Each coil has two windings that are actuated by direct current from the two Rectox units. Four reactors are used to get sensitivity over a wide frequency range, Because variations in reactance are introduced during manufacture, two resistors are provided to balance the systems during the initial adjustment.

Figure 2-49 is a schematic wiring diagram of a phase-failure relay. The windings are identified by numbers that refer to numbered leads in the three-phase bus. Winding 1-3 is connected to lines 1 and 3; winding 1-2 is connected to lines 1 and 2; and the two windings 2-3 are connected to lines 2 and 3. However, the coils are not directly connected to the bus lines. Instead, connection is made through the Rectox units, which are connected to the line in series with a reactor.

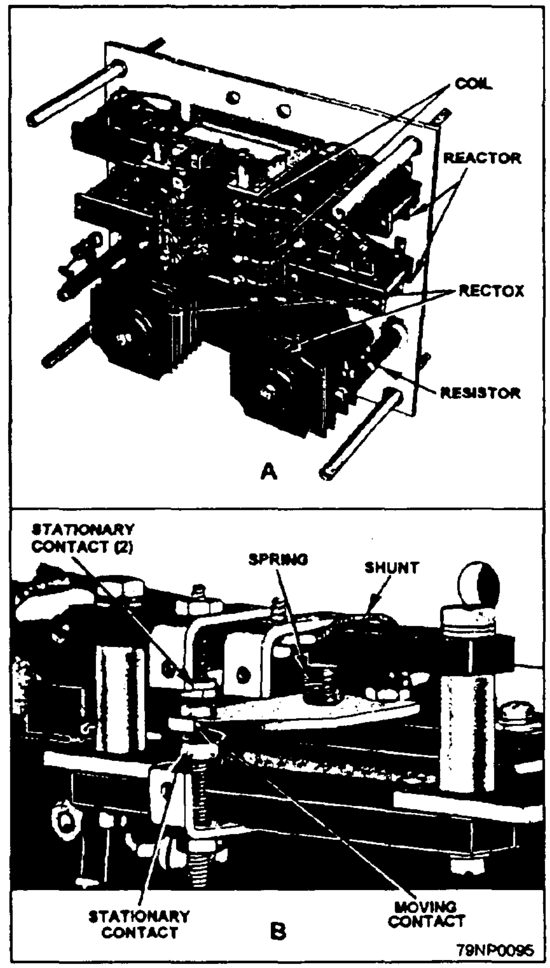


Figure 2-48.—A phase-failure day.

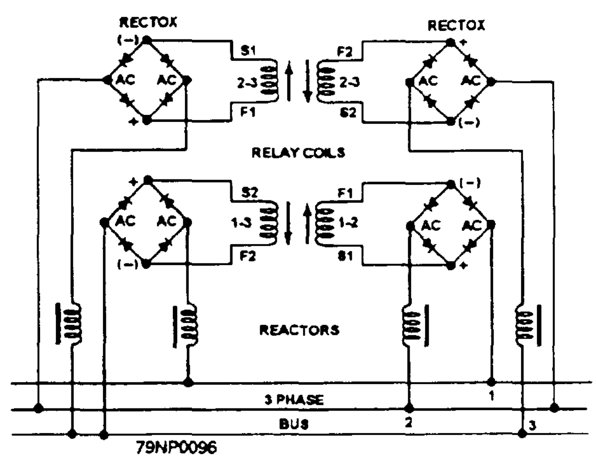


Figure 2-19.—Schematic wiring of a phase-failure relay.

When all three-phase voltages are balanced, the flux produced by winding 1-2 is exactly equal and opposite to that produced by winding 2-3. The flux produced by winding 1-3 is exactly equal and opposite to that produced by the other 2-3 winding. Therefore, the resultant flux is zero, and no magnetic pull is exerted on the armature of the relay.

If a short circuit is placed across lines 1 and 2, no flux is produced by winding 1-2. This means that the flux produced by one of the 2-3 windings is no longer balanced, and there is a resultant flux, which exerts pull on the relay armature. The armature moves until the moving contact hits stationary contact 2 (fig. 2-48, view B). This action opens the circuit between the moving contact and stationary contact 1. As soon as the short circuit is removed from lines 1 and 2, the resultant flux is zero, which allows the spring to return the armature to its original position. Similarly, if shorts occur on lines 2 and 3 or lines 1 and 3, the resultant flux is no longer zero, and the relay will operate.

Never open the dc circuit to the Rectox unit while the voltage is being applied to the ac side. This precaution is necessary because the voltage across the Rectox is only a small portion of the total voltage drop due to the reactor being in the circuit. If the dc side is opened, full voltage is applied across the unit, which may cause the unit to break down.

Very little maintenance is required for this relay. No lubrication is needed. However, the relay must be kept clean so that dirt and dust will not interfere with its operation.

Because the relay rarely operates, check its operation every month or two as recommended by *Naval Ships' Technical Manual,* chapter 320.

CIRCUIT BREAKERS

The purposes of circuit breakers are normal switching operation, circuit protection, and circuit isolation.

Air circuit breakers are used in switchboards, switch gear groups, and distribution panels. The types installed on naval ships are ACB, AQB, AQB-A, AQB-LF, NQB-A, ALB, and NLB. They are called air circuit breakers because the main current-carrying contacts interrupt in air.

Circuit breakers are available in manually or electrically operated types. Some types may be operated both ways, while others are restricted to one mode. Manually or electrically operated types may or may not provide protective functions. The differences and uses of the various types of circuit breakers are described in the following sections.

ACB

The ACB type of circuit breaker maybe for either manual local closing or electrical remote closing. It has an open metallic frame construction mounted on a drawout mechanism and is normally applied where heavy load and high short-circuit currents are available. Figure 2-50 shows the external view of a type ACB circuit breaker.

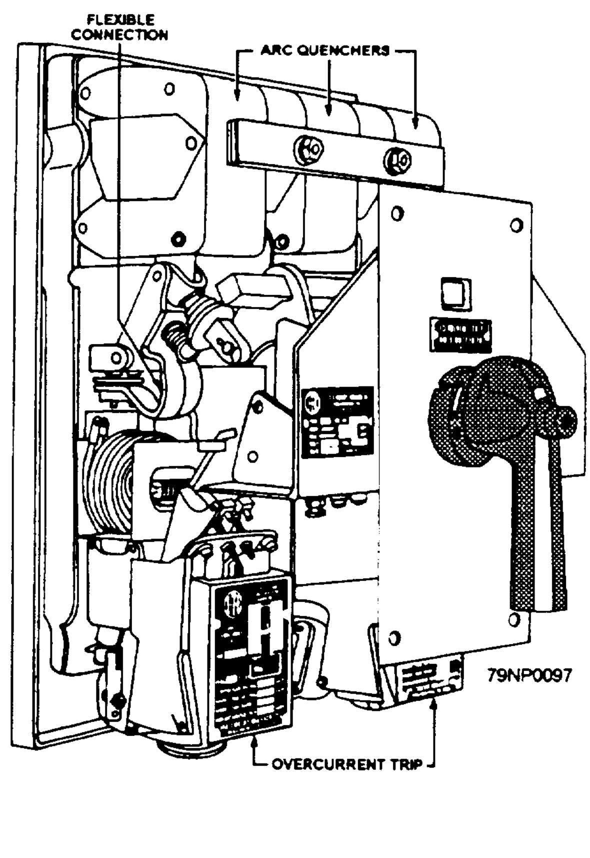


Figure 2-50.—Type ACB circuit breaker.

Type ACB circuit breakers are used to connect ship's service and emergency generators to the power distribution system, bus ties, shore connection circuits, and some feeder circuits from the ship's service switchboard. They are also used on submarines to connect batteries, reactor coolant pump motors, and trim and drain pump motors.

The reverse-power relay is mounted on the panel close to the circuit breaker when it is used with ship's service and emergency generator breakers. Other automatic controls may be located at remote points to give maximum protection to the circuit.

Circuit breaks designed for high currents have a double-contact arrangement. The complete contact assembly consists of the main bridging contacts and the arcing contacts. All current-carrying contacts are high-conductivity, arc-resisting silver or silver-alloy inserts.

Each contact assembly has a means of holding the arcing to a minimum and of extinguishing the arc as soon as possible. The arc control section is called an arc chute or arc runner. The contacts are so arranged that when the circuit is closed, the arcing contacts close first. Proper pressure is maintained by springs to ensure the arc contacts close first. The main contacts then close.

When the circuit opens, the main contacts open first. The current is then flowing through the arc contacts, which prevents burning of the main contacts. When the arc contacts open, they pass under the front of the arc runner. This causes a magnetic field to be set up, which blows the arc up into the arc quencher and quickly extinguishes the arc.

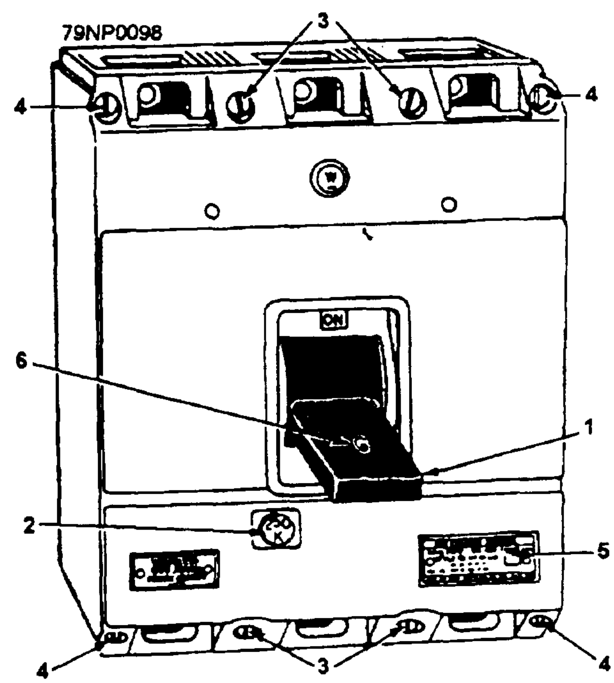
Type ACB circuit breakers are available in both manually (hand-operated) and electrical] y operated types. Electrically operated ACB breakers may be operated from a remote location. The high interrupting types are electrically operated because it is then unnecessary for personnel to approach them to open or close the circuit.

No circuit breaker, regardless of type, should be worked on without opening the circuit. Remember, certain terminals may have voltage applied to them even though the breaker is open. Aboard ship, power maybe supplied to either end of the circuit breaker.

AQB

Type AQB circuit breakers (fig. 2-51) are mounted in supporting and enclosing housings of insulating material and have direct-acting automatic tripping devices. The y are used to protect single-load circuits and all feeder circuits coming from a load center distribution panel.

Where the requirements are low enough, the type AQB may be used on generator switchboards. When it becomes necessary to replace one of the older types of circuit breakers, replace it with the newer AQB-A101, AQB-A250, AQB-A400, AQB-A600, or AQB-A800 as required.



1. Operating handle shown in latched position
2. Ampere rating marker
3. Mounting screws
4. Cover screws
5. Breaker nameplate
6. Cotter key hole

Figure 2-51.—AQB-A250 circuit breaker complete, front view.

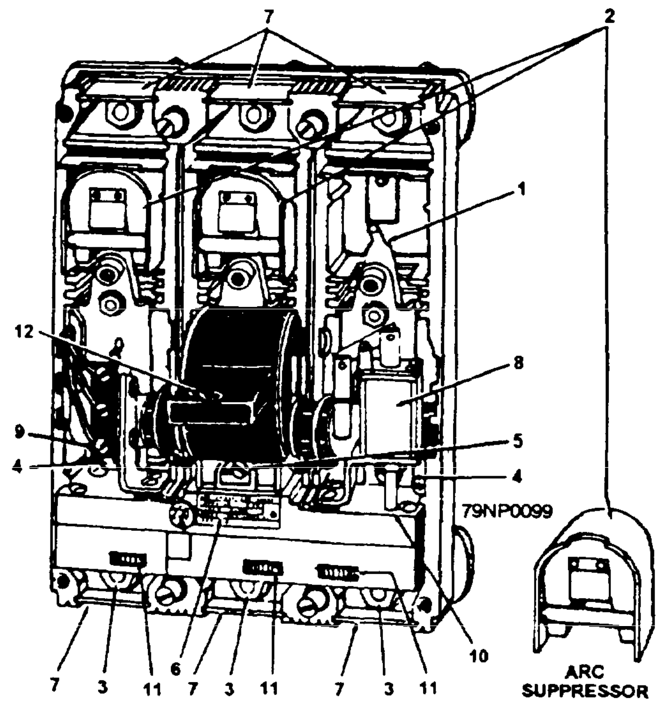
The newer AQB type of circuit breakers, such as the AQB-A250, have several advantages over the older types. The outside dimensions of these new breakers are the same for both the two-pole and three-pole circuit breakers. They are designed for front and rear connections. They may be mounted so as to be removable from the front without removing the circuit breaker cover. The voltage rating of the AQB-A250 are 500 volts ac, 60/400 hertz or 250 volts dc.

The 250 part of the circuit breaker designation indicates the frame size of the circuit breaker. In a 250-ampere frame size circuit breaker, the current-carrying parts of the breaker have a continuous rating of 250 amperes. Trip units (fig. 2-52) for this breaker are available with current ratings of 125, 150, 175, 225, and 250 amperes.

The trip units houses the electrical tripping mechanisms, the thermal elements for tripping the circuit breaker on overload conditions, and the instantaneous trip for tripping on short-circuit conditions.

In addition, 100-, 160-, and 250-ampere rating trip units with a special calibration are available for use with generator circuit breakers. Regardless of the trip unit used, the breaker is still a 250-ampere frame size. The automatic trip devices of the AQB-A250 circuit breaker are "trip free" of the operating handle; in other words, the circuit breaker cannot be held closed by the operating handle if an overload exists. When the circuit breaker has tripped due to overload or short circuit, the handle rests in a center position. To reclose the circuit breaker after automatic tripping, move the handle to the extreme OFF position. This resets the latch in the trip unit. Then move the handle to the ON position.

The AQB-A250 circuit breaker may have auxiliary switches, shunt trip (for remote tripping), or undervoltage release attachments. A shunt trip cannot be provided in the same breaker with an undervoltage release. Figure 2-53 shows a trip unit with a shunt trip (view A) and a trip unit with an undervoltage trip (view B). The coil for a shunt trip has a dual rating for ac and dc voltages. The undervoltage trip coils are wound for a specific voltage, such as 450 ac or 250 dc and have rated pickup and dropout values. The instantaneous trip

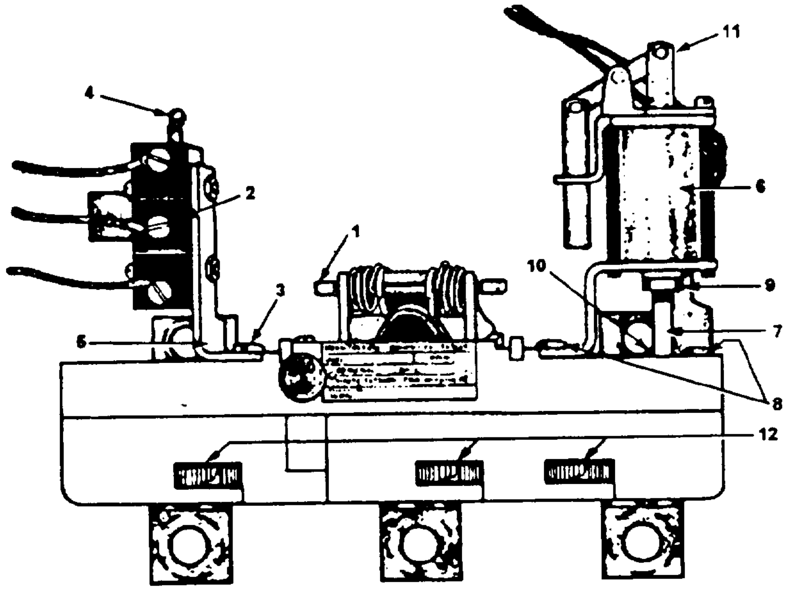


1. Stationary contact
2. Arc suppressors
3. Terminal stud nuts and washers
4. Trip unit line terminal screw-outer poles
5. Trip unit line terminal screw-center pole
6. Trip unit nameplate
7. Terminal barriers
8. Shunt trip or undervoltage device
9. Auxiliary switch
10. Hole for shunt trip or undervoltage release plunger
11. Instantaneous trip adjusting wheels
12. Cotter key hole

Figure 2-52.—AQB-A250 circuit breaker complete front view, with cover and arc suppressor removed.

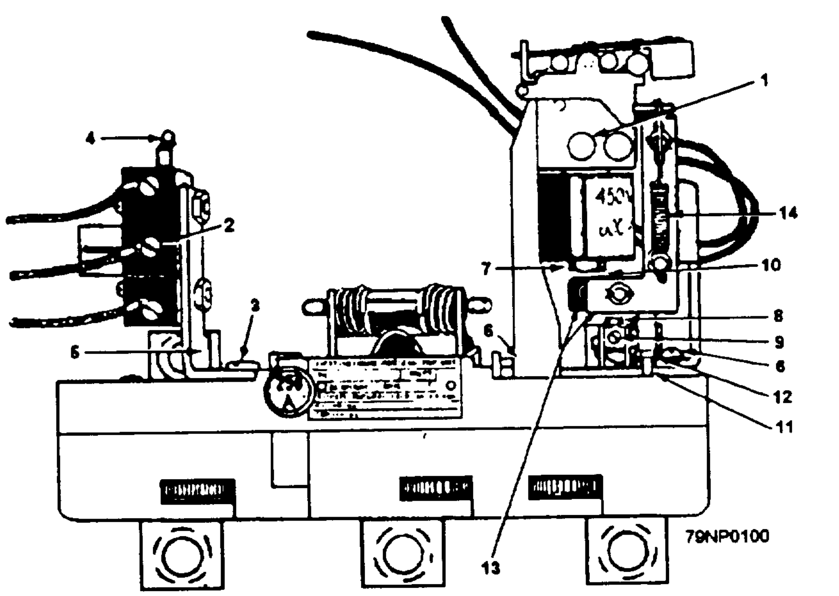
setting of the AQB-A250 trip units maybe adjusted by the instantaneous trip adjusting wheels (12) shown in figure 2-53, view A. These trip adjusting wheels are marked for five positions, LO-2-3-4-HI. The trip unit label (not shown) will list the instantaneous trip value obtainable for each marked position. Identical settings must be made on each pole of the circuit breaker. NEVER remove a circuit breaker cover to perform adjustments while the circuit breaker is in the closed (ON) position.

Terminal mounting block assemblies used in conjunction with the circuit breaker



1. TRIP UNIT LATCH PIN
2. AUXILIARY SWITCH
3. AUXILIARY SWITCH MOUNTING SCREWS
4. AUXILIARY SWITCH LEVER
5. AUXILIARY SWITCH MOUNTING BRACKET
6. SHUNT TRIP
7. SHUNT TRIP TUBULAR CORE
8. SHUNT TRIP MOUNTING SCREWS
9. TUBULAR CORE LOCK NUT
10. HOLE FOR SHUNT TRIP PUSH PIN
11. SHUNT TRIP PLUNGER
12. TRIP ADJUSTING WHEELS

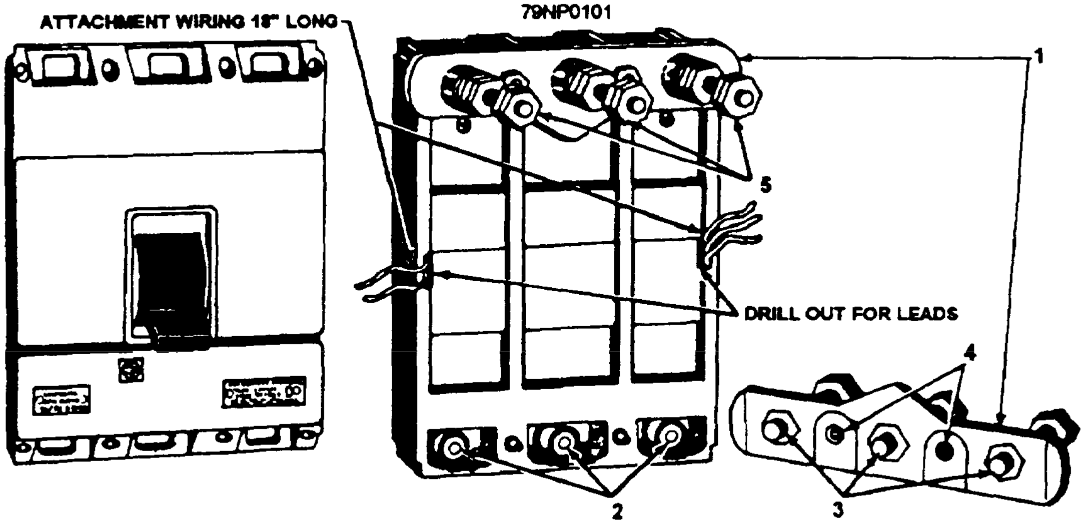
A



1. UNDERVOLTAGE RELEASE
2. AUXILIARY SWITCH
3. AUXILIARY SWITCH MOUNTING SCREWS
4. AUXILIARY SWITCH LEVER
5. AUXILIARY SWITCH MOUNTING BRACKET
6. UNDERVOLTAGE RELEASE MOUNTING SCREWS
7. UNDERVOLTAGE RELEASE MAGNET
8. ARMATURE TRAVEL ADJUSTING SCREW
9. SET SCREW FOR ARMATURE TRAVEL ADJUSTING SCREW
10. ARMATURE-MAGNET AIR GAP
11. UNDERVOLTAGE RELEASE PUSH ROD
12. LOCK NUT FOR PUSH ROD
13. UNDERVOLTAGE RELEASE ARMATURE
14. ARMATURE RETAINING SPRINGS

B

Figure 2-53.—AQB-A250 trip unit; (a) with shunt trip and auxiliary unit; (b) with undervoltage release and auxiliary switch.



1. TERMINAL MOUNTING BLOCKS (2 REQUIRED)
2. SLIP-TYPE CONNECTORS
3. TERMINAL STUDS
4. TERMINAL MOUNTING BLOCK INSERTS FOR BREAKER MOUNTING BOLTS
5. TERMINAL STUD NUTS

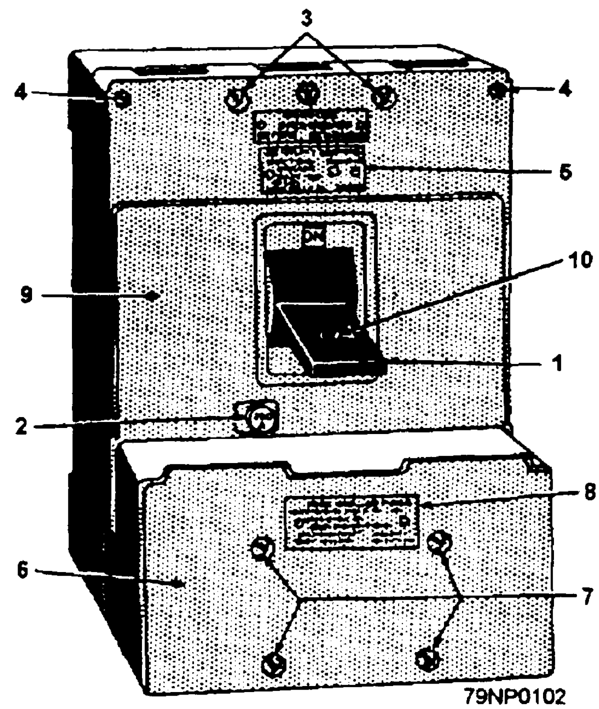
Figure 2-54.—AQB-A250 circuit breaker, rear view, with terminal mounting blocks.

(fig. 2-54) for drawout mounting consist of terminal studs in terminal mounting blocks of insulating material. The terminals of the circuit breaker have slip-type connectors, which engage the terminal studs as shown in figure 2-54. Two mounting blocks are usually required for each circuit breaker. This method of connecting a circuit breaker to a bus or circuit is known as a back-connected circuit breaker. Circuit breakers that have solderless connectors attached to their terminals are commonly called front-connected circuit breakers. The interrupting rating of the AQB-A250 circuit breaker is 20,000 amperes at 500 volts ac, 60 hertz; 10,000 amperes at 500 volts ac, 400 hertz; or 15,000 amperes at 250 volts dc.

AQB-LF250

The AQB-LF250 circuit breaker (fig. 2-55) combines the standard AQB circuit breaker and a current-limiting fuse unit, which interrupts the circuit when the current is in excess of the interrupting rating of the breaker. Constructed as one compact unit, the AQB-LF circuit breaker incorporates the current-limiting fuses (fig. 2-56) as integral parts of the circuit breaker. The common trip features and trip units in this type of circuit breaker are identical to those in the AQB-A250 circuit breakers.

The current-limiting fuse unit is designed so that it trips the breaker and opens all poles if any current-limiting fuse (fig. 2-57) is blown. After a fuse



1. OPERATING HANDLE SHOWN IN LATCHED POSITION
2. AMPERE RATING MARKER
3. BREAKER MOUNTING SCREWS
4. COVER SCREWS
5. BREAKER NAMEPLATE
6. FUSE UNIT ASSEMBLY
7. FUSE UNIT MOUNTING SCREWS
8. FUSE UNIT NAMEPLATE
9. BREAKER COVER
10. COTTER KEY HOLE

Figure 2-55.—AQB-LF250 complete circuit breaker, front view.

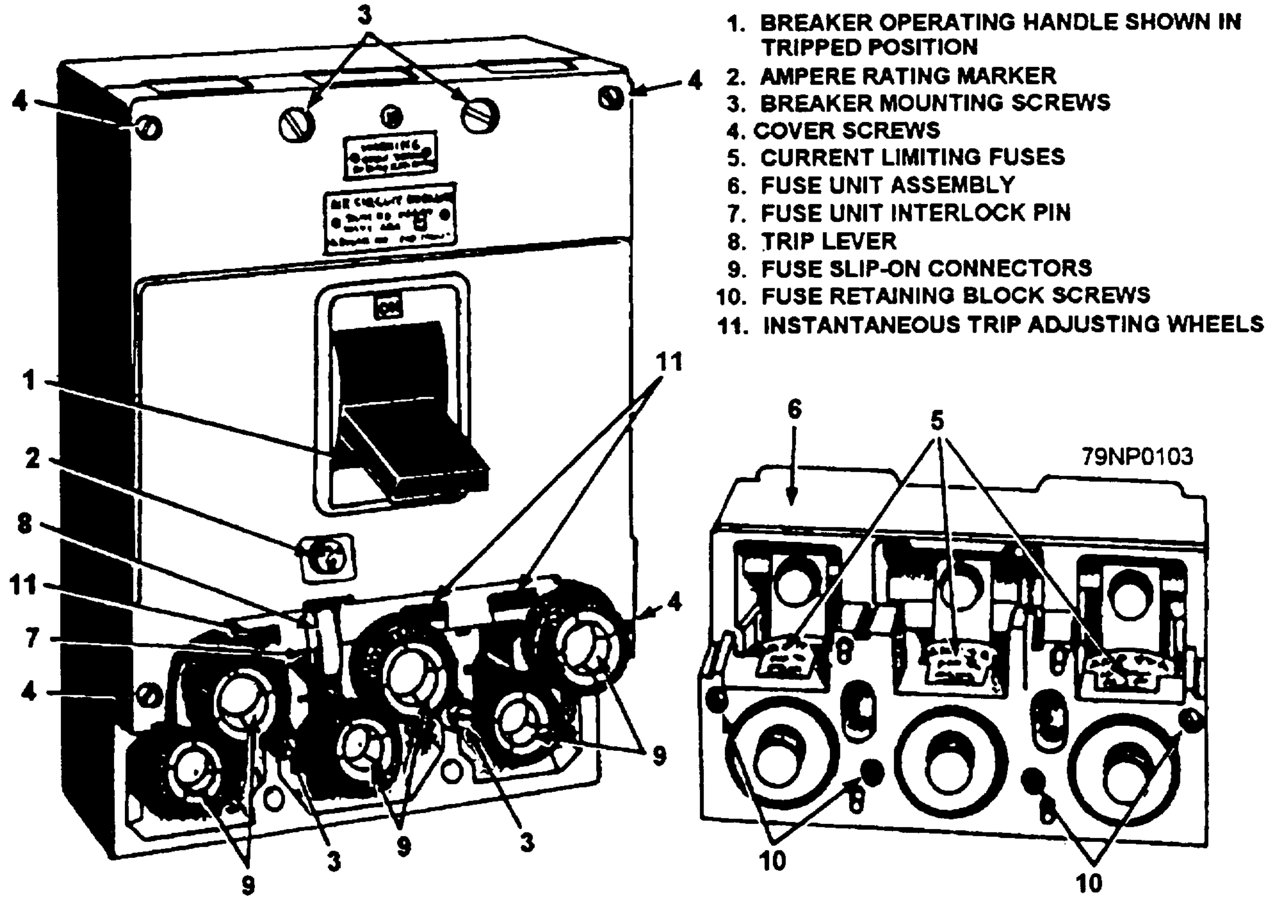


Figure 2-56.—Complete circuit breaker, front view, with fuse unit removed.

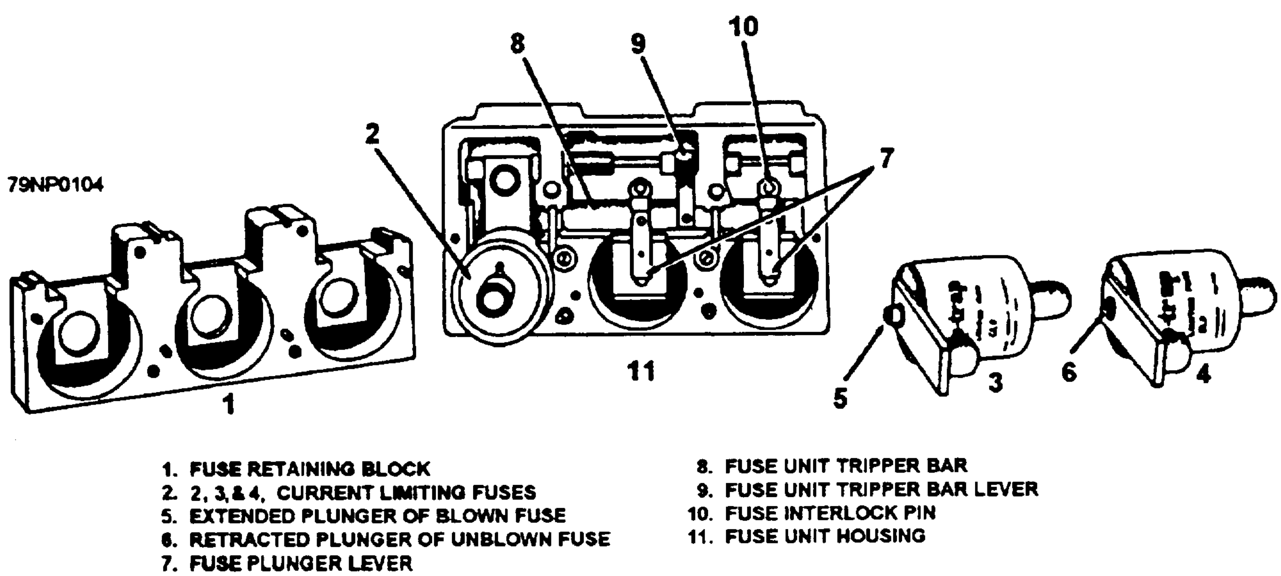


Figure 2-57.—Current-limiting fuse unit assembly.

has blown, the circuit breaker cannot be reclosed until the blown fuse is replaced. Any attempt to remove the fuse unit when the circuit breaker is in the closed position will automatically trip the breaker.

The AQB-LF250 circuit breaker is interchangeable with the AQB-A250 circuit breaker except a larger cutout is required in the switchboard front panel to accommodate the fuse unit of the AQB-LF250.

The AQB-LF250 circuit breaker is a 250-ampere frame size. However, the circuit breaker has an interrupting rate of 100,000 amperes at 500 volts ac, 60 hertz. The AQB-A250 circuit breakers has an interrupting rating of 20,000 amperes at 500 volts ac, 60 hertz.

While the AQB-A250 circuit breaker could be either front or back connected, the AQB-LF250 is designed only for back (drawout type) connection. It uses the same type of slip connector terminal studs as shown in figure 2-54.

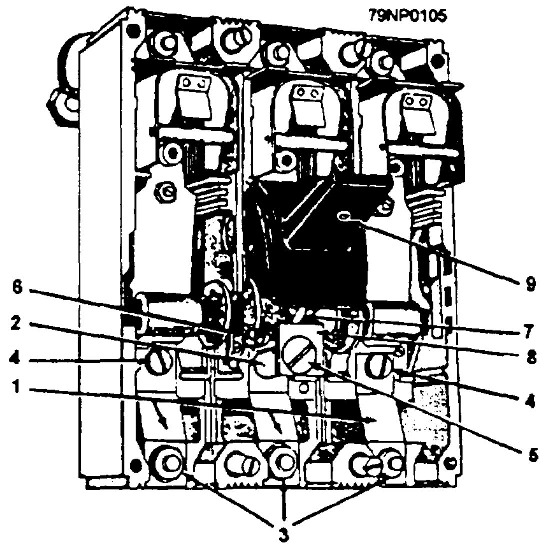
NQB-A250

The NQB-A250 circuit breaker (fig. 2-58) is similar to the AQB-A250 circuit breaker except the NQB-A250 has no automatic tripping devices. This type of circuit breaker is used for circuit isolation and manual transfer , applications. The NQB-A250 is still a 250-ampere frame size. The current-carring parts of the breaker are capable of carrying 250 amperes. Technically, this circuit breaker is simply a large on-and-off switch. Some types of AQB and NQB breakers are provided with electrical operators mounted on the front of the breaker. These are geared motor devices for remote operation of the breaker handle.

ALB

The ALB circuit breakers are designated low-voltage, automatic circuit breakers. The continuous duty rating ranges from 5 through 200 amperes at 120 volts ac or dc. The breaker is provided with a molded enclosure, drawout type of connectors, and nonremovable and nonadjustable thermal trip elements.

This circuit breaker is a quick-make, quick-break type. If the operating handle is in the tripped (midway between ON and OFF) position, indicating a short circuit or overload, the operating handle must be moved to the extreme off position. This automatically resets the overload unit and the breaker can again be closed.



1. Connector straps
2. Latch post
3. Terminal stud nuts & washers
4. Trip unit line terminal screws - outer poles
5. Latch mounting screws
6. Trip unit latch pin slot
7. Mechanism trigger
8. Mechanism trigger latch
9. Cotter key hole

Figure 2-58.—NQB-A250 circuit breaker, front view with cover removed.

NLB

The NLB circuit breakers are identical to the ALB circuit breakers except that they have no automatic tripping device. They are used only as on-off switches.

Maintenance

When you work on circuit breakers, there are several precautions you should take. The most important precaution you should remember to take is to de-energize all control circuits to which the circuit breaker is connected. The procedures differ somewhat with the type of mounting being used.

When working on drawout circuit breakers, make sure that they are switched to the open position. Then the circuit breaker may be removed.

When working on fixed-mounted circuit breakers, open the disconnecting switches ahead of the breakers.

If disconnecting switches are not provided for isolation, you need to de-energize the supply bus to the circuit breaker.

Circuit breakers have different time delay characteristics. Some have a short time, long time, or instantaneous trip.

The adjustments for selective tripping of most circuit breakers are made and sealed at the factory. Normally, you would not make changes to the circuit breaker trip settings because changes may completely disrupt the circuit breaker protection functions. If there is improper tripping action in the compact assemblies, you should correct the problem by replacing the entire breaker.

After circuit breaker covers have been removed, you should check the interior components, such as contacts, overcurrent tripping devices, connections, and moving mechanical parts.

Contacts are small metal parts especially selected to resist deterioration and wear from the inherent arcing. In a circuit breaker, arcing occurs while its contacts are opening and carrying current at the same time. When firmly closed, the contacts must not arc.

The material used to manufacture contacts has been diligently researched. The result of this research is contacts made from various metals and/or alloys that range from pure carbon or copper to pure silver, each used alone and as an alloy with other substances.

SILVER CONTACT MAINTENANCE.— Modem circuit breakers have contacts coated with silver, silver mixed with cadmium oxide, or silver and tungsten. The two silver alloys are extremely hard and resist being filed. Contacts made of silver or silver alloys conduct current when discolored (blackened during arcing) with silver oxide. Therefore, the blackened condition doesn't require filing, polishing, or removal. However, if the silver contact is severely pitted or burned, it may require some filing to remove raised places on surfaces that prevent intimate and overall closure of the contact surfaces. In this case, the contact should be filed by using a fine file or with fine sandpaper, No. 00. If necessary, you may use a clean cloth moistened with **inhibited methyl chloroform.**

NOTE: Ventilate the space when using inhibited methyl chloroform to remove all **deadly** and **toxic** fumes of the solvent.

COPPER CONTACT MAINTENANCE.— When cleaning and dressing copper contacts, maintain the original shape of each contact surface and remove as little copper metal as possible. Inspect the entire contact surface and wipe the copper contact surfaces to remove of the black copper-oxide film. In extreme cases, dress and clean the contact surface using fine (No. 00) sandpaper (the use of fine sandpaper prevents scratching the surface of the contact.) **Never use emery cloth or emery paper.** Because this copper-oxide film is a partial insulator, follow the sanding procedures by wiping with a **clean** cloth moistened with **inhibited methyl chloroform solvent.**

NOTE: Ventilate the space when using inhibited methyl chloroform to remove all deadly and toxic fumes of the solvent.

ARCING CONTACTS.— The function of arcing contacts is not necessarily impaired by surface roughness. You should use a fine file to remove excessively rough spots. Replace arcing contacts when they have been burned severely and cannot be properly adjusted. Make a contact impression and check the spring pressure following the manufacturer's instructions. If information on the correct contact pressure is not available, check the contact pressure with that of similar contacts that are functioning properly. When the force is less than the designed value, you should either replace the contacts if they are worn down or replace the contact springs. Remember, always replace contacts in sets and replace the contact screws at the same time. **Do not clean contacts when the equipment is energized.**

CHECKING CIRCUIT BREAKERS.— Some of the checks you should make on circuit breakers include cleaning the surfaces of the circuit breaker neck, checking arcing contacts, oil piston tripping devices, and sealing surfaces of circuit-breaker contactor and relay magnets.

You should clean all surfaces of the circuit breaker mechanism with a dry cloth or air hose. When cleaning the surfaces, pay particular attention to the insulation surfaces. Before directing the air on the breaker, make sure the water is blown out of the hose, the air is dry, and the pressure is not over 30 psi. Check the pins, bearings, latching, and all contact and mechanism springs for excessive wear or corrosion and evidence of overheating. Replace parts if necessary.

Be certain that the arcing contacts make-before and break-after the main contacts. If poor alignment, sluggishness, or other abnormal conditions are noted, adjust the contacts following the manufacturer's instructions.

Oil-piston type of overcurrent tripping devices (grade B timers) are sealed mechanisms and normally do not require any attention. When oil-film (dashpot) overcurrent tripping devices are used, and the dashpot oil requires replacing, you should remove the oil, clean the interior with kerosene, and refill the dashpot to the proper level with new oil. Ensure that the dashpot is free of dirt, which may hinder the time-delay effect, and that the tripping device is clean, operates freely, and has enough travel to trip the breaker. Do not change the air-gap setting of the moving armature because this would alter the calibration of the tripping device. Lubricate the bearing points and bearing surfaces (including latches) with a drop or two of light machine oil. Wipe off any excess oil.

The sealing surfaces of circuit-breaker contactor and relay magnets should be kept clean and free from rust. Rust on the sealing surfaces decreases the contact force and may result in overheating of the contact tips. Loud humming or chattering will frequently warn of this condition. Alight machine oil wiped sparingly on the sealing surfaces of the contactor magnet will aid in preventing rust.

If wiping arc chutes or boxes with a cloth is not sufficient, clean them by scraping with a file or cleaning pad. Replace or provide new linings when arc chutes or box linings are broken or burned too deeply. Be certain that arc chutes are securely fastened and that there is sufficient clearance to ensure that no interference occurs when the switch or contact is opened or closed

If the shunt and flexible connectors are worn broken or frayed, they should be replaced. The shunt and flexible connectors are flexed by the motion of moving parts.

If working surfaces of circuit breakers, contractors, motor controllers, relays, bearings, and other control equipment show signs of rust, you should disassemble the device and clean the rusted surfaces. Use a light application of oil over the cleaned parts to prevent further rusting. The oil should always be used sparingly when wiping over rusted parts that have been cleaned to prevent further rusting. Remember, oil has a tendency to accumulate dust and grit, which may cause unsatisfactory operation.

Before returning a circuit breaker to service, inspect all mechanical and electrical connections, including mounting bolts and screws, draw-out disconnect devices, and control wiring. lighten where necessay. Operate the circuit breaker manually to make sure that all moving parts function freely. Check insulation resistance.

Inspections

Circuit breakers require careful inspection and cleaning at least once a year. If they are subjected to unusually severe service conditions, you should inspect them more frequently. Also, if a circuit breaker has opened due to a heavy load, it should be inspected.

Calibration

Perform calibration of circuit breakers following the *Naval Ships' Technical Manual,* chapter 300, recommendations.

Metal Locking Devices

Metal locking devices are available that can be attached to the handles of AQB circuit breakers to prevent accidental operation. All breaker handles are provided with a 3/32-inch hole that permits the locking device to be fastened with a standard cotter pin. Naval Ships' Technical Manual, chapter 300, provides a list of the stock numbers for three different sizes of breaker handle locking devices.

SELECTIVE TRIPPING

The purpose of selective tripping is to isolate the faulty section of the system and, at the same time, to maintain power on as much of the system as possible. Selective tripping of circuit breakers is obtained by coordination of the time-current characteristic of the protective devices so that the breaker closest to the fault will open first. The breaker farthest from the fault and closest to the generator will open last.

Figure 2-59 shows a portion of a distribution system with circuit breakers employing selective tripping. The so-called instantaneous tripping time is the minimum time required for a breaker to open and clear a circuit when the operation of the breaker is not intentional y delayed. Each circuit breaker will trip in less than 0.1 second (almost instantaneously) when the current exceeds the instantaneous trip current setting of the breaker. In a shipboard selective tripping power system, the individual circuit breakers (generator, bus tie, shore power, or feeder breakers) differ from each other depending on the following factors:

- The available load current
- The available short-circuit current
- The tripping time band and trip current settings selected

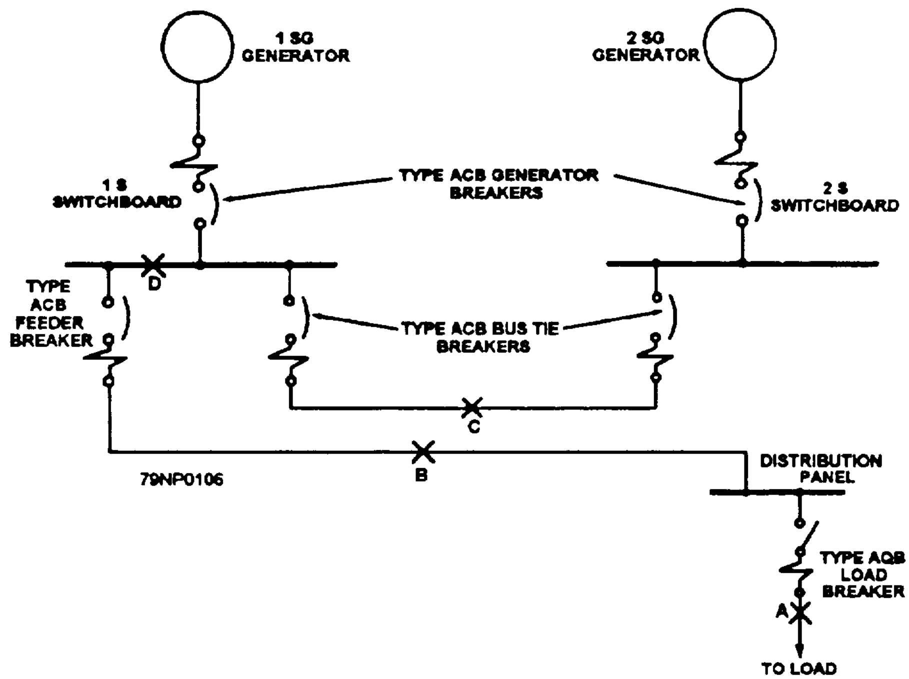


Figure 2-59.—Selected tripping of circuit breakers.

Selective tripping of breakers is normally obtained by a short time-delay feature. This feature is a mechanical time delay and can be varied with limitations. The generator circuit breaker, which is closest to the power source, has the maximum continuous current-carrying rating, the highest available short-circuit current rating, and the maximum short time delay trip. This allows the generator breaker to be the last breaker to trip. However, it will trip on the generator short-circuit current at some definite interval of time within the tolerance of the breaker. Bus tie circuit breakers are usually set to trip after a prescribed time delay that is less than the generator circuit breaker set time delay.

The construction of circuit breakers for selective tripping for currents less than the instantaneous trip current setting causes an intentional delay in the operation of the breaker. The time delay is greater for small currents than for large currents and is therefore known as an *inverse time delay.* The current that would trip the AQB load circuit breaker instantaneous] y and clear the circuit will not trip the ACB feeder circuit breaker unless the current flows for a greater length of time. The same sequence of operation occurs for the other groups of circuit breakers adjusted for selective tripping in the system. The difference between the tripping times of the breakers is sufficient to permit each breaker to trip and clear the circuit before the next breaker starts to operate.

Refer to figure 2-59. Assume that a fault or defect develops in the cable insulation at point A. An overcurrent flows through the AQB load circuit breaker and the ACB feeder circuit breaker. The AQB load breaker will open the circuit and interrupt the current in an interval of time that is less than the time required to open the ACB feeder circuit breaker. Thus, the ACB feeder breaker will remain closed when the AQB breaker clears the circuit. However, if the fault current should exceed the interrupting capacity of the AQB load breaker (for example, an excess of 10,000 amperes), this breaker would be unable to interrupt the fault current without damage to the breaker. To prevent damage to the AQB load breaker, the ACB feeder breaker (on switchboard 1S) serves as a backup breaker for the AQB load breaker and will open almost instantaneously.

A fault at point B with overcurrent would trip the ACB feeder breaker in time but not the ACB generator or bus tie breakers. They require longer time intervals in which to trip.

A fault at point C with overcurrent would trip both ACB bus tie breakers.

A fault at D with overcurrent on switchboard 1S would trip the associated ACB generator breaker and one or both of the ACB bus tie breakers.

In each case, the faulty section of the system is isolated, but power is maintained on as much of the system as possible with respect to the location of the fault.

The attainment of selective tripping requires careful coordination of time-current characteristics for the different groups of circuit breakers. For example, if the system shown in figure 2-59 is operating split plant (bus ties open) and if the time-current characteristics of the ACB feeder breaker and the ACB generator breaker were interchanged, a fault at B with overcurrent would trip generator 1SG off the line but would leave the feeder connected to the switchboard. This action would disconnect power to all equipment supplied by switchboard 1S and also would not isolate the faulty section. Therefore, no unauthorized changes should be made to circuit breaker trip settings because these changes may completely disrupt the scheme of protection based on selective tripping.

System protection by selective tripping of circuit breakers cannot be provided to all types of naval ships or for all circuits. For example, dc distribution systems in older ships and all lighting circuits use fuses to a great extent. Time delay can be incorporated only to the extent that is permitted by the characteristics of the fuses. The use of progressively large fuse sizes from the load to the generator provide some degree of selectivity for overload or limited fault protection.

GROUNDED RECEPTACLES

Grounded receptacles are installed aboard naval vessels to ensure that grounded plugs, portable cables, and portable electrical tools are grounded to the ship's structure when they are in use. The ground wire prevents the occurrence of dangerous potentials between the tool or equipment housing and the ship's structure. This protects the user from fatal shock.

The grounded receptacles most widely used aboard naval vessels have metal enclosures internally connected to the ground terminal of the receptacle. Grounding the enclosures will ground the grounded terminal. Grounded receptacles with plastic enclosures are also used aboard some vessels. In some types, the grounded terminal is connected to ground through a conductor. In later types, the grounding ferrules are molded within the mounting. The ground wire is also molded within the bottom of the box and connects the grounding terminal to the metal insert. The cross-sectional area of the conductor used to connect the grounded terminal to ground must be at least the same size or greater than that of the conductors that supply a receptacle.

TYPES OF RECEPTACLES

On the older ships with single 125-volt, 10-ampere, single-phase ac (or two-wire de), stub-type watertight receptacles are used for all applications except for electric shavers and some electronic applications. For electric shavers and some electronic applications, double 125-volt, 15-ampere, single-phase ac (or two-wire dc) bladed-type receptacles are used

On new ships, general-purpose grounded receptacles are provided as follows:

1. Double 125-volt, 15-ampere, single-phase ac (or two-wire dc) bladed-type receptacles are used for all below-deck applications.
2. Single 125-volt, 15-ampere, single-phase ac (or two-wire de) watertight bladed-type receptacles are installed on radar platforms and open bridges for use of electronic test equipment.
3. Single 125-volt, 10-ampere, single-phase ac (or two-wire dc) stub-type submersible receptacles are used topside and for applications where a watertight receptacle is require&except on radar platforms and open bridges.

RECEPTACLE LOCATION

Receptacles must be spaced to permit the use of portable tools at anyplace on the ship without requiring more than 50 feet of flexible cable between a tool and receptacle. Receptacles installed for specific applications, such as radiant heaters, are included in the receptacle spacing to meet the 50-foot limit. They may be considered as available for portable tools.

If additional receptacles are required to meet the 50-foot limit, make sure that added receptacles don't result in overloading the circuits. In some ships the receptacles are on an isolated circuit as an additional means of preventing fatal shocks.

RECEPTACLE TESTING

The routine ground continuity test of each installed receptacle is required by PMS. Before a receptacle is ground tested, it must be de-energized, safety tagged, and checked for voltage. This safety precaution will protect you and the test equipment.

In one method of testing, you connect one test lead of an ohmmeter or multimeter to the ground lead of a dummy plug of the receptacles to be tested. The power prongs of this plug are to be left unconnected. Insert the plug into the receptacle to be tested. Touch the probe of the other test lead of the meter to the ship's structure. The reading should be less than 1 ohm.

If a receptacle tests unsatisfactory, it should be immediately repaired or tagged with a red danger tag to indicate that it must not be used Keep a record of the locations of all grounded receptacles and the dates they were tested.

ELECTRICAL EQUIPMENT ABOARD SHIP

The Navy has adopted a policy to use commercially available tools and equipment, when feasible. No specific guidance can be provided to cover all portable tools and equipment. Much of the burden of accepting and rejecting portable electrical and electronic equipment falls on the electrical or electronic officer or other designated personnel to perform the initial inspection.

APPROVAL FOR USE

Nonconducting cased portable tools and equipment do not require grounding cords or plugs, provided the equipment meets both of the following requirements:

1. Passes an initial inspection for rugged, safe construction, and
2. Has a minimum of 1 megohm dc resistance from any phase to any exposed metal part (such as chuck housing, mounting screws, ear plug jacks, or antennas) or metal chassis.

The following equipment is acceptable for use aboard ship:

- If the portable tool or equipment has the words **DOUBLE INSULATION** or **DOUBLE INSULATED** stamped on its enclosure, it is assumed to be of rugged, safe construction. This stamping designation is an underwriters requirement; however, this requirement is only applicable to selected type of equipment. Portable equipment, which hasn't been stamped DOUBLE **INSULATION** or **DOUBLE INSULATED,** will be acceptable if they meet the two requirements listed above.

- All equipment, when tested with a Megger, must have at least 1 megohm resistance between either sides of the line and any exposed metal of the equipment.

When equipment meets the above criteria, it is acceptable for use with a two prong plug and cord. However, if the equipment was originally provided with a grounding cord and plug, this type cord and plug must be retained throughout the life of the device. Equipment stamped **DOUBLE INSULATION** or **DOUBLE INSULATED** must have only two prong plugs and cords. At the discretion of the inspection authority, three-prong plugs and cords may be installed on other equipment if the ground conductor can be conveniently connected to the exposed metal parts, and the modification does not compromise the equipment operation or the enclosure integrity.

CAUTION

A wide range of miscellaneous portable electric equipment may be received aboard ship without being provided with a cord that has a grounding conductor and a grounded plug that is not plastic encased. This equipment includes galley equipment (fruit juice extractors, food-mixing machines, coffee pots, toasters); office equipment (adding machines, addressograph machines); shop equipment (key duplicating machines, valve grinders, mica undercutter, hot plates); medical equipment (infrared lamps, ultraviolet lamps, sterilizers); barber shop equipment (hair clippers); and laundry equipment(flatirons)

When electrically operated equipment is issued to the ship without a grounding conductor or grounded plug, it must have a three-conductor flexible cable and grounded plug installed before it is used. (Nonconducting plastic-cased portable electric tools are excluded.)

The three-conductor flexible cable should be type SO or ST color-ceded black, white, and green, as listed in the Navy Stock List of General Stores, Group 61. For general use, the plugs should be bladed and have U-shaped grounding prongs. These plugs are available for use with small and large diameter cords. Stub-type plugs that can be made watertight (formerly designed as type SNR) are now furnished with plastic shells.

PERMANENTLY MOUNTED EQUIPMENT

Electrical equipment that is permanently mounted to the hull of the ship does not require an additional ground wire. However, equipment installed with shock mounts does require an external ground cable.

Additionally, this equipment must be "hard wired" to the power source vice having a cord with a plug attached

TESTING ELECTRICAL EQUIPMENT

Before using portable electrical equipment for the first time, test the plug connections of the equipment for correct wiring. Do the testing in a workshop equipped with a nonconducting surface workbench and approved rubber deck covering. Conduct the test according to current PMS procedures.

Portable and Mobile Equipment

All portable and mobile electrical equipment must be periodically tested and visually inspected. A list of such equipment must be established noting the locations and serial numbers. The following items should be included:

1. Portable, hand-held electric tools that are permanently loaned out to other shipboard departments or divisions
2. Electric equipment that is frequently touched, such as hot plates, coffee makers, toasters, portable vent sets, movie projectors, and office equipment.

All faulty equipment must be removed from service until they are repaired and properly safety checked.

Bladed Plugs (Round or U-shaped Contact)

Before testing a bladed plug, check to see that the insulation and contacts are in good condition and that the conductors are secured properly under the terminal screws. Using a volt-ohmmeter, measure the resistance from the ground contact to the equipment housing. The measurement must be less than 1 ohm. Move or work the cable around by bending or twisting it. A change of resistance indicates broken strands in the grounding conductor. This means the cable must be replaced

Navy SNR Plugs

You must examine the type SNR plugs to make sure the insulation and contacts are in good condition and that the conductors are secured properly under the terminal screws. Then check to see that the plug is clean and that the contacts (in particular the ground contact) are free of hangover fringes of molded insulation that could prevent making good contact. Measure the resistance from the ground contact to the equipment housing. Again, the measurement must be less than 1 ohm. If bending or twisting the cable causes a change in resistance, the strands in the grounding conductor are broken and the cable must be replaced.

The SNR plug must be checked on equipment and extension cord. Using a megohmmeter, measure the insulation resistance between the brass shell and each contact on the plug. Push on, pull on, twist, and bend the cable while you take measurements. If the resistance measures less than 1 megohm, check for twisted bare wires in the plug. Rewire a defective plug and replace the brass shell of the plug with a nonconducting plastic (nylon) shell. If the plug has to be replaced due to wear and tear, renew the plug tip and replace the brass plug shell with a nylon shell. Reuse brass shells only if the nylon plug shells are not in stock. In this case, rewire and retest the brass shell plug for temporary use until the nylon shell becomes available. There are two sizes of nylon plug shells. One size is used for 0.425-inch-diameter cables or smaller, the other size for 0.560-inch-diameter cables.

WORKMANSHIP

Cord conductors must be fastened securely and properly to wiring terminals. Aboard ship in portable equipment, extension cords, portable receptacles, and plugs, the conductor ends are crimped or soldered into standard eyelets (or hooks where the terminal screws are not removable). If eyelets or hooks are not available, twist the strands of each conductor together tightly and form into an eyelet or a hook. Then, coat the formed eyelet or hook with solder to hold the strands together unless the manufacturer's instructions forbid tinning of the leads. There must be no loose strands to come in contact with metal parts. This would place line potential on the metal shell of the plug when it is partially inserted in an energized receptacle. A fatal hand-to-hand electrical shock can result if the receptacle is on the end of an energized extension cord and has its metal case raised to line potential (of opposite polarity to that on the shell of the plug) by loose conducting strands at the cord connection to the receptacle.

Examine all cords to make sure they are connected properly to their terminals. Remove damaged plugs and cords that are improperly connected, torn, or chafed from service. (**NOTE:** Don't cut open molded rubber plugs and receptacles for examination.)

If the grounding conductor connected to the metallic equipment casing is inadvertently connected to a line contact of the plug, a dangerous potential will be placed on the equipment casing. The person handling the portable metal-cased equipment will receive a fatal shock when it is plugged into a power receptacle, because the line voltage will be on the exposed parts of the equipment. **Make sure that all connections are right before using the tool, equipment, or receptacle.**

Extension cords are authorized for use with portable tools and equipment. They consist of 25 feet of three-conductor flexible cable (which includes the grounding wire) with a grounded plug attached to one end and a grounded type of portable receptacle suitable for receiving the grounded type of tool or equipment plug on the other end.

SUMMARY

In this chapter, you learned about the electrical cables presently installed aboard ship and the newer low-smoke cables now being used. By reading this chapter, you were introduced to the various types and sized of cable; nonflexing and flexing service; cable construction, selection, and installation; conductor identification; and cable markings and maintenance.

Other information contained in this chapter includes a discussion of casualty power cables, shore-power cables, the phase-sequence indicator, stuffing tubes, deck risers, wireways, and cable supports. Additionally, we provided information about control devices, relays, circuit breakers, grounded receptacles, and plugs and cords.

For technical information not included in this TRAMAN, please refer to the *Cable Comparison Guide,* NAVSEA 0981-052-8090; *Cable Comparison Handbook,* MIL-HDBK-299 (SH); the *Electronics Installation and Maintenance Book,* NAVSEA 0967-000-0110; and *Naval Ships' Technical Manual,* Chapters 300, 320, and 475.

CHAPTER 3

ELECTRICAL DISTRIBUTION SYSTEMS

Almost every function undertaken aboard a naval ship depends upon electric power for its accomplishment. From the launching of missiles against an aggressive force to baking bread for lunch, electric power is vital to a ship's ability to accomplish its mission.

LEARNING OBJECTIVES

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

1. *Identify the various electrical distribution systems installed on board Navy ships.*
2. *Identify the characteristics and construction features of and recognize the operation of ac generators.*
3. *Identify some working principles, characteristics, and design features of transformers.*
4. *Recognize several factors that determine the output voltage and frequency of ac generators.*
5. *Identify various operating fundamentals of ship's service distribution systems, including switchboards, bus transfer equipment, and shore power.*
6. *Recognize various principles and procedures in rigging or unrigging casualty power.*
7. *Recognize distinct maintenance and test procedures used in keeping an electric plant on the line.*

AC POWER DISTRIBUTION SYSTEM

The ship's service electric plant is that equipment that takes the mechanical power of a prime mover and converts it into electrical energy. The prime mover may be steam, gas turbine, diesel, or motor driven. The mechanical energy of the prime mover is converted into electrical energy in the ship's service generators. These generator sets supply power to the ships ac power distribution system to be distributed to the various electrical loads throughout the ship.

The ac power distribution system aboard ship is made up of the following parts:

- AC power plant
- Switchboards that distribute the power
- The equipment that consumes the power

The ac power distribution system consists of the following three parts:

1. The service power distribution system
2. The emergency power distribution system
3. The casualty power distribution system

ELECTRICAL DISTRIBUTION SYSTEM

The electrical distribution system is the link between the ship's source of electrical power and the ship's electrical loads. Power is normally supplied from the ship's own generators but can be supplied from an external source through the shore power cables. In naval ships, most ac power distribution systems are 450-volt, three-phase, 60-Hz, three-wire systems.

Bus ties interconnect the ship's service generator and distribution switchboards. Therefore, any switchboard can be connected to feed power from the generators to one or more of the other switchboards allowing the generators to operate in parallel. In large installations (fig. 3-1), power from the generators goes through distribution switchboards or switchgear groups to the load centers, through distribution panels, and on to the loads. Distribution may also be direct from the load centers to some loads.

On some large ships, such as aircraft carriers, a system of zone control of the ship's service and emergency power distribution system is provided. The system sets up several vertical zones that contain one or more load center switchboards supplied through bus feeders from the ship's service switchgear group. A load center switchboard supplies power to the electrical loads

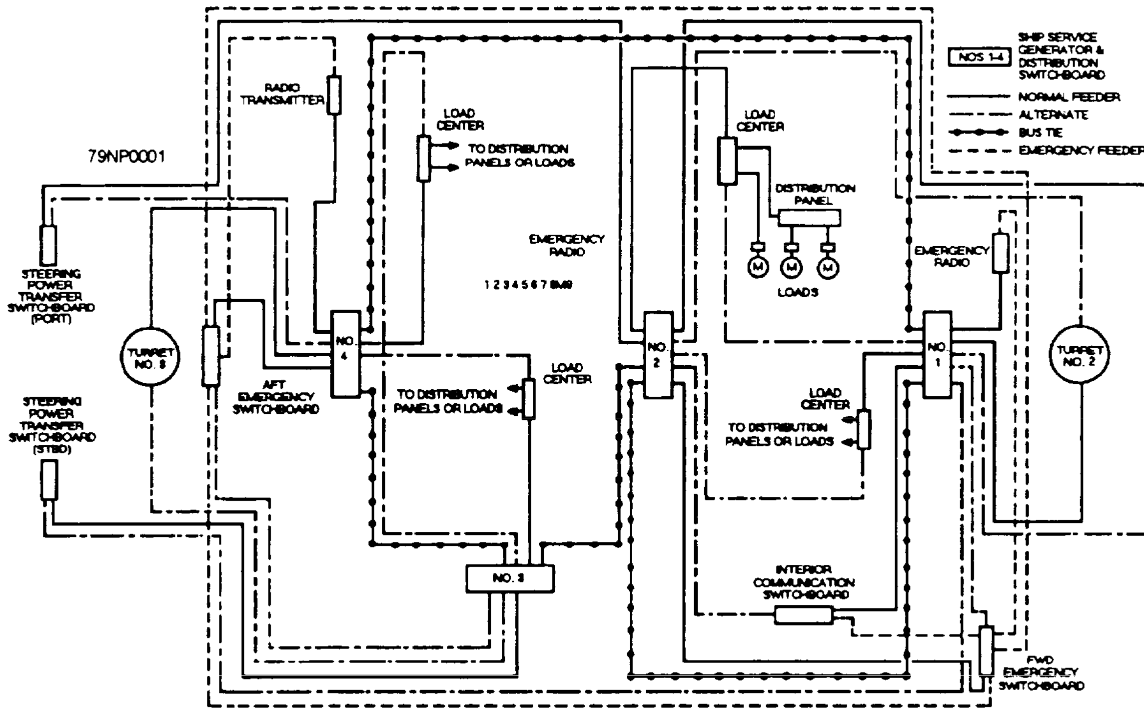


Figure 3-1.—Power distribution in a large combatant ship.

within the electrical zone in which it is located. Thus, zone control is provided for all power within the electrical zone. An emergency switchboard may supply more than one zone.

In small installations (fig. 3-2), the distribution panels may or may not be fed directly from the generator and distribution switchboards. The distribution panels and load centers, if installed, are located centrally with respect to the loads that they feed. This arrangement simplifies the installation and requires less weight, space, and equipment than if each load were connected to a switchboard.

Circuit Markings

All distribution panels and bus transfer equipment have cabinet information plates (shown below). These plates contain the following information in the order listed:

1. The name of the space, apparatus, or circuits served
2. The service (power, lighting, electronics) and basic location number
3. The supply feeder number

CREW LIVING SPACE, FRAMES XX -XX

FIRST PLATFORM

LIGHTING PANEL 4-108-2

2S-4L-(4-103-2)

If a panel contains two or more sets of buses and each set is supplied by a separate feeder, the number of each feeder is indicated on the identification plate.

Distribution panels have circuit information plates next to the handle of each circuit breaker or switch. These plates contain the following information in the order listed:

1. The circuit number
2. The name of the apparatus or circuit controlled
3. The location of the apparatus or space served
4. The circuit breaker element or fuse rating

Vital circuits are shown by red markers attached to circuit information plates. In addition to the red marker, information plates for circuit breakers supplying circle W- and circle Z-class ventilation systems contain, the class designation of the ventilation system supplied.

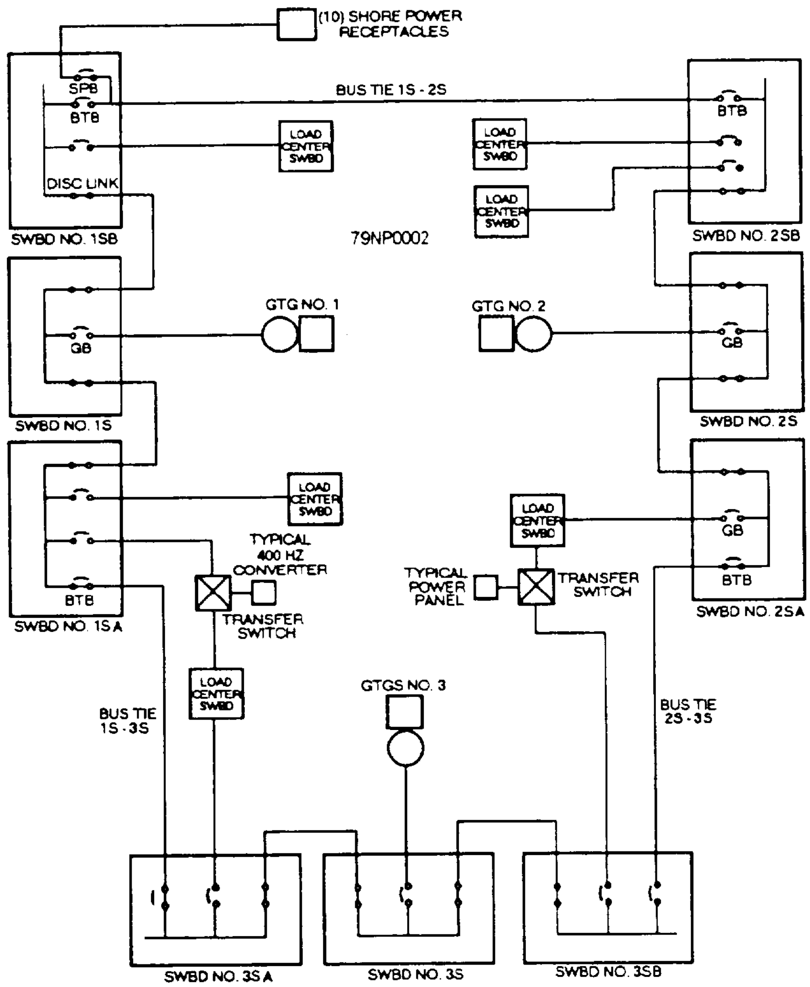


Figure 3-2.—Power distribution in a gas turbine powered DDG.

Information plates without markings are provided for spare circuit breakers mounted in distribution panels. Panel switches controlling circuits that are de-energized during darkened ship operations are marked DARKENED SHIP. The ON and OFF position of these switches are marked LIGHT SHIP and DARKENED SHIP, respectively.

Circuit information plates are provided inside fuse boxes (next to each set of fuses). They show the circuit controlled, the phases or polarity, and the ampere rating of the fuse.

Phase Sequence

The phase sequence. in naval ships is ABC (fig. 3-3); that is, the maximum positive voltages on the three phases are reached in the order A, B, and C. Phase sequence determines the direction of rotation of three-phase motors. Therefore, a reversal of the phase sequence could cause damage to loads, especially pumps, driven by three-phase motors. The phase sequence of the power supply throughout a ship is always ABC (regardless of whether power is supplied from any of the switchboards or from the shore power

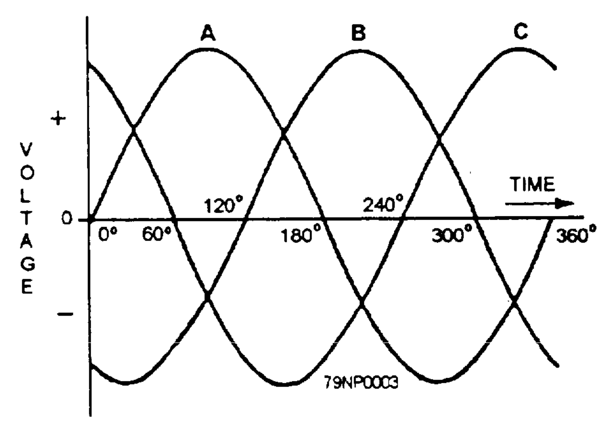


Figure 3-3.—Sine curve for three-phase circuit.

connection) to ensure that three-phase, ac motors will always run in the correct direction.

Phase identification is shown by the letters *A, B,* and *C* in a three-phase system. Switchboard and distribution panel bus bars and terminals on the back of switchboards are marked to identify the phase with the appropriate letters, *A, B,* or *C*. The standard arrangement of phases in power and lighting switchboards, distribution panels, feeder distribution boxes, feeder junction boxes, and feeder connection boxes is in the order A, B, and C from top to bottom, front to back, or right to left when facing the front of the switchboard, panel, or box, and left to right when facing the rear of the switchboard, panel, or box.

BUS TRANSFER SWITCHES

Bus transfer equipment is used to provide two sources of power to equipment that is vital to the ship. **(NOTE:** Vital equipment is that equipment needed to operate safely or that could cause the ship to become disabled if it became de-energized.) Depending upon the application, the transfer from one source to another may be done manually, by a manual bus transfer switch, or automatically by an automatic bus transfer switch.

Manual Bus Transfer (MBT) Switches

When normal power to vital equipment is lost, power must be restored as soon as possible to ensure the safety of the ship. MBTs may be used to switch from normal to alternate or emergency power for those loads that draw a large starting current or that must meed some condition before energizing.

By having a manual transfer of the power source, the electrician on watch can make sure that all conditions are met before energizing the equipment after a loss of power.

Automatic Bus Transfer (ABT) Switches

ABTs are used to provide two sources of power to those loads that **MUST** be re-energized as soon as possible. Examples of loads that **must** be re-energized include lighting in main engineering spaces, the ship's steering motors and controls, motor driven fuel pumps and lubricating oil pumps in the engineering spaces.

The Model A-2 ABT switch operates on 120-volt, 60Hz circuits. It is usually used to handle small lighting circuits. It may be used on single- or three-phase circuits. For explanation purposes, the three-phase unit will be discussed. As you read this section, refer to figures 3-4 and 3-5.

The A-2 ABT is designed to shift automatically from normal to the alternate or emergency source of power when the source voltage drops to the dropout range (81 -69 volts) across any two of the three phases. Upon restoration of normal power (98-109 volts), the unit will transfer back to the normal power supply. An intentional time delay of 0.3 to 0.5 seconds in both the transfer and retransfer operations is built in to prevent unnecessary transfer of power during line voltage surges and very short duration losses of power.

Operation

Table 3-1 lists the sequence of events in transferring from the normal to the alternate source of power through the A-2 ABT switch:

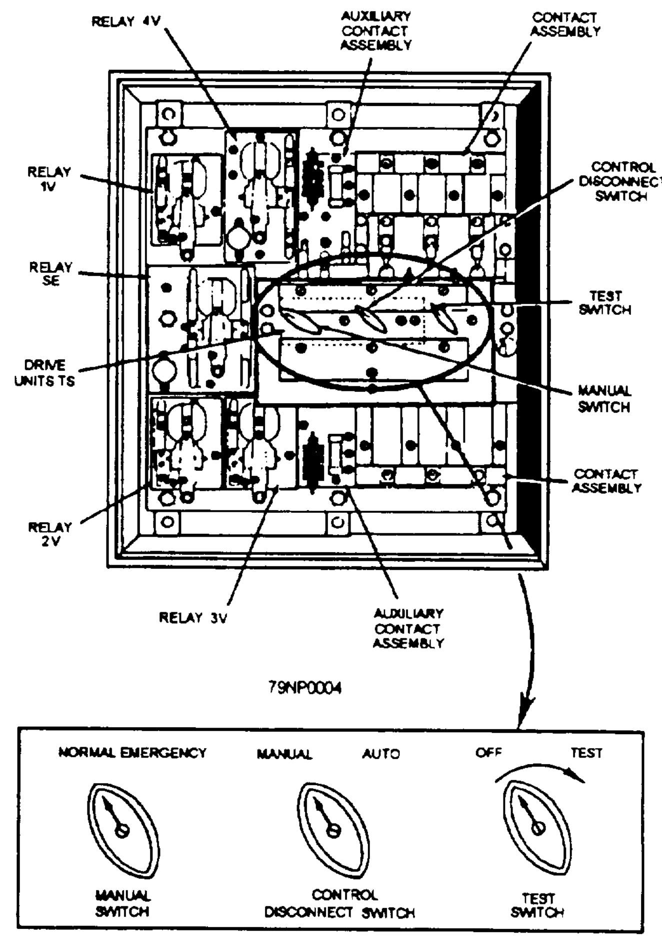


Figure 3-4.—A pictorial view of the A-2 ABT.

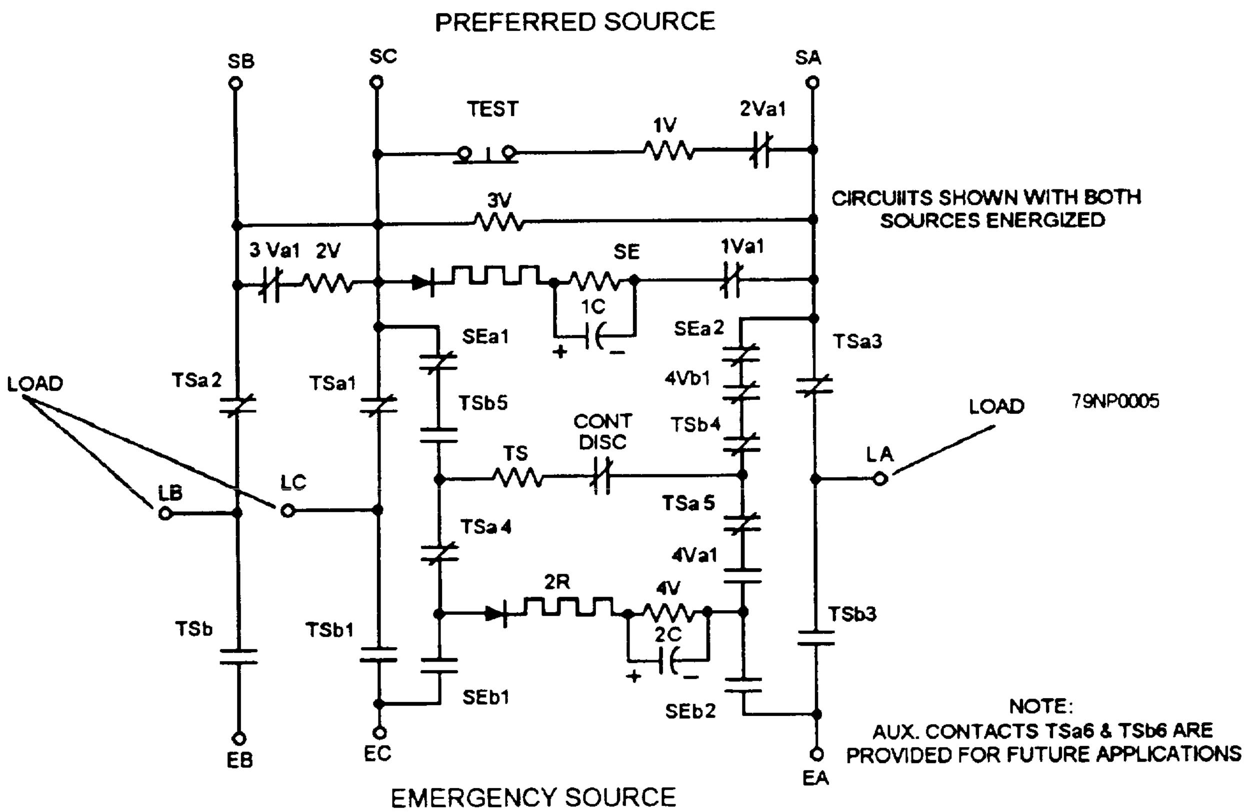


Figure 3-5.—Schematic diagram of the A-2 ABT.

Table 3-1.—Transfer from Normal to Emergency Power

Step	Action
1.	Normal supply voltage drops to the dropout range (81-69 volts).
2.	Relays 1V, 2V, and 3V open.
3.	Contact 1Va1 opens, disconnecting the SE relay.
4.	Following a time delay of 0.3-0.5 seconds, the SE relay opens.
5.	Contacts SEb1 and SEb2 close, energizing relay 4V from the emergency source.
6.	Contact 4Va1 closes, connecting the emergency source to coil TS of the transfer switch.
7.	The transfer switch operates to transfer the load to the emergency source of power.
8.	Contacts TSa4 and TSa5 open to disconnect coil TS of the transfer switch.

Upon restoration of the normal power supply, the ABT automatically switches back through the sequence of events in table 3-2:

Table 3-2.—Transfer from Emergency to Normal Power

Step	Action
1.	Relays 1V, 2V, and 3V energize.
2.	Following a time delay of 0.3-0.5 seconds, the SE relay closes.
3.	Contacts SEb1 and SEb2 open, removing relay 4V from the emergency source of power.
4.	Following a time delay of 0.3-0.5 seconds, the 4V relay opens.
5.	Contact 4Vb1 closes, completing the normal supply circuit to the transfer switch coil TS.
6.	Transfer switch TS operates, transferring the load back to the normal source of power.
7.	Transfer coil contacts TSb4 and TSb5 open to disconnect transfer coil TS from the circuit.
8.	The ABT is now ready for any further interruptions in normal power.

Testing

When testing any ABT, make sure any vital or sensitive loads fed from the ABT are isolated. This momentary interruption of power could damage sensitive electronic circuitry. Therefore, before beginning testing an ABT, you must notify all personnel concerned of the power supply system interruptions.

SHIP'S SERVICE SWITCHBOARDS

Aboard modem Navy vessels, there are three distinct groups or shipsets of distribution switchboards. A shipset of main power distribution switchboards consists of three groups, each group being made up of three units. Figures 3-6 through 3-8 show the switchboards making up shipset 1S.

The units, physically separated and connected by cables, form a switchgear group. The physical separation of sections provides greater protection from damage since it is less likely that more than one unit can be damaged by one hit in battle. It also provides a means for removing a damaged section for repairs or replacement.

Switchboards provide three distinct functions aboard ship:

1. The distribution of 450-volt, three-phase, 60Hz power throughout the ship
2. The protection of distribution circuits
3. The control, monitoring, and protection of the gas turbine generator sets (GTGSs)

Capabilities

Each switchboard group is an operationally independent system, capable of monitoring and controlling an associated generator. Because it is operated as an independent system, a switchboard is capable of distributing the power produced by the

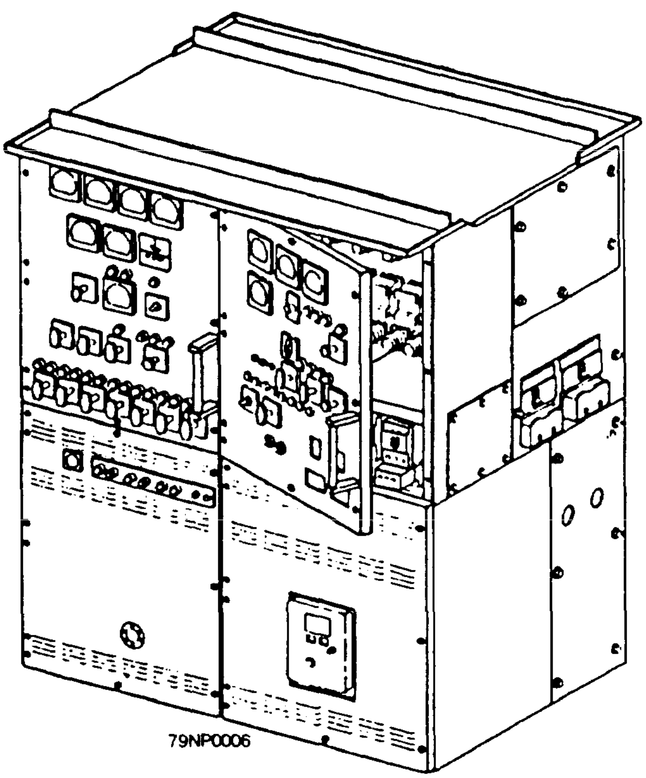


Figure 3-6.—1S Ship's service switchboard.

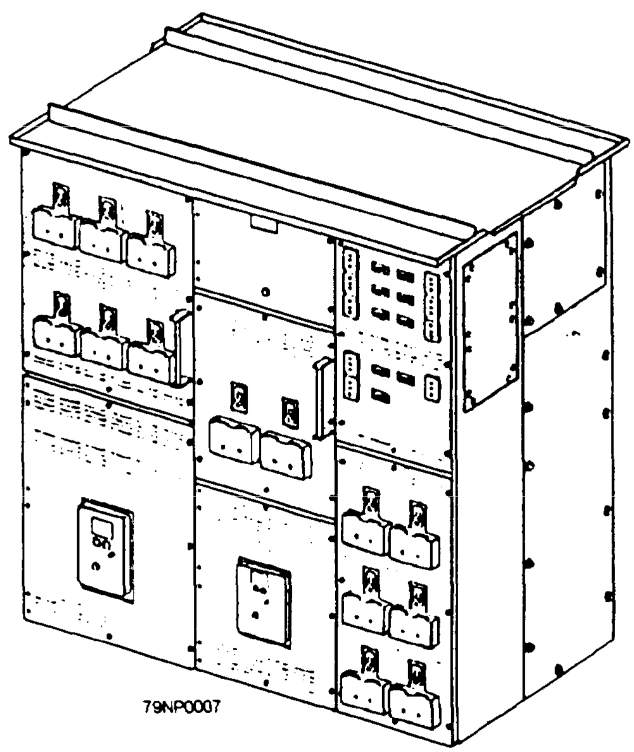


Figure 3-7.—1SA Ship's service switchboard.

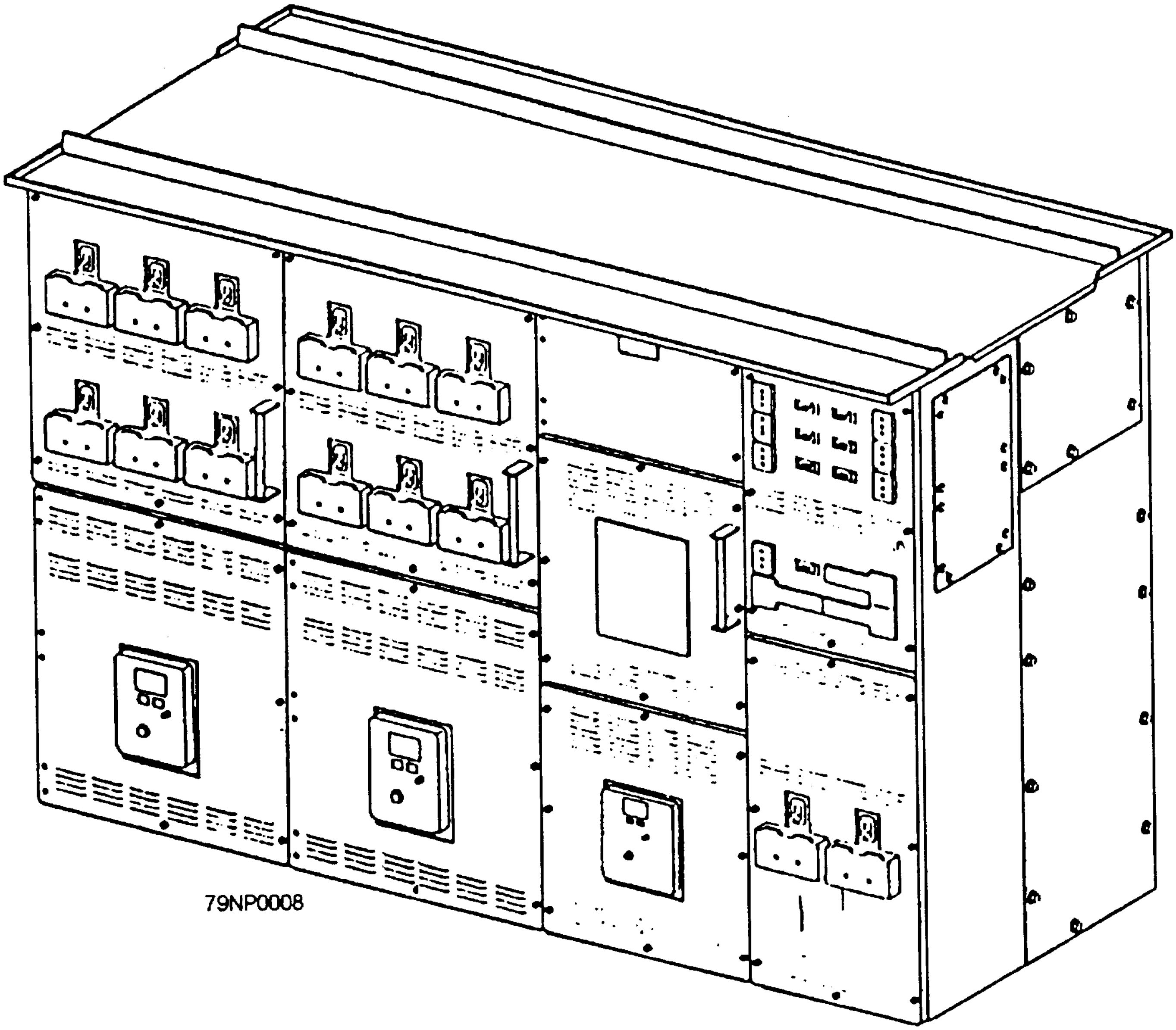


Figure 3-8.—1SB Ship's service switchboard.

associated generator to equipment and zones fed by the switchboard bus. Operated in parallel with either one or both of the other groups, power can be supplied to the entire ship's service load.

Description

Power is produced by the GTGSs, inputted to the switchboards through the generator circuit breakers, and distributed to the various ships loads via feeder breakers and load centers.

Control and monitoring of the ship's service power is accomplished by the various manual, remote, and automatic control functions associated with the switchboards. In addition, the metering and indications used to maintain proper power plant performance give the electrician on watch the status of the power plant at any given time.

The distribution system is protected from damage by the various mechanical and electrical devices used to interrupt the flow of electricity, either by command or automatically y, should a problem arise.

The switchboards shown in figures 3-6, through 3-9 are representative of those found on most gas turbine powered ships today, These switchboards use sheet steel panels or enclosures from which only the meters and the operating handles protrude to the front. The rear handles protrude to the front. The rear panels can be removed to gain access to the internal components including the meter connections, the bus bars, and the disconnect links (fig. 3-9). Distribution of the generated power begins with the switchboard. These switchboards can be connected together through bus tie circuit breakers to forma continuous loop. This allows any two of the three GTGSs to supply the demand for power while the third can be set up to start automatically in the event of a power loss.

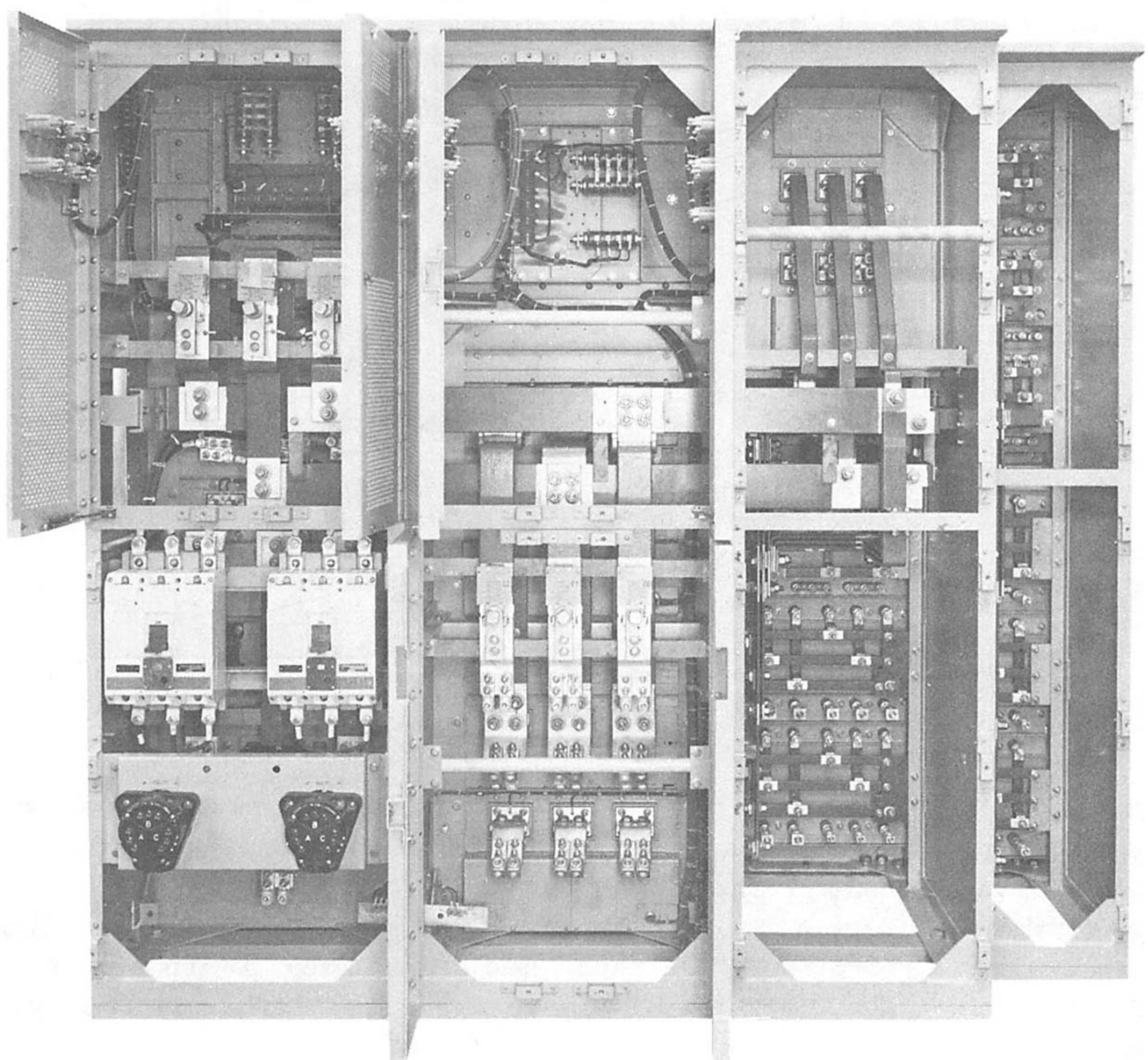


Figure 3-9.—Rear view of a switchboard showing bus bars and disconnect links.

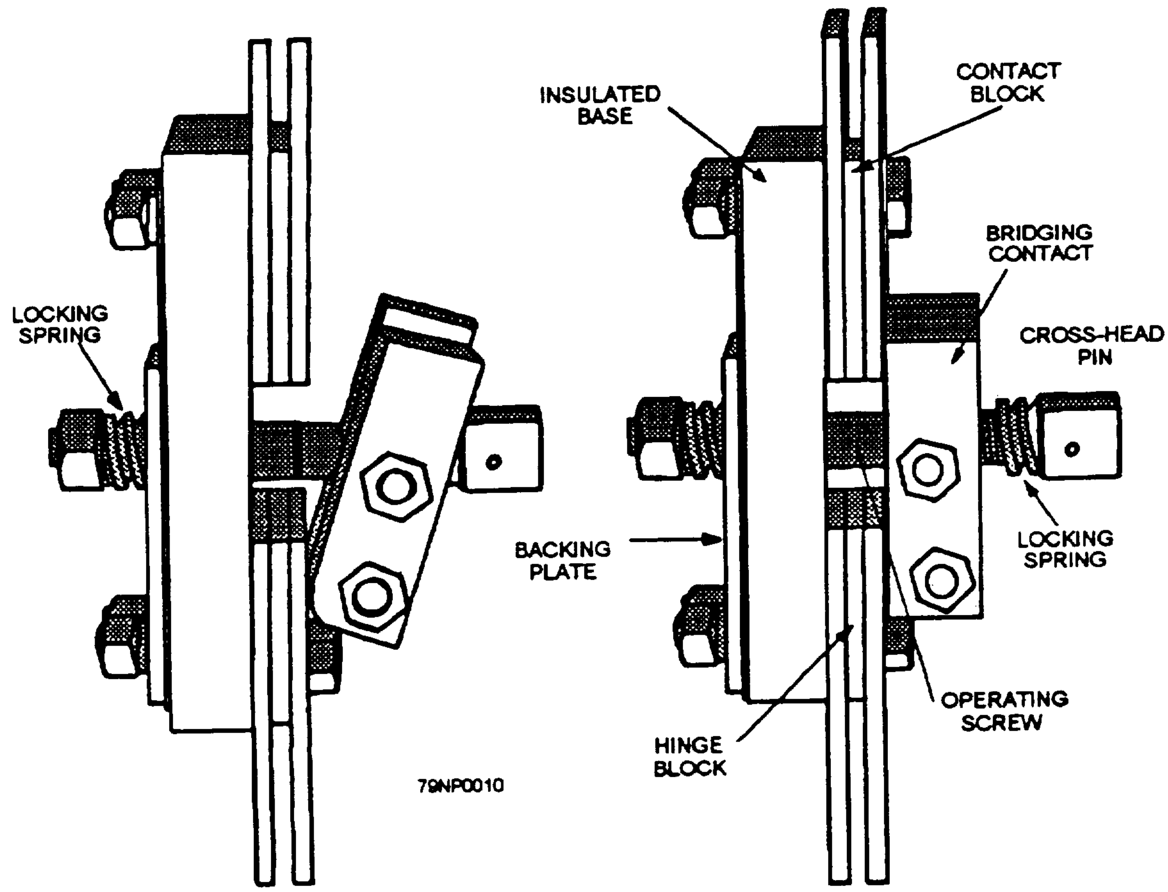


Figure 3-10.—Disconnect links.

Each of the switchboard units of a group are connected together through disconnect links (fig. 3-10). By removing the links between any two of the switchboads, repairs or replacement of parts may be accomplished without interfering with the operation of the other units.

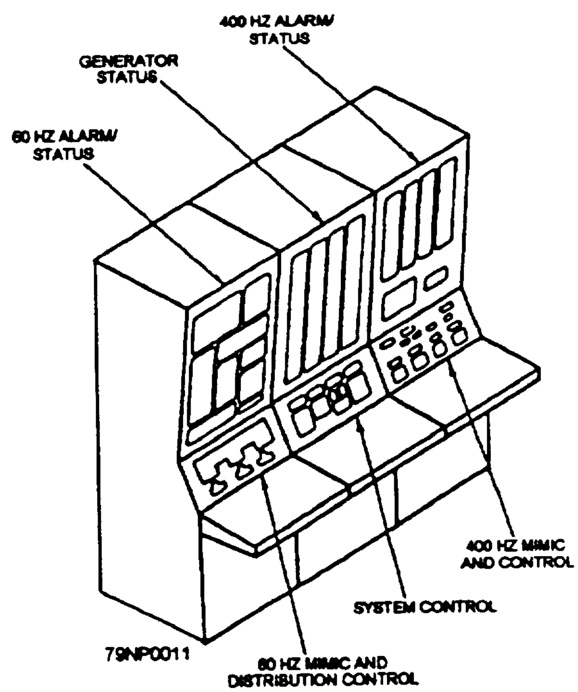


Figure 3-11.—Electric plant control console (EPCC).

Control Equipment

Control of the electrical load can be accomplished from the central control station (CCS) at the electric plant control console (EPCC) (fig. 3-11) or by local manual control at each GTGS and switchboard station. The CCS and switchboard stations have the capabilities of starting/stopping and distribution control. Only start/stop control is available at the GTGS local control panels.

Generator switchboards are equipped with meters to indicate the generator voltage, current, power, frequency, and, in older ships, power factor meters (fig. 3-12). Synchroscopes and synchronizing lamps are provided for paralleling ac generators. Also, indicator lamps are provided to show the operating conditions of various circuits.

The frequency is controlled by the generator speed, which is automatically controlled by the speed governor of the prime mover. The speed governors for large machines can be set to the required speed by a control device mounted on the switchboard.

When running in parallel with other generating a generator is prevented from operating as a motor by a reverse power relay. The reverse power relay trips the

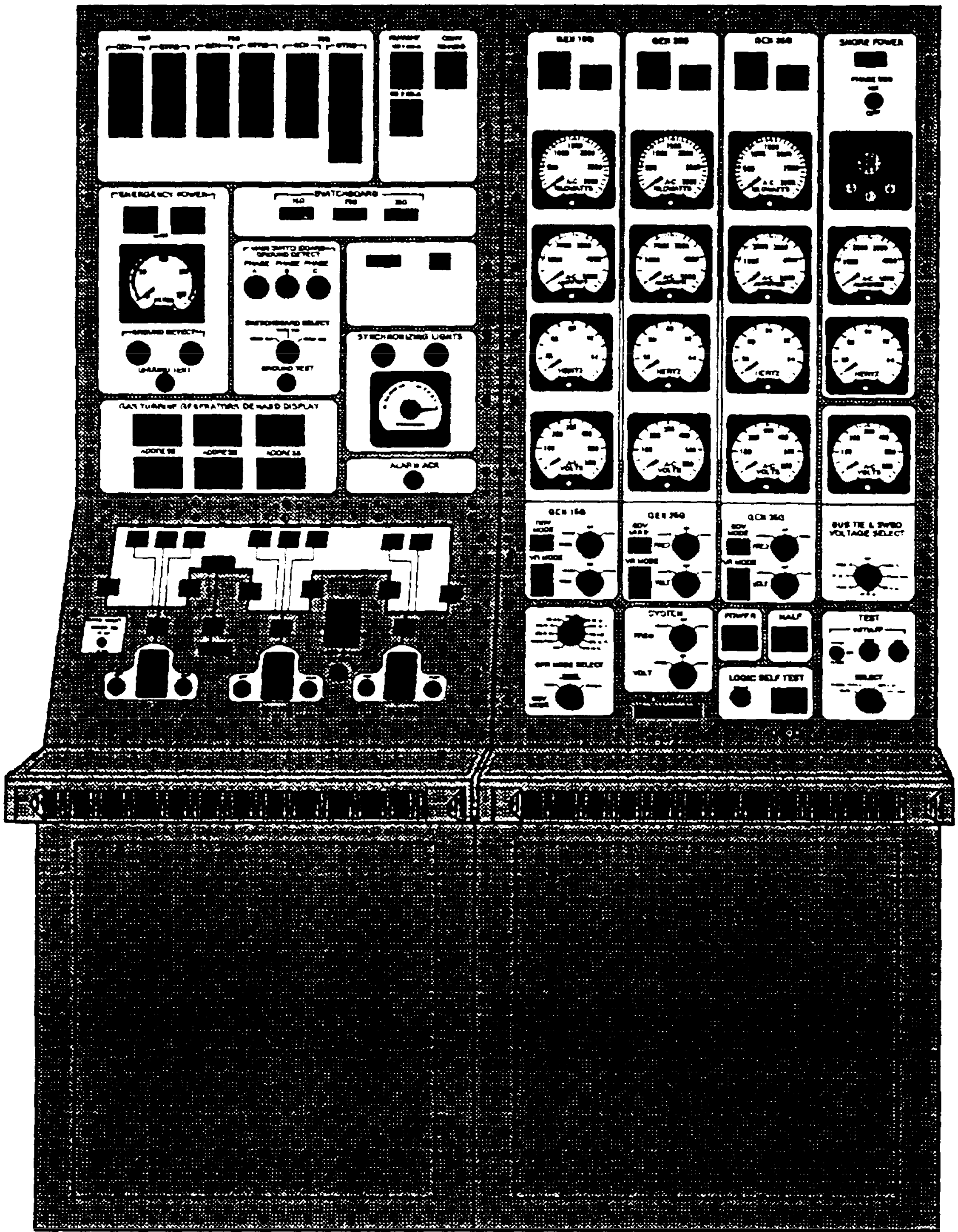


Figure 3-12.—EPCC showing distribution and system status and control sections.

generator breaker and takes the generator off the line when power is fed from the line to the generator instead of from the generator to the line.

A voltage regulator is mounted on each switchboard and operates automatically to vary the field excitation to maintain the generator voltage constant throughout normal changes in load. In all installations, a means is provided to manually adjust the voltage if the automatic regulator fails.

Ground Detector Circuits

A set of three ground detector lamps (fig. 3-13) is connected through transformers to the main bus of each ship's service switchgear group. It provides you with a means to check for grounds on any phase of the three-phase system. To check for a ground, turn switch Son and observe the brilliancy of the three lights, and look for the conditions shown below.

IF	THEN
If the lights are equally bright	All lights are receiving the same voltage, and not ground exists
If lamp A is dark and lamps B and C are bright	Phase A is grounded. In this case, the primary of the transformer in phase is shunted to ground, and lamp A receives no voltage.
If lamp B is dark and lamps A and C are bright	A ground exists on phase B
If lamp C is dark and lamps A and B are bright	A ground exists on phase C

AC GENERATORS

Alternating-current generators produce most electric power used today. AC generators are also used in aircraft and automobiles.

AC generators come in many different sizes, depending on their intended use. For example, anyone of the huge generators at Boulder Dam can produce millions of volt-amperes, while the small generators used on aircraft produce only a few thousand volt-amperes.

Regardless of their size, all generators operate on the same basic principle-a magnetic field cutting

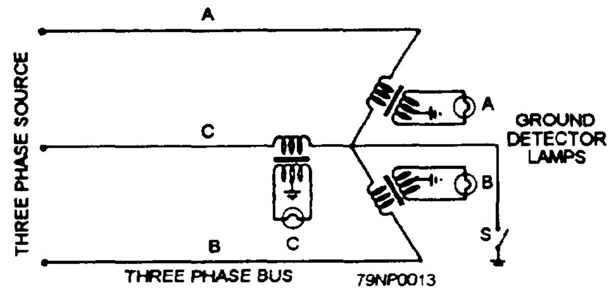


Figure 3-13.—An ac ground detector lamp circuit.

through conductors, or conductors passing through a magnetic field.

All generators have at least two distinct sets of conductors.

1. The *armature winding,* which consists of a group of conductors in which the output voltage is generated.
2. The *field winding,* which consists of a group of conductors through which dc is passed to obtain an electromagnetic field of fixed polarity.

Since relative motion is needed between the armature and field flux, ac generators are built in two major assemblies-the stator and the rotor. The rotor rotates inside the stator. It is driven by several commonly used power sources, such as gas or steam turbines, electric motors, and internal-combustion engines.

TYPES OF AC GENERATORS

There are various types of ac generators used today. They all perform the same basic function. The types discussed in this chapter are typical of the ones used in shipboard electrical systems.

Revolving Armature

In the revolving-armature ac generator, the stator provides a stationary electromagnetic field. The rotor, acting as the armature, revolves in the field, cutting the lines of force, thereby producing the desired output voltage. In this generator, the armature output is taken from slip rings, retaining its alternating characteristic.

The use of the revolving-armature ac generator is limited to low-power, low-voltage applications. The primary reason for this limitation is its output power is conducted through sliding contacts (slip rings and brushes). These contacts are subject to frictional wear and sparking. In addition, they are exposed and liable to arc-over at high voltages.

Revolving Field

The rotating-field ac generator (fig. 3-14) is the most widely used type of generator. The rotating magnetic field produced by the rotor extends outward and cuts through the armature windings imbedded in the surrounding stator. As the rotor turns, alternating voltages are induced in the windings since magnetic fields of first one polarity and then the other cut through them. Since the output power is taken from stationary windings, the output may be connected through fixed terminals (T1 and T2 in fig. 3-14). This is helpful because there are no sliding contacts, and the whole output circuit is continuously insulated, reducing the danger of arc-over.

The rotating-field ac generator maybe constructed with or without brushes. In both types, dc from a separate source is passed through windings on the rotor to develop the rotating magnetic field. The source of dc may be a permanent magnet generator with its output going to the rotor winding slip rings through a commutator (fig. 3-15, view A) or an alternator with its output rectified by a silicon rectifier (fig. 3-15, view B) before being sent to the rotor.

Slip rings and brushes or silicon rectifier units are adequate for the dc field supply because the power level in the field is much smaller than in the armature circuit.

RATING OF AC GENERATORS

Alternators are rated according to the voltage and current they are designed to produce. The normal load rating is the load it cart carry continuous y. The overload rating is the above normal load it cart carry for a specific length of time. The rating of a generator is identified very closely with its current capacity.

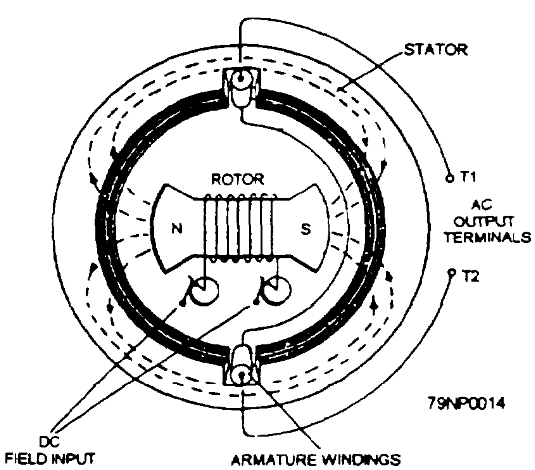


Figure 3-14.—Essential parts of a rotating-field generator.

Temperature

The rating of any electric device must take into account its allowable temperature rise; that is, the amount of rise in temperature (above ambient) the machine can withstand and still be expected to operate normally. The load rating of a particular generator is determined by the rise in temperature it can withstand, caused primarily by the current flow. The rise in temperature is caused by the losses of the generator. The majority of losses are I^2R losses in the armature windings.

The maximum current that can be supplied by an ac generator depends upon the following factors:

1. The maximum heat loss (I^2R power loss) that cart be sustained in the armature, and;
2. The maximum heat loss that can be sustained in the field.

The armature current varies with the load and is similar to that of dc generators. In ac generators, lagging power factor loads tend to demagnetize the field. The terminal voltage is maintained only by an increase in the dc field current. Therefore, ac generators are rated for armature load current and voltage output, or kilovolt-ampere (kVA) output, at a specified frequent y and power factor.

Power Factor

The power factor is an expression of the losses within the electrical distribution system. It is determined by the amount the current and voltage sine waves are out of phase, which is determined by the characteristics of the total load seen on the circuit (resistive, inductive, or capacitive). The power factor can be found by using two methods:

Trigonometric Method	Algebraic Method
Determine the angle of lead or lag between voltage and current	Determine true power (kW) consumed by load from wattmeter
Power factor is cosine of phase angle	Determine apparent power (kVA) consumed by load by multiplying line voltage and current from meters on swbd
	Power Factor = kW/kVA

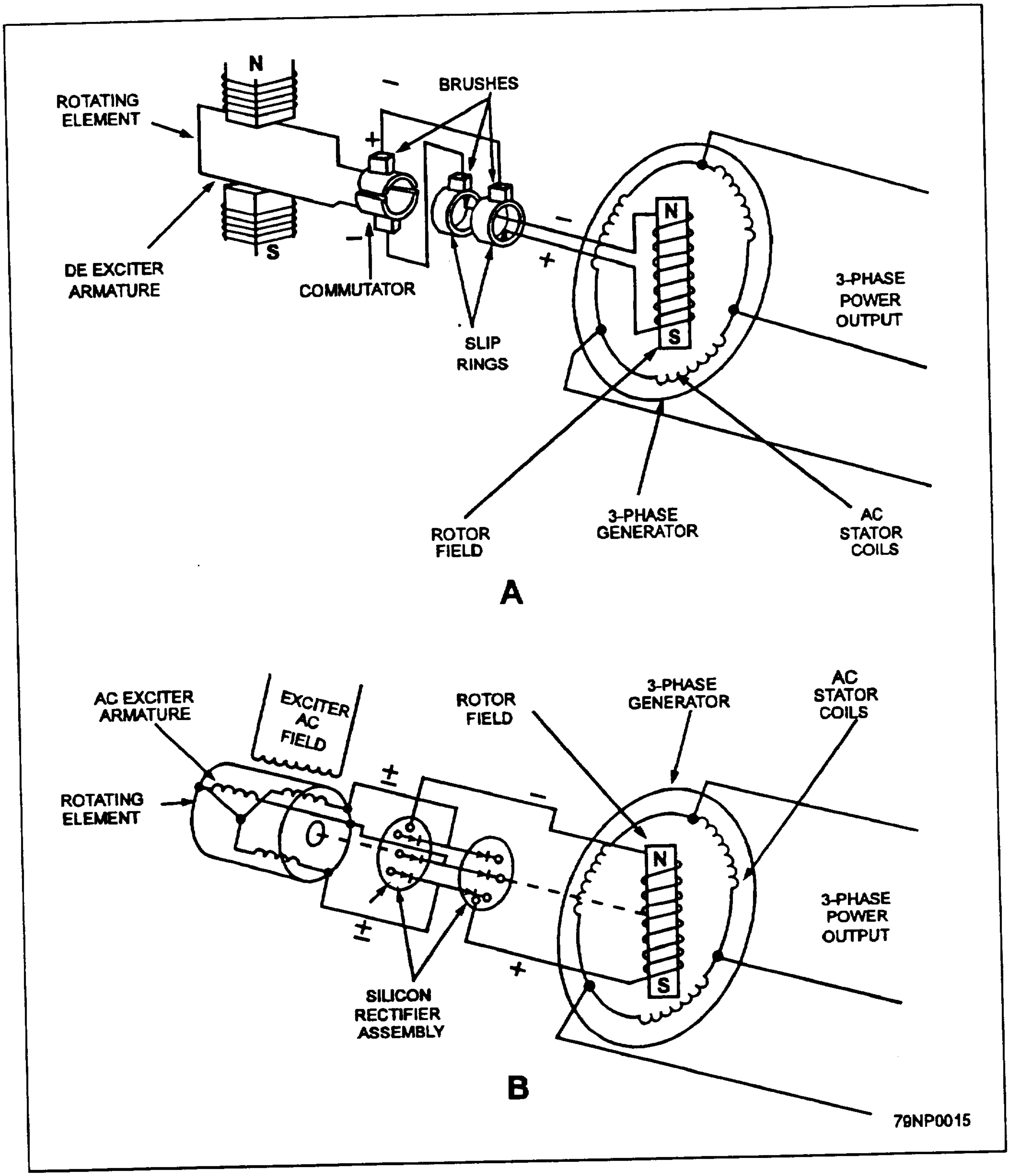


Figure 3-15.—An ac generator: A. Brush type. B. Brushless type.

The specified power factor is usually 80 percent lagging. For example, a single-phase ac generator designed to deliver 100 A at 1,000 V is rated at 100 kVA. his machine will supply a 100-kW load at unity power factor or an 80-kW load at 80 percent power factor. If this ac generator were to supply a 100-kVA load at 20% power factor, the required increase in dc field current needed to maintain the desired terminal voltage would cause excessive heating in the field.

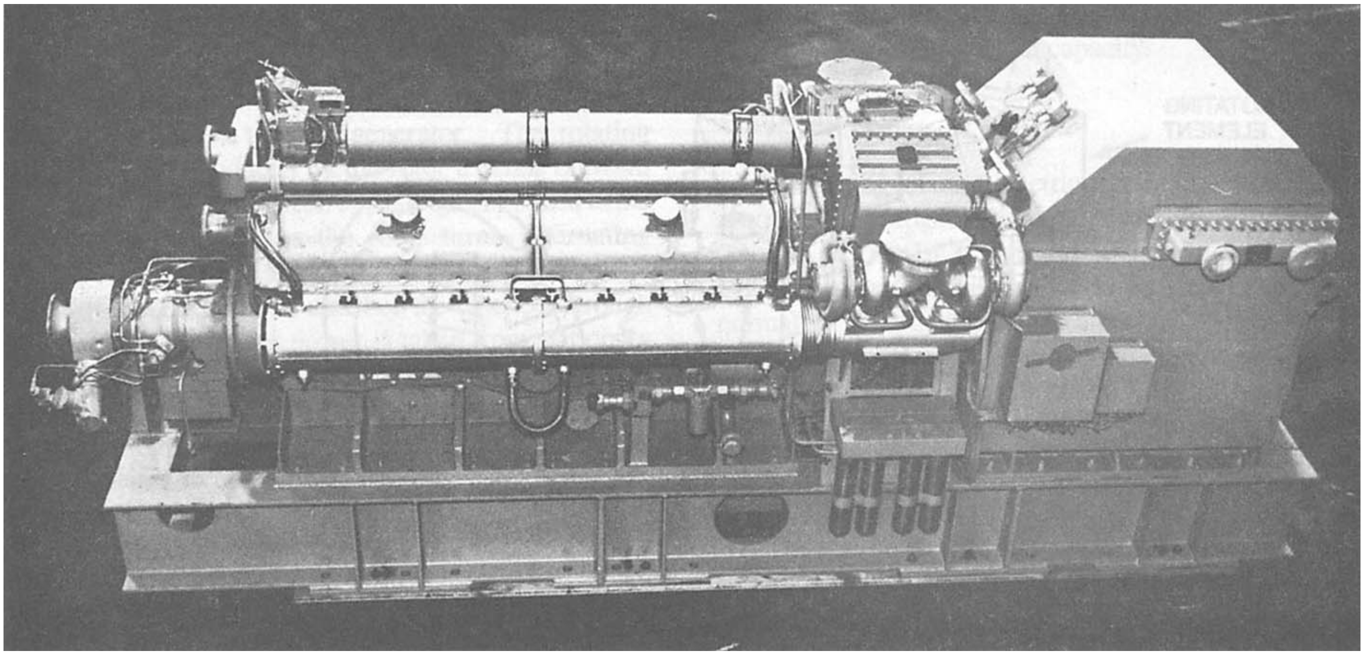


Figure 3-16.—Low-speed, engine-driven ac generator.

CONSTRUCTION AND OPERATION OF AC GENERATOR SETS

AC generator sets maybe divided into the following two classes according to the speed of the generator:

1. Low speed, engine driven

2. High speed, turbine driven

The stator, or armature, of the revolving-field ac generator is made of steel punchings called *laminations*. The laminations of an ac generator stator form a steel ring keyed or bolted to the inside circumference of a steel frame. The inner surface of the laminated ring has slots in which the stator winding is placed.

A low-speed, engine-driven ac generator (fig. 3-16) has a large-diameter revolving field with many poles and a stationary armature that is relatively short in axial length. The stator contains the armature windings. The rotor consists of salient poles, on which are mounted the do field windings.

The high-speed, turbine-driven ac generator (fig. 3-17) is connected to a turbine either directly or through gears. The enclosed metal structure is a part of a forced ventilation system that carries away the heat by circulation of the air through the stator (fig. 3-17, view A) and the rotor (fig. 3-17, view B). (The exciter is a separate unit and is not shown.) The enclosed stator not only directs the paths of the circulating, air-cooling currents, it also reduces windage noise.

Many of today's modern ship's utilize gas turbine units to provide power for propulsion and generating

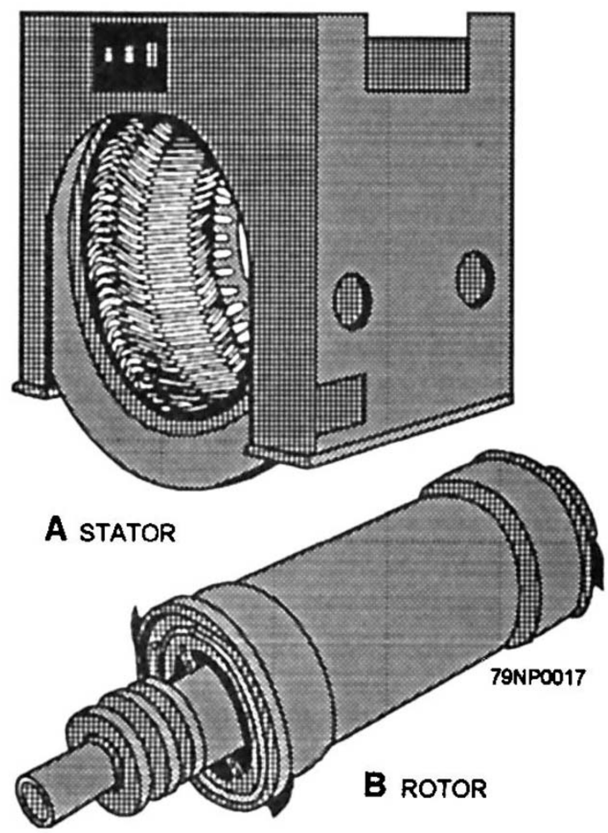


Figure 3-17.—High-speed, steam turbine-driven ac generator.

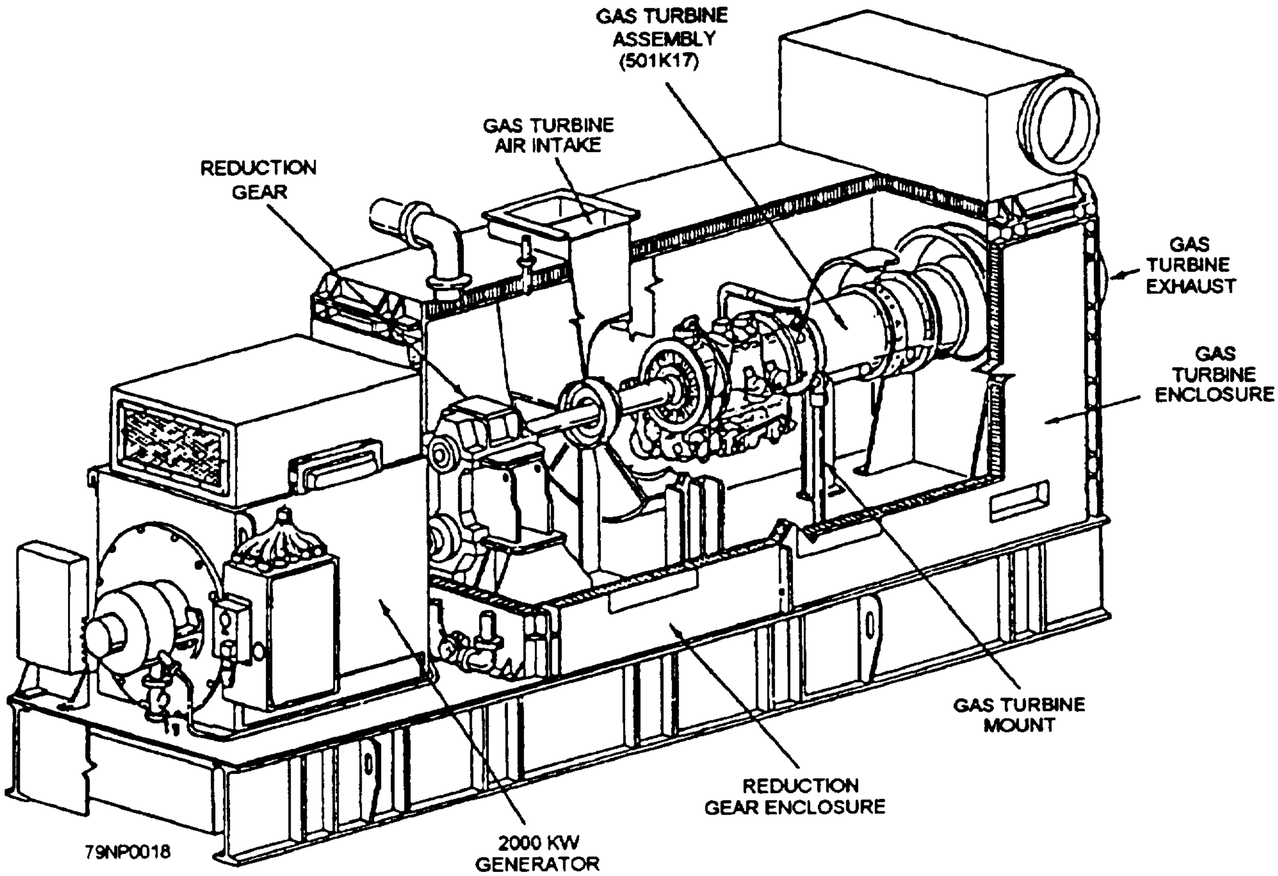


Figure 3-18.—Model 104 gas turbine generator set.

electrical power. The gas turbine units (fig. 3-18) are small, efficient, easily replaed, and simple to operate. While Gas Turbine Specialist's (GS's) are primarily responsible for maintenance on the unit itself, EM's often stand electrical watch on the units.

Basic Functions of Generator Parts

A typical rotating-field ac generator consists of an ac generator and a smaller dc generator built into a single unit. The ac generator section supplies alternating current to the load for which the generator was designed. The dc generator supplies the direct current required to maintain the ac generator field. This dc generator is referred to as the exciter. Atypical ac generator is shown in figure 3-19, view A. Figure 3-19, view B, is a simplified schematic of the generator. The parenthetical numbers in the following paragraph are indicated on figure 3-19.

Operation

Any rotary generator (fig. 3-19) requires a prime moving force to rotate the ac field and exciter armature. This rotary force is usually furnished by a combustion engine, turbine, or electric motor and transmitted to the generator through the rotor drive shaft (1) (view A). The exciter shunt field (2) (view B) creates an area of intense magnetic flux between its poles. When the exciter

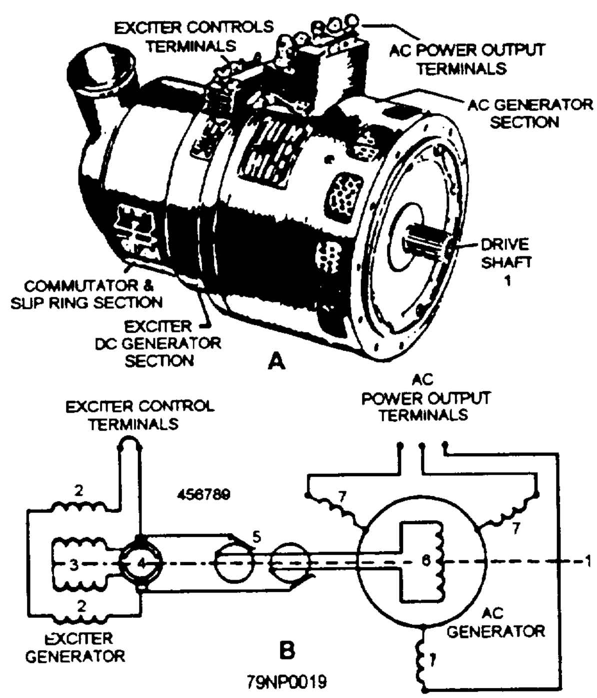


Figure 3-19.—An ac generator and schematic.

armature (3) is rotated in the exciter field flux, voltage is induced into the exciter armature windings. The exciter output commutator and brushes (4) connect the exciter output directly to the ac generator field input slip rings and brushes (5). Since slip rings, rather than a commutator, are used to supply current through the ac generator field (6), current always flows in one direction through these windings. Thus, a fixed polarity magnetic field is maintained at all times in the ac generator field windings. When the ac generator field is rotated, its magnetic flux is passed through and across the ac generator armature windings (7). A voltage is induced into the stator windings by the relative motion of the magnetic lines of flux cutting across and through the windings in the stator. The alternating voltage induced in the ac generator armature windings is connected through fixed terminals to the ac load.

THREE-PHASE GENERATORS

As the name implies, a three-phase ac generator has three single-phase windings spaced so that the voltage induced in each winding is 120° out of phase with the voltages in the other two windings. A schematic diagram of a three-phase stator showing all the coils becomes complex, and it is difficult to see what is actually happening. A simplified schematic diagram showing all the windings of a single phase lumped together as one winding is shown in figure 3-20, view A. The rotor is omitted for simplicity. The waveforms of voltage are shown to the right of the schematic. The three voltages are 120° apart and are similar to the voltages that would be generated b y three, single-phase ac generators whose voltages are out of phase by angles of 120°. The three phases are independent of each other.

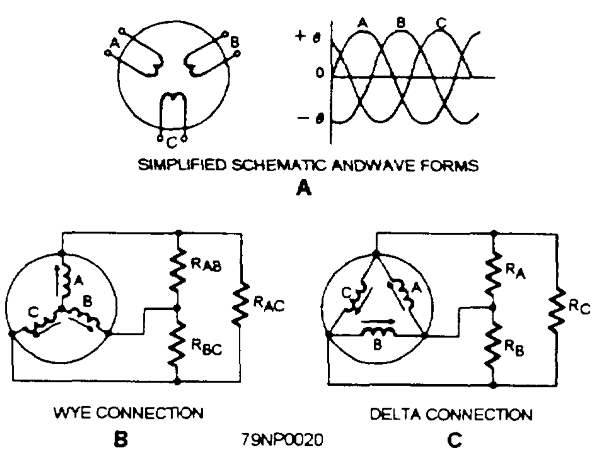


Figure 3-20.—Three-phase ac generator.

Wye Connection

Rather than have six leads come out of the three-phase ac generator, one of the leads from each phase is connected to form a common junction. The stator is then said to be wye, or star, connected. The common lead may or may not be brought out of the machine, If it is brought out, it is called the neutral. A simplified schematic (fig. 3-20, view B) shows a wye-connected stator with the common lead not brought out. Each load is connected across two phases in series as follows:

- R_{AB} is connected across phases A and B in series
- W_{AC} is connected across phases A and C in series
- R_{BC} is connected across phases B and C in series

Thus, the voltage across each load is larger than the voltage across a single phase. In a wye-connected ac generator, the three start ends of each single-phase winding are connected together to a common neutral point, and the opposite, or finish, ends are connected to the line terminals, A, B, and C. These letters are always used to designate the three phases of a three-phase system or the three line wires to which the ac generator phases connect.

A three-phase, wye-connected ac generator supplying three separate loads is shown in figure 3-21. When unbalanced loads are used, a neutral may be added as shown in the figure by the broken line between the common neutral point and the loads. The neutral wire serves as a common return circuit for all three phases and maintains a voltage balance across the loads. No current flows in the neutral wire when the loads are balanced. This system is a three-phase, four-wire circuit and is used to distribute three-phase power to shore-based installations. The three-phase, four-wire system is not generally used aboard ship, but it is widely used in industry and in aircraft ac power systems.

Delta Connection

A three-phase stator may also be connected as shown in figure 3-22. This type of connection is called

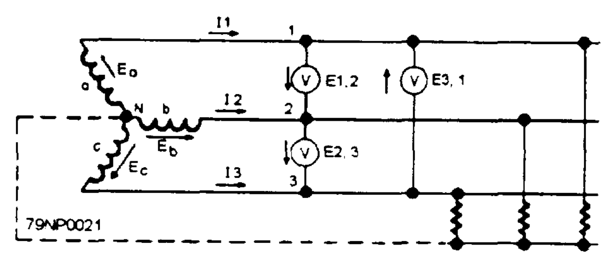


Figure 3-21.—Three-phase, ac generator showing neutral connection.

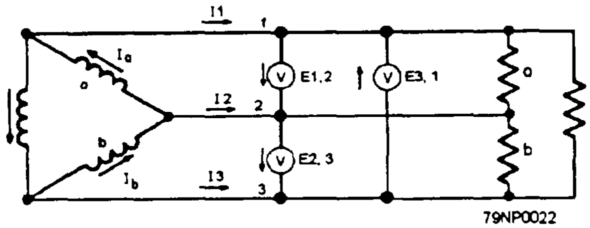


Figure 3-22.—Three-phase, delt-connected system.

the *delta connection.* In a delta-connected ac generator, the connections are made as follows:

- The start end of one phase winding is connected to the finish end of the third.
- The start of the third phase winding is connected to the finish of the second phase winding.
- The start of the second phase winding is connected to the finish of the first phase winding.

The three junction points are connected to the line wires leading to the load.

The three-phase, delta-connected ac generator is connected to a three-phase, three-wire circuit, which supplies a three-phase, delta-connected load at the right-hand end of the three-phase line. Because the phases are connected directly across the line wires, phase voltage is equal to line voltage. When the generator phases are properly connected in delta, no appreciable current flows within the delta loop when there is no external load connected to the generator. If any one of the phases is reversed with respect to its correct connection a short-circuit current flows within the windings of no load, causing damage to the windings.

Vector Analysis

A scalar quantity has only one facet, magnitude. On the other hand, a vector quantity has more than one facet, as shown by a vector diagram. In the vector diagram, the vector is shown by a line drawn to scale with an arrow head to indicate direction. This line showing a vector quantity indicates both magnitude and direction. Good examples of both quantities are shown below:

Scalar Quantity	Vector Quantity
Temperature	Force
Area	Voltage
Volume	Motion

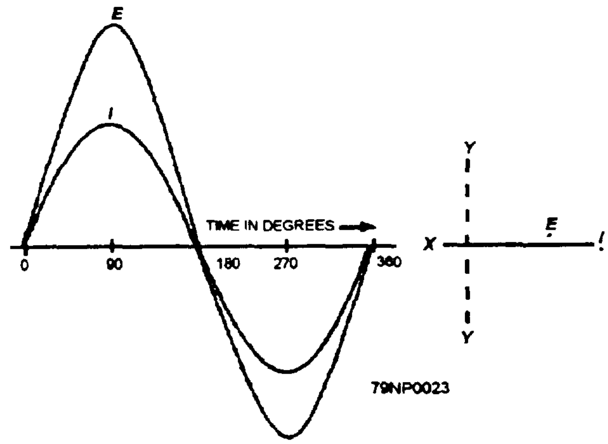


Figure 3-23.—Waves and vectors of alternating current and voltage in a circuit containing only resistance.

The magnitude of a vector is represented by its length: the longer the vector, the higher its magnitude. The direction in which the vector acts is shown by the direction of the arrow.

Alternating current and voltage vectors are referenced to a coordinate plane, which represents 360 electrical degrees. By agreement, *counterclockwise rotation represents positive* and *clockwise rotation represents negative.* The horizontal axis of an analysis diagram represents the *reference axis,* and any vectors in the diagram are referenced to this position.

In figure 3-23, you can that the voltage (E) and the current (I) are in phase with one another. Since the two values are in phase, the angle θ between them is 0 in the vector diagram. This represents a purely resistive ac circuit.

Look at figure 3-24. Here, you can see that the voltage (E) is leading the current (1) by θ degrees. You

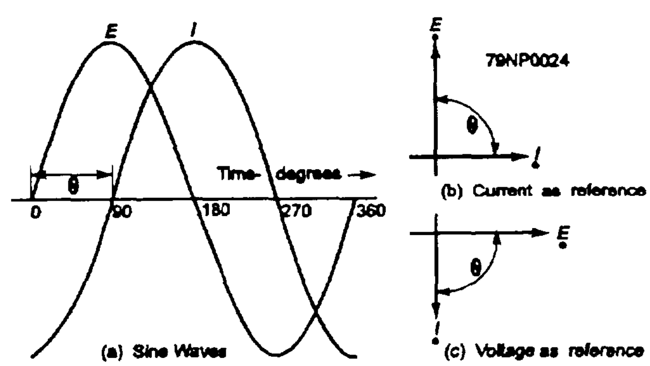


Figure 3-24.—Waves and vectors of alternating current and voltage in a circuit containing only inductance.

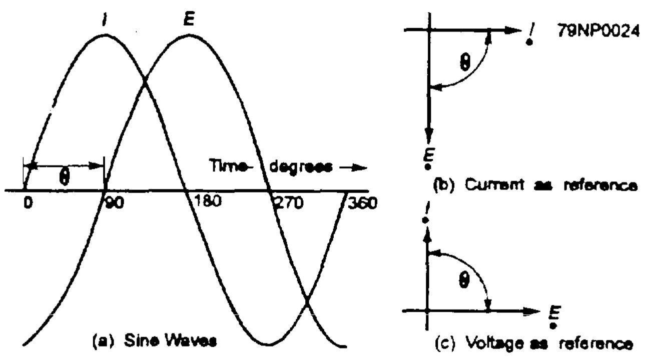


Figure 3-25.—Waves and vectors of alternating current and voltage in a circuit containing only capacitance.

can remember this by the memory hint ELI **—voltage leads current in an inductive circuit).** Since voltage is leading current, the vector diagram shows voltage in a counterclockwise or positive direction from current.

Now, look at figure 3-25, which shows the current (I) leading the voltage (E) by θ degrees. Using the memory hint ICE— **current leads voltage in a capacitive circuit** —you can remember this vector. Since current leads voltage by θ degrees, the vector representing voltage is in a clockwise or negative direction from the vector representing current.

Analysis of Wye Connected Stators

The phase relationships in a three- wire, three-phase, wye-connected system are shown in figure 3-26. In constructing vector diagrams of three-phase circuits, a counterclockwise rotation is assumed in order to maintain the correct phase relation between line voltages and currents. Thus, the ac generator is assumed to rotate in a direction that three-phase voltages are generated in the following order: E_a, E_b, and E_c.

The voltage in phase b, or E_b, lags the voltage in phase a, or E_a, by 120°. Likewise, E_c lags E_b by 120°, and E_a lags E_c by 120°. In figure 3-26, the arrows, E_a, E_b, and E_c, represent the positive direction of generated voltage in the wye-connected ac generator. The arrows, I1, I2, and I3, represent the positive direction of phase and line currents supplied to balance unit power-factor loads connected in wye. The three voltmeters connected between lines 1 and 2, 2 and 3, and 3 and 1 indicate effective values of line voltage. The line voltage is greater than the voltage of a phase in the w ye-connected circuit because there are two phases connected in series between each pair of line leads, and their voltages combine. However, line voltage is not twice the value of phase voltage because the phase voltages are out of phase with each other.

The relationship between the phase and the line voltages is shown in the vector diagram (fig. 3-27). Effective values of phase voltage are indicated by vectors E_a, E_b, and E_c. Effective values of line and phase current are indicated by vectors I_a, I_b, and I_c. Because there is only one path for the current between any given phase and the line lead to which it is connected, the phase current is equal to the line current. The respective phase currents have equal values because the load is assumed to be balanced. For the same reason, the respective line currents have equal values. When the load has unity power factor, the phase currents are in phase with their respective phase voltages.

In combining ac voltages, it is important to know the direction in which the positive maximum values of the voltages act in the circuit as well as the magnitudes of the voltages. **(NOTE:** As you read this section, look

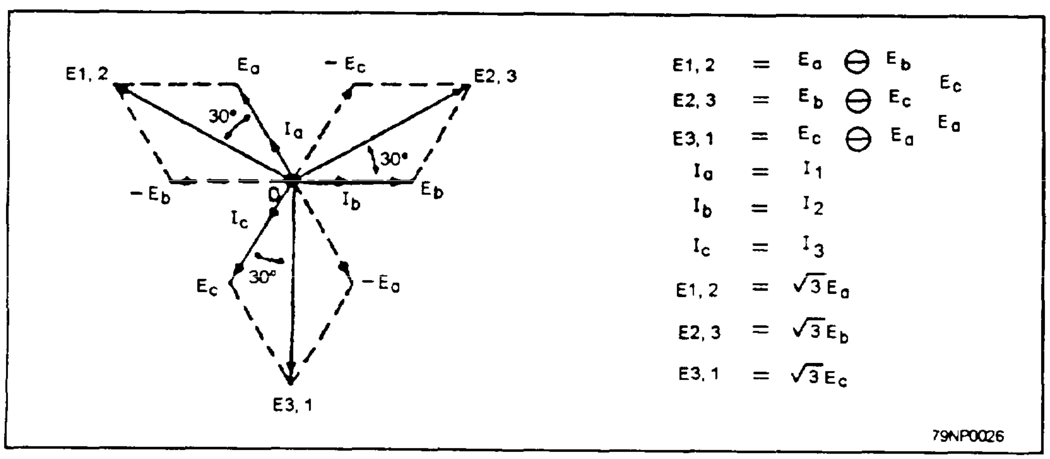


Figure 3-26.—Three-phase, wye-connected system.

at figure 3-27.) For example, in view A, the positive maximum voltage generated in coils A and B act in the direction of the arrows, and B leads A by 120°. This arrangement may be obtained by assuming coils A and B to be two armature windings located 120° apart. If each voltage has an effective value of 100 volts, the total voltage is E_r = 100 volts, as shown by the polar vectors in view B.

If the connections of coil B are reversed (view C) with respect to their original connections, the two voltages are in opposition. You can see this by tracing the circuit in the direction of the arrow in coil A.

1. The positive direction of the voltage in coil B is opposite to the direction of the trace
2. The positive direction of the voltage generated in coil A is the same as that of the trace. Therefore, the two voltages are in opposition.
3. This effect is the same as though the positive maximum value of E_b were 60° out of phase with that of E_a, and E_b acted in the same direction as& when the circuit trace was made (view D) to vector.
4. E_a is accomplished by reversing the position of E_b from that shown in view B, to the position shown in view D, which completes the parallelogram.

In equation form: If E_a and E_b are each 100 volts, then

$$E_r = \sqrt{3} \times 100, \textit{ or } 173 \textit{ volts}.$$

The value of E_r may be derived as follows:

1. Erect a perpendicular to E_r divides the isosceles triangle into two equal right triangles.
2. Each right triangle has a hypotenuse of 100 volts and abase of 100 cos 30°, or 86.6 volts.
3. The total length of E_r is 2 x 86.6, or 173.2 volts.

To construct the line voltage vectors E1,2, E2,3, and E3,1, in figure 3-26, it is first necessary to trace a path around the closed circuit that includes the line wires, armature windings, and one of the three voltmeters. For example, in figure 3-21, consider the circuit that includes the upper and middle wires, the voltmeter connected across them, and the ac generator phases a and b. The circuit trace is started at the center of the wye, proceeds through phase a of the ac generator, out line 1, down through the voltmeter from line 1 to line 2, and through phase b of the ac generator back to the starting point. Voltage drops along line wires are disregarded. The voltmeter indicates an effective value equal to the vector sum of the effective value of voltage in phases a and b. This value is the line voltage, E1,2. According to Kirchhoff's law, the source voltage

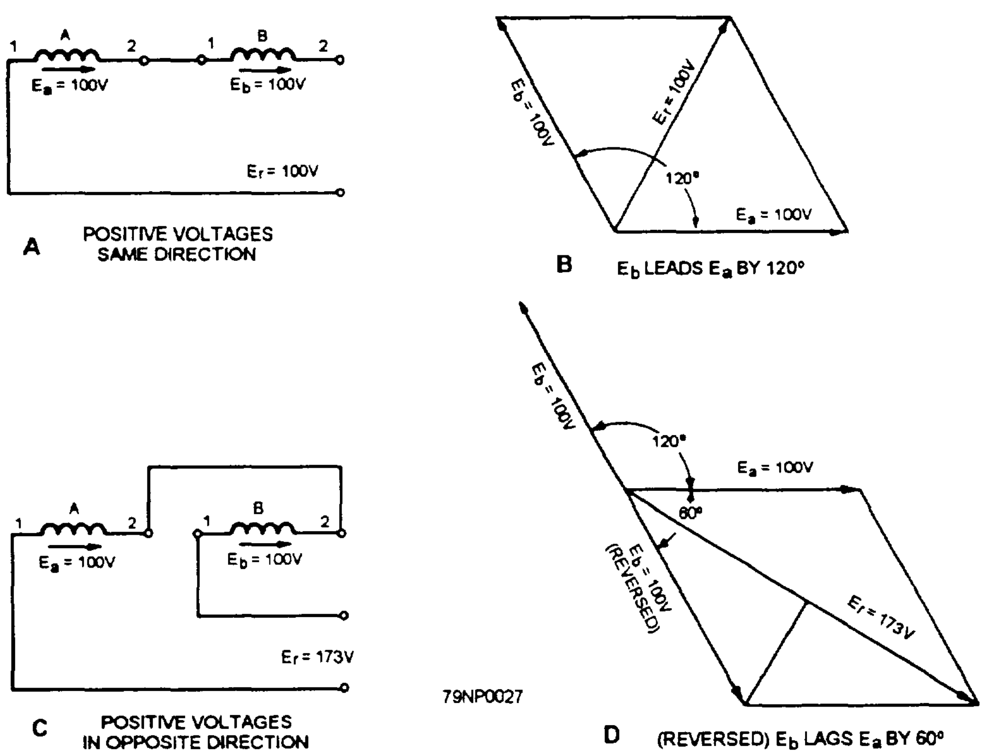


Figure 3-27.—Vector analysis of voltage in series aiding and opposing.

between lines 1 and 2 equals the voltage drop across the voltmeter connected to these lines.

If the direction of the path traced through the generator is the same as that of the arrow, the sign of the voltage is plus; if the direction of the trace is opposite to the arrow, the sign of the voltage is minus. If the direction of the path traced through the voltmeter is the same as that of the arrow, the sign of the voltage is minus; if the direction of the trace is opposite to that of the arrow, the sign of the voltage is plus.

The following equations for voltage are based on the preceding explanation:

$$E_a + (-E_b) = E1,2, \text{ or } E1,2 = E_a - E_b$$

$$E_b + (-E_c) = E2,3, \text{ or } E2,3 = E_b - E_c$$

$$E_c + (E_a) = E3,1, \text{ or } E3,1 = E_c - E_a$$

The signs + and – mean vector addition and vector subtraction, respective y. One vector is subtracted from another by reversing the position of the vector to be subtraced through an angle of 180° and constructing a parallelogram, the sides of which are the reversed vector and the other vector. The diagonal of the parallelogram is the difference vector.

These equations are applied to the vector diagram of figure 3-26. They are used, to derive the line voltages. The line voltages (E1,2, E2,3, and E3,1) are the diagonals of three parallelograms whose sides are the phase voltages E_a, E_b, and E_c. From this vector diagram, the following facts are observed:

1. The line voltages are equal and 120° apart.
2. The line currents are equal and 120° apart.
3. The line currents are 30° out of phase with& line voltages when the power factor of the load is 100%.
4. The line voltage is the product of the phase voltage and the $\sqrt{3}$.

Analysis of Delta-Connected Stators

The three-phase currents, I_a, I_b, and I_c, are indicated by accompanying arrows in the generator phases in figure 3-22. These arrows point in the direction of the positive current and voltage of each phase. The three voltmeters connected across lines 1 and 2, 2 and 3, and 3 and 1, respectively, indicate effective values of line and phase voltage. Line current 11 is supplied by phases a and c, which are connected to line 1. Line current is greater than phase current, but it is not twice as great because the phase currents are not in phase with each other. The relationship between line currents and phase currents is shown in figure 3-28.

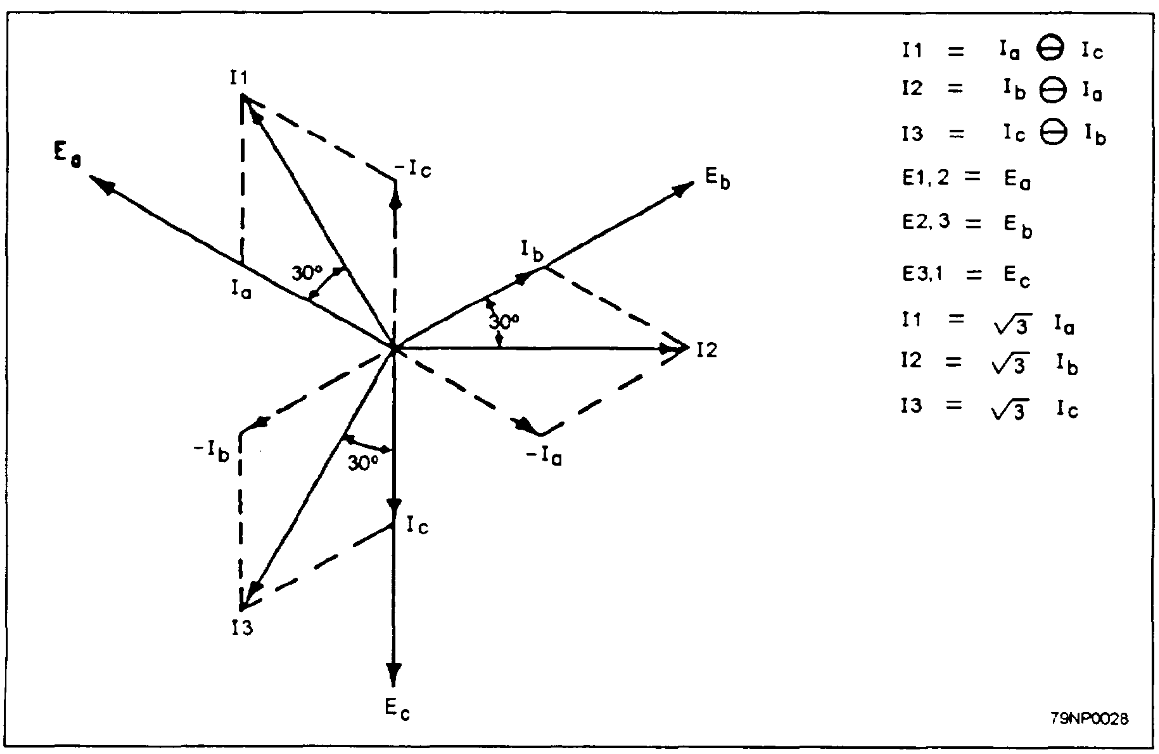


Figure 3-28.—Three-phase delta/connected system.

Effective values of line and phase voltages are indicated in figure 3-28 by vectors E_a, E_b, and E_c. Note that the vector sum of E_a, E_b, and E_c is zero. The phase currents are equal to each other because the loads are balanced. The line currents are equal to each other for the same reason. At unity-power-factor loads, the phase current and phase voltage have a 0-degree angle between them.

The power delivered by a balanced, three-phase, delta-connected system is also three times the power delivered by each phase. Mathematically, you can prove this as follows:

Because

$$E_{phase} = E_{line} \text{ and } I_{phase} = \frac{I_{line}}{\sqrt{3}}$$

the total true power is

$$P_t = 3E_{line} \frac{I_{line}}{\sqrt{3}} \cos\theta$$

$$= \sqrt{3}E_{line}\, I_{line} \cos\theta$$

Thus, the expression for three-phase power delivered by a balanced delta-connected system is the same as the expression for three-phase power delivered by a balanced wye-connected system. Two examples are given to illustrate the phase relations between current, voltage, and power in (1) a three-phase, wye-connected system and (2) a three-phase, delta-connected system.

Example 1: A three-phase, wye-connected ac generator has a terminal voltage of 450 volts and delivers a full-load current of 300 amperes per terminal at a power factor of 80 percent. Find (a) the phase voltage, (b) the full-load current per phase, (c) the kilovolt-ampere, or apparent power, rating, and (d) the true power output.

$$\text{(a) } E_{phase} = \frac{E_{line}}{\sqrt{3}} = \frac{450}{\sqrt{3}} = 260 \text{ volts}$$

$$\text{(b) } I_{phase} = I_{line} = 300 \text{ amperes}$$

$$\text{(c) Apparent power} = \sqrt{3}E_{line}\, I_{line}$$

$$= \sqrt{3} \times 450 \times 300 = 233{,}600$$

$$VA, \text{ or } 233.6 kVA$$

$$\text{(d) True power} = \sqrt{3}E_{line}\, I_{line} \cos\theta$$

$$= \sqrt{3} \times 450 \times 300 \times 0.8$$

$$= 186{,}800 \text{ watts, or } 186.8 kW$$

Example 2: A three-phase, delta-connected ac generator has a terminal voltage of 450 volts, and the current in each phase is 200 amperes. The power factor of the load is 75 percent. Find (a) the line voltage, (b) the line current, (c) the apparent power, and (d) the true power.

$$\text{(a) } E_{phase} = E_{line} = 450 \text{ volts}$$

$$\text{(b) } I_{line} = \sqrt{3}I_{phase} = 1.732 \times 200 = 346 \text{ amperes}$$

$$\text{(c) Apparent power} = \sqrt{3}E_{line}\, I_{line}$$

$$= 1.73 \times 450 \times 346 = 269{,}000 \text{ VA, or } 269 kVA$$

$$\text{(d) True power} = \sqrt{3}E_{line}\, I_{line} \cos\theta$$

$$= 1.73 \times 450 \times 346 \times 0.75$$

$$= 202{,}020 \text{ watts, or } 202.02 kW$$

MEASUREMENT OF POWER

The wattmeter connections for measuring the true power in a three-phase system are shown in figure 3-29. The method shown in figure 3-29, view A, uses three wattmeters with their current coils inserted in series with the line wires and their potential coils connected between line and neutral wires. The total true power is equal to the arithmetic sum of the three wattmeter readings.

The method shown in figure 3-29, view B, uses two wattmeters with their current coils connected in series

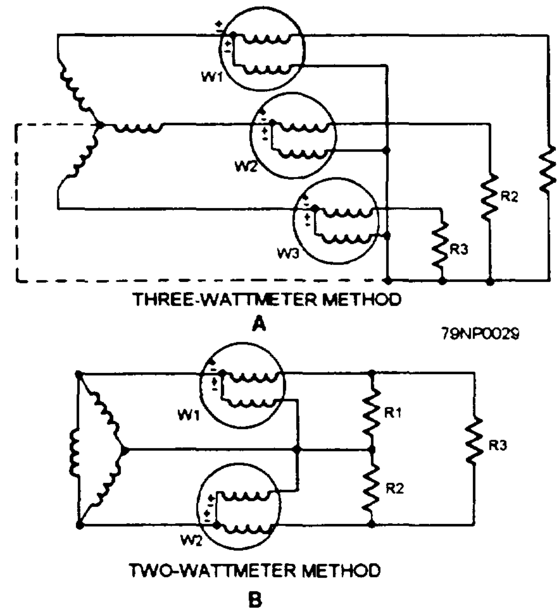


Figure 3-29.—Wattmeters.

with two line wires and their potential coils connected between these line wires and the common, or third, wire that does not contain the current coils. The total true power is equal to the algebraic sum of the two wattmeter readings. If one meter reads backward, its potential coil connections are first reversed to make the meter read upscale, and the total true power is then equal to the difference in the two wattmeter readings. If the load power factor is less than 0.5 and the loads are balanced, the total true power is equal to the difference in the two wattmeter readings. If the load power factor is 0.5, one meter indicates the total true power and the other indicates zero. If the load power factor is above 0.5, the total true power is equal to the sum of the two wattmeter readings.

FREQUENCY

The frequency of the ac generator voltage depends upon the speed of rotation of the rotor and the number of poles. The faster the speed the higher the frequency. Conversely, the lower the speed, the lower the frequency. The more poles there are on the rotor, the higher the frequency is for a given speed. When a rotor has rotated through an angle so that two adjacent rotor poles (a north and a south pole) have passed one winding, the voltage induced in that winding will have modulated through one complete cycle. For a given frequency, the more pairs of poles, the lower the speed of rotation. A two-pole generator rotates at twice the speed of a four-pole generator for the same frequency of generated voltage. The frequency of the generator in Hz (cycles per second) is related to the number of poles and the speed as expressed by the equation

$$f = \frac{P}{2} \times \frac{N}{60} = \frac{PN}{120}$$

where P is the number of poles and N the speed in rpm. For example, a two-pole, 3,600-rpm generator has a frequency of

$$\frac{2 \times 3{,}600}{120} = 60Hz;$$

a four-pole 1,800-rpm generator has the same frequency; a six-pole, 500-rpm generator has a frequency of

$$\frac{6 \times 500}{120} = 25Hz;$$

and a 12-pole, 4,000-rpm generator has a frequency of

$$\frac{12 \times 4{,}000}{120} = 400Hz.$$

GENERATED VOLTAGE

Generated voltage of a generator is expressed by the formula:

$$E_g = K\theta N$$

Where:

E_g is generated voltage

K is a constant determined by the construction of the generator

θ is the strength of the rotating magnetic field

N is the synchronous speed

Its impractical to vary the frequency of power supplied throughout the ship in order to regulate the voltage generated, and the constant can't be changed once the machine has been designed and built; therefore, the generated voltage of an ac generator is controlled by varying the dc excitation voltage applied to the rotor field winding thus varying θ.

GENERATOR CHARACTERISTICS

When the load on a generator is changed, the terminal voltage varies with the load. The amount of variation depends on the design of the generator and the power factor of the load. With a load having a lagging power factor, the drop in terminal voltage with increased load is greater than for unity power factor. With a load having a leading power factor, the terminal voltage tends to rise. The causes of a change in terminal voltage with load change are:

- armature resistance,
- armature reactance, and
- armature reaction.

Armature Resistance

When current flows through a generator armature winding, there is an IR drop due to the resistance of the winding. This drop increases with load, and the terminal voltage is reduced. The armature resistance drop is small because the resistance is low.

Armature Reactance

The armature current of an ac generator varies approximately as a sine wave. The continuously varying current in the generator armature is accompanied by an IX_L voltage drop in addition to the IR drop. Armature reactance in an ac generator may be from 30 to 50 times the value of armature resistance because of the relatively large inductance of the coils compared with their resistance.

A simplified series equivalent circuit of one phase of an ac generator is shown in figure 3-30. The voltage generated in the phase winding is equal to the vector sum of the terminal voltage for the phase and the internal voltage loss in the armature resistance, R, and the armature reactance, X_L, associated with that phase. The voltage vectors for a unity power-factor load are shown in figure 3-30, view A. The armature IR drop is in phase with the current, I, and the terminal voltage, E_T. Because the armature IX_L drop is 90° out of phase with the current, the terminal voltage is approximate] y equal to the generated voltage, less the IR drop in the armature.

The voltage vectors for a lagging power-factor load are shown in figure 3-30, view B. The load current and IR drop lag the terminal voltage by angle θ. In this example, the armature IZ drop is more nearly in phase with the terminal voltage and the generated voltage. Hence, the terminal voltage is approximately equal to the generated voltage, less the armature IZ drop. Because the IZ drop is much greater than the IR drop, the terminal voltage is reduced that much more. The volt age vectors for a leading power-factor load are shown in figure 3-30, view C. The load current and IR drop lead the terminal voltage by angle θ. This condition results in an increase in terminal voltage above the value of E_G. The total available voltage of the ac generator phase is the combined effect of Ec (rotational y induced) and the self-induced voltage (not shown in the vectors). The self-induced voltage, as in any ac circuit, is caused by the varying field (accompanying the varying armature current) linking the armature conductors. The self-induced voltage always lags the current by 90°; hence, when I leads E_T, the self-induced voltage aids E_G, and E_T increases.

Armature Reaction

When an ac generator supplies no load, the dc field flux is distributed uniformly across the air gap. When

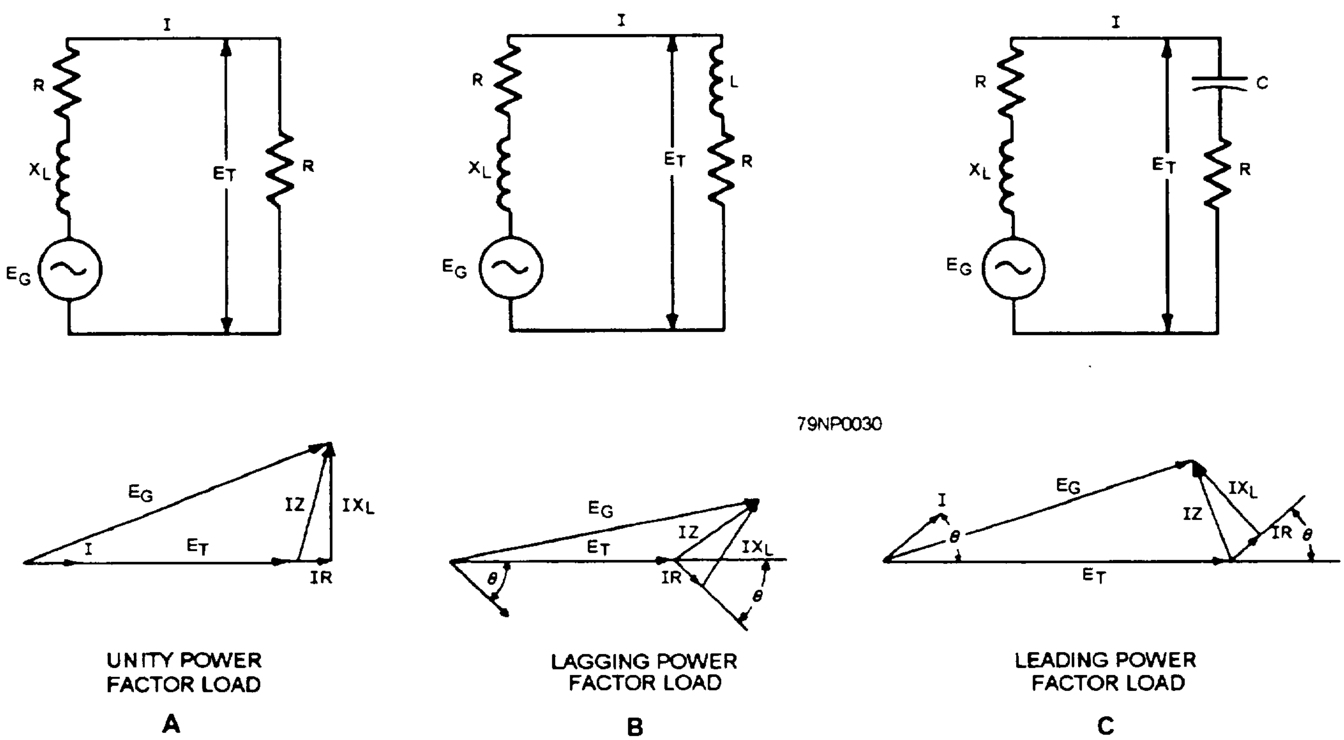


Figure 3-30.—The ac generator voltage characteristics.

an ac generator supplies a reactive load, however, the current flowing through the armature conductors produces an armature magnetomotive force (mmf) that influences the terminal voltage by changing the magnitude of the field flux across the air gap. When the load is inductive, the armature mmf opposes the dc field and weakens it, thus lowering the terminal voltage. When a leading current flows in the armature, the dc field is aided by the armature mmf, and the flux across the air gap is increased, thus increasing the terminal voltage.

TRANSFORMERS

A transformer is a device that has no moving parts and that transfers energy from one circuit to another by electromagnetic induction. The energy is always transferred without a change in frequency, but usually with changes in voltage and current. A step-up transformer receives electrical energy atone voltage and delivers it at a higher voltage, Conversely, a step-down transformer receives energy at one voltage and delivers it at a lower voltage. Transformers require little care and maintenance because of their simple, rugged, and durable construction. The efficiency of transformed is high. Because of this, transformers are responsible for the more extensive use of alternating current than direct current. The conventional constant-potential transformer is designed to operate with the primary connected across a constant-potential source and to provide a secondary voltage that is substantially constant from no load to full load.

Various types of small, single-phase transformers are used in electrical equipment. In many installations, transformers are used on switchboards to step down the voltage for indicating lights. Low-voltage transformers are included in some motor control panels to supply control circuits or to operate overload relays,

Instrument transformers include potential, or voltage, transformers and current transformers. Instrument transformers are commonly used with ac instruments when high voltages or large currents are to be measured.

Electronic circuits and devices employ many types of transformers to provide the necessary voltages for proper electron-tube operation, interstage coupling, signal amplification, and so forth. The physical construction of these transformers differs widely.

Power-supply transformers, used in electronic circuits, are single-phase, constant-potential transformers with either one or more secondary windings, or a single secondary with several tap connections. These transformers have a low volt-ampere capacity and are less efficient than large constant-potential power transformers. Most power-supply transformers for electronic equipment are designed to operate at a frequency of 50 to 60 Hz. Aircraft power-supply transformers are designed for a frequency of 400 Hz. The higher frequencies permit a saving in size and weight of transformers and associated equipment.

CONSTRUCTION

The typical trzansformer has two windings insulated electrically from each other. These windings are wound on a common magnetic core made of laminated sheet steel. The principal parts of a transformer and their functions areas follows:

Piece	Function
Core	Provides a path for the magnetic lines of flux
Primary winding	Receives the energy from the ac source
Secondary winding	Receives energy from the primary winding and delivers it to the load
Enclosure	Protects the above components from dirt, moisture, and mechanical damage

When a transformer is used to step up the voltage, the low-voltage winding is the primary. Conversely, when a transformer is used to step down the voltage, the high-voltage winding is the primary. The primary is always connected to the source of the power; the secondary is always connected to the load It is common practice to refer to the windings as the primary and secondary rather than the high-voltage and low-voltage windings.

There are two principal types of transformer construction—the core type and the shell type (fig. 3-31, views A and B). The cores are built of thin stampings of silicon steel. Eddy currents, generated in the core by the alternating flux as it cuts through the iron, are minimized by using thin laminations and by insulating adjacent laminations with insulating varnish. Hysteresis losses, caused by the friction developed

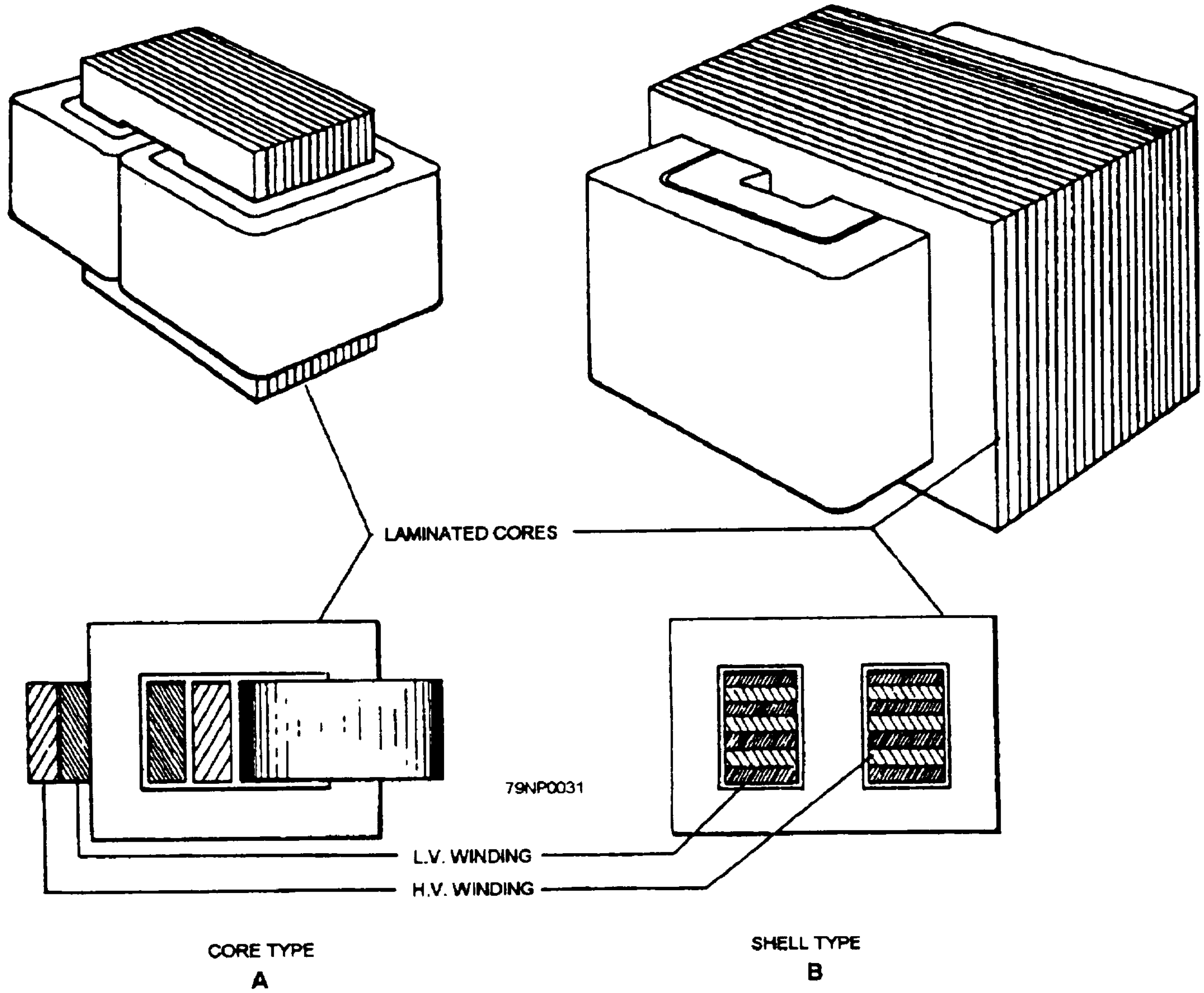


Figure 3-31.—Types transformer construction.

between magnetic particles as they are rotated through each cycle of magnetization, are minimized by the use of a special grade of heat-treated, grain-oriented, silicon-steel laminations.

In the core type of transformer, copper windings surround the laminated iron core. In the shell type of transformer, an iron core surrounds the copper windings. Distribution transformers are generally of the core type, whereas some of the largest power transformers are of the shell type.

If the windings of a core-type transformer were placed on separate legs of the core, a relatively large amount of the flux produced by the primary winding would fail to link the secondary winding and a large leakage flux would result. The effect of the leakage flux would be to increase the leakage reactance drop, IX_L, in both windings. To reduce the leakage flux and reactance drop, half of each winding is placed on each leg of the core. The windings may be cylindrical in form and placed one inside the other with the necessary insulation, as shown in figure 3-31, view A. The low-voltage winding is placed with a large part of its surface area next to the core, and the high-voltage winding is placed outside the low-voltage winding in order to reduce the insulation requirements of the two windings. If the high-voltage winding were placed next to the core, two layers of high-voltage insulation would be required, one next to the core and the other between the two windings.

In another method, the windings are built up in thin, flat sections called pancake coils. These pancake coils are sandwiched together with the required insulation between them, as shown in figure 3-31, view B.

The complete core and coil assembly (fig. 3-32, view A) is placed in a steel tank. In some transformers, the complete assembly is immersed in a special mineral oil to provide a means of insulation and cooling, while in other transformers they are mounted in dripproof enclosures, as shown in figure 3-32, view B.

Transformers are built in both single-phase and polyphase units. A three-phase transformer consists of separate insulated windings for the different phases, which are wound on a three-legged core capable of establishing three magnetic fluxes displaced 120° in time phase.

VOLTAGE AND CURRENT RELATIONSHIPS

The operation of the transformer is based on the principle that electrical energy can be transferred efficiently by mutual induction from one winding to another. When the primary winding is energiaed from an ac source, an alternating magnetic flux is established in the transformer core. This flux links the turns of both primary and secondary, thereby inducing voltages in them. Because the same flux cuts both windings, the same voltage is induced in each turn of both windings. Hence, the total induced voltage in each winding is proportional to the number of turns in that winding; that is,

$$\frac{E1}{E2} = \frac{N_1}{N_2}$$

where, E1 and E2 are the induced voltages in the primary and secondary windings, and

N_1 and N_2 are the number of turns in the primary and secondary windings.

In ordinary transformers, the induced primary voltage is almost equal to the applied primary voltage; hence, the applied primary voltage and the secondary induced voltage are approximately proportional to the respective number of turns in the two windings.

A constant-potential, single-phase transformer is represented by the schematic diagram in figure 3-33, view A. For simplicity, the primary winding is shown as being on one leg of the core and the secondary winding on the other leg. The equation for the voltage induced in one winding of the transformer is

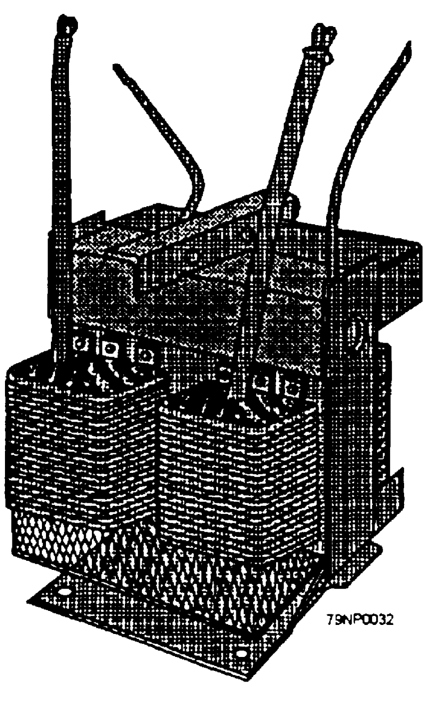
$$E = \frac{4.44BSfN}{10^8}$$

where:

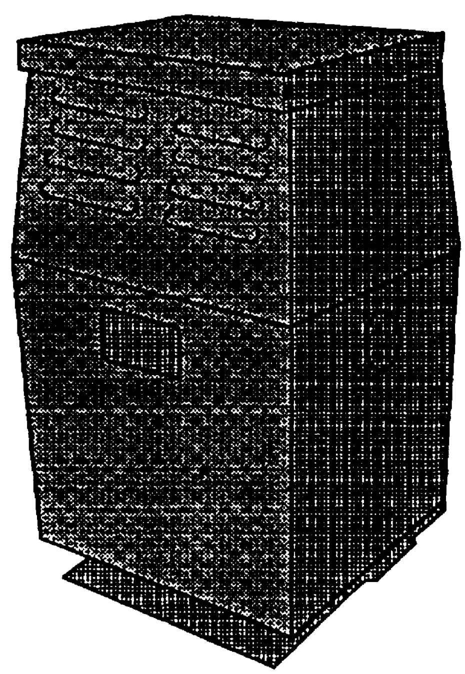
E is the rms voltage

B is the maximum value of the magnetic flux density in lines per square inch in the core

S is the cross-sectional area of the core in square inches



A COIL AND CORE ASSEMBLY



B ENCLOSURE

Figure 3-32.—Single-phase transformer.

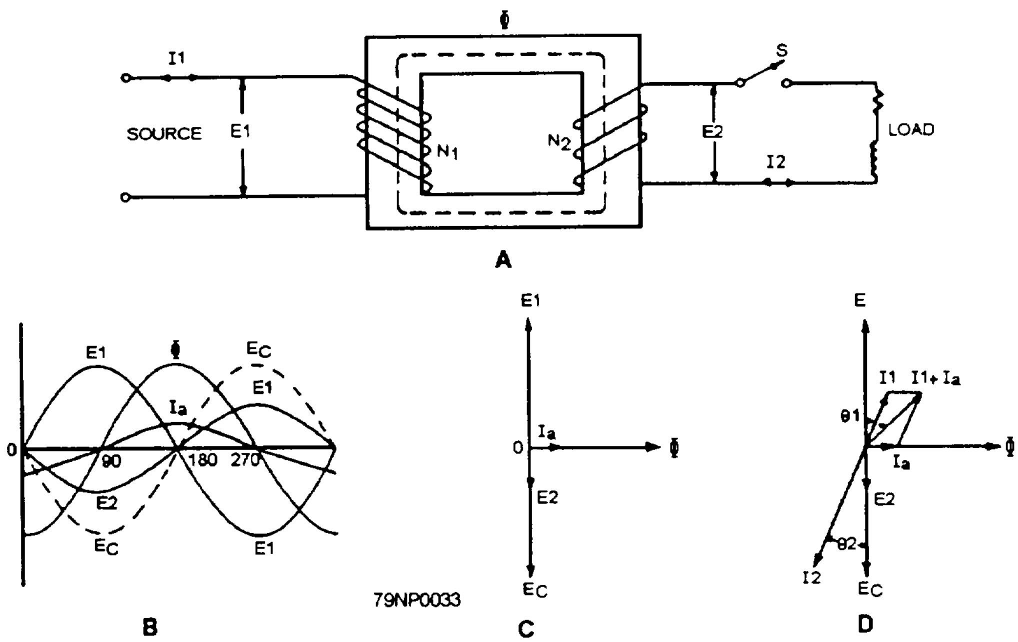


Figure 3-33.—Constant-potential transformer.

f is the frequency in hertz, and

N is the number of complete turns in the winding

For example, if the maximum flux density is 90,000 lines per square inch, the cross-sectional area of the core is 4.18 square inches, the frequency is 60 Hz, and the number of turns in the high-voltage winding is 1,200, the voltage rating of this winding is

$$E1 = \frac{4.44 \times 90{,}000 \times 4.18 \times 60 \times 1{,}200}{10^8} = 1{,}200 \textit{ volts.}$$

If the primary-to-secondary turns ratio of this transformer is 10 to 1, the number of turns in the low-voltage winding will be

$$\frac{1{,}200}{10} = 120 \textit{ turns}$$

and the voltage induced in the secondary will be

$$E2 = \frac{1{,}200}{10} = 120 \textit{ volts.}$$

For a more in-depth explanation of voltage and current relations, refer to NEETS, Module 2, *Introduction to Alternating Current and Transformers,* NAVEDTRA 172-02-00-88, Topic 5, Transformers.

The waveforms of the ideal transformer with no load are shown in figure 3-33, view B. When E1 is applied to the primary winding, N_1, with the switch, S, open, the resulting current, I_a, is small and lags E1 by almost 90° because the circuit is highly inductive. This no-load current is called the exciting, or magnetizing, current because it supplies the magnetomotive force that produces the transformer core flux ϕ. The flux produced by 1. cuts the primary winding, N_1, and induces a counter voltage, E_c, 180° out of phase with E1 in this winding. The voltage, E2, induced in the secondary winding is in phase with the induced (counter) voltage, E., in the primary winding, and both lag the exciting current and flux, whose variations produce them, by an angle of 90°. These relations are shown in vector form in figure 3-33, view C. The values are only approximate and are not drawn exactly to scale.

When a load is connected to the secondary by closing switch S (fig. 3-33, view A), the secondary current, I2, depends upon the magnitude of the secondary voltage, E2, and the load impedance, Z. For example, if E2 is equal to 120 volts and the load impedance is 20 ohms, the secondary current will be

$$I2 = \frac{E2}{Z2} = \frac{120}{20} = 6 \textit{ amperes.}$$

If the secondary power factor is 86.6 percent, the phase angle, θ2, between secondary current and voltage will be the angle whose cosine is 0.866, or 30°.

The secondary load current flowing through the secondary turns comprises a load component of magnetomotive force, which, according to Lenz's law, is in such a direction as to oppose the flux that is producing it. This opposition tends to reduce the transformer flux a slight amount. The reduction in flux is accompanied by a reduction in the counter voltage induced in the primary winding of the transformer. Because the internal impedance of the primary winding is low and the primary current is limited principally by the counter emf in the winding, the transformer primary current increases when the counter emf in the primary is reduced.

The increase in primary current continues until the primary ampere-turns are equal to the secondary ampere-turns, neglecting losses. For example, in the transformer being considered, the magnetizing current, I_a, is assumed to be negligible in comparison with the total primary current, I1 + I_a, under load conditions because I_a is small in relation to I1 and lags it by an angle of 60°. Hence, the primary and secondary ampere-turns are equal and opposite; that is,

$$N_1 I1 = N_2 I2.$$

In this example,

$$I1 = \frac{N_2}{N_1} I2 = \frac{120}{1200} \times 6 = 0.6 \textit{ ampere.}$$

Neglecting losses, the power delivered to the primary is equal to the power supplied b the secondary to the load. If the load power is $P^2 = E^2 1^2 \cos \theta 2$, and cosine $\theta 2$ equals cosine 30° (0.866), then P^2 = 120 x 6 x 0.866= 624 watts.

The load component of primary current, 11, increases with secondary load and maintains the transformer core flux at nearly its initial value. This action enables the transformer primary to take power from the source in proportion to the load demand, and to maintain the terminal voltage approximately constant. The lagging power-factor load vectors are shown in figure 4-31, view D. Note that the load power factor is transferred through the transformer to the primary and that $\theta 2$ is approximately equal to $\theta 1$, the only difference being that $\theta 1$ is slightly larger than $\theta 2$ because of the presence of the exciting current, which flows in the primary winding but not in the secondary.

The copper loss of a transformer varies as the square of the load current; whereas the core loss depends on the terminal voltage applied to the primary and on the frequency of operation. The core loss of a constant-potential transformer is constant from no load to full load because the frequency is constant and the effective values of the applied voltage, exciting current, and flux density are constant.

If the load supplied by a transformer has a unity power factor, the kilowatt (true power) output is the same as the kilovolt-ampere (apparent power) output. If the load has a lagging power factor, the kilowatt output is proportionally less than the kilovolt-ampere output. For example, a transformer having a full-load rating of 100 kVA can supply a 100-kW load at a unity power factor, but only an 80-kW load at a lagging power factor of 80 percent.

Many transformers are rated in terms of the kVA load that they can safely carry continuously without exceeding a temperature rise of 80°C when maintaining rated secondary voltage at rated frequency and when operating with an ambient (surrounding atmosphere) temperature of 40°C. The actual temperature rise of any part of the transformers the difference between the total temperature of that part and the temperature of the surrounding air.

It is possible to operate transformers on a higher frequency than that for which they are designed, but it is not permissible to operate them at more than 10 percent below their rated frequency because they will overheat. The exciting current in the primary varies directly with the applied voltage and, like any impedance containing inductive reactance, the exciting current varies inversely with the frequency. Thus, at reduced frequency, the exciting current becomes excessively large, and the accompanying heating may damage the insulation and the windings.

EFFICIENCY

The efficiency of a transformer is the ratio of the output power at the secondary terminals to the input power at the primary terminals. It is also equal to the ratio of the output to the output plus losses. That is,

$$\textit{Efficiency} = \frac{\textit{output}}{\textit{input}}$$

$$= \frac{\textit{output}}{\textit{output} + \textit{copper loss} + \textit{core loss}}.$$

The ordinary power transformer has an efficiency of 97 to 99 percent. The losses are due to the copper losses in both windings and the hysteresis and eddy-current losses in the iron core.

The copper losses vary as the square of the current in the windings and as the winding resistance. In the transformer being considered, if the primary has 1,200 turns of number 23 copper wire, having a length of 1,320 feet, the resistance of the primary winding is 26.9 ohms. If the load current in the primary is 0.5 ampere, the primary copper loss is $(0.5)^2$x 26.9 = 6.725 watts. Similarly, if the secondary winding contains 120 turns of number 13 copper wire, having a length of approximately 132 feet, the secondary resistance will be 0.269 ohm. The secondary copper loss is $I_2 R_2$, or

$(5)^2 \times 0.269 = 6.725$ watts, and the total copper loss is $6.725 \times 2 - 13.45$ watts.

The core losses, consisting of the hysteresis and eddy-current losses, caused by the alternating magnetic flux in the core are approximate] y constant from no load to full load with rated voltage applied to the primary.

In the transformer of figure 3-33, view A, if the core loss is 10.6 watts and the copper loss is 13.4 watts, the efficiency is

$$\frac{output}{output + copper\ loss + core\ loss} =$$

$$\frac{624}{624 + 13.4 + 10.6} = \frac{624}{648} = 0.963$$

or 96.3 percent. The rating of the transformer is

$$\frac{E1I1}{1{,}000} = \frac{1{,}200 \times 0.5}{1{,}000} = 0.60\ kVA.$$

The efficiency of this transformer is relatively low because it is a small transformer and the losses are disproportionately large.

CONNECTIONS

In this section we will discuss the differences encountered when dealing with transformer windings connected for single- and three-phase operation.

Single-Phase Connections

Single-phase distribution transformers usually have their windings divided into two or more sections, as shown in figure 3-34, view A. When the two secondary windings are connected in series (fig. 3-34, view A), their *voltages* add. When two secondary windings are connected in parallel (fig. 3-34, view B), their *currents*

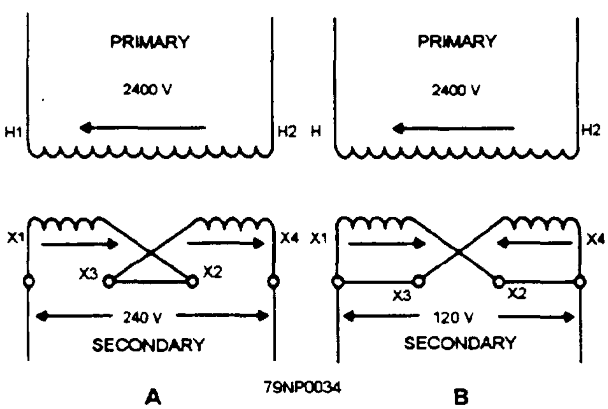


Figure 3-34.—Single-phase transformer connections.

add. For example, if each secondary winding is rated at 120 volts and 100 amperes, the series-connection output rating will be 240 volts at 100 amperes, or 24 kVA; the parallel-connection output rating will be 120volts at 200 amperes, or 24 kVA.

In the series connection, care must be taken to connect the coils so their voltages add. The proper arrangement is indicated in figure 3-34, view A. A trace made through the secondary circuits from X1 to X4 is in the same direction as that of the arrows representing the maximum positive voltages.

In the parallel connection, care must be taken to connect the coils so their voltages are in opposition. The correct connection is indicated in figure 3-34, view B. The direction of a trace made through the secondary windings from X1 to X2 to X4 to X3 and returning to X1 is the same as that of the arrow in the right-hand winding. This condition indicates that the secondary voltages have their positive maximum values in directions opposite to each other in the closed circuit, which is formed by paralleling the two secondary windings. Thus, no circulating current will flow in these windings on no load. If either winding were reversed, a short-circuit current would flow in the secondary, and this would cause the primary to draw a short-circuit current from the source. This action would, of course, damage the transformer as well as the source.

Three-Phase Connections

Power may be supplied through three-phase circuits containing transformers in which the primaries and secondaries are connected in various wye and delta combinations. For example, three single-phase transformers may supply three-phase power with four possible combinations of their primaries and secondaries. These connections are

1. primaries in delta and secondaries in delta,
2. primaries in wye and secondaries in wye,
3. primaries in wye and secondaries in delta, and
4. primaries in delta and secondaries in wye.

Earlier under the heading Three-Phase Generators, delta and wye connections were discussed. Also discussed was the phase relationship between line and phase voltages and that current is the same as in ac generators.

If the primaries of three single-phase transformers are properly connected (either in wye or delta) to a three-phase source, the secondaries may be connected in delta, as shown in figure 3-35. A topographic vector diagram of the three-phase secondary voltages is shown in figure 3-35, view A. the vector sum of these three voltages is zero. This may be seen by combining any two vectors, for example, E_A and E_B, and noting that their sum is equal and opposite to the third vector, E_c. When the windings are connected properly, a voltmeter inserted within the delta will indicate zero voltage, as shown in figure 3-35, view B.

Assuming all three transformers have the same polarity, the delta connection consists of connecting the X2 lead of winding A to the X1 lead of B, the X2 lead of B to X1 of C, and the X2 lead of C to X1 of A. If any one of the three windings is reversed with respect to the other two windings, the total voltage within the delta will equal twice the value of one phase; and if the delta is closed on itself, the resulting current will be of short-circuit magnitude, resulting in damage to the transformer windings and cores. The delta should never be closed until a test is first made to determine that the voltage within the delta is zero or nearly zero. This may be accomplished by using a voltmeter, fuse wire, or test lamp. In figure 3-35, view B, when the voltmeter is inserted between the X2 lead of A and the X1 lead of B, the delta circuit is completed through the voltmeter, and the indication should be approximately zero. Then, the delta is completed by connecting the X2 lead to A and the X1 lead to B.

If the three secondaries of an energized transformer bank are properly connected in delta and are supplying a balanced three-phase load the line current will be equal to 1.73 times the phase current. If the rated current of a phase (winding) is 100 amperes, the rated line current will be 173 amperes. If the rated voltage of a phase is 120 volts, the voltage between any two line wires will be 120 volts.

The three secondaries of the transformer bank may be reconnected in wye to increase the output voltage. The voltage vectors are shown in figure 3-35, view C. If the phase voltage is 120 volts, the line voltage will be 1.73 x 120 = 208 volts. The line voltages are represented by vectors, E1,2, E2,3, and E3,1. A voltmeter test for the line voltage is represented in figure 3-35, view D. If the three transformers have the same polarity, the proper connections for a wye-connected secondary bank are indicated in the figure. The X1 leads are connected to forma common or neutral connection, and the X2 leads of the three secondaries are brought out to the line leads. If the connections of any one

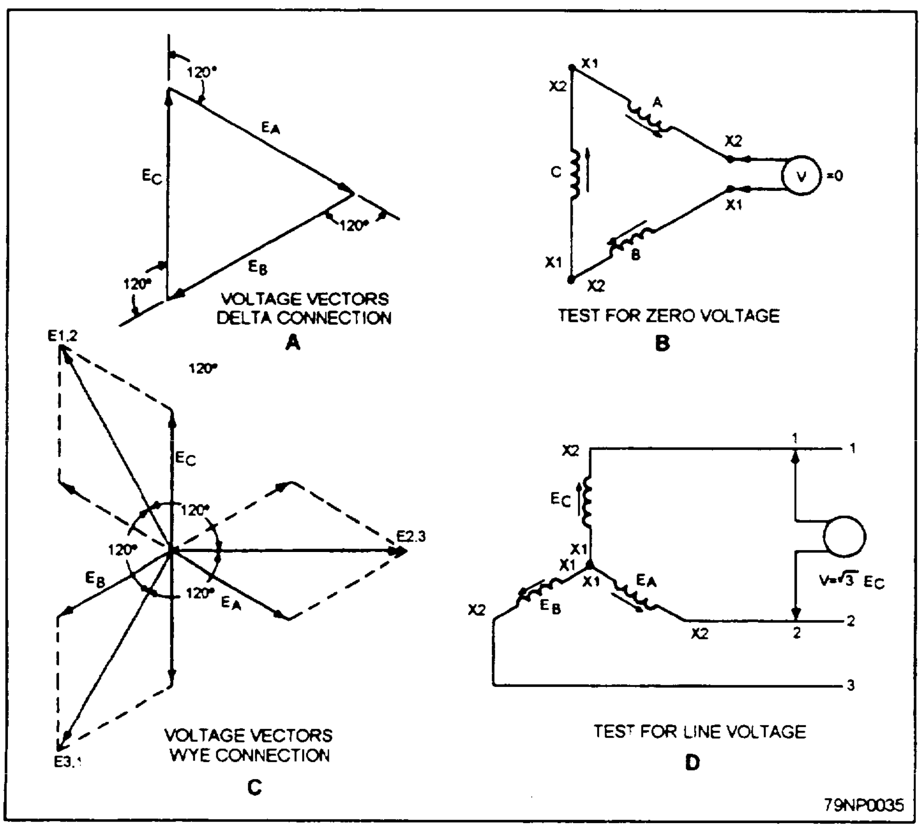


Figure 3-35.—Delta-connected transformer secondaries.

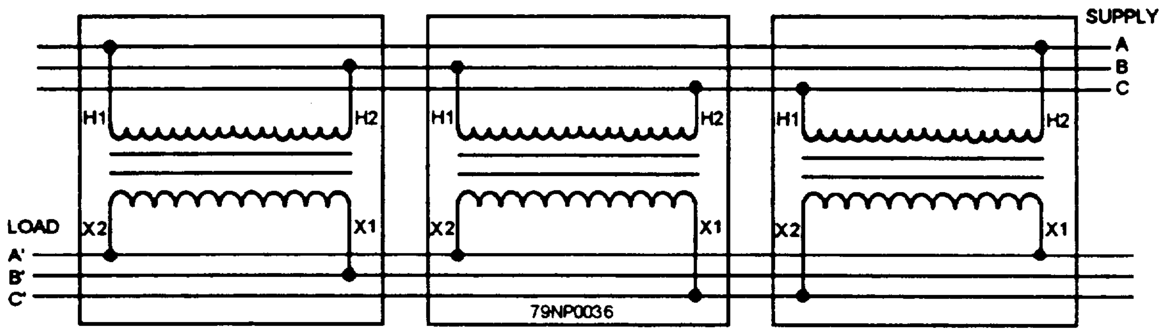


Figure 3-36.—Change connections.

winding are reverses the voltages between the three line wires will become unbalanced, and the loads will not receive their proper magnitude of load current. In addition, the phase angle between the line currents will be changed, and they will no longer be 120° out of phase with each other. Therefore, it is important to properly connect the transformer secondaries to preserve the symmetry of the line voltages and currents.

Three single-phase transformers with both primary and secondary windings delta connected are shown in figure 3-36. The H1 lead of one phase is always connected to the H2 lead of an adjacent phase, the X1 lead is connected to the X2 terminal of the corresponding adjacent phase, and so on; and the line connections are made at these junctions. This arrangement is based on the assumption that the three transformers have the same polarity.

An open-delta connection results when any one of the three transformers is removed from the delta-connected transformer bank without disturbing the three-wire, three-phase connections to the remaining two transformers. These transformers will maintain the correct voltage and phase relations on the secondary to supply a balanced three-phase load. An open-delta connection is shown in figure 3-37.

The three-phase source supplies the primaries of the two transformers, and the secondaries supply a three-phase voltage to the load. The line current is equal to the transformer phase current in the open-delta connection. In the closed-delta connection, the transformer phase current

$$I_{phase} = \frac{I_{line}}{\sqrt{3}}.$$

Thus, when one transformer is removed from a delta-connected bank of three transformers, the remaining two transformers will carry a current equal to

$$\sqrt{3}\, I_{phase}.$$

This value amounts to an overload current on each transformer of 1.73 times the rated current, or an overload of 73.2 percent.

Thus, in an open-delta connection, the line current must be reduced so as not to exceed the rated current of the individual transformers if they are not to be overloaded. Therefore, the open-delta connection results in a reduction in system capacity. The full load capacity in a delta connection at unity power factor is

$$P\Delta = 3I_{phase}\, E_{phase} = \sqrt{3}\, E_{line}\, I_{line}.$$

In an open-delta connection, the line current is limited to the rated phase current of

$$\frac{I_{line}}{\sqrt{3}},$$

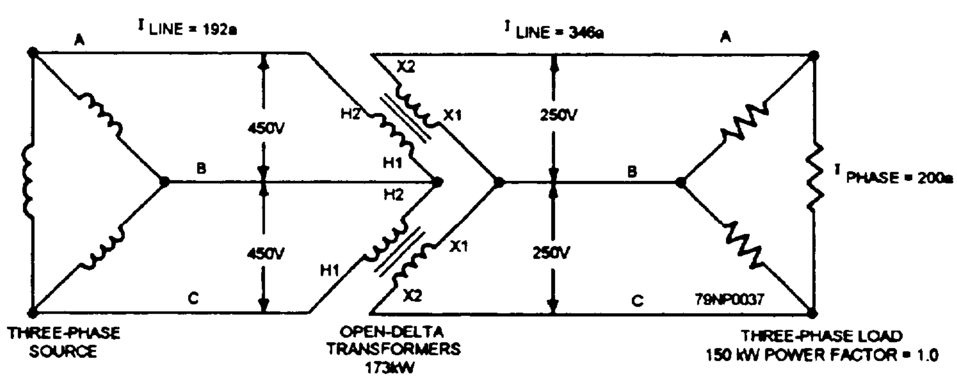


Figure 3-37.—Open-delta transformer connection.

and the full-load capacity of the open-delta, or V-connected, system is

$$P_V = \sqrt{3} E_{line} \frac{I_{line}}{\sqrt{3}} = E_{line} I_{line}.$$

The ratio of the load that can be carried by two transformers connected in open delta to the load that can be carried by three transformers in closed delta is

$$P_V = \frac{E_{line} I_{line}}{\sqrt{3} E_{line} I_{line}} = \frac{1}{\sqrt{3}}$$

$$= 0.577, \text{ or } 57.7 \text{ percent}$$

of the closed-delta rating.

For example, a 150-kW, three-phase balanced load operating at unity power factor is supplied at 250 volts. The rating of each of three transformers in closed delta is

$$\frac{150}{3} = 50\, kW,$$

and the phase current is

$$\frac{50{,}000}{250} = 200 \text{ amperes}.$$

The line current is

$$200\sqrt{3} = 346 \text{ amperes}.$$

If one transformer is removed from the bank, the remaining two transformers would be overloaded.

$$346 - 200 = 146 \text{amperes}, \text{ or } \frac{146}{200} \times 100 = 73 \text{percent}$$

To prevent overload on the remaining two transformers, the line current must be reduced from 346 amperes to 200 amperes, and the total load reduced to

$$\sqrt{3} \times \frac{250 \times 200}{1{,}000} = 86.6\, kW$$

or

$$\frac{86.6}{150} \times 100 = 57.7 \text{ percent}$$

of the original load.

The rating of each transformer in open delta necessary to supply the original 150-kW load is

$$\frac{E_{phase} I_{phase}}{1{,}000}, \text{ or } \frac{250 \times 346}{1{,}000} = 86.6 kW,$$

and two transformers require a total rating of 2 x 86.6= 173.2 kW, compared with 150 kW for three transformers in closed delta. The required increase in transformer capacity is

$$173.2 - 150 = 23.2 kW, \text{ or } \frac{23.2}{150} \times 100 = 15.5 \text{percent},$$

when two transformers are used in open delta to supply the same load as three 50-kW transformers in closed delta.

Three single-phase transformers with both primary and secondary windings wye connected are shown in figure 3-36. Only 57.7 percent of the line voltage

$$\frac{E_{line}}{\sqrt{3}}$$

is impressed across each winding, but full-line current flows in each transformer winding.

Three single-phase transformers delta connected to the primary circuit and wye connected to the secondary circuit are shown in figure 3-38. This connection

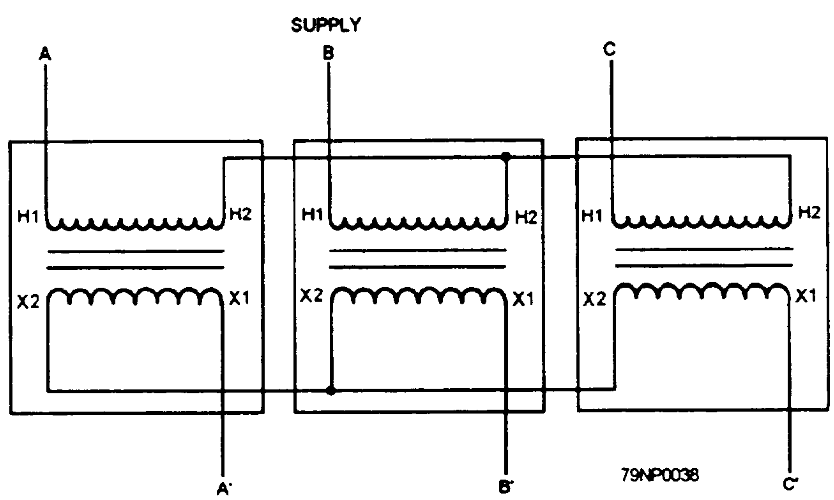


Figure 3-38.—Wye-wye transformer connections.

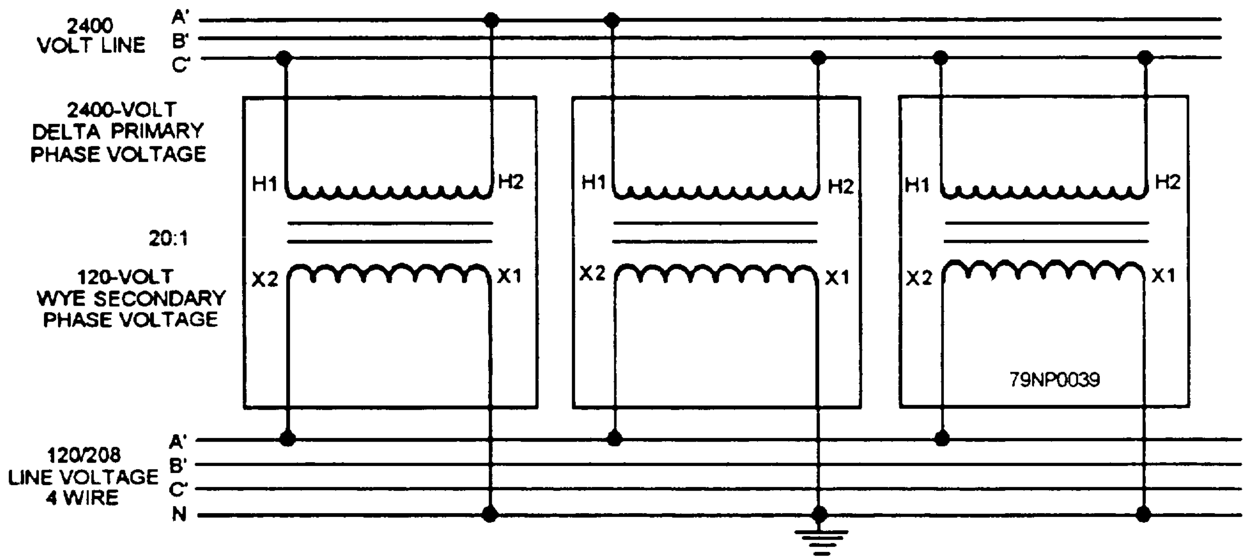


Figure 3-39.—Delta-wye transformer connections.

provides four-wire, three-phase service with 208 volts between line wires A'B'C' and

$$\frac{208}{\sqrt{3}},$$

or 120 volts between each line wire and neutral N.

The delta-connected primary, wye-connected secondary (fig. 3-39) is desirable in installations when a large number of single-phase loads are supplied from a three-phase transformer bank. The neutral, or grounded, wire extends from the midpoint of the wye connection, permitting the single-phase loads to be distributed evenly across the three phases. At the same time, three-phase loads can be connected directly across the line wires. The single-phase loads have a voltage rating of 120 volts, and the three-phase loads are rated at 208 volts. This connection is often used in high-voltage, plate-supply transformers. The phase voltage is

$$\frac{1}{1.73}, \textit{or } 0.577$$

of the line voltage.

Three single-phase transformers with wye-connected primaries and delta-connected secondaries are shown in figure 340. This arrangement is used for stepping down the voltage from approximately 4,000 volts between line wires on the primary side to either 120 volts or 240 volts, depending upon whether the secondary windings of each transformer are connected in parallel or in series. In figure 3-40, the two secondaries of each transformer are connected in parallel, and the secondary output voltage is 120 volts. There is an economy in transmission with

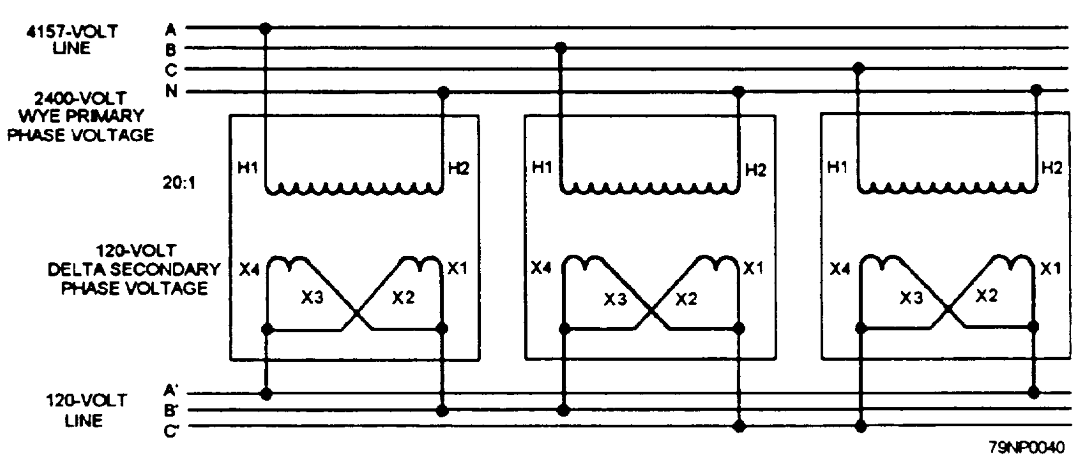


Figure 3-40.—Wye-delta transformer connections.

the primaries in wye because the line voltage is 73 percent higher than the phase voltage, and the line current is accordingly less. Thus, the line losses are reduced, and the efficiency of transmission is improved.

POLARITY MARKING OF POWER TRANSFORMERS

It is essential that all transformer windings be properly connected and that you have a basic understanding of the coding and the marking of transformer leads.

The leads of large power transformers, such as those used for lighting and public utilities, are marked with numbers, letters, or a combination of both. This type of marking is shown in figure 3-41. Terminals for the high-voltage windings are marked H1, H2, H3, and so forth. The increasing numerical subscript designates an increasing voltage, denoting a higher voltage between H1 and H3 than the voltage between H1 and H2.

The secondary terminals are marked X1, X2, X3, and so forth. There are two types of markings that may be employed on the secondaries. When the H1 and X1 leads are brought out on the same side of the transformer (fig. 3-41, view A), the polarity is called subtractive. The reason this arrangement is called subtractive is as follows: If the H1 and X1 leads are connected and a reduced voltage is applied across the H1 and H2 leads, the resultant voltage that appears across the H2 and X2 leads in the series circuit formed by this connection will equal the difference in the voltages of the two windings. The voltage of the low-voltage winding opposes that of the high-voltage winding and subtracts from it, hence the term *subtractive polarity.*

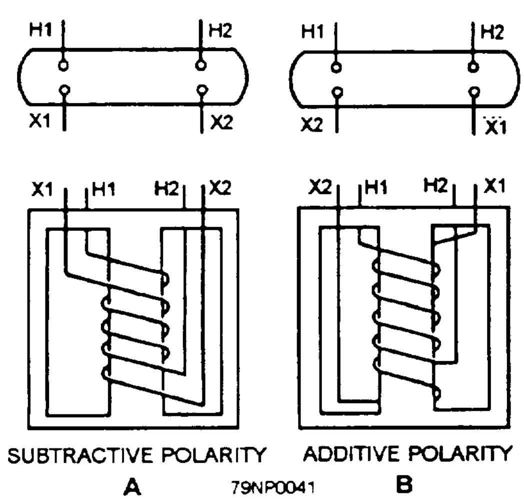


Figure 3-41.—Polarity markings for large transformers.

When the H1 and X1 leads are brought out on opposite corners of the transformer (fig. 3-41, view B), the polarity is additive. If the H1 and X2 leads are connected and a reduced voltage is applied across the H1 and H2 leads, the resultant voltage across the H2 and X1 leads in the series circuit formed by this connection will equal the sum of the voltages of the two windings. The voltage of the low-voltage winding aids the voltage of the high-voltage winding and adds to it, hence the term *additive polarity.*

Polarity markings do not indicate the internal voltage stress in the windings. They are useful only in making external connections between transformers.

400-HERTZ POWER DISTRIBUTION

In addition to the 60-hertz power supplied by the ship's service generators, ships also have 400-hertz

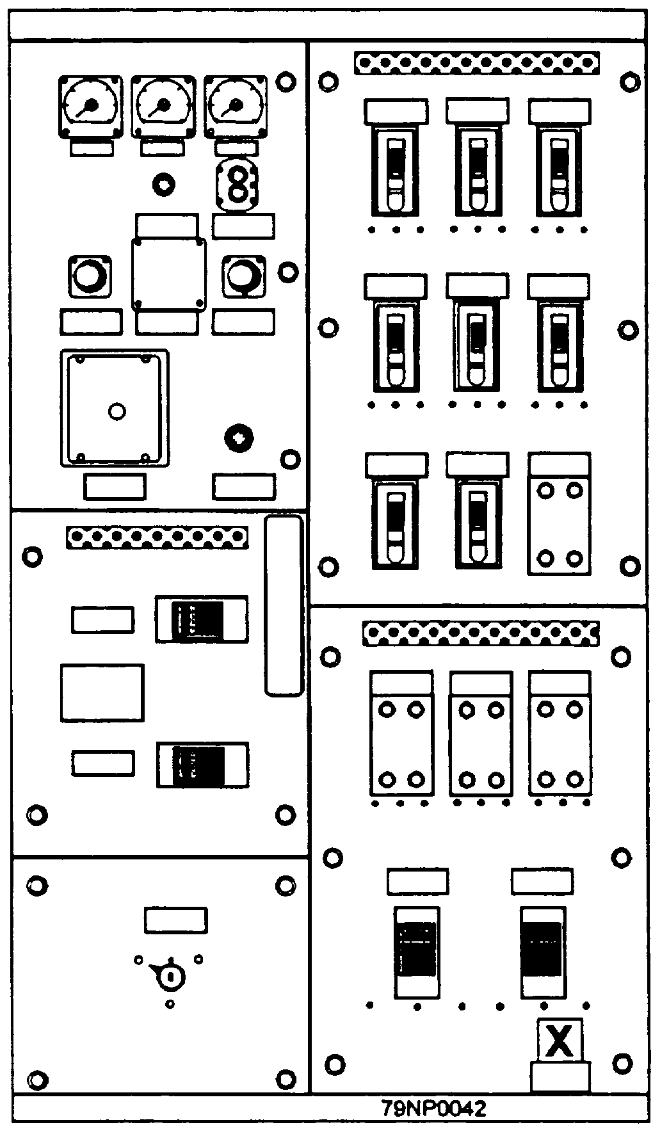


Figure 3-42.—400-hertz switchboard.

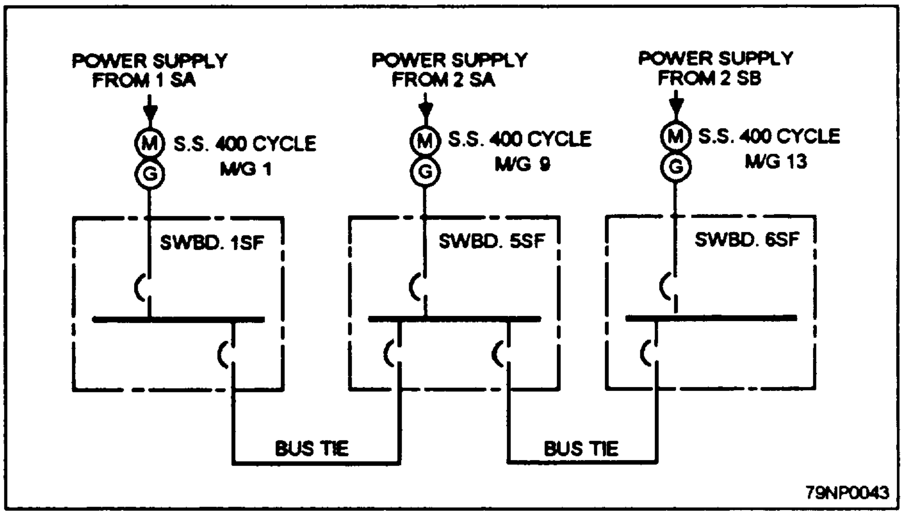


Figure 3-43.—Bus tie connections on 400-hertz ship's service system.

systems. On some ships 400-hertz power is generated by motor-generator sets and distributed via special frequency switchboards (fig. 3-42) to the various 400-hertz equipment.

These motor generators supply power to ship's service special frequency switchboards. Figure 3-43 is a simplified line diagram of the 400-hertz ship's service bus tie interconnections on an older ship. The circuits being fed from the 400-hertz ship's service switchboards are deleted from the figure for simplicity.

Newer ships get their supply of 400-Hz power through the use of 60/400-Hz static converters. The 400-Hz system consists of four MBT's supplying 60 Hz power to four 60/400-Hz static frequency converters (STC 1 thru STC 4), each rated at 150 KW at 0.8 power factor (fig. 3-44) and distributed to 400 Hz loads through two distribution switchboards, designated 1SF and 2SF.

Both distribution switchboards provide for centralized distribution of 450-volt, three-phase, 400-hertz power. Each switchboard is also capable of controlling and monitoring converter input, converter output, and bus tie circuit breakers.

CASUALTY POWER DISTRIBUTION SYSTEM

Damage to ship's service and emergency distribution systems in wartime led to the development

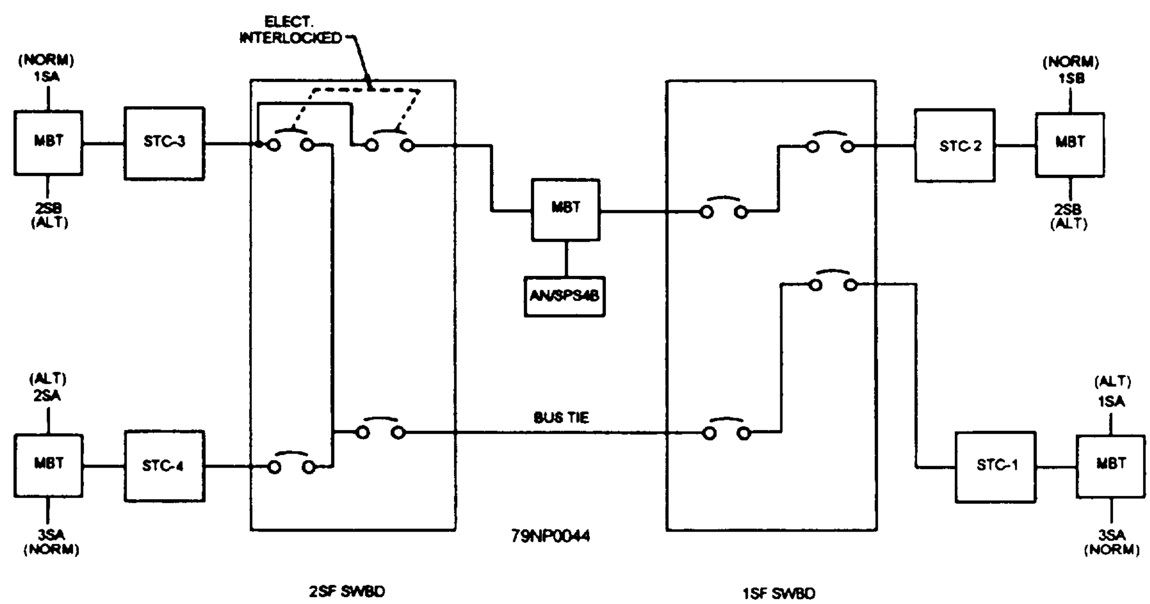


Figure 3-44.—400Hz electric power distribution system aboard a new DDG.

of the casualty power system. This system provides the means for making temporary connections to vital circuits and equipment. The casualty power distribution system is limited to those facilities that are necessary to keep the ship afloat and permit it to get out of the danger area. It also provides a limited amount of armament, such as weapons systems and their directors to protect the ship when in a damaged condition.

Optimum continuity of service is ensured in ships provided with ship's service, emergency, and casualty power distribution systems. If one generating plant should fail, a remote switchboard can be connected by the bus tie to supply power from the generator or generators that have not failed

If a circuit or switchboard fails, the vital loads can be transferred to an alternate feeder and source of ship's service power by means of a transfer switch near the load

If both the normal and alternate sources of the ship's service power fail because of a generator, switchboard, or feeder casualty, the vital auxiliaries can be shifted to an emergency feeder that receives power from the emergency switchboard.

If the ship's service and emergency circuits fail, temporary circuits can be rigged with the casualty power distribution system and used to supply power to vital auxiliaries if any of the ship's service or emergency generators can be operated.

The casualty power system includes suitable lengths of portable cable stowed on racks throughout the ship. Permanently installed casualty power bulkhead terminals form an important part of the casualty power system. They are used for connecting the portable cables on opposite sides of bulkheads, so that power may be transmitted through compartments without loss of watertight integrity; also included are permanently installed riser terminals between decks. The vital equipment selected to receive casualty power will have a terminal box mounted on or near the equipment or panel concerned and connected in parallel with the normal feeder for the equipment.

Sources of supply for the casualty power system are provided at each ship's service and emergency generator switchboard. A casualty power riser terminal is installed on the back of the switchboard or switchgear group (fig. 3-45) and connected to the busses through a 225- or 250-ampere AQB circuit breaker. This circuit breaker is connected between the generator circuit breaker and the generator disconnect links. By opening the disconnect links, you will isolate the generator from the switchboard. Then, it can be used exclusively for casualty power purposes.

RIGGING CASUALTY POWER

To eliminate the necessity of handling live cables, and to reduce the hazards to personnel and equipment, there are definite procedures that must be followed and safety precautions that must be observed in rigging casualty power.

Only qualified Electrician's Mates should do the actual connecting; however, the portable cables maybe laid out by other repair party personnel. The repair party electrician must wear rubber gloves, rubber boots, and stand on a rubber mat while making connections. Each casualty power riser or bulkhead terminal must be tested with a voltage tester before a connection can be made to that terminal. It is the duty of the repair party Electrician's Mate to determine that all sources of power to the equipment concerned are de-energized before rigging casualty power. The portable cable connections for casualty power should always be made by first connecting the load and then working back to the source of power.

On large ships, casualty power runs involve more than one repair party. All repair parties should rig simultaneously, but the rule of "rig from load to source" should always be observed. Each repair party must report its section rigged from riser or bulkhead terminal number to riser or bulkhead terminal number to damage control central (DCC).

In all instances of rigging and energizing any part of the casualty power system, only the damage control assistant, with the authority of the chief engineer, has the authority to order the system energized.

In making casualty power connections at a load where there are no circuit breakers or transfer switches to interrupt the incoming feeder cable, the load must be disconnected or cut at the equipment. It is quite possible that the feeder cable may be damaged by the casualty that caused the loss of power. A damaged cable, if energized, would probably trip the casualty power circuit breakers. If not disconnected, this incoming feeder cable may be re-energized and present a hazard to personnel handling the casualty power cables.

To keep the phase sequence correct in ac systems, exercise care in making all connections. The riser terminals, bulkhead terminals, and portable cable ends are marked to identify the A-, B-, and C-phases. You can make the identification visually by color cede. In

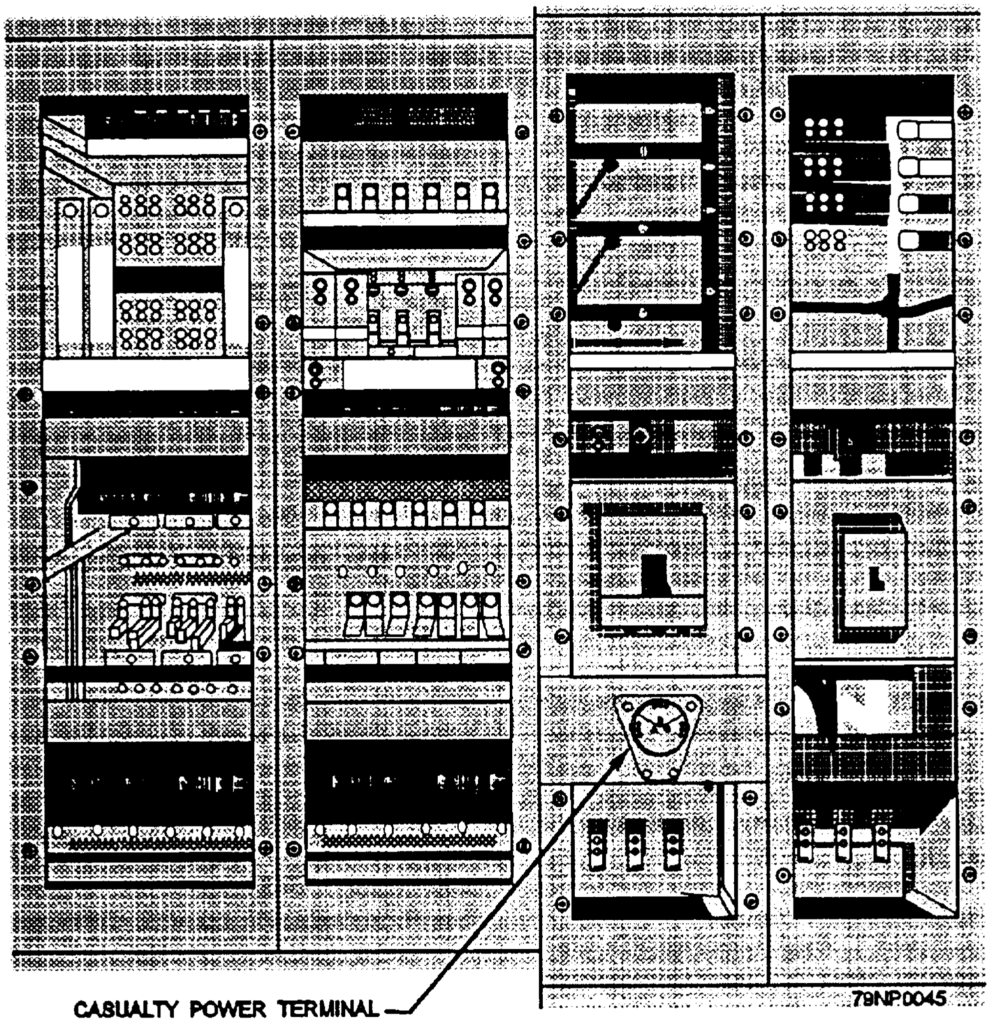


Figure 3-45.—Rear of switchboard showing casualty power terminal.

the dark you can make the identification by feeling the bumps on the riser terminals or feeling the twine wrappings or O-rings installed on the cables.

Ordinarily, portable casualty power cables should be tied to the overhead. High-voltage signs should be attached at each connection and the information passed over the ship's 1MC system informing all hands to stand clear of the casualty power cables while energized.

As previously stated, power panels supplying equipment designated for casualty power service will have a power terminal box mounted on the panel so that power may be fed into the panel. Remember that these panels can also be used as a source of power for the casualty power system should power still be available from the permanent feeder or feeders to the panel. Some judgment should be exercised, however, in the choice of panels to be used for supplying casualty power loads. Heavy loads should be connected to power panels having large incoming feeders for greater assurance that circuit breakers will not trip and that the cable will not become overheated. Current loading of casualty power cables is not considered excessive when you can grasp the cable by hand and it does not cause burning. Portable cable used in ac casualty power systems is Navy LSTHOF 42. Although the normal current carrying capacity of this cable is 93 amperes, its casualty rating is 200 amperes. Under normal conditions this cable will carry 200 amperes for 4 hours without damage to the cable. Cables maybe run in parallel to circuits that overload a single cable.

Recommended SAFE procedures to be used in rigging casualty power include the following:

- Upon report of loss of power, DCC orders the repair party nearest the equipment concerned to investigate.

- The repair party EM of the investigating team immediate] y tests to determine if all sources of power to the equipment have been lost.

• Upon determining that all power is lost, the EM opens all supply switches to the equipment and reports to DCC that power is lost to the equipment.

• Upon receiving report of all power lost, DCC requests main engine control to designate a source of casualty power for the equipment concerned. The request for a casualty power source maybe made to the electrical officer on ships having a combined main engine control and DCC or where the electrical officer is stationed in DCC for the control of generators and power distribution.

• Main engine control or the electrical officer, as appropriate, informs damage control central of the casualty power source to be used (giving riser terminal number) and, at the same time, informs the EM on the appropriate switchboard that his or her board has been designated as a source of casualty power to the riser terminal by number.

• Upon receiving this information, DCC orders the repair parties concerned to rig casualty power from the equipment to the designated source.

• Repair parties rig casualty power and report each section completed to DCC.

• After all sections have reported the rigging completed, damage control central requests the main engine control electrical officer to "energize casualty power."

• Upon receiving the request to energize, main engine control or the electrical officer directs the designated switchboard to "connect and energize casualty power," and to report compliance.

• The EM on the designated switchboard rigs the first cable from the source of the system, closes the casualty power circuit breaker, reports casualty power energized to main engine control, and then reports compliance to DCC.

UNRIGGING CASUALTY POWER

Unrigging casualty power can be hazardous if not handled correctly. The steps to be taken to unrig casualty power lines are as follows:

1. DCC requests main engine control to de-energize the casualty power system.

2. Main engine control directs the designated switchboard to de-energize and disconnect casualty power and to report compliance.

3. The EM at the switchboard opens the casualty power circuit breaker, unrigs both ends of the first portable cable, and reports "casualty power de-energized" to main engine control. Main engine control reports compliance to damage control central.

4. Upon receiving the de-energized report, DCC orders casualty power disconnected at the equipment.

5. The repair party's EM disconnects both ends of the last portable cable in the system at the load and reports, when completed, to DCC.

6. DCC requests main engine control to energize normal circuits to the equipment and orders repair parties concerned to unrig and restow the remainder of the portable cables.

7. Main engine control directs the designated switchboard to energize all normal circuits to the equipment and to report compliance. Main engine control reports compliance to DCC. The exercise is not considered completed until DCC receives the report that the equipment is operating on normal power and that all portable cables are restowed on their proper racks.

Speed is desirable in all casualty power operation; however, safety precautions must never be sacrificed to attain speed. A thorough knowledge of the casualty power system and frequent drills by all personnel involved are necessary for safe and expeditious results.

SHORE POWER

The number and locations of shore power connections vary on different types of ships. Shore power connections are provided at, or near, a suitable weather-deck location to which portable cables from the shore or from ships alongside can be connected to supply power for the ship's distribution system when the ship's service generators are not in operation. This connection also can be used to supply power from the ship's service generators to ships alongside.

Shore-power arrangements and hardware used on both ship and shore installations are so diversified that no specific installation instructions can be outlined in detail. Ashore installation that has one circuit breaker supplying a number of cable sets presents a particular hazard. In this case, you can verify phase rotation and phase orientation only by energizing all shore terminals. You should check phase rotation with only one set of cables installed. The latest designs have a single, three-phase receptacle for ship and shore-power terminals. These receptacles are keyed in such a manner that phase rotation and orientation cannot be altered, provided both the ship and shore use these receptacles, and the cables are not spliced. Phase orientation need not be checked prior to hookup. Systems that use three-phase receptacles are normally designed so that interlocks on receptacles automatically trip associated circuit breakers whenever the cover of the receptacle is open, and a shore-power cable plug is not in place. However, you should still check voltage to these receptacles to ensure they are de-energized before installing the shore cables.

RIGGING SHORE POWER

The following procedures apply to the shore installation that has a separate circuit breaker or disconnect for each set of cables and that the single, three-phase receptacle is not used You should follow these basic instructions and procedures prior to and when connecting to shore power:

- Connect and disconnect shore power under the direct supervision of the electrical officer, a qualified leading electrician, and shore-activity personnel.

- Visually inspect shore-power cables for any sign of defects (such as cracks, bulges, and indications of overheating), thoroughly examine spliced cables, in particular, because improperly spliced cables are extremely dangerous. Strip lug-to-lug connection splices of insulation and check the connection for cleanliness, tightness, and good surface contact. Repair all defects and reinsulate all lugs before cables are placed in service. Check cables for insulation resistance using a 500-volt Megger (megohmmeter). Insulation resistance readings should meet requirements of *Naval Ships' Technical Maunual,* "Electric Plant General," chapter 300. Check the resistance between phases and between each phase and ground. For purposes of the test, shore ground should be the enclosure that houses shore-power terminals or receptacles. On ships, ground should be the hull of the ship or any metal extension of the hull. During the physical inspection and Megger tests, check the phase identification of the cables. Pay particular attention to cables that have been spliced to ensure that the phases of the cables are continuous and have not been altered at the splices.

- Tag with high-voltage signs and, if possible, rope off the work area surrounding the ship's shore-power terminal box or receptacle. This box or receptacle is often exposed to elements, and any moisture present can cause a serious problem. With the ship's shore-power breaker tagged in the open position, disconnect all equipment (such as meters and indicator lights) that could be damaged by a Megger test or cause a false reading. Test the terminals in the ship's shore-power terminal box or receptacle with a voltage tester to ensure that they are de-energized. Next, with a 500-volt Megger, test the insulation resistance between terminals and from each terminal to ground.

- Lay out the cable between the supplying shore-power outlet and the ship's shore-power terminal box or receptacle. Ensure that the cable is of sufficient length to allow enough slack for the rise and fall of the tide, but not of such length as to permit the cable to dip into the water or become wedged between the ship and pier. Do not permit cables to rest on sharp or ragged objects, such as gunwales. Avoid sharp bends. Lay cables in wood saddles or wrap them in canvas. Raise splices and connectors from the deck or pier for protection against water contamination. Neatly fake out excess cable to minimize damage from vehicle and pedestrian movements.

- Connect the shore cables to the ship's shore-power terminals according to phase or polarity markings in the box and on the cables.

- Ensure correct phase orientation (phase relationship) by checking color coding or phase identification markings on cables. Reconfirm correct phase identification by meggering between like phases of cables. Cables that give a zero indication will have the same phase relationship. After meggering, reconnect any disconnected equipment.

- With a voltmeter, check to ensure that the shore-power terminals are de-energized

- Connect the shore-power cable to the terminals.

- Check for proper phase rotation either by alternately energizing shore-power receptacles, one at a time, and observing the ship phase rotation indicator mounted in the ship's service switchboard, or use a portable meter connected to an appropriate bus. After checking phase rotation, de-energize each source shore-power receptacle before energizing the next receptacle for the phase rotation check.

- Energize all source shore-power terminals or receptacles and proceed with the transfer of electrical load to shore power following engineering department operating instructions. Instructions will vary depending upon whether or not the ship is equipped to synchronize with shore power.

After cables are carrying the load, inspect all connections to locate any possible overheating resulting from poor connections or reduced copper in the circuit. Inspect cable ends at the point of connection for heavy strain or overheating.

Shore-power cables are rated at 400 amperes, Check switchboard meters to ensure that the total load on shore-power cables does not exceed the combined rating of shore-power cables. Total shore-power load in amperes should be no more than 400 times the number of shore-power, three-phase cables connected per phase.

PHASE-SEQUENCE INDICATOR

A phase-sequence indicator is used when you are connecting shore-power to your ship to ensure proper phase relationship between ship power and shore power.

An approved type of phase-sequence indicator (fig. 3-46.) has a miniature, three-phase induction motor and three leads with insulated clips attached to the ends. Each lead is labeled A, B, and C. The miniature motor can be started by a momentary contact switch. This switch is mounted in the insulated case with a switch button protruding out the front of the case to close the switch. When the motor starts turning, you can tell its direction of rotation through the three ports in the front of the case. Clockwise rotation would indicate correct phase sequence. You can stop the motor by releasing the momentary contact switch button.

UNRIGGING SHORE POWER

When you disconnect shore power, observe the same safety precautions outlined in the connecting sequence except for those regarding meggering cables and checking phase orientation and phase rotation. Again, tag shore-power breakers and disconnect

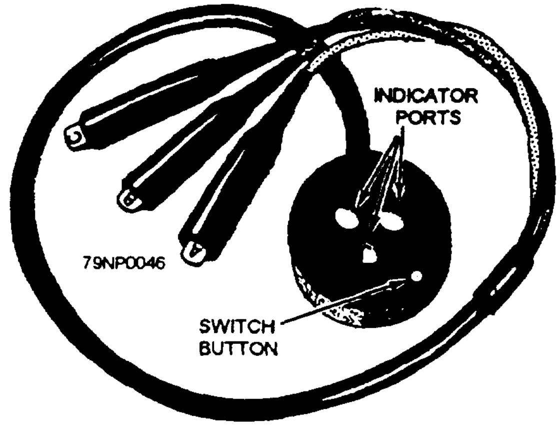


Figure 3-46.—Phase-sequence indicator.

following safety procedures. Determine that the shore-power busing and cables are de-energized by using a voltage tester that has just been checked with a known energized power source.

NOTE: Moving energized shore-power cables is prohibited.

SUMMARY

In this chapter, the major components of an ac distribution system were covered. You must remember that there are many different types of systems and components other than the ones described in this chapter. Also, you must remember that no work on electrical equipment should be done without using the proper technical manual.

For additional information about ac distribution systems,. refer to Naval Ship's Technical Manual, chapters 300, 310, 320, and 491.

CHAPTER 4

SHIPBOARD LIGHTING

As an Electrician's Mate, you are responsible for maintaining the lighting distribution system aboard naval ships. This system comprises the ship's service general lighting, and navigation and signal lights, including searchlights.

The lighting system must maintain the continuity of power to selected vital lighting circuits. This is done by means of separate power sources and switching equipment that selects, in an orderly fashion, a power source suitable for proper system operation.

LEARNING OBJECTIVES

Upon completion of this chapter you will be able to:

1. *Identify the purpose of both the normal and emergency lighting distribution system.*
2. *Recognize the operation of the automatic bus transfer (ABT) switch.*
3. *Identify the classification of lamps according to bulb shape, finish, and base.*
4. *Identify the operating characteristics of incandescent and fluorescent lamps and fixtures.*
5. *Identify the various navigation and signal lights used aboard ship.*
6. *Identify the maintenance requirements for the various lighting fixtures in use aboard ships today.*

At times you will be directed to install new lighting circuits or equipment and may find yourself without installation plans or drawings. Other times you will be correcting deficiencies found while conducting PMS checks, routine tests, or inspections. For these and various other reasons you should be very familiar with the lighting system aboard your ship. Always refer to the applicable blueprints, drawings, and Ship Information Book, volume 3, "Power and Lighting Systems," before attempting repairs on the system. Additional information is found in *Naval Ships' Technical Manual (NSTM),* chapters 300, 320, 330, 422, and 583, and "Lighting on Naval Ships," NAVSEA 0964-000-2000.

LIGHTING DISTRIBUTION SYSTEMS

The lighting distribution system in naval ships is designed for satisfactory illumination, optimum operational economy, maximum continuity of service, and the minimum vulnerability to mechanical and battle damage. Most ships have the following sources of lighting available:

- A normal (ships' service) supply from the ship's service bus
- An emergency (or alternate) source of power to supply a designated number of fixtures
- Relay-operated battery-powered hand lanterns

SHIPS' SERVICE LIGHTING DISTRIBUTION SYSTEM

The ships' service lighting distribution system is designed to meet the illumination needs of any activity throughout the ship. It is set up in such a manner as to provide a balanced load on each of the three phases while providing power to both the ship service lighting system and the 120-volt auxiliaries. These auxiliaries include hotel services such as coffee makers, drinking fountains, toasters, and small tools.

It consists of feeders from the ship's service or emergent y power switchboards, switchgear groups, or load centers to distribution panels or feeder distribution points, which supply power to local lighting circuits. The lighting supply circuits are 450-volt, three-phase, 60-hertz, three- wire circuits supplied from the power distribution system to 450/120-volt transformer banks.

EMERGENCY LIGHTING DISTRIBUTION SYSTEM

The emergency or alternate lighting distribution system is designed to provide a suitable distribution system that, upon failure of the ships' service lighting system, will assure continuity of lighting in vital spaces and inboard watch stations. Continuous illumination is essential in these areas because of functional requirements, and when personnel are required to remain on duty.

The emergency or alternate system consists of selected groups of fixtures that are fed through automatic bus transfer (ABT) equipment. Atypical vital lighting load is supplied from two separate switchboards (fig. 4-1). Normally the power is supplied from the ship service distribution system but, upon loss of power, is shifted by the ABT to the emergency or alternate source to keep vital lighting loads energized

OPERATION

Under normal conditions, the system shown in figure 4-2 operates as follows:

1. Power is supplied from the ship service distribution switchboard.
2. If an undervoltage condition develops on the ship service switchboard which is the normal supply for the ABT, the ABT switch will transfer the emergency lighting load to the alternate source of power.

The emergency/alternate switchboard is energized through either the bus tie circuit breaker from the ships service switchboard or its attached emergency/alternate generator through a generator circuit breaker. Transfer between these supplies is accomplished automatically by three electrical y operated circuit breakers. The circuit breakers are electrical y and mechanical] y interlocked to prevent the closing of more than one breaker at a time.

If an undervoltage condition occurs while the ships service generator(s) is/are supplying the load with an output frequency of 57 Hz or higher, the following conditions will occur:

- circuitry in the switchboard will operate to open the bus tie circuit breakers in the emergency or alternate switchboard
- the emergency or alternate generator will be started
- when the emergency or alternate generator is up to speed and producing 450 VAC, the generator

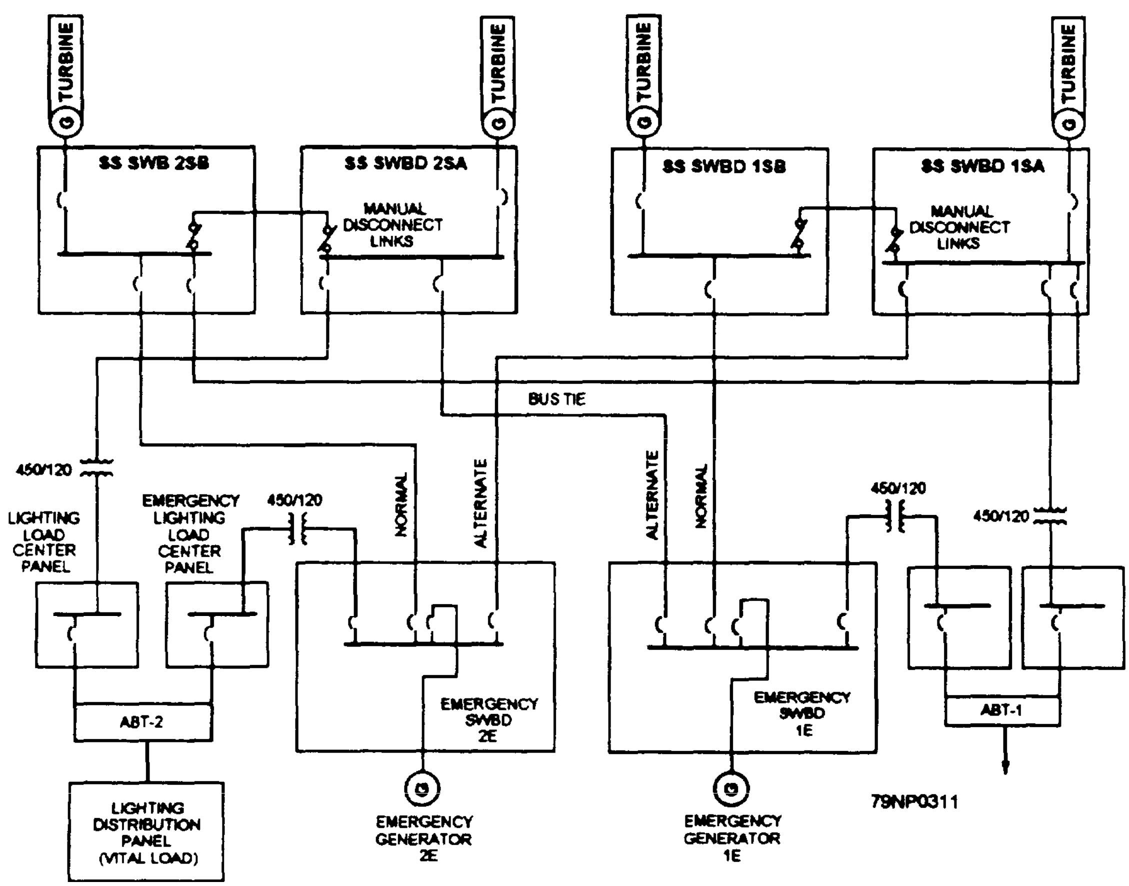
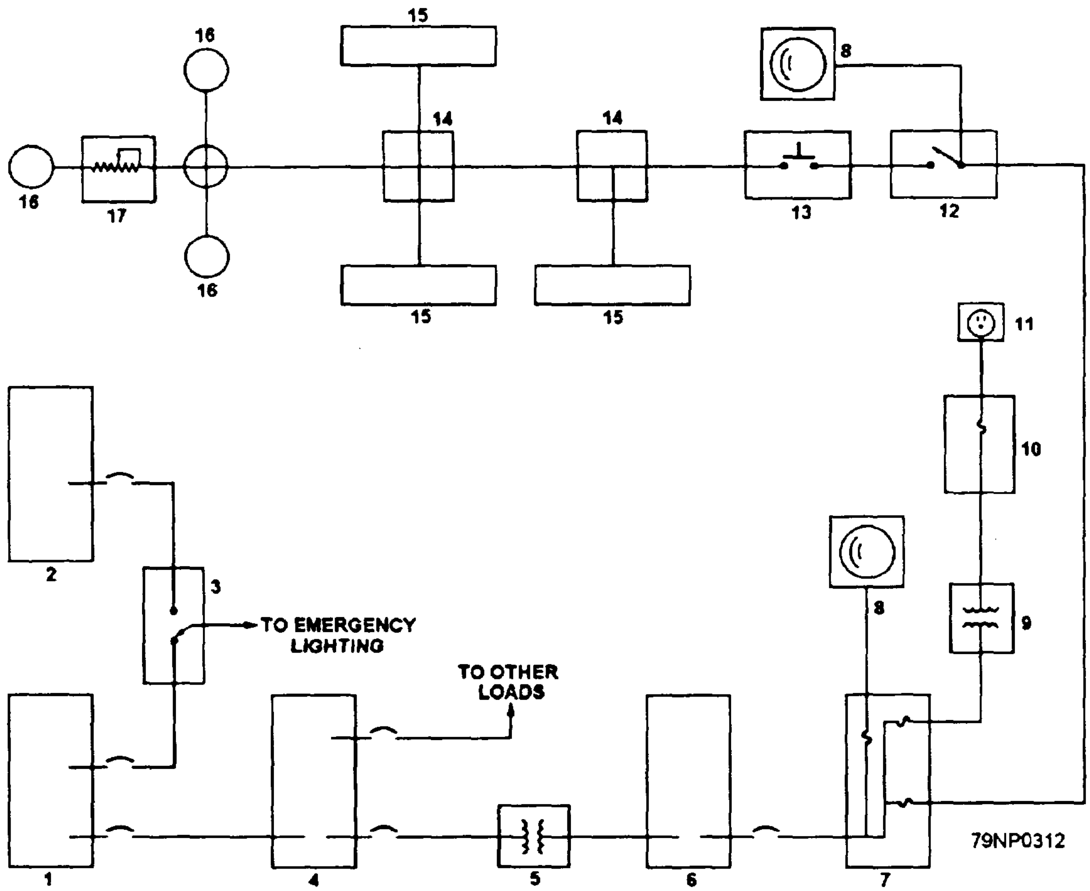


Figure 4-1.—Lighting distribution system.



1. Ships service switchboard
2. Emergency (alternate) switchboard
3. Automatic bus transfer (abt) switch
4. Load center
5. 450/120 stepdown transformer bank (3 ea)
6. Lighting distribution panel
7. Feeder distribution fuse box
8. Relay operated lantern
9. 120/120 isolation transformer
10. Feeder distribution fuse panel
11. 120 vac receptacle
12. Light switch (LVRE type)
13. Door operated (darken ship) switch (when required)
14. Connection box
15. Fluorescent lights
16. Incandescent lights
17. Dimmer

Figure 4-2.—Block diagram of lighting distribution system.

circuit breaker will close allowing the emergency/alternate switchboard loads to be energized

AUTOMATIC BUS TRANSFER (ABT) SWITCHES

ABTs are used to keep vital lighting loads energized by shifting to the alternate power source when the normal source of power is lost. Upon restoration of normal power, the ABT will automatically shift back to the normal source. Their operation is described in greater detail in chapter 3.

LIGHTING TRANSFORMERS

Three small single-phase transformers are used instead of one large three-phase transformer because the loss of a composite unit would result in a loss of power. Reliability is increased by the use of three separate transformers. If battle damage, or failure to one of the banks of the three single-phase transformers occurs, the remaining two will still carry about 58 percent of the initial load capacity. The remaining two transformers will be connected open delta by disconnecting the defective transformer. In an open delta connection, the line current must be reduced so that it will not exceed the rated current of the individual transformers. Each

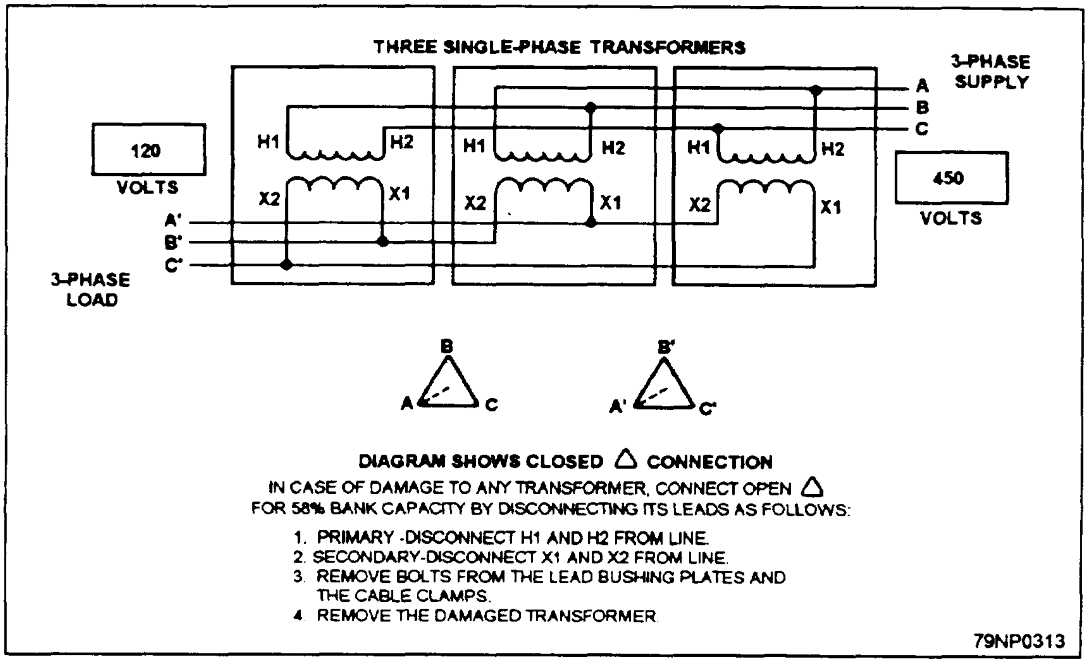


Figure 4-3.—Delta-delta transformer connections.

transformer bank consists of three single-phase, delta-delta connected transformers (fig. 4-3).

LIGHT SOURCES

The four sources of electric light used in naval ships are (1) incandescent, (2) fluorescent, (3) glow, and (4) low-pressure sodium lamps.

A complete list of lamps used by the Navy is contained in federal item identification number sequence in the *Illustrated Shipboard Shopping Guide (ISSG),* carried aboard all ships. 'This list includes the electrical characteristics, physical dimensions, applications, ordering designation, and an outline of each Navy-type lamp.

INCANDESCENT LAMPS

The incandescent lamp consists of a tungsten filament supported by a glass stem (fig. 4-4). The glass stem is mounted in a suitable base that provides the necessary electrical connections to the filament. The filament is enclosed in a transparent, or translucent, glass bulb from which the air has been evacuated. The passage of an electric current through the filament causes it to become incandescent and to emit light.

All Navy-type 115- or 120-volt lamps (up to and including the 50-watt sizes) are of the vacuum type and all lamps above 50 watts are gas filled. The use of an inert gas, which is a mixture of argon and nitrogen gases, allows the lamp to operate at higher temperatures, resulting in higher efficiency. Lamps of 50 watts or less are of the vacuum type because inert gas would not increase their luminous output.

The incandescent lamp is further subdivided into tungsten- and carbon-filament types. The tungsten-filament lamps comprise most of those listed in this group.

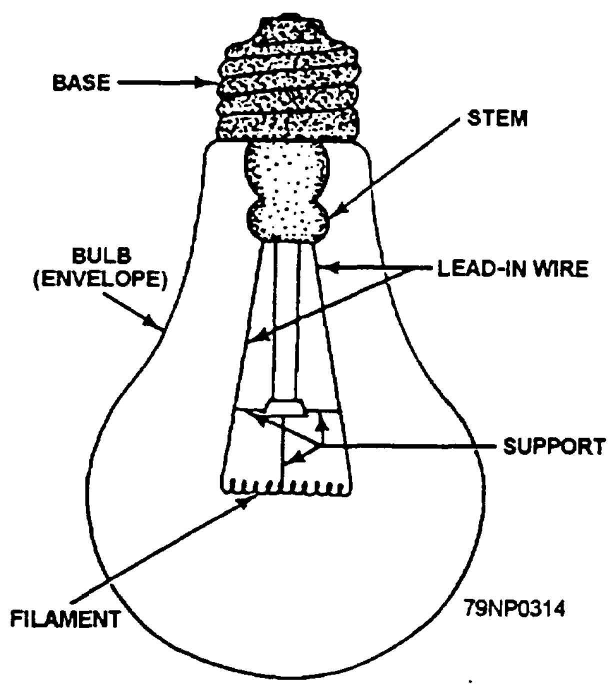


Figure 4-4.—Components of an incandescent lamp.

Rating

Incandescent lamps are rated in watts, amperes, volts, candlepower, or lumens, depending on their type. Generally, large lamps are rated in volts, watts, and lumens. Miniature lamps are rated in amperes for a given single voltage and in candlepower for a voltage-range rating.

Classification

Standard incandescent lamps are classified according to their shape of the bulb, finish of the bulb, and type of base.

BULB SHAPE.— The classification of lamps according to the shape of the bulb with the corresponding letter designation is illustrated in figure 4-5. The designation letter, which denotes the shape of the bulb, is followed by a numeral (not shown) that denotes the diameter of the bulb in eighths of an inch

BULB FINISH.— The clear lamp consists of a bulb that is made of unclouded or luminous glass, which exposes the filament to view. These lamps are used with reflecting equipment that completely conceals the lamps to avoid glare. Clear lamps can be used with open-bottom reflecting equipment when the units are mounted sufficiently high so that the lamps will be out of the line of vision.

The inside frosted lamp consists of a glass bulb that has the entire inside surface coated with a frosting. The frosting conceals the filament and diffuses the light emitted from the lamp. These lamps can be used with or without reflecting equipment.

The silvered bowl lamp is provided with a glass globe that has a coating of mirror silver on the lower half. The coating shields the filament and provides a highly efficient reflecting surface. The upper portion of the bulb is inside frosted to eliminate shadows of the fixture supports. These lamps are used with units that are designed for indirect lighting systems.

The colored lamp may consist of a colored glass bulb. These lamps are used for battle and general lighting and for safety lights.

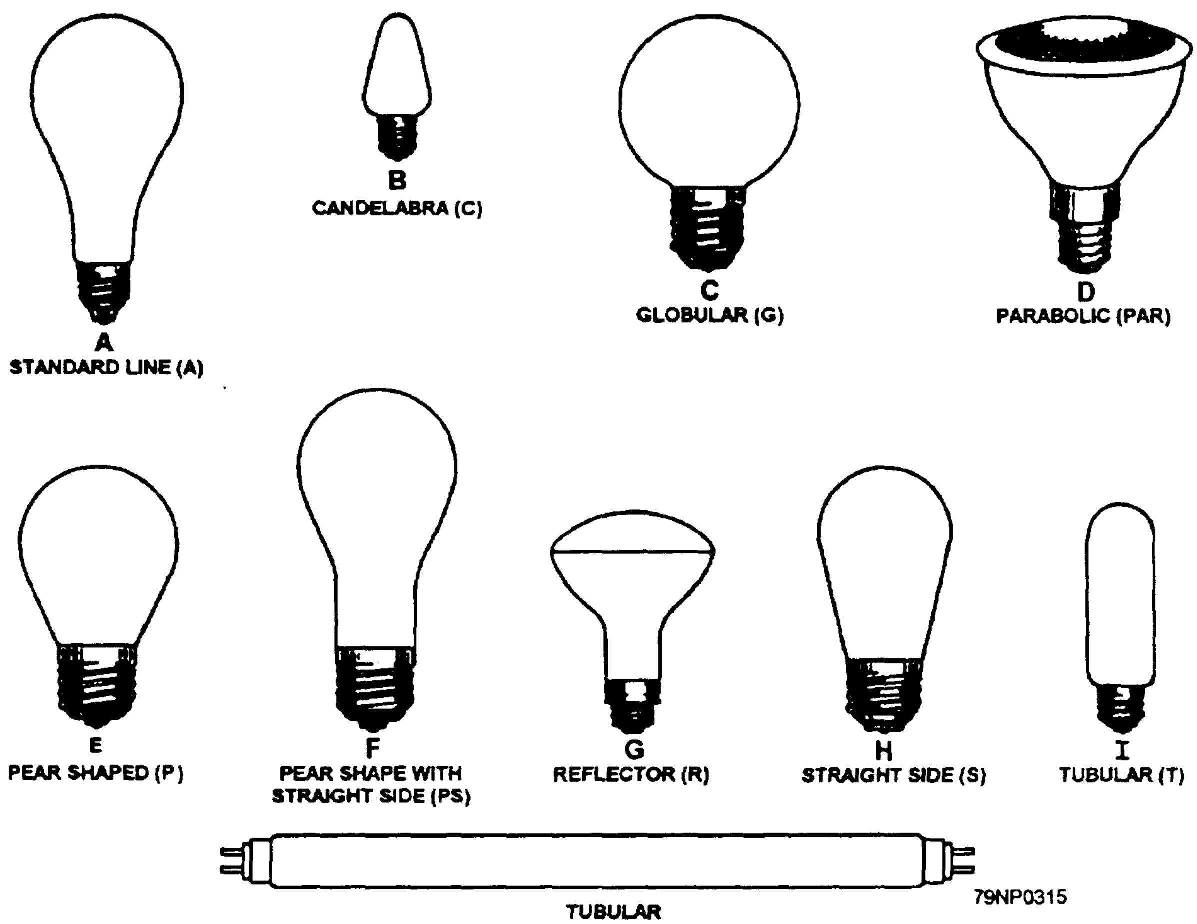


Figure 4-5.—Classification of lamps according to the shape of the bulb.

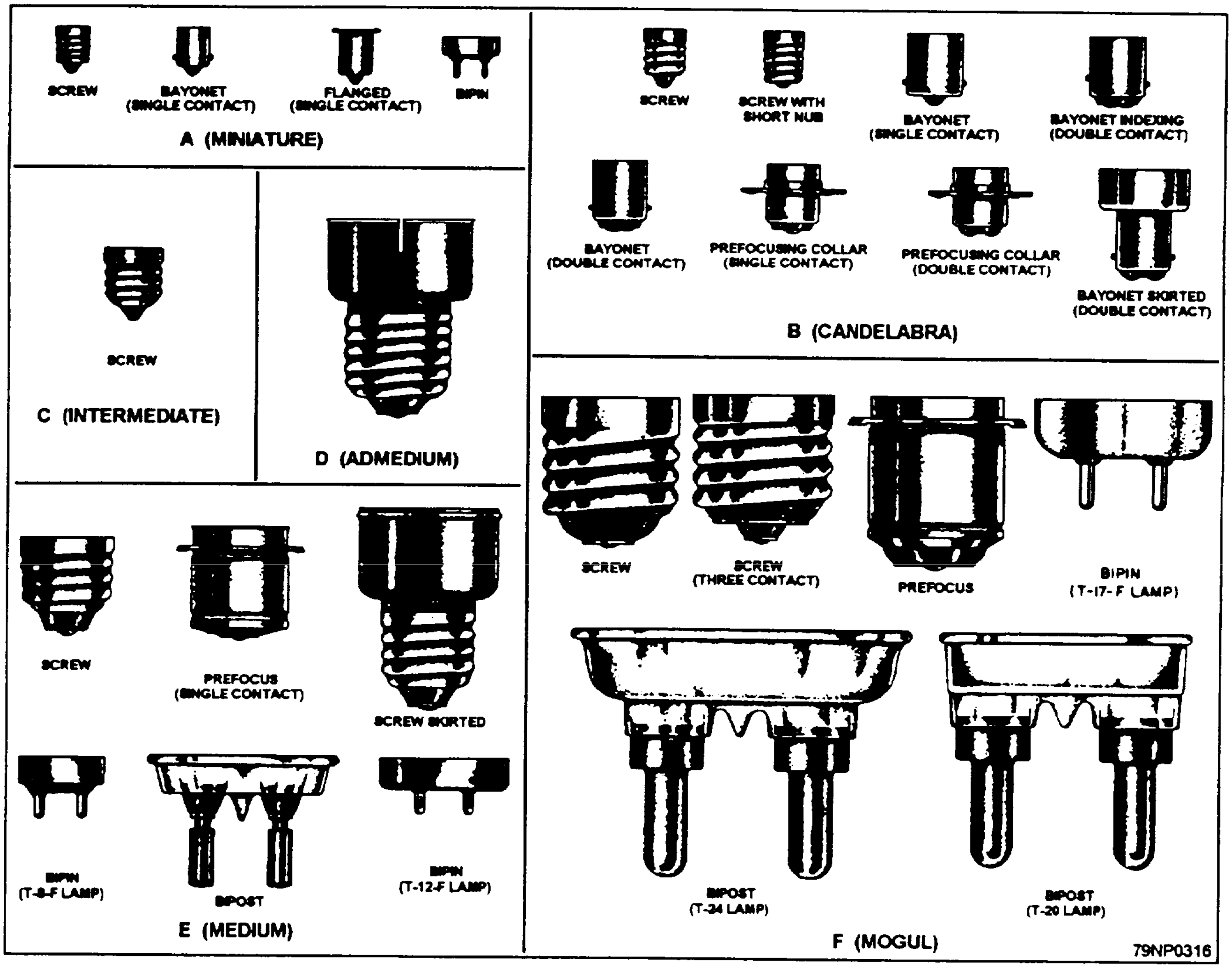


Figure 4-6.—Classification of lamps according to the type of base.

BULB BASE.— The classification of lamps according to the type of base is illustrated in figure 4-6. The size of the base is indicated by name, including miniature, candelabra, intermediate, medium, admedium, and mogul. They can be further classified by application, including screw, bayonet, prefocus, and bipin.

The classification and description of the various type of lamps and their bases is given in the following tables.

Table 4-1 gives a brief description of the types of lamps classified as Miniature.

Table 4-1.—Description of Miniature Lamps.

Size	Type(s)	Description
A (Miniature)	Screw	Used on small sized lamps for detail lighting
	Bayonet w/single contact	"
	Flanged w/single contact	"
	Bipin	"

Table 4-2 gives a brief description of lamps with bases classified as Candelabra.

Table 4-3 gives a brief description of lamps classified as Intermediate.

Table 4-4 gives a brief description of lamps with bases classified as Admedium.

Table 4-5 gives a brief description of lamps classified as Medium.

Table 4-2.—Description of Candelabra Lamps.

Size	Type(s)	Description
B (Candelabra)	Screw	Used on small sized lamps for detail lighting
	Screw w/short nub	"
	Bayonet w/single contact	"
	Bayonet Indexing w/double contact	"
	Bayonet w/double contact	"
	Prefocussing Collar w/single contact	"
	Prefocussing Collar w/double contact	"
	Bayonet Skirted w/double contact	"

Table 4-3.—Description of Intermediate Lamps

Size	Type(s)	Description
C (Intermediate)	Screw	Used on small sized lamps for detail lighting

Table 4-4.—Description of Admedium Lamps

Size	Type(s)	Description
D (Admedium)	Screw	Slightly larger in diameter than the medium base. Used on some mercury lamps

Table 4-5.—Description of Medium Lamps

Size	Type(s)	Description
E (Medium)	Screw Skirted	Most commonly used type. Used on lamps (up to 300 watts) for general lighting
	Prefocus w/single contact	Used on lamps with concentrated filaments
	Screw	Used on lower wattage three-way lamps
	Bipin (T-8-F lamp)	Used on fluorescent lamps
	Bipin (T-12-F lamp)	"
	Bipost	Used on lamps of 500,750,1000,1250, & 1500 watts for indirect lighting fixtures

Table 4-6.—Description of Mogul Lamps

Size	Type(s)	Description
F (Mogul)	Screw	Used on lamps rated above 300 watts
	Screw w/three contact	Used on higher wattage three-way lamps
	Prefocus	Used on lamps with concentrated filaments
	Bipin (T-17-F lamp)	Used on fluorescent lamps for general lighting
	Bipost (T-20 lamp)	Used on 500, 1000, and 1500 watt and above lamps including floodlights
	Bipost (T-24 lamp)	"

Table 4-6 describes lamps with bases classified as Mogul (fig. 4-7).

Characteristics

The average life of standard incandescent lamps for general lighting service, when operated at rated voltage, is 750 hours for some sizes and 1,000 hours for others. The light output, life, and electrical characteristics of a lamp are materially affected when it is operated at other than the design voltage. Operating a lamp at less than rated voltage will prolong the life of the lamp and decrease the light output. Conversely, operating a lamp at higher than the rated voltage will shorten the life and increase the light output. Lamps should be operated as closely as possible to their rated voltage.

Because of their low efficiency, incandescent lamps are used less frequently as light sources for interior lighting on naval ships.

FLUORESCENT LAMPS

The fluorescent lamp is an electric discharge lamp that consists of an elongated tubular bulb with an oxide-coated filament sealed in each end to comprise two electrodes (fig. 4-8). The bulb contains a drop of mercury and a small amount of argon gas. The inside surface of the bulb is coated with a fluorescent phosphor. The lamp produces invisible, short-wave (ultraviolet) radiation by the discharge through the mercury vapor in the bulb. The phosphor absorbs the invisible radiant energy and reradiates it over a band of wavelengths to which the eye is sensitive.

NOTE: black dot inside a lamp symbol designates a gas-filled tube. (See fig. 4-8, views A and B.)

Fluorescent lamps are now used for the majority of both red and white lighting on naval ships. For lighting fixtures that can be seen external to the ship by another

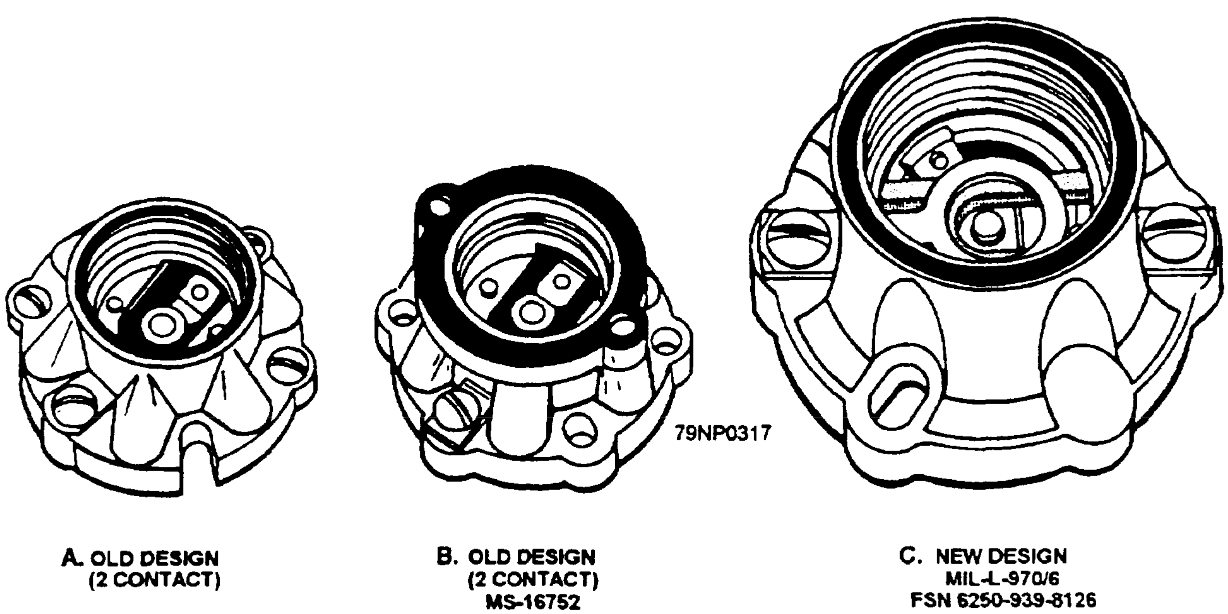


Figure 4-7.—Lamp sockets.

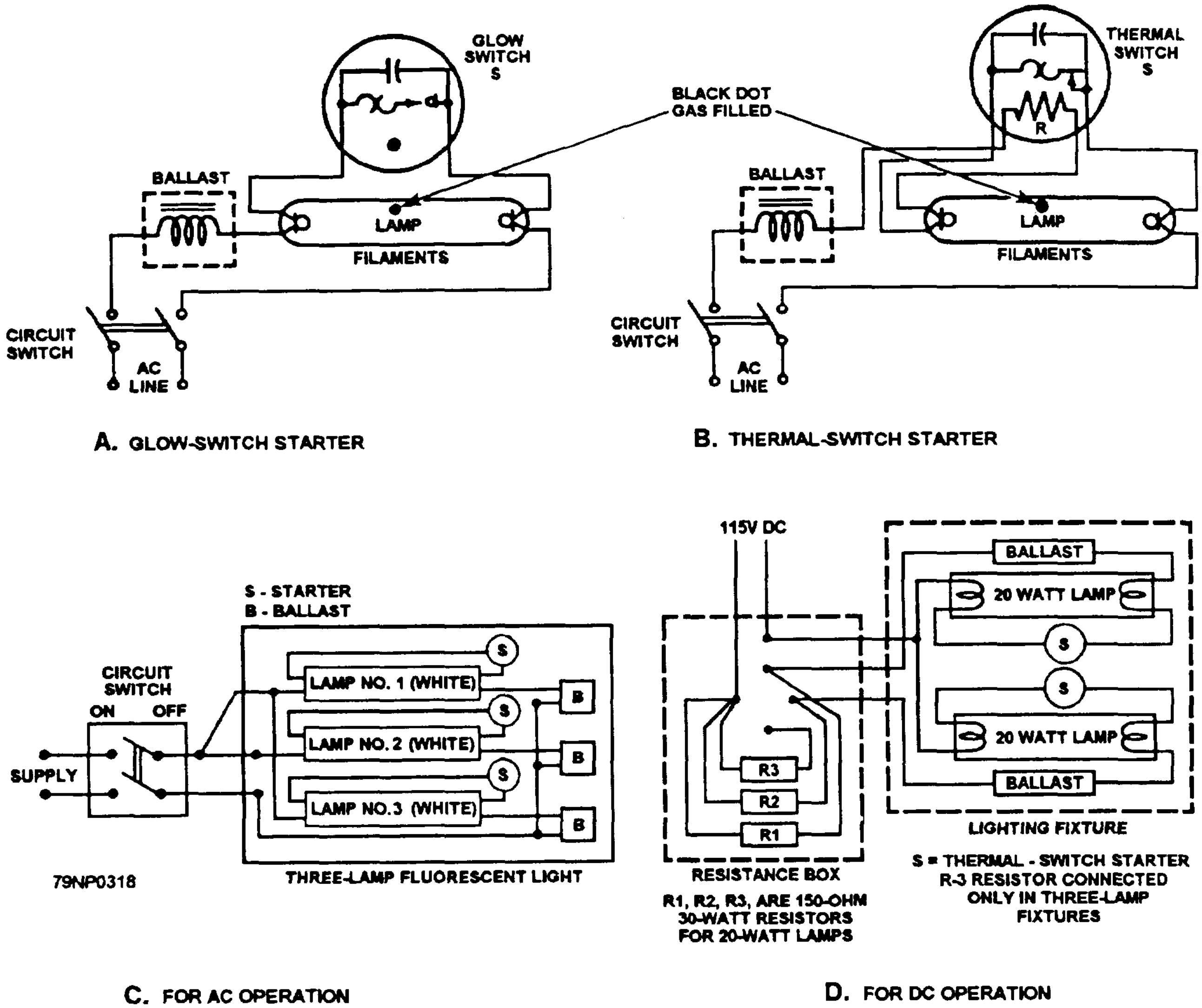


Figure 4-8.—Fluorescent lamps with auxiliary equipment.

ship, yellow lighting in lieu of red is used to eliminate confusion of the red navigation lights with other red lights. Red or yellow lighting is achieved through the use of red or yellow plastic sleeves that slide over the lamps. For 180-watt fixtures, red or yellow lighting is achieved by the use of red or yellow windows. The Navy has standardized three lamp sizes:

1. 8 watts, used primarily in berthing spaces and desk lamps
2. 15 watts, used chiefly as mirror lights in berthing spaces and staterooms
3. 20 watts, used in one, two, or three lamp fixtures throughout the ship for general lighting

The use of fluorescent lamps over 20 watts has been limited to special installations. For example, 60-watt lamps are being used in 180-watt fixtures in hangar spaces, over workbenches in weapons repair shops, and in dock basins on landing ship docks (LSDs).

Fluorescent lamps installed aboard ship are the hot-cathode, preheat starting type. A fluorescent lamp equipped with a glow-switch starter is illustrated in figure 4-8, view A. The glow-switch starter is essentially a glow lamp containing neon or argon gas and two metallic electrodes. One electrode has a fixed contact, and the other electrode is a U-shaped, bimetal strip having a movable contact. These contacts are normally open.

Table 4-7 describes the sequence of events in energizing a fluorescent lamp with a glow-switch starter (fig. 4-8, view A).

Table 4-7.—Energizing a Fluorescent Lamp with a Glow-switch Starter

Step	Action
1.	When the circuit switch is closed voltage, across the starter S, is sufficient to produce a glow around the bimetallic strip in the glow lamp
2.	The heat from the glow causes the bimetal strip to distort and touch the fixed electrode
3.	The starting circuit of the fluorescent lamp is completed. This shorts out the glow discharge and the bimetal strip starts to cool
4.	The starting current flows through the lamp filament in each end of the fluorescent tube, causing the mercury to vaporize
5.	Current does not flow across the lamp between the electrodes at this time because the path is short circuited by the starter and because the gas in the bulb is nonconducting when the electrodes are cold
6.	The preheating of the fluorescent tube continues until the bimetal strip in the starter cools sufficiently to open the starting circuit
7.	The starting circuit opens, the collapsing field of the ballast caused by the absence of current produces an "inductive kick" which forms an arc across the lamp electrodes. The magnitude of this voltage is sufficient to ionize the mercury vapor and start the lamp
8.	The resulting glow discharge (arc) through the fluorescent lamp produces a large amount of ultraviolet radiation that impinges on the phosphor, causing it to fluoresce and emit a relatively bright light
9.	The voltage across the fluorescent lamp is not sufficient to produce a glow in the starter. Hence, the contacts remain open and the starter consumes no energy

A fluorescent lamp equipped with a thermal-switch starter is illustrated in figure 4-8, view B (table 4-8). The thermal-switch starter consists of two normally closed metallic contacts and a series resistance contained in a cylindrical enclosure. One contact is fixed, and the movable contact is mounted on a bimetal strip.

Table 4-8.—Energizing a Fluorescent Lamp with a Thermal-switch Starter

STEP	ACTION
1.	When the circuit switch is closed, the starting circuit of the fluorescent lamp is completed (through the series resistance, R)
2.	This starting current flows through the electrodes preheating them
3.	The current through the series resistance produces heat that causes the bimetal strip to bend and open the starting circuit
4.	The induced voltage of the ballast, caused by the collapse of the ballast field when the circuit is opened, starts the lamp
5.	The normal operating current through the resistor produces heat which holds the thermal switch open

The majority of thermal-switch starters use some energy during normal operation of the lamp. However, this switch ensures more positive starting by providing an adequate preheating period and a higher induced starting voltage.

The efficiency of the energy conversion of a fluorescent lamp is very sensitive to changes in temperature of the bulb; therefore, a fluorescent bulb in a cold place will burn very dim and appear to be defective.

The efficiency decreases slowly as the temperature is increased above normal, but also decreases very rapidly as the temperature is decreased below normal. Hence, the fluorescent lamp is not satisfactory for locations in which it will be subjected to wide variations in temperature.

Fluocrescent lamps should be operated at voltage within ±10% of their rated voltage. If the lamps are operated at lower voltages, uncertain starting may result, and if operated at higher voltages, the ballast may overheat. Operation of the lamps at either lower or higher voltages results in decreased lamp life. The performance of fluorescent lamps depends, to a great extent, on the characteristics of the ballast, which determines the power delivered to the lamp for a given line voltage.

When fluorescent lamps are operated on ac circuits, the light output creates cyclic pulsations as the current passes through zero. This reduction in light output produces a flicker that is not usually noticeable at frequencies of 50 and 60 hertz, but may cause unpleasant stroboscopic effects when moving objects are viewed. When using a two- or three-lamp fixture, you can minimize the cyclic flicker by connecting each lamp to a different phase of a three-phase system (fig. 4-9).

The fluorescent lamp is inherently a high power-factor device, but the ballast required to stabilize the arc is a low power-factor device. The voltage drop across the ballast is usually equal to the drop across the arc, and the resulting power factor for a single-lamp circuit with ballast is about 60 percent.

Although the fluorescent lamp is basically an ac lamp, it can be operated on dc with the proper auxiliary equipment. The current is controlled by an external resistance in series with the lamp (fig. 4-8, view D). Since there is no voltage peak, starting is more difficult and thermal-switch starters are required.

Because of the power loss in the resistance ballast box in the dc system, the overall lumens per watt efficiency of the dc system is about 60 percent of the ac system. Also, lamps operated on dc may provide as little as 80 percent of rated life.

The majority of the difficulties encountered with fluorescent lights are caused by either worn-out or defective starters, or by damaged or expended lamps. Lamps are considered defective when the ends are noticeably black in color. When observing the abnormal operation of a fluorescent fixture, you can usually take care of the problem by replacing either the starter or the lamp or both.

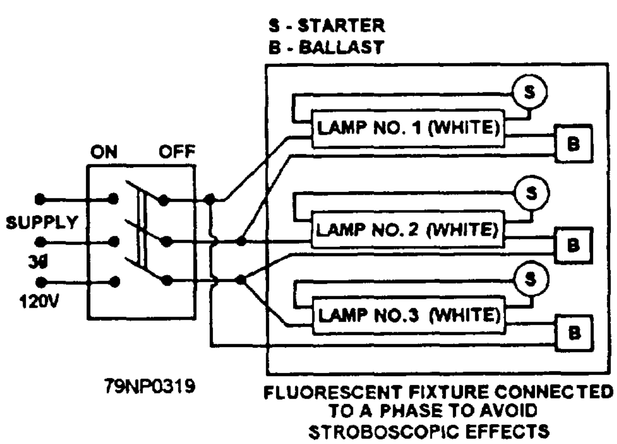


Figure 4-9.—Fluorescent fixture three-phase connections.

CAUTION

Fluorescent lamps contain mercury, which is extremely toxic! Mercury can be swallowed, inhaled, or absorbed through the skin. Although the amount of mercury contained in each fluorescent lamp is small, the combined numbers of lamps used on board ship could impact on health and marine life if not proper] y discarded. All used fluorescent lamps must be turned in at the nearest defense property disposal office, ship repair facility, or naval shipyard. If a fluorescent lamp is broken, avoid breathing the mercury vapor, and be extremely careful in handling the broken glass to avoid cuts. Mercury spillage must be cleaned up promptly. Detailed cleanup and disposal instructions are contained in *NSTM,* chapter 330, and, *Mercury, Mercury Compounds, and Components Containing Mercury or Mercury Compounds, control of,* NAVSEAINST 5100.3B.

GLOW LAMPS

The glow lamp is a device that produces light by an ionization process that creates the flow of electrons through an inert gas such as neon or argon. This creates a visible colored glow at the negative electrode.

Glow lamps are used as indicator or pilot lights for various instruments and control panels. These lamps have a relatively low-light output. They are used to provide indication of circuit status or to indicate the operation of electrical equipment installed in remote locations. The lamp in figure 4-10 energizes when the fuse is open to draw the attention of the operator.

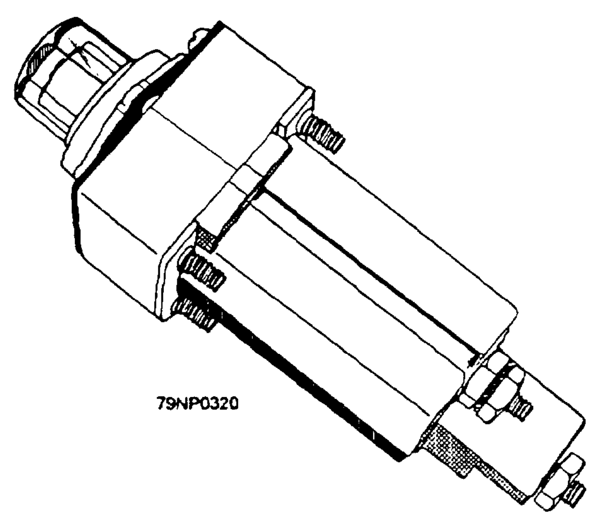


Figure 4-10.—Fuse holder with glow lamp.

The glow lamp consists of two closely spaced metallic electrodes sealed in a glass bulb that contains an inert gas. The color of the light emitted by the lamp depends on the gas. Neon gas produces an mange-red light, and argon gas produces a blue light. The lamp must be operated in series with a current-limiting device to stabilize the discharge. This current-limiting device consists of a high resistance that is sometimes contained in the lamp base.

The glow lamp produces light only when the voltage exceeds a certain striking voltage. As the voltage is decreased slightly below this value, the glow suddenly vanishes. When the lamp is operated on alternating current, light is produced only during a portion of each half cycle, and both electrodes are alternately surrounded with a glow. When the lamp is operated on direct current, light is produced continuously, and only the negative electrode is surrounded with a glow. This characteristic makes it possible to use the glow lamp as an indicator of alternating current and direct current. The glow lamp has five advantages that make it useful in lighting circuits:

1. It is small in size.
2. It is rugged.
3. It has a long life span.
4. It has negligible current consumption.
5. It can be operated on standard lighting circuits.

LOW-PRESSURE SODIUM LAMPS

Low-pressure sodium (LPS) lamps are installed aboard aircraft carriers in special applications (flight decks and hangar areas). The LPS lamp is characterized by a large diameter (2 to 3 inches), relatively long arc tube that is double backed on itself to save space, with a two-pin, single bayonet type of base at one end (fig. 4-11). The lamp contains small quantities of sodium which appear as silver-colored droplets that become vaporized/ionized when the lamp is operating. The starting gas is neon with small additions of argon, xenon, or helium. Electrically the LPS ballast is similar to those used with high intensity discharge (HID) lamps. The light produced by LPS lamps is different from the light produced by incandescent or fluorescent lamps in that the color is a monochromatic yellow. All objects other than yellow appear as various shades of gray. The characteristics of LPS lamps are as follows:

- The starting time to full light output is 7 to 15 minutes. If a power failure occurs and the power immediately is restored some lamps may return to full brilliance; other lamps may take the full starting time.
- The lamp, has a high efficiency that varies from 131 to 183 lumens per watt.
- The light output cannot be dimmed.
- The fixtures cannot be converted to red or other colors since the colors other than yellow are not produced by the lamp.
- The lamps must be handled, stored, and disposed of with caution.

CAUTION

The LPS lamps contain sodium, a highly active chemical element, which will oxidize rapidly and generate a high degree of heat when exposed to small amounts of water or moisture-laden air. This could cause a highly explosive hydrogen gas to be produced.

The amount of sodium contained in each LPS is small (100 to 1000 mg). The combined number of lamps aboard ship could cause a potential hazard if not handled, stored, or disposed of properly.

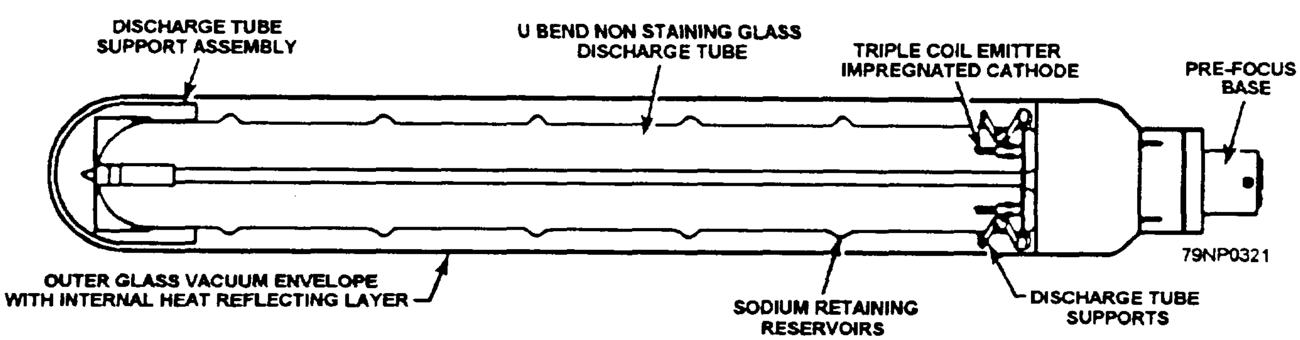


Figure 4-11.—A typical low-pressure sodium (LPS) lamp.

Handling

You should be extremely careful in handling, using, or replacing LPS discharge lamps. The electric discharge lamp is designed for use in fixtures and circuits wired with the proper auxiliary equipment. Do not scratch the glass, as the lamp is vacuum jacketed and may explode if broken or subjected to undue pressure. If the outer jacket is broken, remove and replace the lamp promptly. Avoid making contact with the arc tube supporter to prevent an electrical shock hazard. Before you replace the lamp, ensure the power is secured and the lamp has cooled.

Storage

You should store the LPS lamps horizontally to keep the sodium evenly distributed throughout the discharge tube. Store the lamps in their original, individual, shipping/storage containers, as they are wrapped in waxed paper or other water repellent material. If breakage occurs during storage, the wrapping keeps the sodium from contacting the corrugated paper shipping container and possibly producing a reaction. If possible, ensure lamps are stored in spaces equipped with a sprinkling system.

Disposal

You may dispose of the LPS lamps at sea provided you observe the proper precautions. Break the burned-out lamps and dispose of them according to the manufacturer's instructions. This means breaking a few lamps at a time in a dry container in a well-ventilated area, and then filling the container with water to deactivate the sodium. Observe caution when breaking the lamps since the tubes may explode. Wear eye protection a nose mask, gloves, and adequate clothing to protect exposed skin areas.

LIGHT FIXTURES

A lighting fixture, or unit, is a complete illuminating device that directs, diffuses, or modifies the light from a source to obtain more economical, effective, and safe use of the light. Alighting fixture usually consists of a lamp, globe, reflector, refractor (baffle), housing, and support that is integral with the housing or any combination of these parts (fig. 4-12, view A). A globe

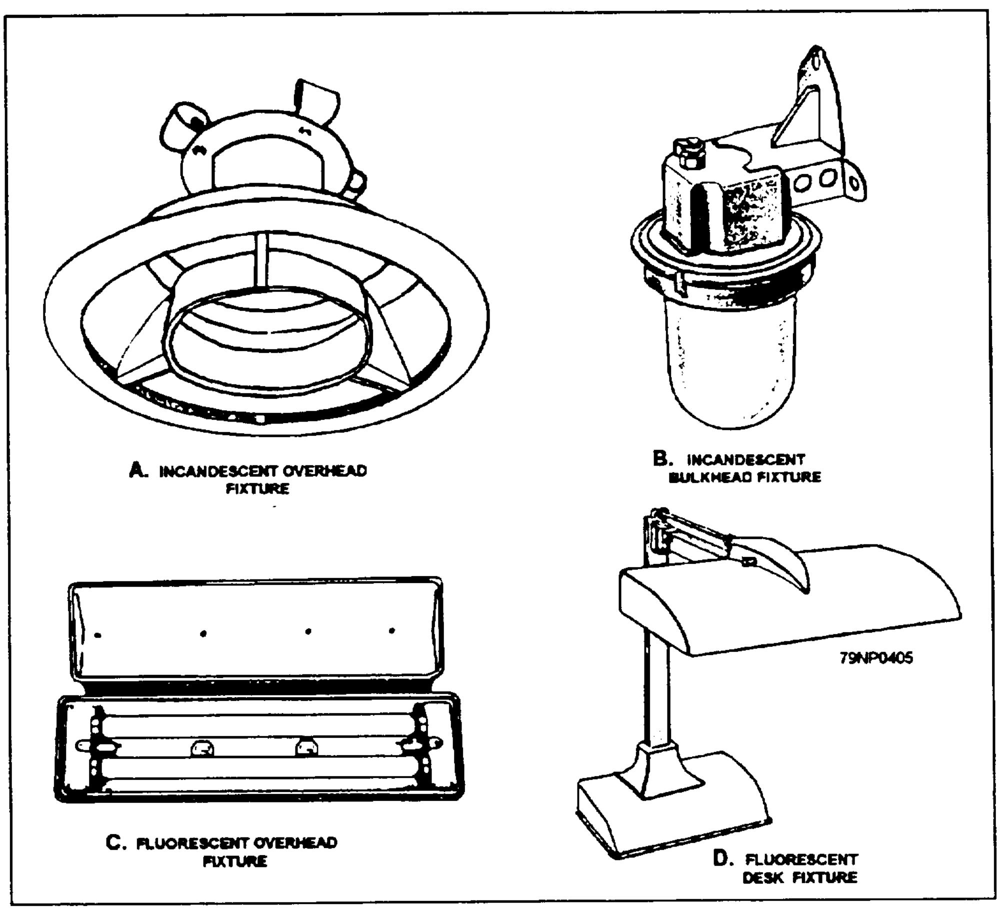


Figure 4-12.—Lighting fixtures.

alters the characteristics of the light emitted by the lamp. A clear glass globe (fig. 4-12, view B) absorbs a small percentage of the light without appreciably changing the distribution of the light. A diffusing glass globe absorbs a little more light and tends to smooth out variations in the spherical distribution of the light; whereas, a colored-glass or plastic globe absorbs a high percentage of the light emitted by the lamp. A baffle conceals the lamp and reduces glare. A reflector intercepts the light traveling in a direction in which it is not needed and reflects it in a direction in which it will be more useful.

CLASSIFICATION OF FIXTURES

Lighting fixtures are classified according to the type of enclosure provided, such as

- watertight,
- nonwatertight,
- pressure-proof, or
- explosionproof.

They are further classified according to use, such as

- regular permanent white-light fixtures,
- regular permanent red- or yellow-fixtures,
- portable fixtures,
- miscellaneous fixtures,
- navigation lights, and
- lights for night-flight operations.

Regular permanent white-light fixtures (incandescent, fig. 4-12, views A and B, fluorescent, fig. 4-12, views C and D) are permanently installed to provide general illumination and such detail illumination as may be required in specific locations. General illumination is based on the light intensity required for the performance of routine duties. Detail illumination is provided where the general illumination is inadequate for the performance of specific tasks. Sources include berth fixtures, desk lamps, and plotting lamps.

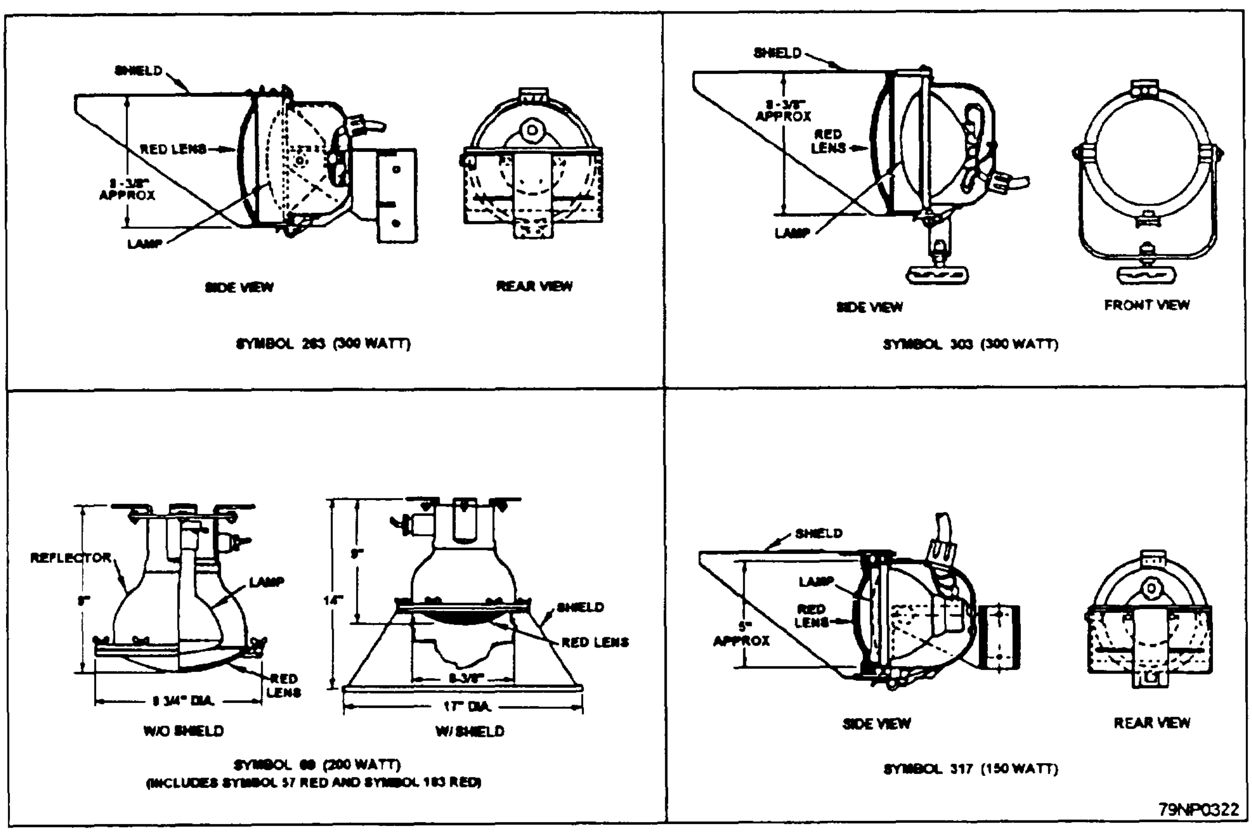


Figure 4-13.—Weatherdeck floodlights.

Regular red- or yellow-light fixtures (incandescent or fluorescent) are permanently installed to provide low-level, red or yellow illumination in berthing areas, in access routes to topside battle and watch stations, and in special compartments and stations. The incandescent fixtures are equipped with steamtight, inside acid-etched, red or yellow globes.

Portable fixtures (incandescent and fluorescent) are provided for lighting applications for which the need is infrequent or cannot be served by permanent y installed fixtures. These units are energized by means of portable cables that are plugged into outlets in the ship's service wiring system and include bedside lights, deck lights, extension lights, and floodlights.

Weatherdeck lighting fixtures are provided to illuminate topside areas for underway replenishment and for flight deck operations. The fixtures are watertight and are shown in figure 4-13. Previously, red lighting was used for weatherdeck illumination involving replenishment-at-sea stations, and white lighting was used for special in applications such as inport deck lights, carrier flightdeck lights, and salvage operation lights. A change was authorized by the Chief of Naval Operations (CNO) to change all external lighting to yellow, with the exception of red navigation and signal lights. This change consisted of replacing all converters, lenses, sleeves, windows, and lamps from red to yellow. The removed items must be retained on board for wartime use.

Miscellaneous fixtures (incandescent or fluorescent) are provided for detail and special lighting applications that cannot be served by regular permanent or regular portable lighting fixtures. These fixtures include boom lights, crane lights, gangway lights, portable flood lanterns, hand lanterns, and flashlights.

Navigation lights (incandescent) include all external lights (running, signal, and anchor), except searchlights, which are used for navigation and signaling while underway or at anchor.

Lights for night-flight operations are used to assist pilots (at night) when taking off and landing. These lights also provide visual aid to pilots for locating and identifying the parent ship.

MAINTENANCE OF FIXTURES

The lighting system should be maintained at its maximum efficiency because artificial light has an important bearing on the effectiveness of operation of a naval ship. All lighting fixtures should be cleaned at regular intervals to prevent a waste of energy and low intensity illumination.

The loss of light caused by the accumulation of dirt, dust, and film on the lamps and fixtures greatly reduces the efficiency of a lighting system. The actual loss of light from this cause depends on the extent that oil fumes, dust, and dirt are present in the surrounding atmosphere, and how often the fixtures are cleaned.

When a fixture requires cleaning, turn off the light and remove the glassware from the lamp. Inspect internal components, wiring, and lamp holders for deterioration breaks, or cracks.

Replace them if necessary. Wash the glassware, lamp, and reflector with soap and water. When washing aluminum reflectors, avoid the use of strong alkaline and acid detergents. Rinse the washed parts with clean, fresh water that contains a few drops of ammonia added to remove the soap film. Dry the parts with a soft cloth and replace them in the fixture.

To replace a burned-out lamp in a watertight fixture (fig. 4-14), unscrew the securing ring with a spanner wrench, remove the globe, and replace the burned-out lamp with a new one. Inspect the rubber gasket in the base and the centering gasket on the outside of the

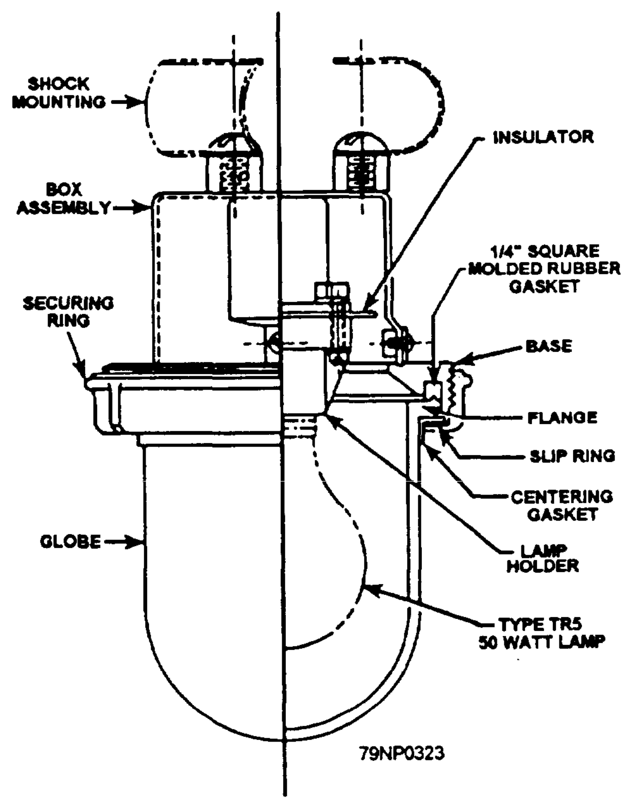


Figure 4-14.—A symbol 92.2 watertight fixture.

flange. If the gaskets are worn or deteriorated, replace them with new gaskets. Insert the globe and tighten the securing ring onto the base.

NAVIGATION AND SIGNAL LIGHTS

Navigation and signal lights include all external lights used to reduce the possibility of collision and to transmit intelligence. Figure 4-15 shows the general location of many of these lights aboard ship.

NAVIGATION LIGHTS

The number, location, arc, and range of visibility of the navigation lights, which must be displayed from sunset to sunrise by all ships in international waters, are established by the International Regulations for Preventing Collisions at Sea, 1972, (COLREGS). Statutory law requires naval compliance with the *International Rules of the Road.* However, for ships that cannot fully comply with the regulations with respect to number, position, arc, or range of visibility of these lights without interfering with the special construction or function of the ship, a certification of the closest possible compliance with the regulations issued by SECNAV is required. The certification requests are initiated by the Naval Sea Systems Command Figure 4-16 illustrates the arcs of visibility for some of the shipboard navigation running lights.

Presently, the U.S. Navy has two types of fixtures in use for running lights (masthead, stern, and sick lights) that are in compliance with the COLREGS.

One type is the cast brass fixtures which use a cylindrical (open at both ends) Fresnel (corrugated) type

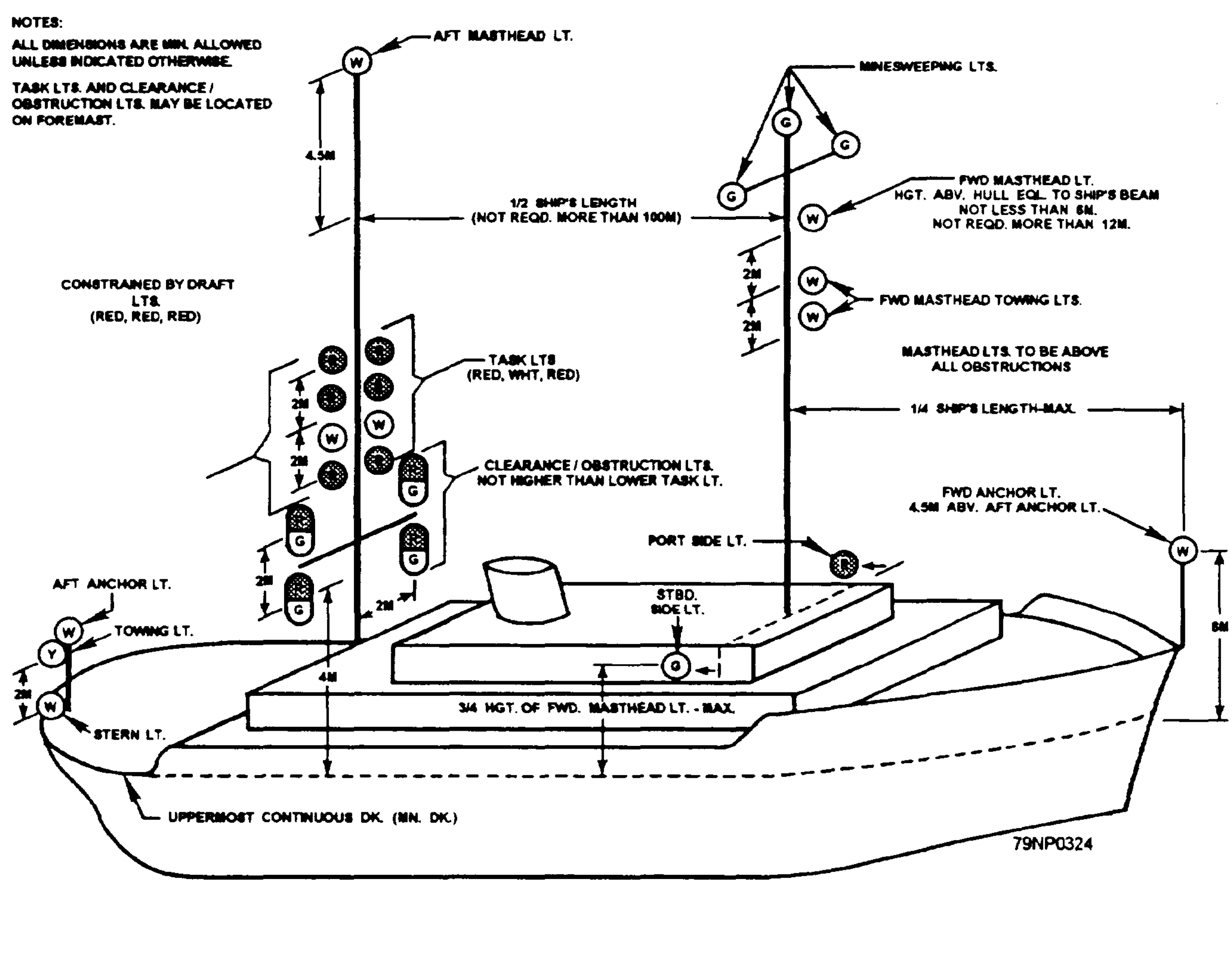
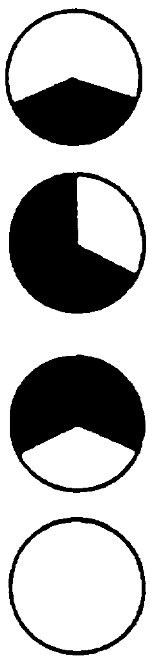


Figure 4-15.—General arrangement of lights for navigation.

THE LIGHTS IN THE FOLLOWING ILLUSTRATIONS ARE REPRESENTED BY PORTIONS OF A DISK. A TOP VIEW OF THE ARC OF VISIBILITY FOR THE VARIOUS LIGHTS REPRESENTED IN SHOWN HERE.



LIGHT	ARC (DEGREES)	ARC (POINTS) (NOTE:)	ON DIAGRAM
FWD & AFT MASTHEAD LIGHT WHITE	225°	20PT	A
SIDE LIGHT STARBOARD-GREEN PORT-RED	112.5°	10PT	B
STERN LIGHT WHITE	135°	12PT	C
ALL AROUND LIGHT	360°	32PT	D

(NOTE: 1 POINT = 11.25 DEGREES)

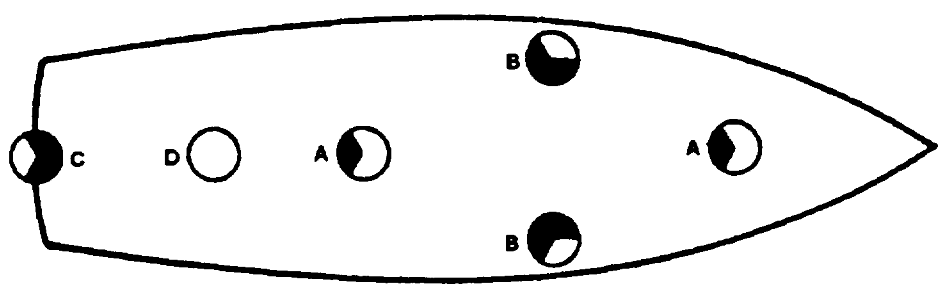


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Figure 4-16.—Arc of visibility for navigation lights.

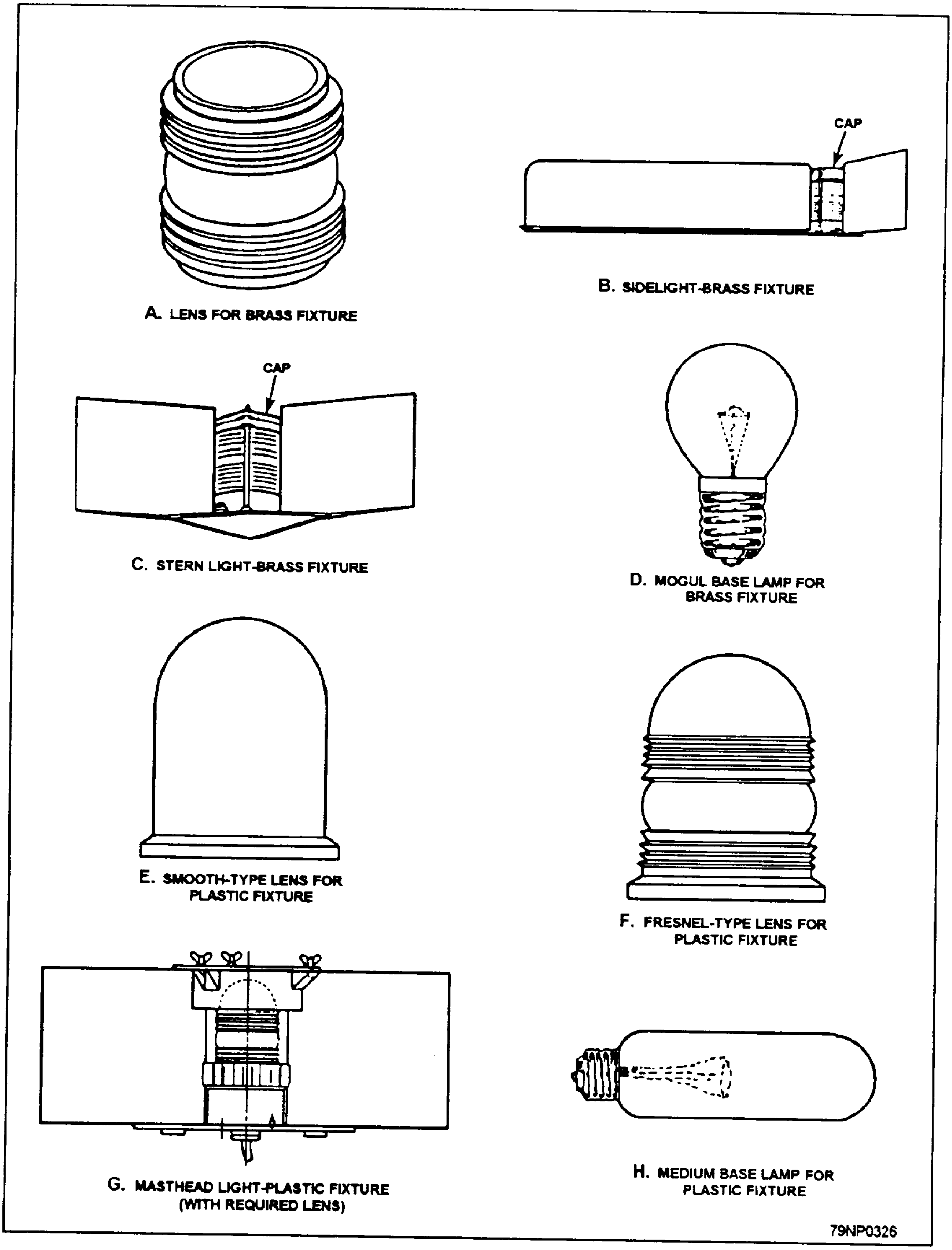


Figure 4-17.—Navigation light fixtures, lamps, and lenses.

of lens, shown in figure 4-17, view A. The lens is attached to the fixture base by a cap piece and four retaining rods and nuts. The cast brass fixtures used for side and stem lights, respectively, are shown in figure 4-17, views B and C. The brass fixture requires a three-contact, dual-filament, mogul screw base, incandescent lamp (fig. 4-17, view D).

Masthead and Stern Lights

The MASTHEAD and STERN LIGHTS require a 50/50-watt lamp. The sidelights require a 100/100-watt lamp. These fixtures and lenses with the correct lamp comply with the 1972 COLREGS and do not have to be replaced

The second type of fixture is a newer lightweight plastic fixture that uses a domed (open at one end) lens. Originally these lenses were the smooth type (fig. 4-17, view E). To comply with the 1972 COLREGS, the Fresnel-type of lens (fig. 4-17, view F') is required when these fixtures are used for masthead or side lights. This plastic fixture requires a three-contact dual-filament, 50/50-watt, medium screw base, incandescent lamp (fig. 4-17, view H). The lamp holder of this plastic fixture contains a spring-loaded center contact for the primary filament, a ring contact for the secondary filament, and a common shell contact The internal wiring diagram of the lamp holder is shown in figure 4-18.

Forward and After Masthead Lights

The FORWARD and AFTER MASTHEAD LIGHTS (white) are spraytight fixtures provided with a 50-watt two-filament lamp and equipped with an external shield to show an unbroken light over an arc of the horizon of 20 points (225°)—that is, from dead ahead to 2 points (22.5°) abaft the beam on either side. The forward masthead light is located on a mast or jackstaff in the forward quarter of the vessel. The after masthead light is located on a mast in the after part of the vessel. The vertical separation between the masthead lights must beat least 4.5 meters (14.75 feet), and the horizontal separation must be at least one half of the overall length of the vessel or 100 meters (330 feet).

NOTE: For detailed requirements of the navigation light locations, refer to the 72 COLREGS requirements, which are printed in the U.S. Coast Guard publication COMMANDANT, INSTRUCTION M16672.2A and *Code of Federal* Regulations, CFR 33-81.20. The U.S. Navy's certifications of closest possible compliance is summarized in CFR 32-706. The U.S. Navy's special lights are covered in CFR 32-707.

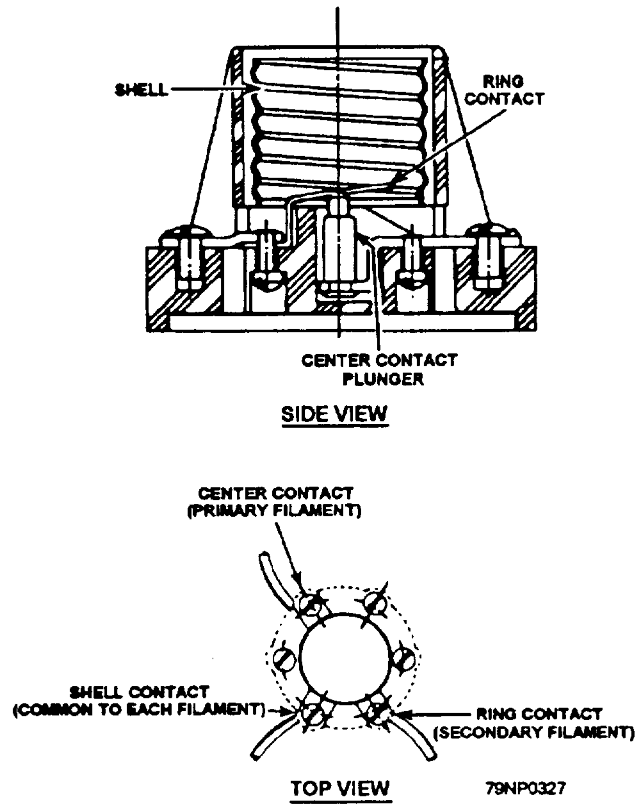


Figure 4-18.—New navigation light fixture lamp holder wiring diagram.

Port and Starboard Side Lights

The PORT and STARBOARD SIDE LIGHTS are 10-point (112 1/2°) lights (fig. 4-19) located on the

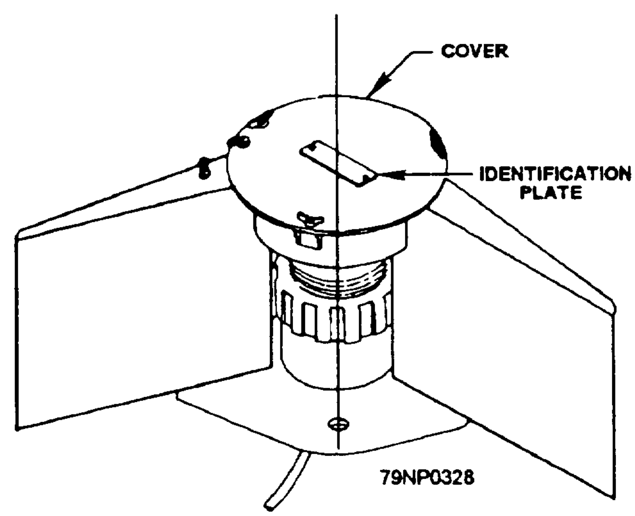


Figure 4-19.—Side light fixture.

respective sides of the vessel, showing red to port and green to stardoard. The fixtures are spraytight, each provided with a 50-watt, two-filament lamp, and equipped with an external shield arranged to show the light from dead ahead to 2 points abaft the beam on the respective sides. On older vessels, these fixtures may be 100-watt brass fixtures.

Stern Light

The STERN LIGHT (white) is a 12-point (135°) light located on the stem of the vessel. It is a watertight fixture provided with a 50-watt filament lamp and equipped with an external shield to show an unbroken light over an arc of the horizon of 12 points of the compass-that is, from dead astern to 6 points on each side of the ship.

Forward Towing Lights

FORWARD TOWING LIGHTS (white) and AFTER TOWING LIGHTS (yellow) are normally for ships engaged in towing operations. The forward upper and lower towing lights are 20-point (225°) lights, identical to the previously described masthead lights. These lights are installed on the same mast with the forward towing operations. The forward upper and lower towing lights are 20-point (225°) lights, identical to the previously described masthead lights. These lights are installed on the same mast with the forward or after masthead lights, and the vertical separation is 2 meters (6.6 feet). The after towing light is a 12-point (135°) light, similar to the previously described stern light except for its yellow lens. It is installed 2 meters (6.6 feet) directly above the white stem light.

Breakdown and Man Overboard Lights

The dual-array BREAKDOWN and MAN OVERBOARD LIGHTS (red) are 32-point (360°) lights located 2 meters (6.6 feet) apart or (vertically) and mounted on brackets on port and starboard of the mast or structure. This arrangement permits visibility, as far as practicable, throughout 360° of azimuth. The fixtures are spraytight and equipped with six 15-watt one-filament lamps. When these lights are used as a man-overboard signal, they are pulsed by a rotary snap switch (fitted with a crank handle) on the signal and anchor light supply and control panel. These lights are mounted and operated in conjunction with the ship's task lights when both are installed.

Constrained by Draft Lights

The CONSTRAINED BY DRAFT LIGHTS (red) are a dual array of three 32-point (360°) lights. This light array is similar to a task light array except that the middle light fixtures are equipped with dual-color (red/white) lenses. (See fig. 4-23, view C.) This middle fixture is spraytight and equipped with a multiple socket (fig. 4-23, view D) provided with nine 15-watt, one-filament lamps. Six lamps are used in the top multiple bulb socket for the red light and three in the bottom socket for the white light. Each light is energized from separate circuits. The middle red lights are used in conjunction with the top red lights and bottom red lights for constrained-by-draft light functions, while the middle white lights are used with these lights for task light functions. The dual, three red light array is displayed simultaneously to indicate the ship is unable to get out of the way of an approaching vessel in a narrow channel, due to ship's deep draft. The switch for this light display is labeled SHIP'S CONSTRAINED BY DRAFT LIGHTS.

Clearance/Obstruction Lights

The CLEARANCE/OBSTRUCTION LIGHTS (red/green) are a dual array of two 32-point (360°) lights. The fixtures are identical to the middle constrained-by-draft light (fig. 4-23, view C) except that the lens of the lower half of the fixture is green. This array is placed port and starboard on the ship, two fixtures in a vertical line, not less than 2 meters (6.6 feet) apart at a horizontal distance of not less than 2 meters (6.6 feet) from the task lights in the athwartship direction (fig. 4-15). Each upper and lower half of the fixture in the array is energized from separate circuits. This dual-light array is used by a ship engaged in dredging or underwater operations, such as salvage, to indicate her ability to maneuver is restricted. The two red lights in a vertical line indicate the side on which the obstruction exists, and the two green lights in a vertical line indicate the side on which another ship may pass.

Minesweeping Lights

The MINESWEEPING LIGHTS (green) are an array of three 32-point (360°) lights placed to form a triangular shape. These fixtures are equipped with 50-watt lamps. One of the lights is placed near the foremast head and one at each end of the fore yardarm (fig. 4-15). These lights indicate that it is dangerous for another ship to approach within 1000 meters (3280.8 feet) of the mine-clearance vessel.

Ship's Task Lights

The SHIP'S TASK LIGHTS are a dual array of three 32-point (360°) lights, port and starboard of the mast or superstructure. They are arranged in a vertical line, one pair over the other so that the upper and lower light pairs are the same distance from, and not less than 2 meters (6.6 feet) above or below, the middle light pairs. The lights must be visible for a distance of at least 3 miles. The upper and lower lights of this array are red, and the center lights are a clear white.

These lights are equipped with multiple 15-watt, one-filament lamps and are connected to the navigation light supply and control (not the telltale) panel. They may be controlled as follows:

- The upper and lower red lights may be burned steadily to indicate the ship is not under command.
- The upper and lower red lights may be flashed by rotating the switch crank handle on the supply and control panel to indicate a man-overboard condition exists.
- The three lights may burn simultaneously to indicate the ship is unable to get out of the way of approaching vessels. (This may be due to launching or recovering aircraft, replenishment-at-sea operations, and so forth) The switch for this application is labeled SHIP'S TASK LIGHTS.

Forward and After Anchor Lights

The FORWARD and AFTER ANCHOR LIGHTS (white) are 32-point (360°) lights. The forward anchor light is located near the stem of the ship, and the after anchor light is at the top of the flagstaff. The fixtures are splashproof, each provided with a 50-watt, one-filament lamp (50/50-watt, dual-filament lamps are used on some ships). The anchor lights are energized through individual on-off rotary snap switches on the signal and anchor light supply and control panel in the pilot house. The after anchor light is placed at least 4.5 meters (14.75 feet) lower than the forward anchor light (table 4-9).

Testing Navigation Lights

The supply, control, and telltale panel for the running lights is a nonwatertight, sheet metal cabinet designed for bulkhead mounting. 'This panel (fig. 4-20) is provided to aid a ship in keeping its running lights lit as prescribed by the rules for preventing collisions at sea. It is installed in or near the pilot house and gives an alarm when one of the navigation lights (forward and after masthead, stem, and side lights) has a failure of its primary filament and is operating on its secondary filament.

All shipboard navigational lights are tested daily while at sea. The test is usually made 1 hour before sunset by the Quartermaster. The following paragraphs describe the indicated warnings of the telltale panel when a malfunction occurs.

1. Failure of the primary filament/circuit of any one of the lights (forward and after masthead, stem, or side lights), will de-energize a relay
2. This relay
   a. effects a transfer of power to the secondary filament of the affected light,
   b. sounds a buzzer
   c. lights an indicator light, and
   d. moves an annunciator target to read OUT (reads RESET when de-energized).

To silence the buzzer, you turn the handle of the reset switch 90° to the horizontal position. However, the indicator lamp of the affected light stays lit until the repair has been completed, and the reset switch is turned back to the normal (RESET) position. Certain ships have permanent towing lights installed and connected to control switches in the telltale panel. The towing light switches are manual. When failure of the primary filament occurs in towing lights connectedto this panel, the switch must be manually turned to the position marked SEC, to energize the secondary filament.

Figure 4-9.—Summary of Navigation Lights

Light	Deg. of Visibility	Color	Location	Purpose
Masthead Light (Fore and Aft)	225° (20pts)	White	Top of fore and aft mast	Define topmost portion of ship, indicate direction traveling
Stern Light	135° (12pts)	White	Mn deck stern area facing aft	Indicate stern of ship and direction of travel
Port Running Light	112.5° (10pts)	Red	Port side above mn deck	Indicate direction of travel
Stbd Running Light	112.5° (10pts)	Green	Stbd side above mn deck	Indicate direction of travel
Forward Towing Light	225° (20pts)	White	Near top of fore mast	Indicates ship is involved in towing ops
After Towing Light	135° (12pts)	Yellow	2 meters directly above white stern light	Indicates ship is involved in towing ops
Breakdown and Man Overboard Lights	360° (32pts)	Red	2 meters apart vertically on both sides of the mast or structure	Indicates ship is not under steerage way or a man is in the water (when blinking)
Constrained by Draft Lights	360° (32pts)	Red	Near top of mast	Indicates ship cannot maneuver clear due to deep draft
Clearance/Obstruction Lights	360° (32pts)	Red/Green	2 meters apart horizontally not less than 2 meters away from task lights in athwartship direction	Indicates which side of ship is obstructed during salvage ops, dredging, etc.
Minesweeping Lights	360° (32pts)	Green	One near foremast head and one at each end of yardarm	Indicates it is dangerous for another vessel to approach within 1000 meters
Ship's Task Lights	360° (32pts)	Upper Red Center Clear Lower Red	Both sides of mast or structure	Indicates ship is in a restricted maneuverability status
Forward Anchor Light	360° (32pts)	White	Near stem of ship	Along w/aft anchor light, indicates length of ship and fwd end from which chain protrudes
After Anchor Light	360° (32pts)	White	On top of flagstaff aft	Along w/ fwd anchor light, indicates length of ship

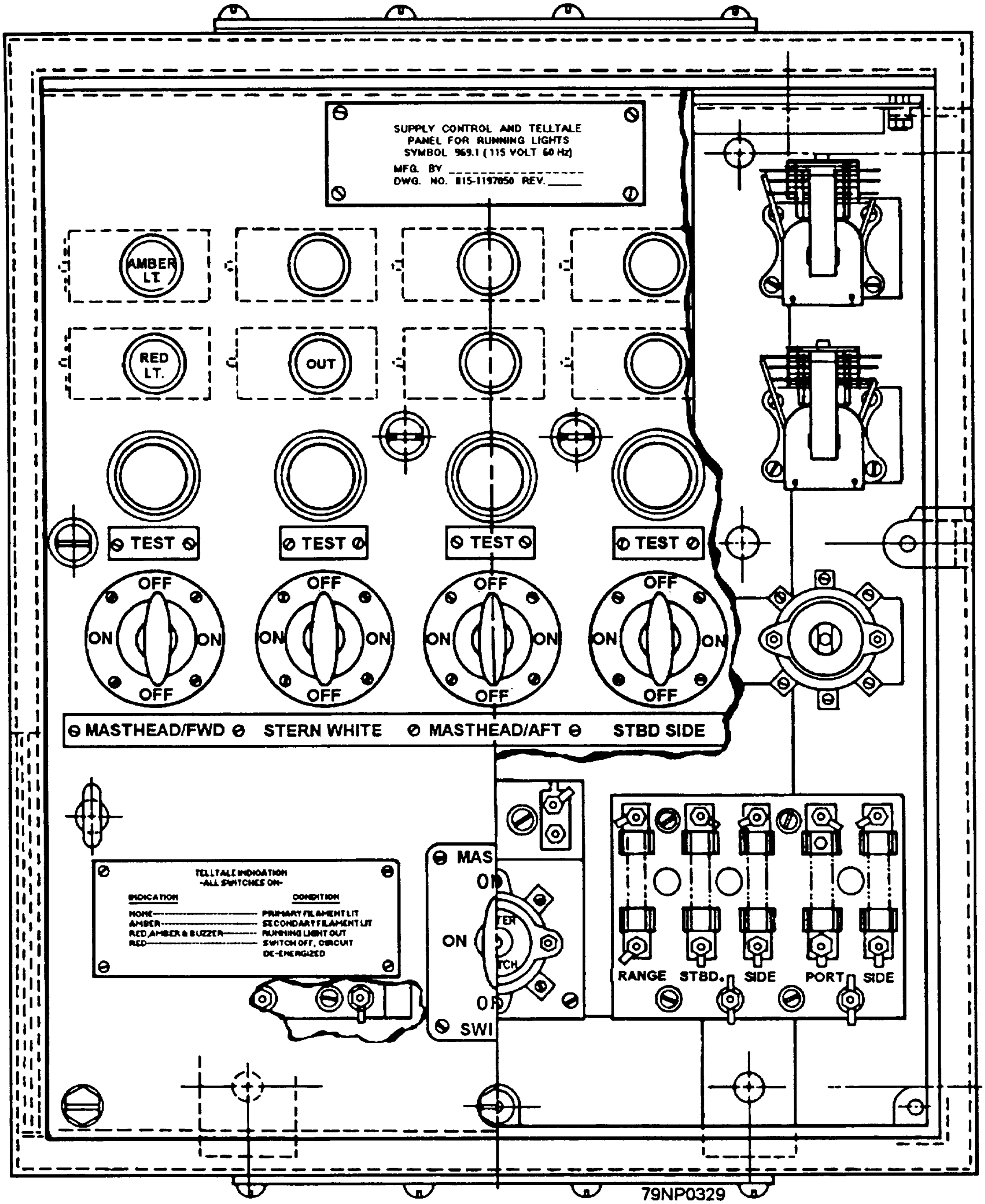


Figure 4-20.—Supply, control, and telltale panel, symbol 969.1.

Sequence of Operations

The operations of the supply control and telltale panel are easily seen by following the schematic diagram in figure 4-21. For simplification this schematic shows only one of the five running lights; the operation is the same for all five.

When the primary filament of a running light is lighted, relay contacts X, Y, and Z are open; the indicator lamps, annunciator, and buzzer are not energized. The reset switch must be kept pointing in the RESET (vertical) position under normal conditions, or the buzzer will not be energized when a failure occurs.

If the primary filament circuit is opened or the filament burns out, the following events will occur:

1. The relay is de-energized, causing contacts X and Y to close.
2. Then the secondary filament and the indicator lamps are lighted, and the annunciator target drops to the OUT position, closing contact Z, and the buzzer sounds.

When the RESET switch handle is turned to the horizontal position, the following events will occur:

1. The buzzer is silenced.
2. The indicator lamps remain lighted.
3. The annunciator target still reads OUT.

When the defective lamp is replaced (or the fault in the primary circuit is corrected), the following events occur:

1. The relay coil is energized and relay contacts X and Y are opened.
2. The annunciator coil is then de-energized, opening contact Z.
3. The target indicates RESET. The secondary filament is now de-energized, and the indicator lamps are lit.
4. The reset switch is returned to the RESET (vertical) position.
5. The indicator lamps go out.
6. The entire unit is again operating in the normal condition.

A dimmer control panel connected as shown in figure 4-22 is provided for dimming the running lights. This panel provides only one dimming position. In the dim position the visibility of the mastheads, side lights, and the stern light is reduced considerably. The sequence of operation of the telltale panel is the same whether the running lights are in the bright or dimmed condition.

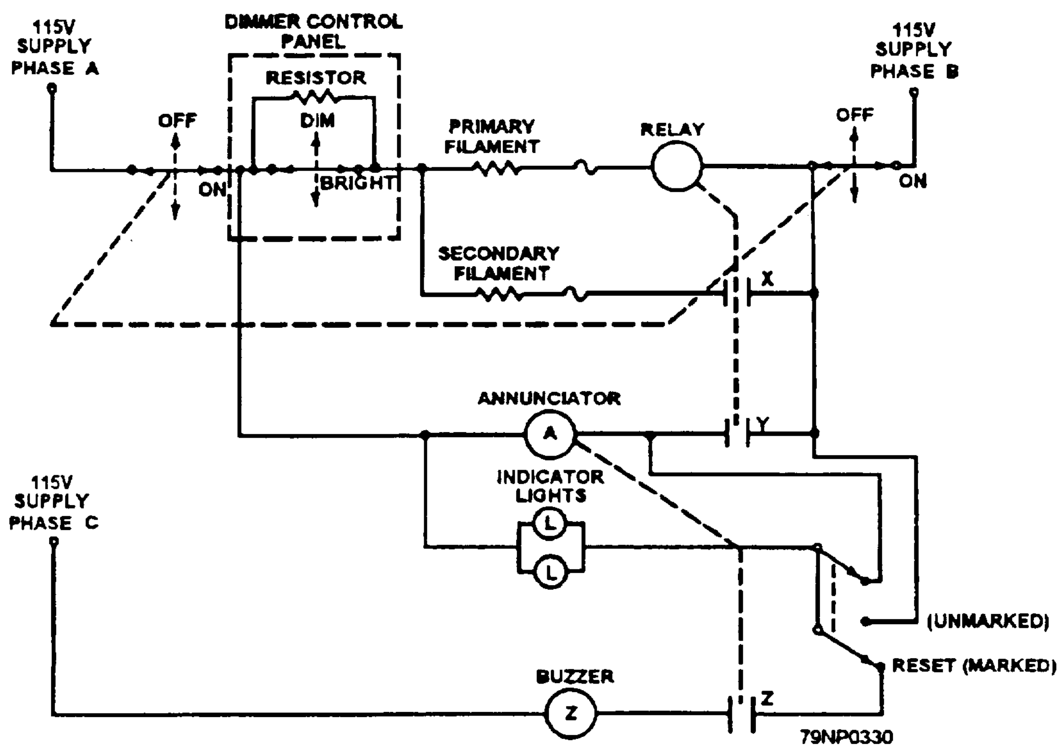


Figure 4-21.—Running light, supply, control, and telltale panel schematic diagram.

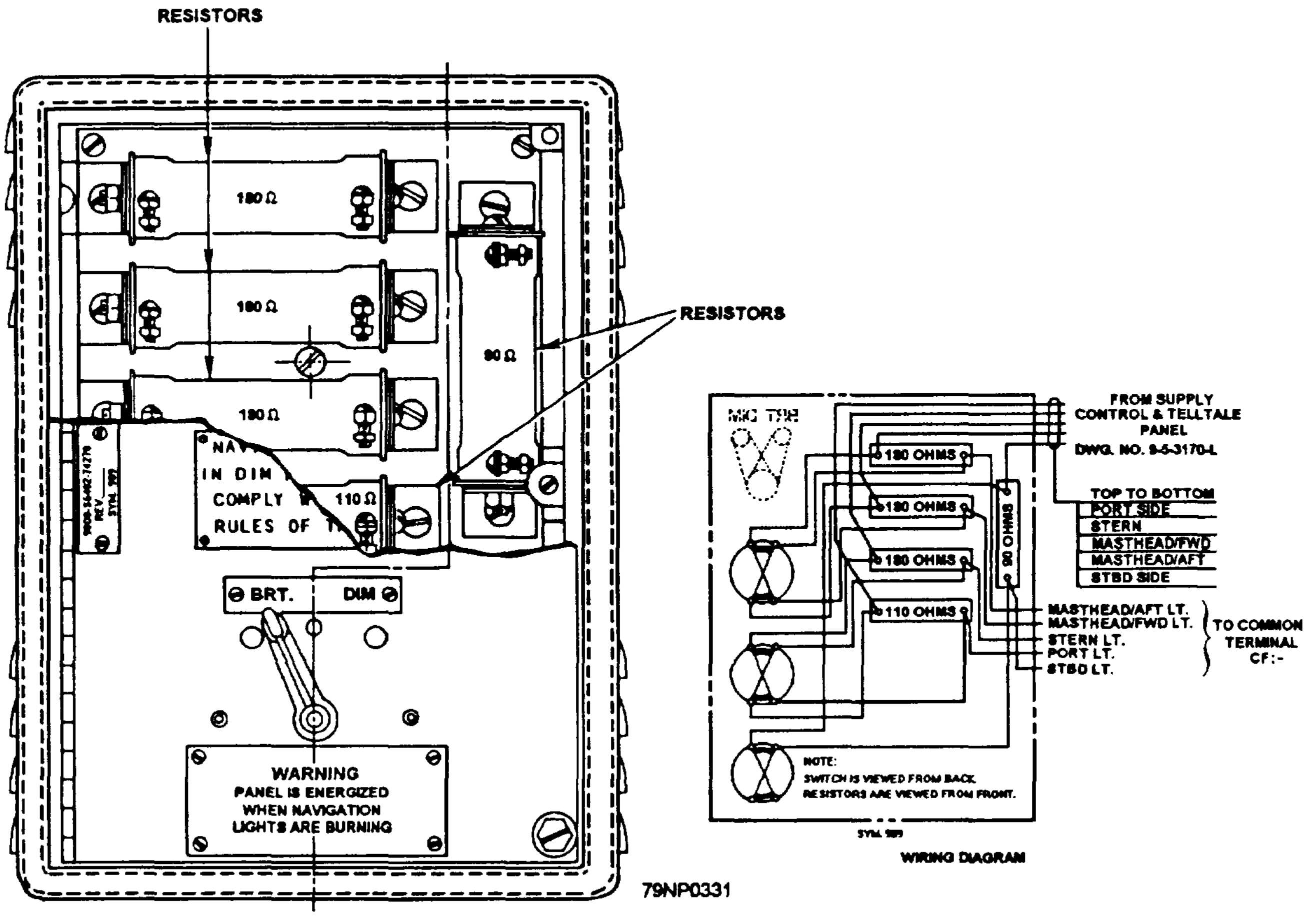


Figure 4-22.—Dimmer control panel, symbol 989.

NOTE: Navigation lights do not conform to the rules of the road when they are in the dim position; therefore, they are dimmed ONLY when directed by higher authority.

SIGNAL LIGHTS (OPERATIONAL OR STATION)

Task lights are used to indicate the ship is in a restricted maneuverability status (replenishment at-sea or aircraft operations). Hull contour lights are required to indicate the contour of the ship. Station marker lights are used on ships, capable of delivery, to mark the replenishment station location.

Stern Light

The STERN LIGHT (blue) is a 12point (135°) light, similar to the previously described white stem light. It is a watertight fixture provided with a 50-watt lamp and is installed near the stem on ships that are engaged in convoy operations and mounted to show an unbroken arc of light from dead astern to 6 points on each side of the ship.

Wake Light

The WAKE LIGHT (white) is installed on the flagstaff or after part of the ship to illuminate the wake and is mounted so that no part of the ship is illuminated. The fixture is spraytight and of tubular construction. One end of the fixture is fitted with an internal screen, having a 1 1/4-inch diameter hole provided with a lens (1 13/16-inch diameter x 3/16-inch thick) through which light is emitted from a 50-watt lamp (T-12 tubular). A suitable mounting bracket is included for adjusting the position of the light, thereby illuminating the ship's wake.

Aircraft Warning Lights

The AIRCRAFT WARNING LIGHTS (red) are 32-point (360°) lights (fig. 4-23, view A) installed at or near the top of each mast. If the light cannot be located so that it is visible from any location throughout 360° of azimuth, two aircraft warning lights (one on each side of the mast) are installed However, a separate aircraft warning light is not required if a 32-point red light is installed at the truck of a nearby mast for another purpose. The fixtures are spraytight and equipped with multiple sockets provided with 15-watt, one-filament lamps (fig. 4-23, view B).

Revolving Beam ASW (Grimes) Light

The REVOLVING BEAM ASW (GRIMES) LIGHT is displayed for intership signaling during ASW operations and is installed on all ships equipped to participate in ASW operations. The light is positioned on either the yardarm or mast platform where it can best be seen all around the horizon. Two red, two green, and two amber lenses are provided with each fixture. The colors used are determined by operating forces.

Station Marker Box Signal Light

The STATION MARKER BOX SIGNAL LIGHT (fig. 4-24) has nine holes, each fitted with a red lens. The hand-operated individual shutters hinge upward. Illumination is by two 25-watt bulbs; one is a standby bulb.

One watertight receptacle is installed at each replenishment-at-sea station, outboard near or under the rail or lifeline. On some underway-replenishment ships, the boxes are permanently mounted The lights have no special arcs-of visibility requirements.

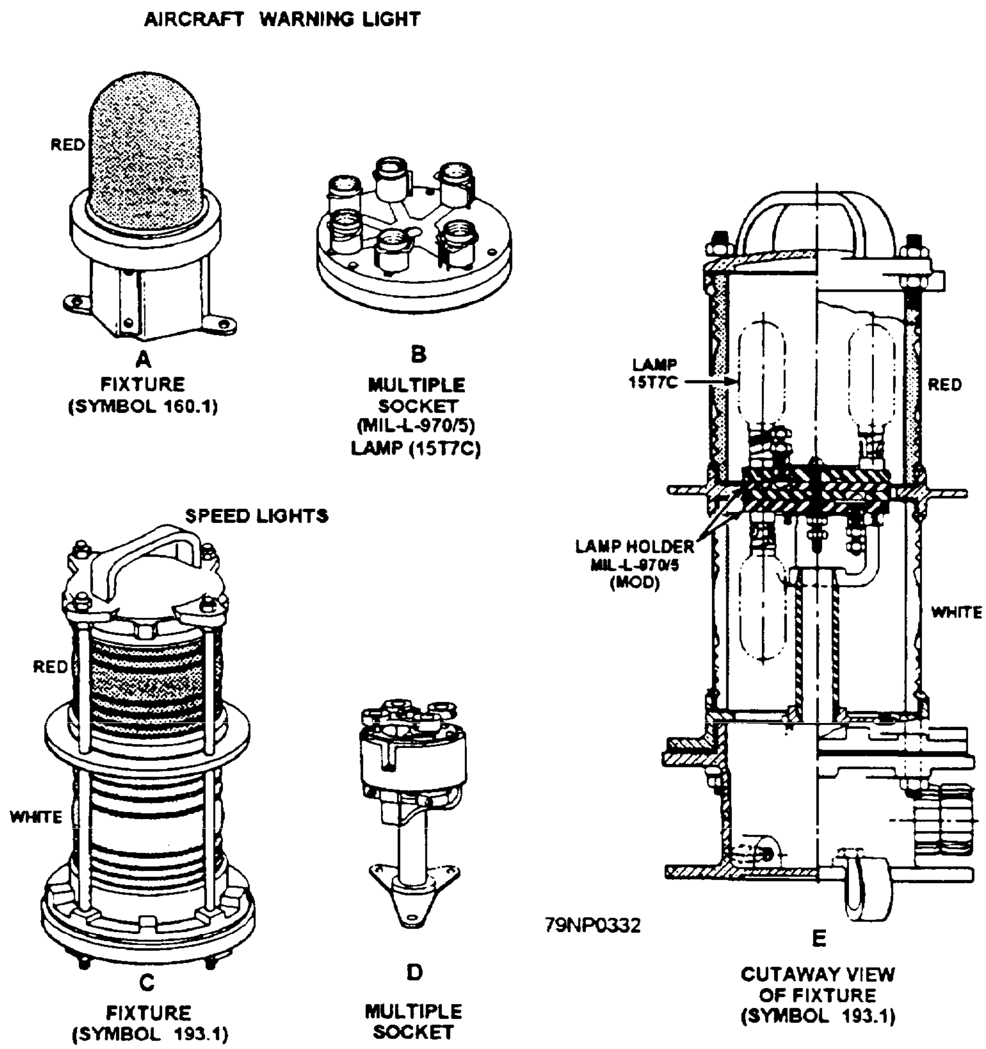


Figure 4-23.—Constrained by draft and/or task light fixtures.

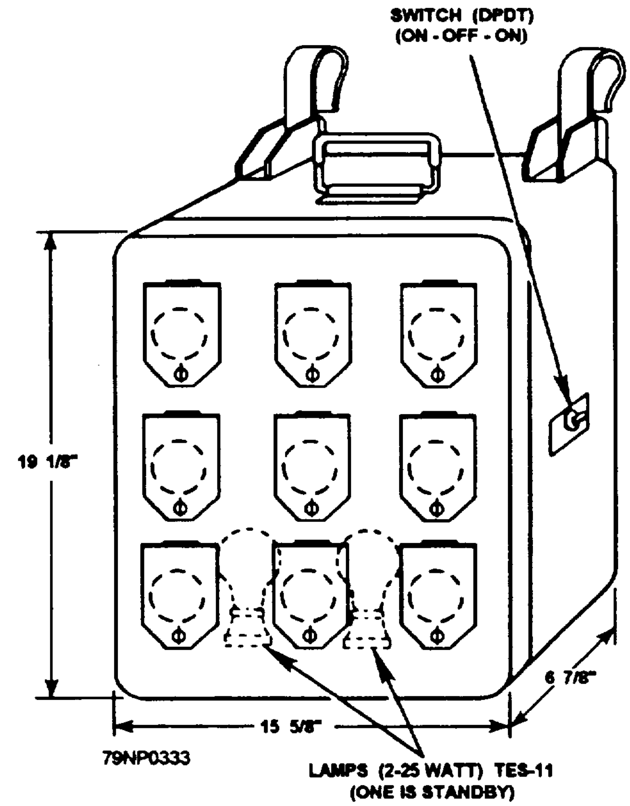


Figure 4-24.—Station marker box, symbol 285.

Station marking boxes are used for visual communications between the replenishment-at sea stations of the sending and the receiving ships. Specific combinations of lights indicate that stores, such as water, fuel oil, and ammunition, are to be sent to certain stations. When the marker box is flagged correctly, there will be little chance of receiving the wrong cargo at a station.

The Boatswain's Mates will usually test the station marker box prior to underway replenishment, but you should be prepared for any possible trouble and have spare light bulbs readily available.

Hull Contour Lights

The HULL CONTOUR LIGHTS (blue) are found on replenishment-at-sea delivery ships. These lights assist the receiving ship coming alongside during replenishment operations by establishing the delivery ship's contour lines. Two or three hull contour (blue) signal lights (135°arc) are located on each side of the delivery ship (fig. 4-25) at the railing. Additional lights may be installed if obstructions exist beyond the delivery ship's parallel contour lines.

SIGNAL LIGHTS VISUAL COMMUNICATIONS

The signal lights for visual communications include the blinker lights located on the yardarm, multipurpose signal lights, and searchlights.

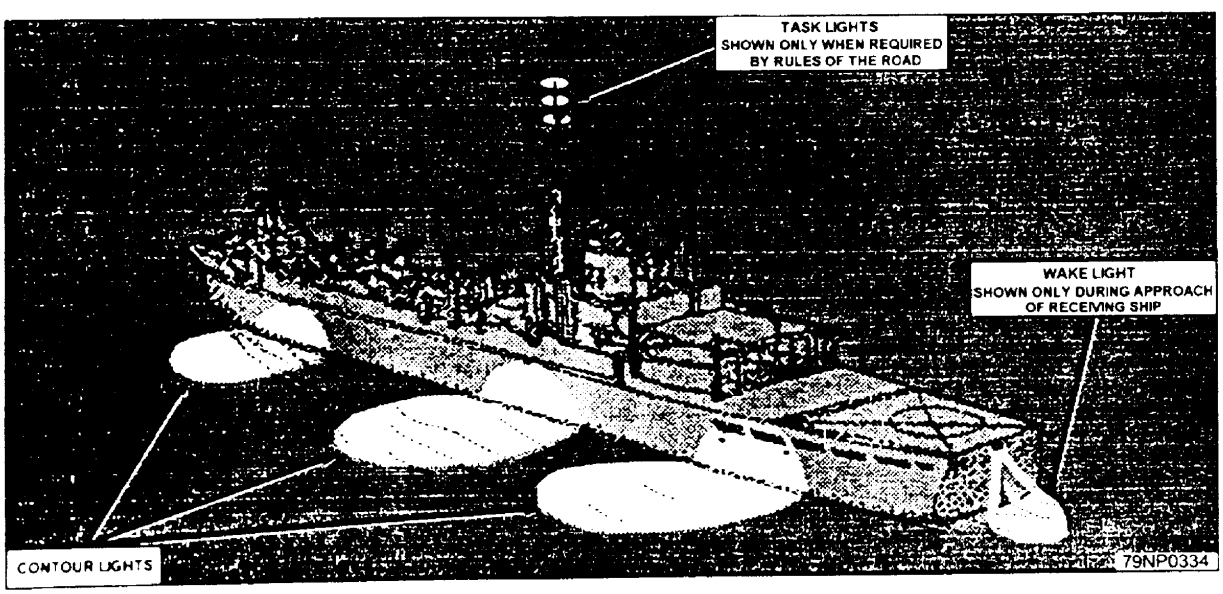


Figure 4-25.—Replensihment at sea lighting.

Blinker Lights

The BLINKER LIGHTS (white) are 32-point (360°) lights (fig. 4-26) located outboard on the signal yardarm, one port and one starboard. The fixtures are spray tight, each provided with multiple 15-watt, one-filament lamps and fitted with a screen at the base to prevent glare or reflection that may interfere with the navigation of the ship. These lights are operated from signal keys located on each side of the signal bridge.

Older blinker units (fig. 4-26, view A) have a cluster of six 15-watt lamps in a single multiple-lamp socket,

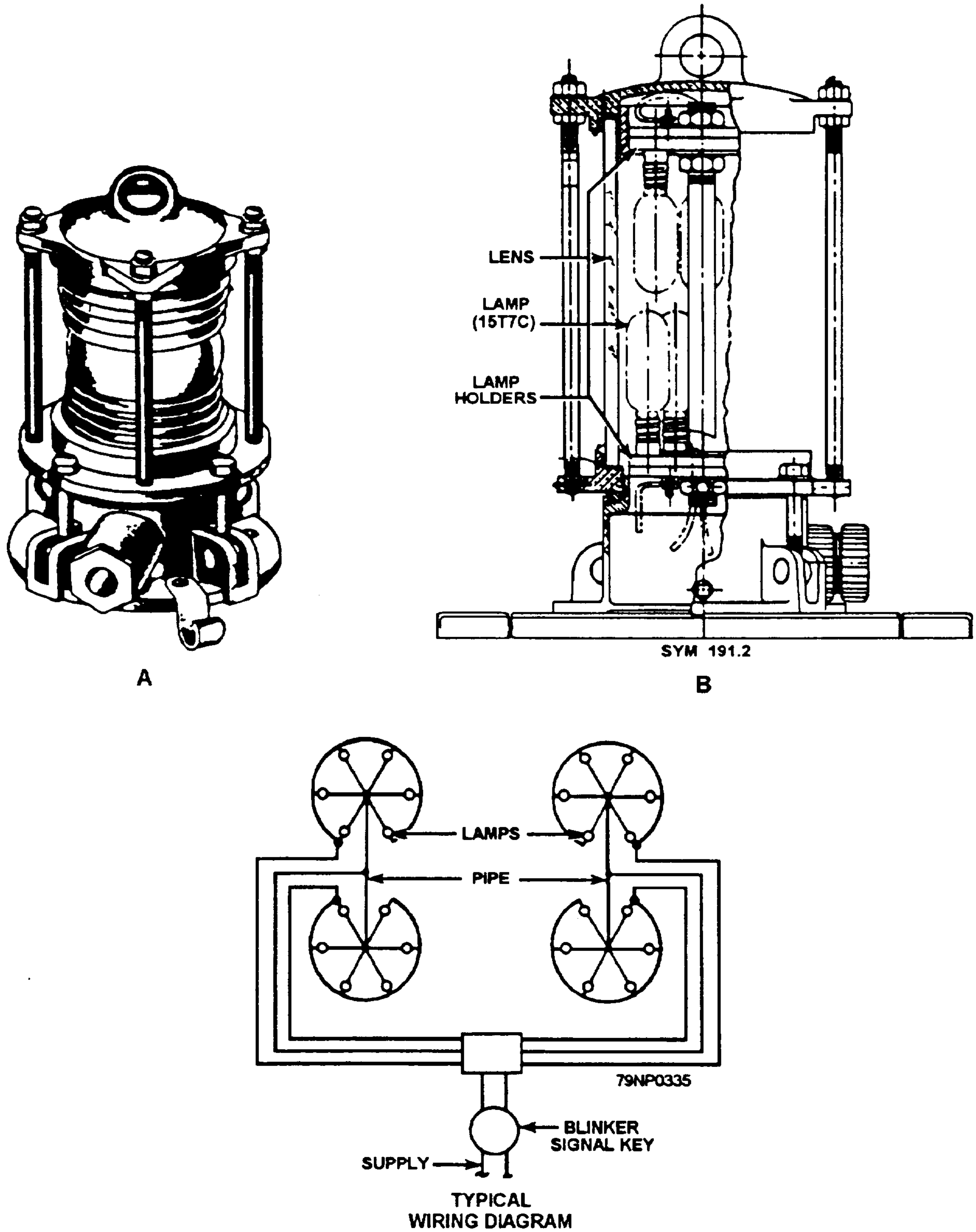


Figure 4-26.—Blinker light fixture.

similarly arranged as in the warning light (fig. 4-23, view B). Newer units are shown in figure 4-26, view B. These newer units have two clusters of six lamps. Cluster No. 1 maybe used only for normal use. Cluster No. 2 maybe added by switching to increase brilliance for communication at greater distance. Cluster No. 2 may be selected alone when No. 1 fails.

Multipurpose Signal Light

The portable multipurpose signal light (fig. 4-27) produces a high-intensity beam of light suitable for use as a spot light or as a blinker light. A trigger switch located on the rear handle is used for communications. The light is designed to operate from an internal battery or from the ship's service power supply using a 120/20-volt transformer mounted in the carrying case. In the signaling operation, an adjustable front handle assures a steady position. Front and rear sights are provided to direct the beam on the desired target.

Supplied with the light, in addition to the stowage box, are red, green, and yellow lenses, a 15-foot power cable for supplying power from the ship's ac source to the stowage box, a 25-foot cable for supplying power from the stowage box to the light, and the manufacturer's technical manual.

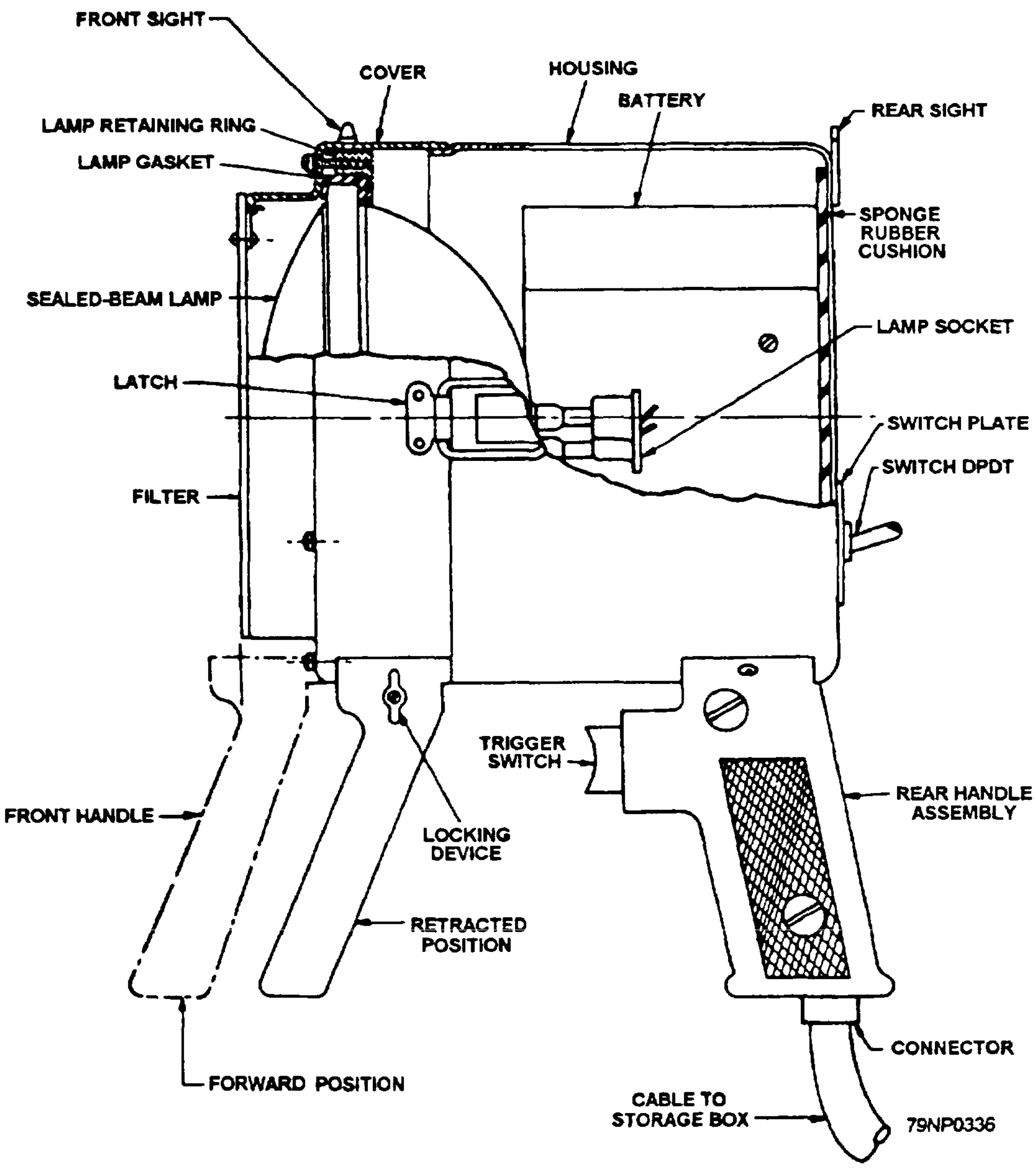


Figure 4-27.—Multipurpose signal light, symbol 106.1.

Searchlights

Naval searchlights are used to project a narrow beam of light for the illumination of distant objects and for visual signaling. To accomplish its purposes, the searchlight must have an intense, concentrated source of light, a reflector that collects light from the source (to direct it in a narrow beam), and a signal shutter (to interrupt the beam of light).

Searchlights are classified according to the size of the reflector and the light source. The three general classes are the 8-inch, 12-inch and 24-inch searchlights. The 8-inch searchlight is of the sealed-beam incandescent type. The 12-inch light are of the incandescent and mercury-xenon type. The 24-inch carbon-arc searchlight is not addressed in this manual. Refer to *Naval Ship's Technical Manual,* chapter 422, for information on this light

8-INCH SEALED-BEAM SEARCHLIGHT.— The 8-inch signaling searchlight (fig. 4-28) uses an incandescent sealed-beam lamp. It is designed to withstand high vibratory shock and extreme humidity conditions and operates equally well in hot or cold climates.

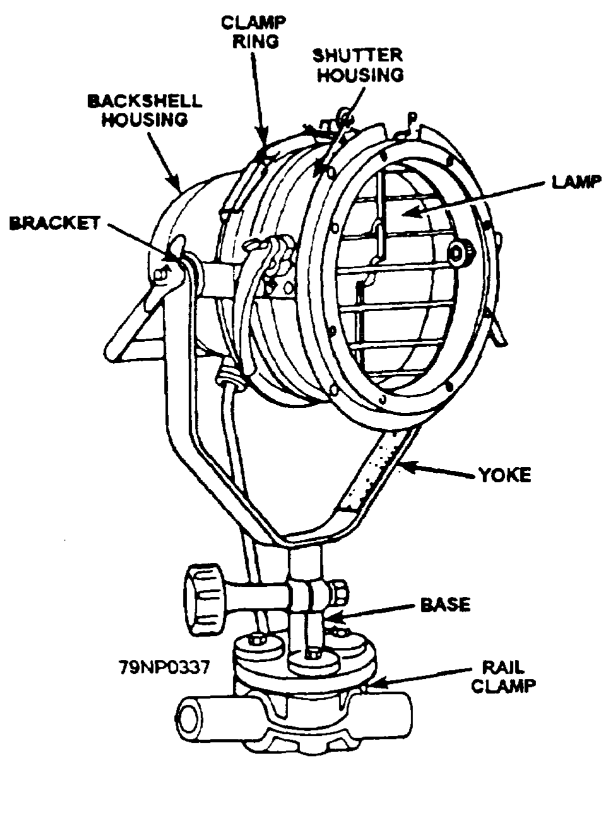


Figure 4-28.—An 8-inch, 60-hertz, sealed-beam searchlight.

his searchlight may be furnished for operation either with a 60-hertz, 115-volt transformer to step the voltage down to 28 volts or without a transformer to operate on 115 volts using the proper rated sealed-beam unit. The same unit is available for use on small craft from a 28-volt power source.

The searchlight has four main parts:

1. The **base,** which is equiped with a rail clamp for securing the searchlight to the rail.
2. The **yoke,** which is swivel mounted on the base to allow it to be trained through 360°.
3. The **housing,** which provides an enclosure for the lamp and is composed of a front and a rear section.
4. The **lamp,** which provides the source of light.

The front section of the housing comprises the shutter housing, and the rear section comprises the backshell housing, containing a 115/28-volt step-down transformer. The two sections are held together by a quick-release clamp ring that permits easy replacement of the lamp. The backshell and lamp assembly, when detached, may be used as a portable searchlight. The entire housing is mounted on brackets attached to the shutter housing and supported by the yoke to allow the searchlight to be elevated or depressed. Clamps are provided for securing the searchlight in train and elevation.

The shutter housing contains the venetian blind shutter, which is held closed by springs and manually opened by a lever on either side of the housing. The front of the shutter housing is sealed by the cover glass and a gasket. The rear of the shutter housing is enclosed by a gasket and adapter assembly. The adapter assembly provides a locating seat for the lamp and incorporates a hook and key arrangement that aligns the backshell housing and retains it in position while attaching the clamp ring to hold the two sections together.

Three filter assemblies (red, green, and yellow) are provided and can be readily snapped in place over the face of the searchlight. The shutter vanes can be locked in the open position for use as a spotlight.

To remove the lamp from the housing for cleaning or replacement, use the following procedure:

1. Tip the rear end of the searchlight up to its highest position and lock it in place.
2. Release the clamp ring toggle and remove the clamp ring (fig. 4-27).
3. Remove the backshell assembly by raising it up. This will disengage it from the hook and tab.
4. Pull the gasketed lamp out of the shutter adapter assembly by gripping the lamp gasket on its periphery and lifting it out. This will disengage the gasket lugs from the notches in the adapter assembly.

To replace the lamp in the housing, take the following actions:

1. Make sure that the word TOP marked on the lamp is aligned with the word TOPon the gasket and that the lugs of the lamp are firmly seated in the recesses provided in the gasket.
2. Make sure that the lugs are set into the notches in the adapter assembly located inside, and at the rear of, the shutter housing.
3. Set the backshell assembly over the shutter assembly, engaging the shutter hook into the slot of the backshell.
4. Using the hook as a hinge, carefully swing the lower part of the backshell down to the shutter assembly, engaging the shutter tab into the notch in the rolled edge of the backshell. Be careful to swing the backshell down in a straight line to make direct engagement and to ensure proper positioning of the lamp contacts on the terminals of the lamp.
5. Replace the clamp ring, making sure that the hinge pin is set into the notches of the adapter and backshell assemblies.

12-INCH INCANDESCENT SEARCHLIGHT.— The 12-inch incandescent searchlight is used primarily for signaling and secondarily for illumination.

The searchlight (fig. 4-29) is comprised of the mounting bracket, yoke, drum, and lamp. The mounting bracket permits the searchlight to be secured to a vertical pipe or to a flat vertical surface. The yoke is swivel mounted on the bracket to allow the searchlight to be rotated continuously in train. The steel drum provides a housing for the lamp, and its trunnion is mounted on the yoke so that it may be elevated or lowered Clamps are provided for locking the searchlight in any position of train elevation.

The signaling shutter is a venetian blind shutter mounted inside the drum behind the front door. It is held in the closed position by two springs and is manually opened by a lever on either side of the drum. The parabolic metal reflectors mounted on the inside of the rear door.

The lamp is usually a 1,000-watt, 117-volt incandescent lamp having special concentrated filaments that reduce the area of the light beam. The lamp is mounted in a mogul bipost socket. The socket is located in front of the reflector and can be adjusted only slightly. The replacement of the lamp is accomplished through the rear door of the searchlight.

12-INCH MERCURY-XENON SEARCHLIGHTS.— Some of the older mercury-xenon searchlights are 12-inch incandescent lamp searchlights converted to use a 1,000-watt compact mercury-xenon arc lamp. The addition of a small amount of mercury to the xenon gas produces a much more brilliant light with a great deal of radiation in the green and ultraviolet parts of the spectrum. The increases in light intensity greatly increase the range of the searchlight.

The modifications needed to convert the incandescent lamp searchlights include installation of a lamp holder, lamp adjuster assembly, and lamp

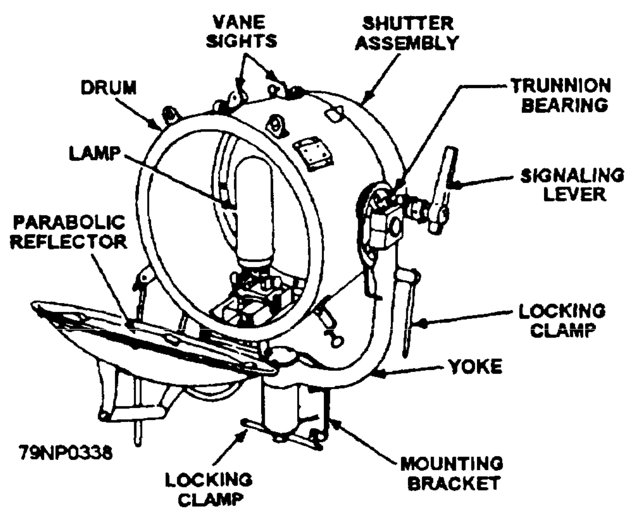


Figure 4-29.—A 12-inch incandescent searchlight.

starter assembly mounted on the searchlight drum (fig. 4-30).

Other modifications include the following:

- Providing a 115-volt, 60-hertz ballast unit mounted below deck near the searchlight, connected by a flexible cable
- Installing the short-arc mercury-xenon arc lamp
- Furnishing the additional onboard repair parts necessitated by the changes, which include a ballast, transformers, capacitors, spark gap, and switch circuit.

The wiring diagram for the early model 12-inch mercury-xenon arc searchlight is shown in figure 4-31.

WARNING

Do not bridge or depress the safety switch when working on the assembly or when replacing the lamp. Opening the searchlight drum opens all contacts of the safety switch, protecting personnel against electric shock. As an additional safety precaution, disconnect the plug on the starter box before opening the door.

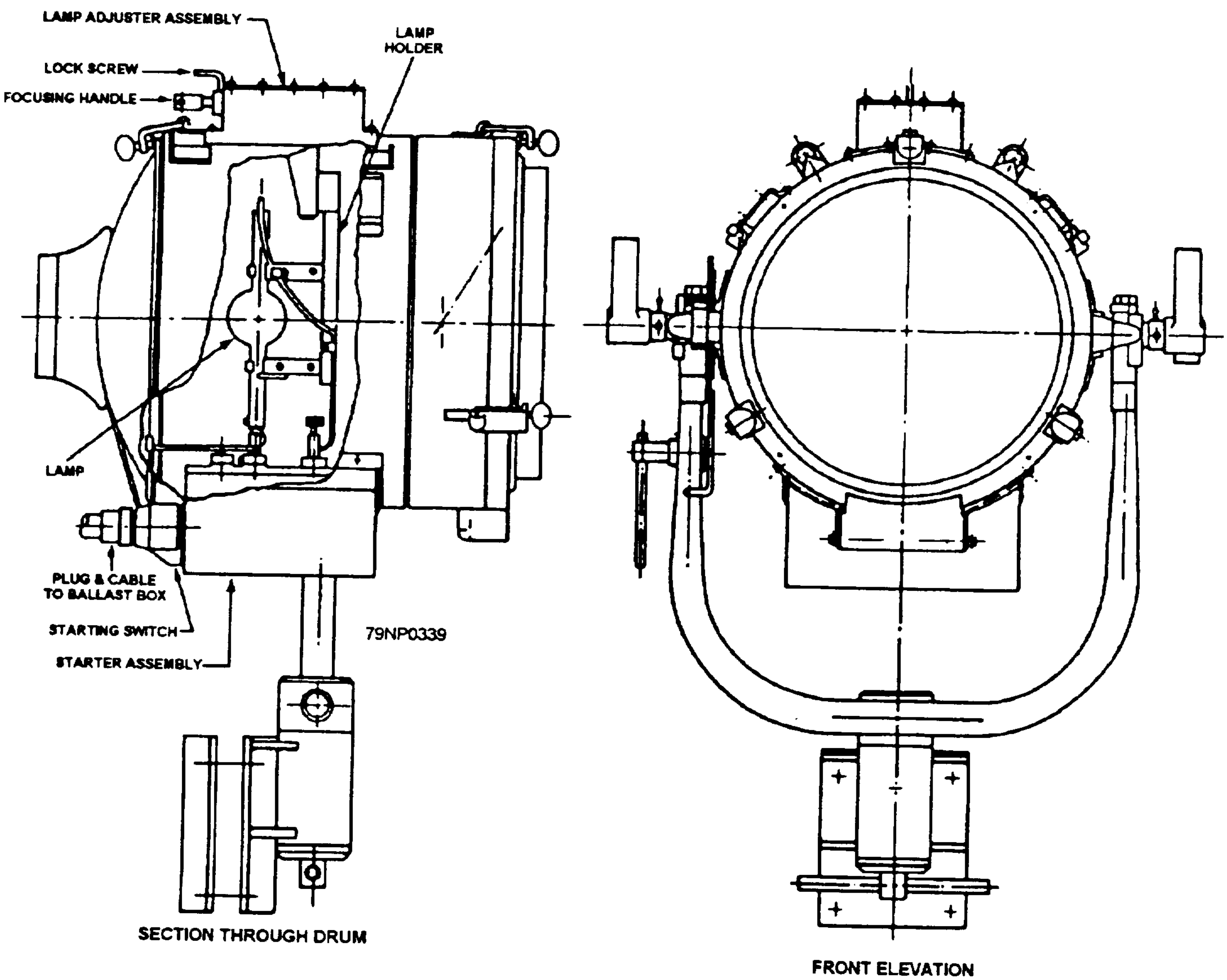


Figure 4-30.—A 12-inch incandescent searchlight converted to use a mercury-xenon arc lamp.

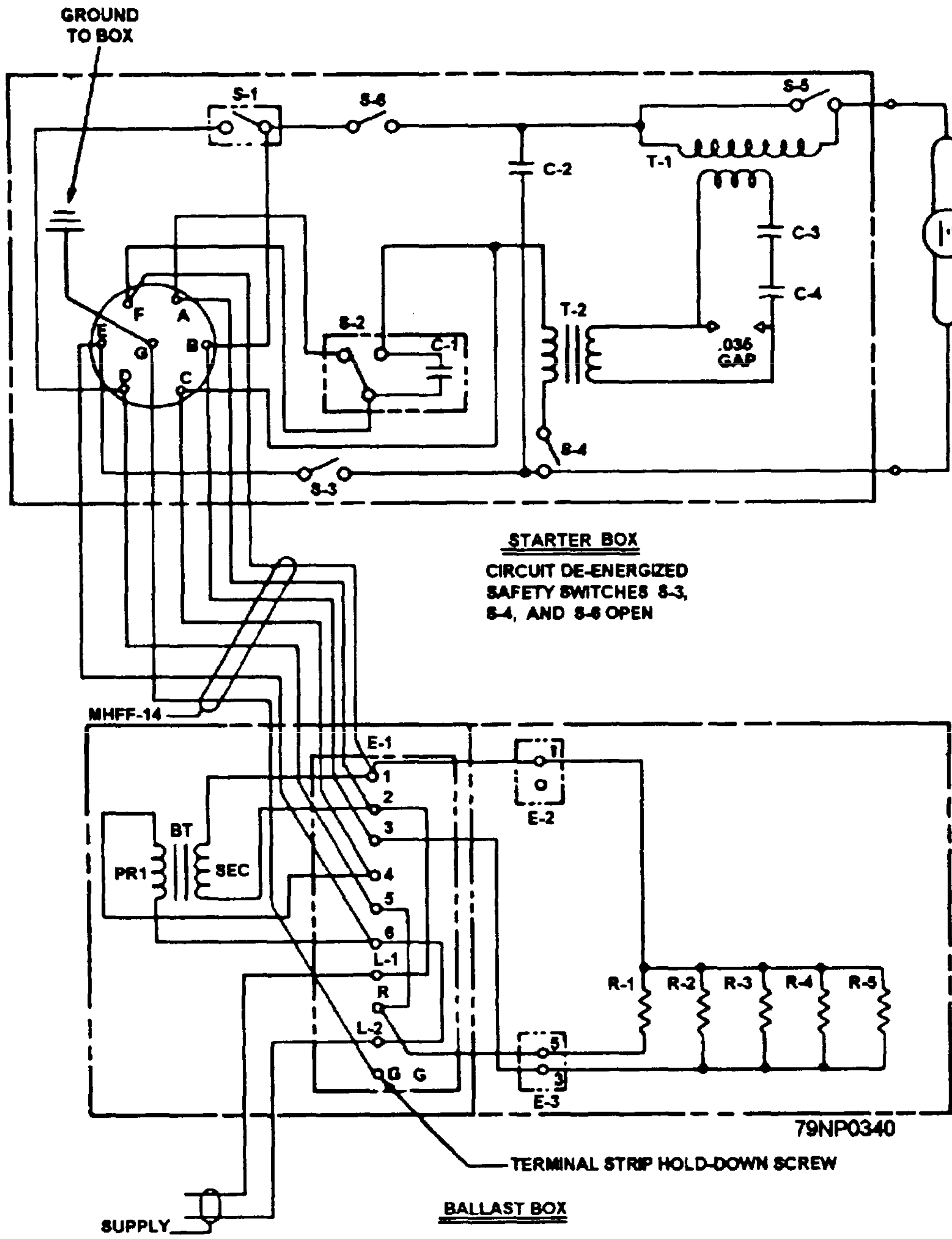


Figure 4-31.—Wiring diagram for an early model 12-inch mercury-xenon arc searchlight.

Starting Circuit.— The secondary of the step-up transformer in the starting circuit supplies high voltage to a radio-frequency circuit consisting of a spark gap, capacitors, and the three-turn primary of the pulse transformer. The secondary of the pulse transformer produces a momentary high voltage for starting the arc.

When the arc starts, the secondary of the pulse transformer is short-circuited and the lamp is now energized on line voltage reduced by the drop in the ballast.

Operating Circuit.—The operating circuit includes four ballast resistors, which permit the lamp to operate at 25 volts during warmup after the arc has been struck and up to 65 volts at full lamp output. A fifth resistor is automatically connected during starting and removed after the arc is struck

Safety Switch.—The safety switch has three contacts, S-3, S-4, and S-6. The actuating lever of this switch projects a short distance into the searchlight drum from the top of the starter assembly. It is mechanically linked to the reflector or the shutter housing, depending on which is hinged, to provide access for relamping or cleaning.

XENON AND MERCURY-XENON ARC LAMPS.— Mercuty-xenon gas-filled arc lamps operate on 60-hertz alternating current or, with some change in the starter circuit and ballast resistor, on 400-hertz alternating current. The light produces a concentrated arc of intense brilliance, which provides sharp focusing. Searchlights with mercury-xenon arc lamps are normally used for signaling, but they may also be used for illumination. The 12-inch mercury-xenon arc searchlight includes the following parts:

1. 1,000-watt lamp
2. Drum
3. Back dome
4. Signaling shutter
5. Mounting yoke
6. Focusing device
7. Automatic lamp starting circuit (attached to the lower part of the drum)
8. Screening hood with various colored falters

The wiring diagram of the 12-inch mercury-xenon arc searchlight is shown in figure 4-32.

Automatic Starting Circuit.— A high-voltage pulse type of circuit is used When the searchlight is turned on, the booster transformer supplies 130 volts to the primary of the transformer, which in turn provides a series of pulses of about 50,000 volts generated by high-frequency discharges through a spark gap.

When the main arc in the lamp is established, the voltage in the primary of the transformer drops to 65 volts. This voltage is not high enough to cause the secondary voltage of the transformer to break down the spark gap. Thus, the high-voltage pulses to the lamp automatically y stop.

Ballast Circuit.— Five parallel-connected resistors are connected in series with the lamp as shown in figure 4-32. These resistors limit the current at starting and during operation, supplying the correct electrical values to the lamp.

MAINTENANCE ON 8- AND 12-INCH SEARCHLIGHTS.— These searchlights are maintained by following the same practice that relates to all electrical and mechanical equipment:

- Keep all electrical contacts clean and bright.
- Check electrical leads daily an replace them as soon as defects appear.
- Lubricate trunnion bearings and stanchion sockets according to PMS requirements.

Adjust the two shutter stop screws, located next to the handles to compensate for wear in the leather bumpers. These bumpers cushion the shock of the shutter vanes closing. The bumpers should just touch the stop adjustment when the vanes are closed to prevent the shaft from twisting. Check the shutter vanes frequently to ensure that all screws are tight.

Clean the reflector weekly or more often to remove dust. Remove salt spray from the lens and reflector as necessary. You should use the following instructions to clean the reflector:

- Ensure that the surface is cool. Touching a hot surface with your bare skin can result in a serious burn.
- Use standard Navy brightwork polish.
- Use a soft, lint-free cloth, or clean the reflector in accordance with the PMS MRC.
- Use a radial motion from the center to the rim of the reflector. Do not use a circular motion.
- Do not paint bolts, locking nuts, and other parts necessary for access to the interior or over nameplate data. Keep oiling holes free of paint.

Only qualified Electrician's Mates should replace the lamp or adjust the focusing unless a member of the signal gang is qualified. The light source must be at the focusing point of the reflector for minimum beam spread and maximum intensity. Some types of 12-inch incandescent searchlights are provided with focusing adjustment screws. Other types can be adjusted by loosening the screws that hold the lamp-socket support plate in position. The entire socket assembly can be moved toward or away from the reflector until the beam has a minimum diameter at a distance of 100 feet or more from the light. The screws must be retightened after the final adjustment. The diameter of the beam must be checked with the rear door clamped tightly shut.

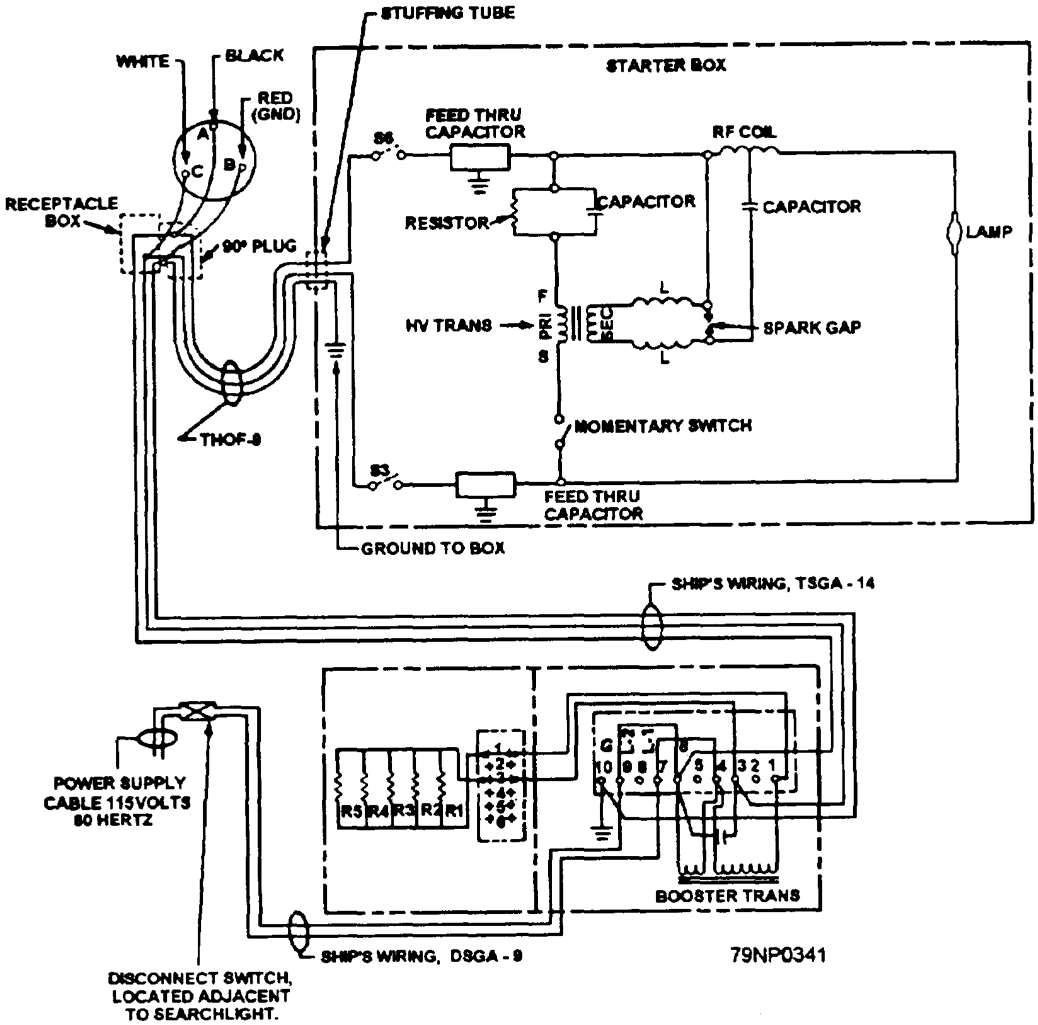


Figure 4-32.—Wiring diagram for a 12-inch mercury-xenon arc searchlight.

A screen hood is provided for attachment to the front door to limit the candlepower of the beam, to cut down its range, and to reduce stray light, which causes secondary illumination around the mainbeam; the hood also allows for the use of colored filters.

DIVERSIFIED LIGHTING EQUIPMENT

Diversified lighting equipment restricts the visibility of light and reduces the amount of glare or background illumination. This equipment includes lights for darkened-ship condition and special lights for various uses.

DARKEN SHIP EQUIPMENT

Darkened ship is a security condition designed to prevent the exposure of light, which could reveal the location of the ship. Darkened ship condition is achieved by the following means:

1. Light traps that prevent the escape of light from illuminated spaces
2. Door switches that automatic-ally de-energize the lights when the doors are opened

When darkened-ship condition is ordered, check every door switch installation aboard ship to determine that all lock devices or short circuiting switches are set in the DARKENED SHIP position.

Inspect the light traps to determine that they are free of all obstructions. A light-colored object of any appreciable size placed in a light trap might be sufficiently illuminated by the interior lighting to be visible beyond the safe limit. Note the positions of the hand lanterns when entering a compartment so that you can find them without delay when they are needed.

Light Trap

Alight trap (fig. 4-33) is an arrangement of screens placed inside access doors or hatches to prevent the escape of direct or reflected light from within. The inside surfaces of the screens are painted fiat black so that they will reflect a minimum of light falling on them. Light traps that are used to prevent the escape of white light should have at least two black, light-absorbing surfaces between the light source and the outboard openings. Light traps are preferred to door switches in locations when the following conditions exist:

1. Egress or ingress is frequent
2. Interruption of light would cause work stoppage in large areas
3. Light might be exposed from a series of hatches, one above the other on successive deck levels
4. Many small compartments and passages are joined by numerous inside and outside doors that would complicate a door-switch installation

Door Switch

A door switch is mounted on the break side of a door jamb (inside the compartment) and operated by a stud welded to the door. When the door is opened, the switch is automatically opened at the same time. Door switches are connected in a variety of ways to suit the arrangement of each compartment.

All door-switch installations are provided with lock-in devices or short-circuiting switches to change the settings of the door switches, as required from lighted ship to darkened ship and vice versa. Each standard door switch is furnished with a mechanical lock-in device for use when only one door switch is installed. When two or more door switches are connected in series, a single, separately mounted short-circuiting switch is installed in an accessible location to avoid the possibility of overlooking any of the door switches when the changeover is made from lighted ship to darkened ship and vice versa.

When a single door switch at an outer door is connected in parallel with door switches at inner doors,

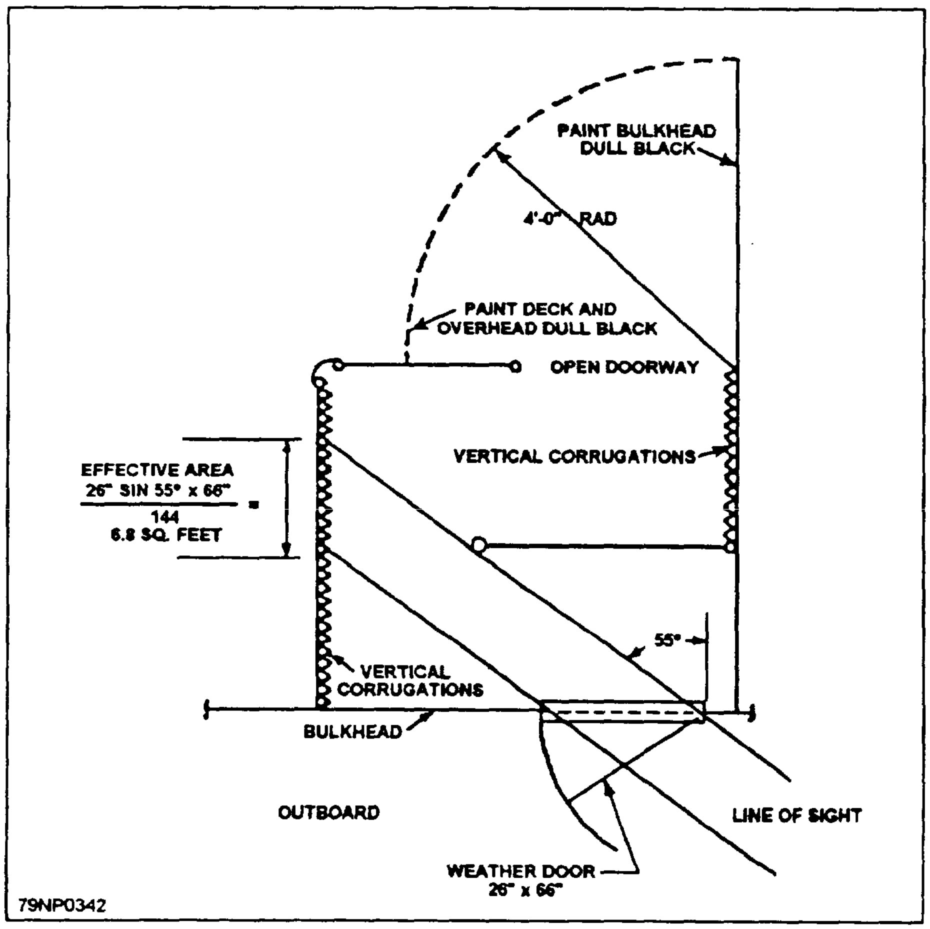


Figure 4-33.—Light trap.

only the door switch at the outer door is provided with a lock-in device, and the lock-in devices are removed from the other outer doors. The location of the control switch is indicated by a plate mounted adjacent to each door switch. The control switch is marked CAUTION-DOOR SWITCH CONTROL. The portion of the short-circuiting switch that connects the door switches in the circuit is marked DARKENED SHIP, and the portion that disconnects the door switches from the circuit is marked LIGHTED SHIP. Personnel should become familiar with the location of the short-circuiting switch in all compartments, and the number of doors that it controls.

SPECIAL LIGHTS

Special lights are provided aboard ships for various uses. These lights include flashlights, floodlights, hand lanterns, and flood lanterns (fig. 4-34). Lights and lighting fixtures are identified by NAVSHIPS symbol numbers (1 through 399), military standard (MS) numbers, national stock numbers (NSN), military specification numbers, or NAVSHIPS drawing numbers. The NAVSHIPS Standard Electrical Symbol List (NAVSEA S0300-AT-GTP-010/ESL, formerly NAVSEA 0960-000-4000) lists the lights and lighting fixtures in current use on naval ships. Fixtures are listed

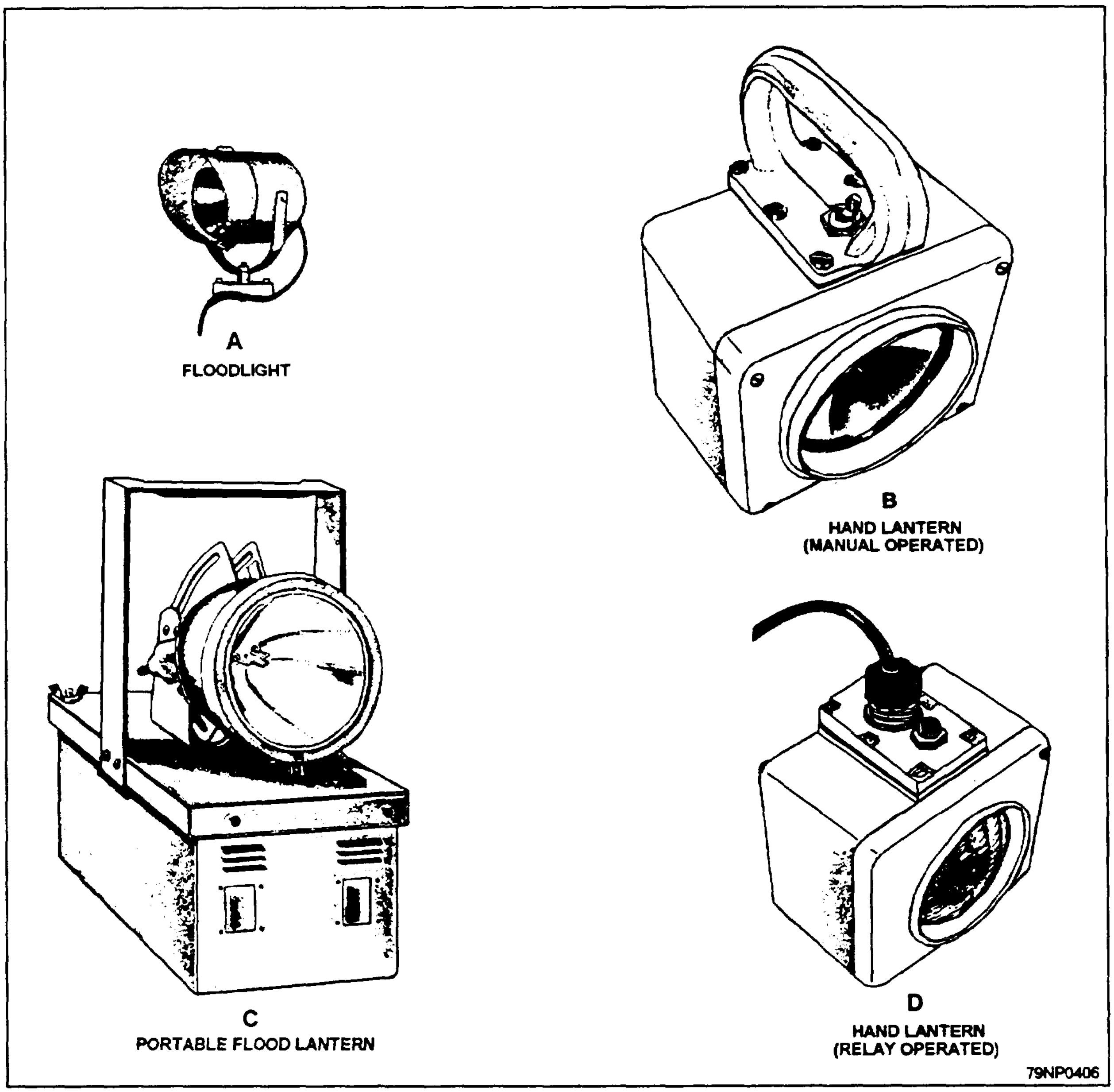


Figure 4-34.—Special lights.

in NAVSEA symbil number order along with the MS or NAVSHIPS drawing number, and NSN.

Floodlights

The white floodlight (fig. 4-34, view A), symbol 300.2, consists of a splashproof housing equipped with a rain-shielded hinged door secured with a latch. The 300-watt lamp is a sealed-beam type. The lamp housing is trunnioned on a yoke, which in turn is mounted on a shock-absorbing base. The light is held in elevation by a clamp on the yoke. Train positioning is accomplished by friction within the shock-absorbing base. Each floodlight is furnished with a three-conductor cable (including a green lead to ground the metal housing) for connecting into a lighting circuit.

Floodlights with 300 watts (symbols 263 and 303), 150 watts (symbol 317), and 200 watts (symbol 69) are also used. Floodlights are installed on weather decks at suitable locations to provide sufficient illumination for the operation of cranes and hoists, and the handling of boats.

Hand Lanterns

Two types of dry battery powered lanterns are available for installation in certain strategic locations to prevent total darkness if all lighting fails. One type is hand operated, while the other is operated automatically by a relay when power to the lighting distribution system fails.

The manually operated portable lantern (fig. 4-34, view B), consists of a watertight plastic case containing two 6-volt batteries connected in parallel. It includes a sealed-beam lamp, rated at 5 volts, but operated at 6 volts (when the batteries are new) to increase the light output. A rigid handle is secured to the top of the case. The lantern is operated by a toggle switch with the lever positioned near the thumb for ease of operation. When the batteries are new, the lantern can be used continuously for about 8 hours before the light output ceases to be useful.

Manually operated lanterns are installed as an emergency source of illumination in spaces that are manned only occasionally. These lanterns are also used in certain areas to supplement the relay-operated lanterns. You should not remove manual] y operated portable lanterns from their compartments unless the compartments are abandoned permanently.

The relay-operated lantern is similar to the manually operated type except the relay housing is mounted on top of the lantern case (fig. 4-34, view D). The 115-volt ac version is identified by symbol 101.2. Symbol 102.2 identifies the 115-volt dc type. A three-conductor cable (including a green conductor to ground the relay metal frame) is provided for the connection to a lighting circuit. THE RELAY-CONTROLLED LANTERN MUST ALWAYS BE INSTALLED WITH THE RELAY UPRIGHT. This specific arrangement of the relay prevents a fire hazard, caused by a chemical action of the electrolytic paste leaking from the battery case to the relay housing as the battery is being discharged (operated).

Relay-controlled lanterns are installed in spaces where continuous illumination is necessary.

These spaces include essential watch stations, control rooms, machinery spaces and battle dressing stations. The lanterns must illuminate the tops and bottoms of all ladders and all flush-mounted scuttles. They must also be mounted to illuminate all gauges at vital watch stations. Operating personnel will depend on these lanterns for illumination when bringing machinery back on the line after a casualty. These lanterns must not be installed in magazine or powder-handling spaces where fixed or semi-fixed ammunition is handled, or in any location where explosion-proof equipment is installed.

The lantern relay is connected in the lighting circuit (in the space in which the lantern is installed) on the power supply side of the local light switch that controls the lighting in the space concerned. Thus, the relay operates and causes the lamp in the lantern to be energized from its batteries only when a power failure occurs, not when the lighting circuit is de-energized by the light switch. If the space is supplied with both emergency and ship's service lights, the lantern relay is connected to the emergency lighting circuit only.

The lantern relay should be fused so that a short circuit in the relay leads of one compartment will be cleared through low-capacity fuses before the fault causes heavier fuses nearer the source of power to blow and cut off the power supply to lighting circuits in other compartments. The fuses that protect the branch circuits are ample protection for the lantern relay. A lantern relay can be connected directly to the load side of the fixes in fuse boxes or switchboxes. If a relay cannot be connected to a branch circuit, it can be connected to the source side of a fuse box or other point on a submain. If the submain supplies lighting no more than one compartment, separate fuses must be installed in the relay circuit.

The operation of the lantern relays should be checked accroding to PMS requirements. When the circuit is de-energized, the relay should operate and automatically turn on the lantern. The circuit may be de-energized by pressure exerted on the push switch located on the relay housing. This simulates a loss of 115-volt power. The relay should then dropout, causing the lantern to light.

To ensure satisfactory operation of hand lanterns, check the batteries according to PMS schedules. Check the batteries by operating the lantern and observing the brightness of the lamp. If the emitted light is dim, replace the batteries immediately. At this time, check the rubber boot on the switch for tears or cracks. Replace immediately if the boot is defective. Ensure the switch is also grounded to the ship's hull. A simple test with a multimeter will verify this.

Lanterns located in spaces where the normal temperature is consistent] y above 90°F should be checked more often. For example, in boiler rooms the batteries may have to be replaced weekly to ensure adequate illumination from the lanterns.

The NAVSEA symbol number 104 (not shown) dry battery type (hand carrying or head attaching) of lantern is used for damage control purposes. It is generally stored in damage control lockers. This lantern's battery container may be clipped over the wearer's belt; the lamp and reflector assembly can be hand held or worn on the head or helmet for repair party personnel by a headband attached to the light.

Portable Flood Lanterns

The NAVSEA symbol number 105 portable flood lantern (fig. 4-34, view C) consists of a sealed-beam lamp enclosed in a built-in lamp housing equipped with a toggle switch. The lamp housing is adjustable, mounted on a drip-proof, acid-resistant case.

The case has two viewing windows at each end to check the condition of the four Navy-type BB-254/U storage cells. Each cell contains a channeled section in which a green, a white, and a red ball denotes the state of charge of the cell when viewed through the window (table 4-10).

The lamp is rated at 6 volts, but it is operated at 8 volts to increase the light output. When operated with fully charged batteries, the lantern can be operated continuously for about 3 hours without recharging. The batteries should be recharged as soon as possible after the green ball (10 percent discharged) has sunk to the bottom. The lanterns should be ckecked according to PMS requirements; if the batteries require charging, they should be charged at a rate of 1 1/2 to 2 amperes until all indicator balls are floating at the indicator line. If the battery is completely discharged, it will require from 20 to 25 hours to recharge it. After the charging voltage has remained constant at 10 volts for 1 hour, the charge may be discontinued

When necessary, add pure distilled water to keep the electrolyte level at the indicator line marked on the front of the cell. Do not add water above the electrolyte level line because overfilling will nullify the nonspill feature of the battery and may cause the electrolyte to spurt out through the vent tube. However, if the electrolyte level is not at the indicator line, the charge indicator balls will not indicate the correct battery state of charge.

Portable flood lanterns are often referred to as damage control lanterns because they are used by damage control personnel to furnish high-intensity illumination for emergency repair work or to illuminate inaccessible locations below deck.

Submarine Identification Lights

Submarines may display, as a distinctive means of identification, an intermittent flashing amber beacon, visible for 360° around the horizon. The sequence of

Table 4-10.—State of Charge of Portable Flood Lanterns

IF	THEN
All three indicator balls float at the surface of the electrolyte	The cell is fully charged
The green ball sinks	About 10% of the cell capacity has been discharged
The white ball sinks	The cell is 50% discharged
The red ball sinks	The cell is 90% discharged

operation will be one flash per second for 3 seconds followed by a 3-second off period.

SMALL BOAT AND SERVICE CRAFT LIGHTS

On many crafts and small boats that are less than 50 meters (165 feet) in length, a 24-volt dc navigation light system is used. These 24-volt dc lights are spraytight fixtures provided with a 25-watt, single vertical-filament lamp. These fixtures are constructed of polycarbonate material with a built-in metal shield to provide the required arc of visibility. These fixtures are shown in figure 4-35.

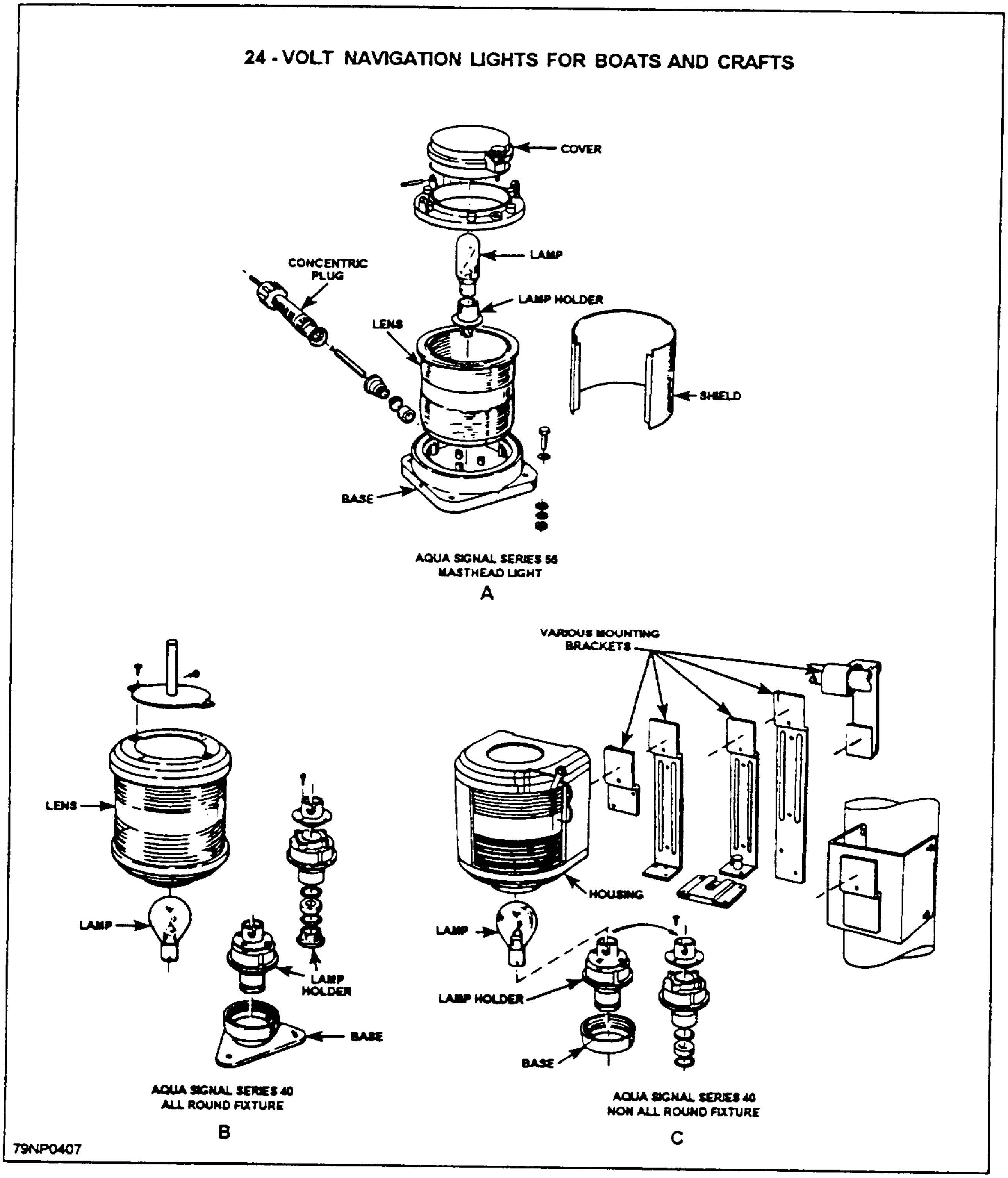


Figure 4-35.—Small boat and service craft lights.

SUMMARY

In this chapter we discussed shipboard lighting systems, light sources, lamps, fixtures, navigation lights, signal lights, searchlights, and their operation and maintenance. For a more thorough description of the material discussed, refer to *Lighting on Naval Ships,* NAVSEA publication 0964-000-2000, and *NSTM,* chapters 300, 320, 330,422, and 583.

CHAPTER 5

ELECTRICAL AUXILIARIES

Electrician's Mates (EMs) are required to maintain various types of electrical equipment aboard ship. This chapter will introduce you to the operating principles of some of the most widely used types of auxiliary equipment and describe methods and procedures for operating and maintaining them.

LEARNING OBJECTIVES

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

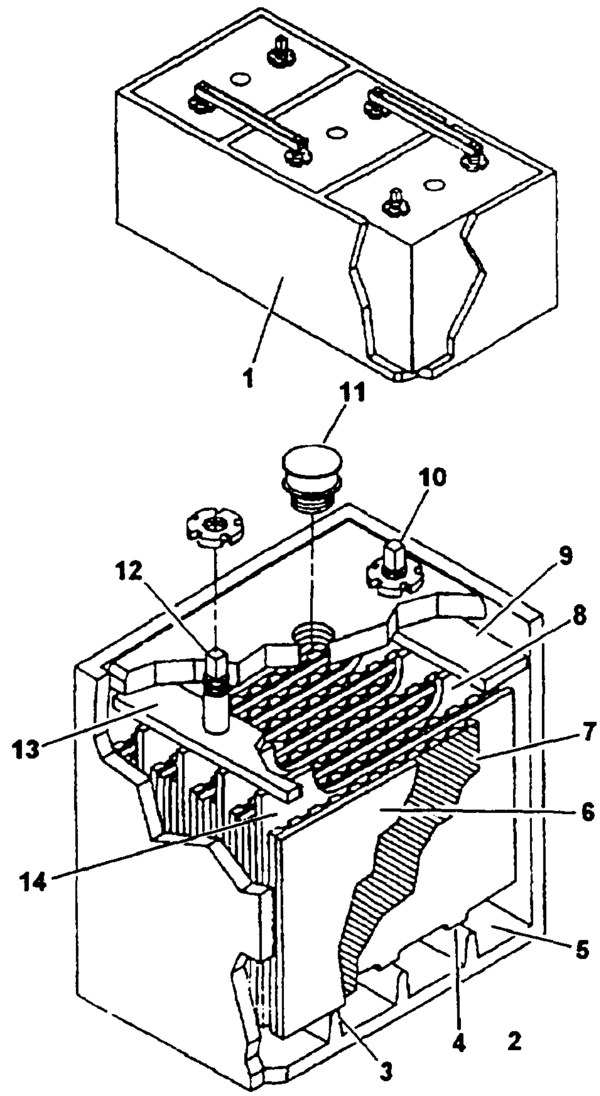
1. *Identify proper use and care of dc systems including batteries, battery chargers, and small craft starting system.*
2. *Identify the operating characteristics and procedures for maintaining air conditioning, refrigeration, and air compressor units.*
3. *Identify the care of and the maintenance procedures for vent fog precipitators.*
4. *Identify the proper operating and maintenance procedures for various deck equipment.*
5. *Identify proper operating and troubleshooting techniques for maintaining electrohydraulic elevators and steering gears.*
6. *Identify the operating characteristics of various galley and laundry equipment.*

STORAGE BATTERIES

Lead-acid storage batteries provide a cheap, portable, rechargeable source of dc power. Batteries have many uses including starting small boat engines and acting as a source of backup power for the ship's gyro. The battery also functions as a voltage stabilizer in the small craft electrical system and supplies electrical power for a limited time when the electrical load exceeds the output of the boat's generator.

CONSTRUCTION

No matter the number of cells, lead-acid batteries used in the Navy are basically the same in construction and operation. The following components make up a typical lead-acid storage battery (fig. 5-1).



1. Jar (monobloc)
2. Cell
3. Element rest or bridge
4. Plate feet
5. Sediment space
6. Separator
7. Rubber retainer (slotted or perforated with glass mat)
8. Negative plate
9. Negative plate strap
10. Negative terminal post
11. Vent plug (vented) or safety valve (sealed)
12. Positive terminal post
13. Positive plate strap
14. Positive plate

Figure 5-1.—Three-cell (6V) lead-acid battery.

1. Jar (monobloc). A container of suitable material in which a single cell is assembled

2. Cell. A unit consisting of positive and negative plates, separators, a cell cover, and electrolyte, properly assembled in a jar or one compartment of a monobloc case.

3. Element rest (bridge). The top surface of the raised ribs forming the sediment spaces serves as the base upon which the elements rest.

4. Plate feet. Projections at the bottom of the plates (containing no active material). They serve as the point of contact between the elements and the bridge, or rest.

5. Sediment space. A space formed by raised ribs built into the bottom of a battery jar or monobloc case. This space serves as a receptacle for residue from the element plates and separators. The residue is due to deterioration caused by the chemical action between the electrolyte and the plates across the separators. The raised ribs also serve as baffles, preventing short circuits between the negative and positive plates by keeping the sediment from building up in any one area.

6. Separator. Spacers placed between positive and negative plates to prevent short circuiting. They maybe made of wood or microporous rubber.

7. Rubber retainer. Sheets of suitable, nonconductive material are used in conjunction with the separators to help hold the active material of the positive plates in place and to protect the separator from the action of the positive material. They may be made of hard rubber or synthetic compounds, perforated or slotted to allow free flow of the electrolyte.

8. Negative plate. One of the elements that makes up the negative group of a battery. Consists of a plate of pure sponge lead (Pb) placed in a cell and submersed in electrolyte.

9. Negative plate strap. A piece of conductive material used to connect all the negative plates to a common post through the top of the battery.

10. Negative terminal post. One of the two lead posts that protrude through the top of the battery. The point at which the negative terminal connection is made to the external circuit.

11. Vent plug (vented) or safety valve (sealed). In a vented battery, a threaded plug of suitable material with a vent hole is used to prevent electrolyte from splashing out of the cell but still allow gases to escape. Sealed batteries use a one-way pressure valve to prevent atmospheric oxygen from entering the battery. The valve allows small quantities of gas to escape when the internal pressure exceeds the valve operating pressure.

12. Positive terminal post. One of the two lead posts that protrude through the top of the battery. The point at which the positive terminal connection is made to the external circuit.

13. Positive plate strap. A piece of conductive material used to connect all the positive plates to a common post through the top of the battery.

14. Positive plate. One of the elements that makes up the positive group of a battery. Consists of a plate of lead peroxide, PbO_2 placed in a cell and submersed in electrolyte.

SPECIFIC GRAVITY

The specific gravity of a liquid is the ratio of the weight of a certain volume of liquid to the weight of the same volume of water is called the specific gravity of the liquid Mathematically, this can be expressed as follows:

$$sp.gr. = \frac{W_{sample}}{W_{water}}$$

Where:

sp.gr. is the specific gravity

W_{sample} is the weight of a volume of the sample being measured

W_{water} is the weight of the same volume of pure water

The specific gravity of pure water is, by definition, 1.000. Sulfuric acid has a specific gravity of 1.830; therefore, sulfuric acid is 1.830 times as heavy as water. The specific gravity of a mixture of sulfuric acid and water varies with the strength of the solution from 1.000 (pure water) to 1.830 (pure acid).

The electrolyte that is usually placed in a lead-acid battery has a specific gravity of 1.350 or less. Generally, the specific gravity of the electrolyte in standard storage batteries (table 5-1) is adjusted between 1.210 and 1.220. However, the specific gravity of the electrolyte in batteries varies according to their intended use.

Table 5-1.—Specific Gravity Range of Batteries

Use	Specific Gravity (low)	Specific Gravity (high)
Surface Ships	1.210	1.220
Submarines	1.250	1.285
Aircraft	1.285	1.300

Hydrometer

As a storage battery discharges, the sulfuric acid is depleted and the electrolyte is gradually converted into water. This action provides a guide in determining the state of discharge of the lead-acid cell.

The specific gravity of the electrolyte in a lead-acid battery is measured with a hydrometer. In the syringe type of hydrometer (fig. 5-2), part of the battery electrolyte is drawn up into a glass tube by a rubber bulb at the top.

The hydrometer float has a hollow glass tube weighted at one end and sealed at both ends. A scale, calibrated in specific gravity, is laid off axially along the body (stem) of the tube. The hydrometer float is placed inside the glass syringe, and the electrolyte to be tested is drawn up into the syringe. This immerses the hydrometer float into the solution. When the syringe is held approximately in a vertical position, the hydrometer float will sink to a certain level in the electrolyte. The extent to which the hydrometer stem protrudes above the level of the liquid depends on the specific gravity of the solution. The reading on the stem at the surface of the liquid is the specific gravity of the electrolyte in the syringe.

The Navy uses two types of hydrometer bulbs, or floats, each having a different scale. The type-A hydrometer is used with submarine batteries and has three different floats with scales from 1.060 to 1.240, 1.200 to 1.280, and 1.228 to 1.316. The type-B hydrometer is used with portable storage batteries and aircraft batteries. It has a scale from 1.100 to 1.300. The electrolyte in a cell should be at the normal level when the reading is taken. If the level is below normal, not enough fluid will be drawn into the tube to cause the float to rise. If the level is above normal, the electrolyte will be weakened and the reading will be too low. If a hydrometer reading is taken immediately after water is added, the reading will be inaccurate because the water tends to remain at the top of the cell. When water is added, the battery should be charged for at least 1 hour to mix the electrolyte before a hydrometer reading is taken.

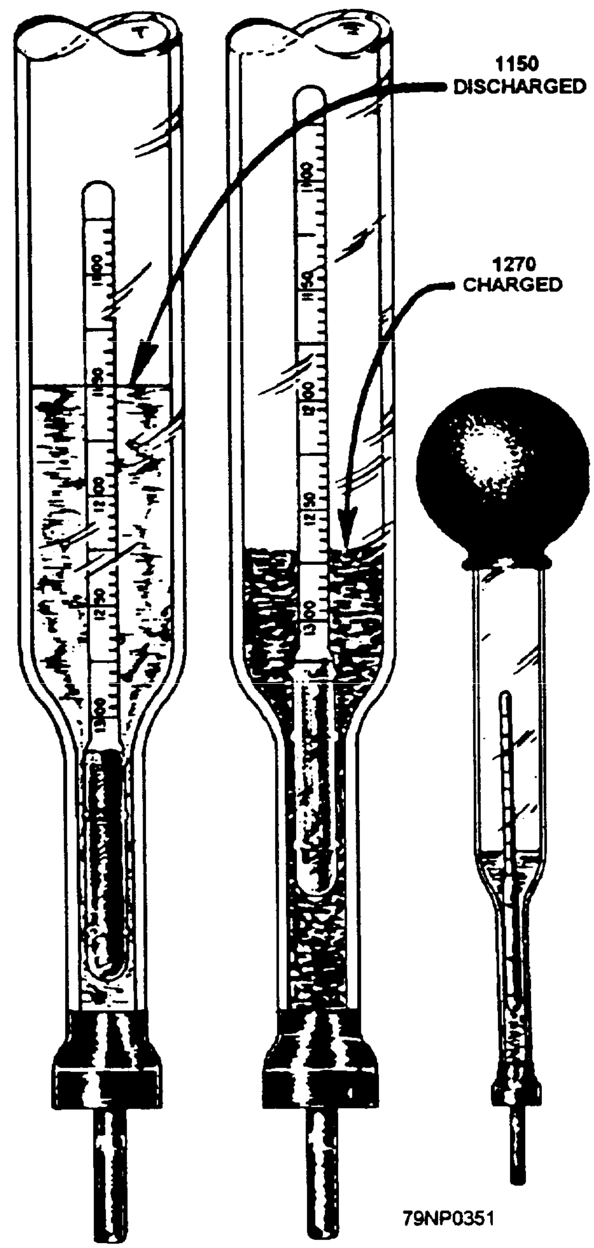


Figure 5-2.—Type-B hydrometer.

> **CAUTION**
>
> Flush hydrometers daily with fresh water to prevent inaccurate readings. Do not use storage battery hydrometers for any other purpose.

Correcting Specific Gravity

The specific gravity of the electrolyte is affected by its temperature. When the electrolyte is heated, it expands and becomes less dense, and its specific gravity reading is lowered. When the electrolyte is cooled, it contracts and becomes denser, and its specific gravity reading is raised. In both cases, the electrolyte maybe from the same fully charged storage cell. As you can see, temperature can distort the readings.

Most standard storage batteries use 80°F as the normal temperature to which specific gravity readings are corrected. To correct the specific gravity reading of a storage battery, add 1 point to the reading for each 3°F above 80°F and subtract 1 point for each 3°F below 80°F.

Adjusting Specific Gravity

Only authorized personnel should add acid to a battery. **Never add acid with a specific gravity above 1350 to a battery.**

If the specific gravity of a cell is more than it should be, you can reduce it to within limits by removing some of the electrolyte and adding distilled water, Charge the battery for 1 hour to mix the solution. Then take the hydrometer readings. Continue the adjustment until you obtain the desired true readings.

Mixing Electrolyte

The electrolyte of a fully charged battery usually contains about 38 percent sulfuric acid by weight or about 27 percent by volume. In preparing the electrolyte, use distilled water and sulfuric acid. New batteries may be delivered with containers of concentrated sulfuric acid of 1.830 specific gravity or electrolyte of 1.400 specific gravity. You must dilute both of these with distilled water to make electrolyte of the proper specific gravity. For diluting the acid, you should use a container made of glass, earthenware, tubber, or lead When mixing electrolyte, **ALWAYS POUR ACID INTO WATER—** never pour water into acid. Pour the acid slowly and cautious] y to prevent excessive heating and splashing. Stir the solution continuously with a nonmetallic rod to mix the heavier acid with the lighter water to keep the acid from sinking to the bottom. When concentrated acid is diluted, the solution becomes very hot.

NOTE: Only use and store premixed electrolyte on U.S. Navy ships. The use and storage of acid for the purpose of preparing electrolyte or for the adjustment of specific gravity are authorized only for shore activities or for ships designated as intermediate maintenance activities (IMAs).

CAPACITY OF BATTERIES

The capacity of a battery is measured in ampere-hours. The ampere-hour capacity is equal to the product of the current in amperes and the time in hours, during which the battery is supplying this current. The ampere-hour capacity varies inversely with the discharge current. The size of a cell is determined generally by its ampere-hour capacity. The capacity of a cell depends upon many factors, the most important of these are as follows:

- The area of the plates in contact with the electrolyte
- The quantity and specific gravity of the electrolyte
- The type of separators
- The general condition of the battery (degree of sulfating, plates buckled, separators warped, sediment in bottom of cells, etc.)
- The final limiting voltage

STORAGE BATTERY RATING

Storage batteries are rated according to their rate of discharge and ampere-hour capacity. Most batteries (except aircraft and some used for radio and sound systems) are rated according to a 1 10-hour rate of discharge—that is, if a fully charged battery is completely discharged during a 10-hour period, it is discharged at the 10-hour rate. For example, if a battery can deliver 20 amperes continuous y for 10 hours, the battery has a rating of 20 x 10, or 200 ampere-hours. Thus the 10-hour rating is equal to the average current that a battery is capable of supplying without interruption for an interval of 10 hours. **(NOTE:** Aircraft batteries are rated according to a 1-hour rate of discharge.) Some other ampere-hour ratings used are 6-hour and 20-hour ratings.

All standard batteries deliver 100 percent of their available capacity if discharged in 10 hours or more, but they will deliver less than their available capacity if discharged at a faster rate. The faster they discharge, the less ampere-hour capacity they have.

As specified by the manufacturer, the low-voltage limit is the limit beyond which very little useful energy can be obtained from a battery. For example, at the conclusion of a lo-hour discharge test on a battery, the closed-circuit voltmeter reading is about 1.75 volts per cell and the specific gravity of the electrolyte is about

1.060. At the end of a charge, its closed-circuit voltmeter reading while the battery is being charged at the finishing rate is between 2.4 and 2.6 volts per cell. The specific gravity of the electrolyte corrected to 80°F is between 1.210 and 1.220. In climates where the temperature is 40°F and below, authority may be granted to increase the specific gravity to 1.280.

STATE OF CHARGE OF BATTERIES

After a battery is discharged completely from full charge at the lo-hour rate, the specific gravity has dropped about 150 points to about 1.060. You can determine the number of points the specific gravity drops per ampere-hour for each type of battery. For each ampere-hour taken out of a battery, a definite amount of acid is removed from the electrolyte and is combined with the plates. For example:

IF	THEN
You know the reduction in specific gravity per ampere-hour.	You can predict the drop in specific gravity for this battery for any number of ampere-hours delivered to a load.
1. A battery is discharged from full charge to the low-voltage limit at the 10-hour rate, and 2. 100 ampere-hours are obtained with a specific gravity drop of 150 points.	There is a drop of 150/100 or 1.5 points per ampere-hour delivered.

For example, if 70 ampere-hours are delivered by the battery at the 10-hour rate or any other rate or collection of rates, the drop in specific gravity is 70 x 1.5, or 105 points.

Conversely,

IF	THEN
The drop in specific gravity per ampere-hour and the total drop in specific gravity are known.	You can determine the ampere-hours delivered by a battery.

For example, if the specific gravity of the previously considered battery is 1.210 when the battery is fully charged and 1.150 when it is partly discharged, the drop in specific gravity is between 1.210 and 1.150, or 60 points. The number of ampere-hours taken out of the battery is 60/1.5, or 40 ampere-hours. You can determine the number of ampere-hours expended in any battery discharge by using the following items:

1. The specific gravity when the battery is fully charged
2. The specific gravity after the battery has been dischargd
3. The reduction in specific gravity per ampere-hour

Voltage alone is not a reliable indication of the state of charge of a battery, except when the voltage is near the low-voltage limit on discharge. During discharge, the voltage falls. The higher the rate of discharge, the lower the terminal voltage. Open-circuit voltage is of little value because the variation between full charge and complete discharge is so small—only about 0.1 volt per cell. However, abnormally low voltage does indicate injurious sulfation or some other serious deterioration of the plates.

TYPES OF BATTERY CHARGES

The following types of charges maybe given to a storage battery, depending upon the condition of the battery:

- Initial charge
- Normal charge
- Equalizing charge
- Floating charge
- Emergency charge

Battery Initial Charge

When anew battery is shipped dry, the plates are in an uncharged condition. After the electrolyte has been added, you must convert the plates into the charged condition. You can accomplish this by giving the batter y a long, low-rate initial charge. The charge is given according to the manufacturer's instructions, which are shipped with each battery. If the manufacturer's instructions are not available, refer to the detailed instruction in current directives.

Battery Normal Charge

A normal charge is a routine charge that is given according to the nameplate data during the ordinary cycle of operation to restore the battery to its charged condition. Observe the following steps when giving a normal charge:

1. Determine the starting and finishing rate from the nameplate data.
2. Add water, as necessary, to each cell.
3. Connect the battery to the charging panel and make sure the connections are clean and tight.
4. Turn on the charging circuit and set the current through the battery at the value given as the starting rate.
5. Check the temperature and specific gravity of pilot cells hourly.
6. When the battery begins togas freely, reduce the charging current to the finishing rate.

A normal charge is complete when the specific gravity of the pilot cell, corrected for temperature, is within 5 points (0.005) of the specific gravity obtained on the previous equalizing charge.

Battery Equalizing Charge

An equalizing charge is an extended normal charge at the finishing rate. It is given periodically to ensure all the sulfate is driven from the plates and all the cells are restored to a maximum specific gravity. The equalizing charge is continued until the specific gravity of all cells, connected for temperature, shows no change for a 4-hour period. For an equalizing charge, you must take readings of all cells every half hour.

Battery Floating Charge

You can maintain a battery at full charge by connecting it across a charging source that has a voltage maintained within the limits of 2.13 to 2.17 volts per cell of the battery. In a floating charge, the charging rate is determined by the battery voltage, rather than by a definite current value. The voltage is maintained between 2.13 and 2.17 volts per cell with an average as close to 2.15 volts as possible.

Battery Emergency Charge

An emergency charge is used when you must recharge a battery in the shortest possible time. The charge starts at a much higher rate than is normally used for charging. Use it only in an emergency, as this type of charge may be harmful to the battery.

BATTERY CHARGING RATE

Normally, the charging rate of Navy storage batteries is given on the battery nameplate. If the available charging equipment does not have the desired charging rates, use the nearest available rates. However, never allow the rate to be so high that violent gassing occurs.

CAUTION

Never allow the temperature of the electrolyte in any cell to rise above 125°F (52°C).

BATTERY CHARGING TIME

Continue a charge until the battery is fully charged. Take frequent readings of specific gravity during the charge. Correct these readings to 80°F and compare them with the reading taken before the battery was placed on charge. If the rise in specific gravity in points per ampere-hour is known, the approximate time in hours required to complete the charge is as follows:

$$\frac{\textit{Rise in specific gravity in points to complete charge}}{\textit{Rise in specific gravity in points per ampere-hour} \times \textit{Charging rate in amperes}} = \textit{ChargeTime}_{\textit{hours}}$$

TEST DISCHARGE OF BATTERIES

The test discharge is the best method for you to determine the capacity of a battery. Most battery switchboards are provided with the necessary equipment for you to perform test discharges to batteries. If proper equipment is not available, a tender, a repair ship, or a shore station may perform the test discharge. A battery test discharge is required when one of the following conditions exists:

1. A functional test reveals a low output.
2. One or more cells are found to have less than normal voltage after an equalizing charge.
3. A battery cannot be brought to within 10 points of normal charge of its specific gravity.
4. A battery has been in service 4 years.

Always precede a test discharge by an equalizing charge. Immediately after the equalizing charge, discharge the battery at its 10-hour rate until the total battery voltage drops to a value equal to 1.75 times the number of cells in series or the voltage of any individual cell drops to 1.65 volts. Keep the rate of discharge constant throughout the test discharge. Because standard batteries are rated at the 10-hour capacity, the discharge rate for a 100 ampere-hour battery is 100/10, or 10 ampres. If the temperature of the electrolyte at the beginning of the charge is not exactly 80°F, correct the time duration of the discharge for the actual temperature of the battery.

A battery at 100 percent capacity discharges at its 10-hour rate for 10 hours before reaching its low-voltage limit. If the battery or one of its cells reaches the low-voltage limit before the 10-hour period has elapsed, discontinue the discharge immediately and determine the percentage of capacity using the following equation:

$$C = \frac{H_a}{H_t} \times 100$$

Where:

C = percentage of ampere hour capacity available

H_a = total hours of discharge

H_t = total hours for 100 percent capacity

For example, a 100-ampere-hour, 6-volt battery delivers an average current of 10 amperes for 10 hours. At the end of this period, the battery voltage is 5.25 volts. On a later test, the same battery delivers an average current of 10 amperes for only 7 hours. The discharge was stopped at the end of this time because the voltage of the middle cell was found to be only 1.65 volts. The percentage of capacity of the battery is now 7/10 x 100, or 70 percent. Thus the ampere-hour capacity of this battery is reduced to 0.7 x 100 = 70 ampere-hours.

Record the date for each test discharge on the storage battery record sheet.

BATTERY GASSING

When a battery is being charged, a portion of the energy is dissipated in the electrolysis of the water in the electrolyte. Hydrogen is released at the negative plates and oxygen at the positive plates. These gases bubble up through the electrolyte and collect in the air space at the top of the cell. If violent gassing occurs when the battery is first placed on charge, the charging rate is too high. If the rate is not too high, steady gassing, which develops as the charging proceeds, indicates that the battery is nearing a fully charged condition.

WARNING

A mixture of hydrogen and air can be dangerously explosive. Do not permit smoking, electric sparks, or open flames near charging batteries.

TREATMENT OF ACID BURNS

If acid or electrolyte from a lead-acid battery comes into contact with the skin, wash the affected area as soon as possible with large quantities of fresh water. Afterwards, apply a salve, such as petrolatum, boric acid, or zinc ointment. If none of these salves are available, clean lubricating oil will suffice. When you wash the area, use large amounts of water. A small amount of water might do more harm than good and spread the acid burn. You can neutralize acid spilled on clothing with diluted ammonia or a solution of baking soda and water.

SUMMARY

The information included in this section is an introduction to the operation and use of lead-acid storage batteries aboard ship. For in-depth coverage, you should refer to Naval Ships' Technical Manual, chapter 313.

BATTERY CHARGERS

The U.S. Navy uses numerous types and styles of battery chargers. A battery charger is designed to replace the electrical energy a lead-acid storage battery has consumed (lost) while being used. The battery charger is essentially a regulated, constant supply with adjustable outputs, current, and voltage. The battery charger discussed in this chapter is the 24-302-BN-1 Battery Charger.

DESCRIPTION OF THE 24-302-BN-1 BATTERY CHARGER

The model 24-302-BN-1 battery charger is designed to operate with an input voltage of 115 volts ac ±5 percent, at 60 Hz ±5 percent, single-phase, 20 amperes. The output is determined by the number of cells selected to be charged (3, 4, 6, 12, or 18) and the current rating selected (2, 8, 15, or 30 amperes).

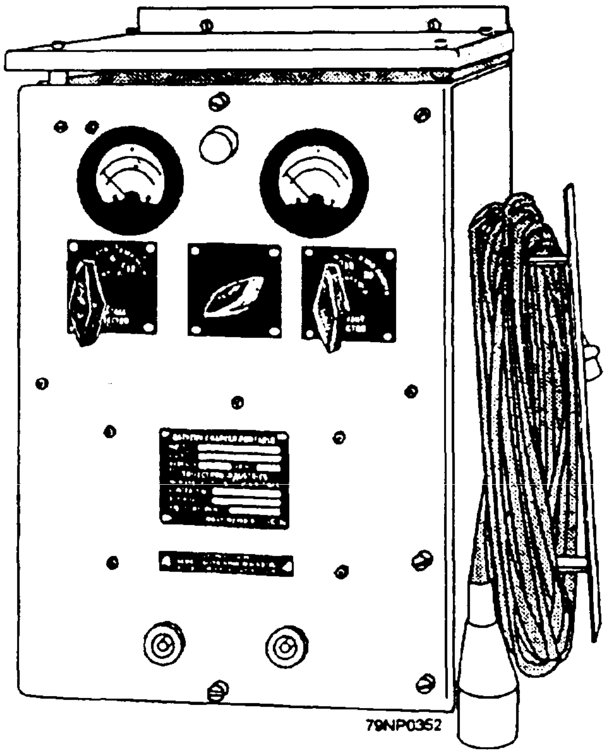


Figure 5-3.—Front view of Battery charger, model 24-302-BN-1.

The battery charger shown in figure 5-3 has a single unit enclosed in a dripproof enclosure. All parts are accessible through the front hinged panel. The output connections (jacks) for the cables to be cm.netted to the batteries are located on the lower front of the panel. The only moving parts of this charger are the adjustable resistors, the rheostats, and the meters.

This type of battery charger has three selector switches on the front panel. The output voltage is selected by the voltage selector switch located on the upper left side; the current selector switch is located on the upper right side; the on/off selector switch is in the middle between the voltage and current selector switches.

OPERATION OF THE 24-302-BN-1 BATTERY CHARGER

The control and regulation is accomplished with SCRs and associated circuitry. Figure 5-4 is a wiring diagram of the battery charger. Please refer to this diagram as you read about the operation of the battery charger.

The first step you must take is to select the number of cells to be charged. To do this, place the voltage selector switch (S3) in the respective position (3, 4, 6, 12, or 18). Then select the current rating to be used during charging with the current selector switch

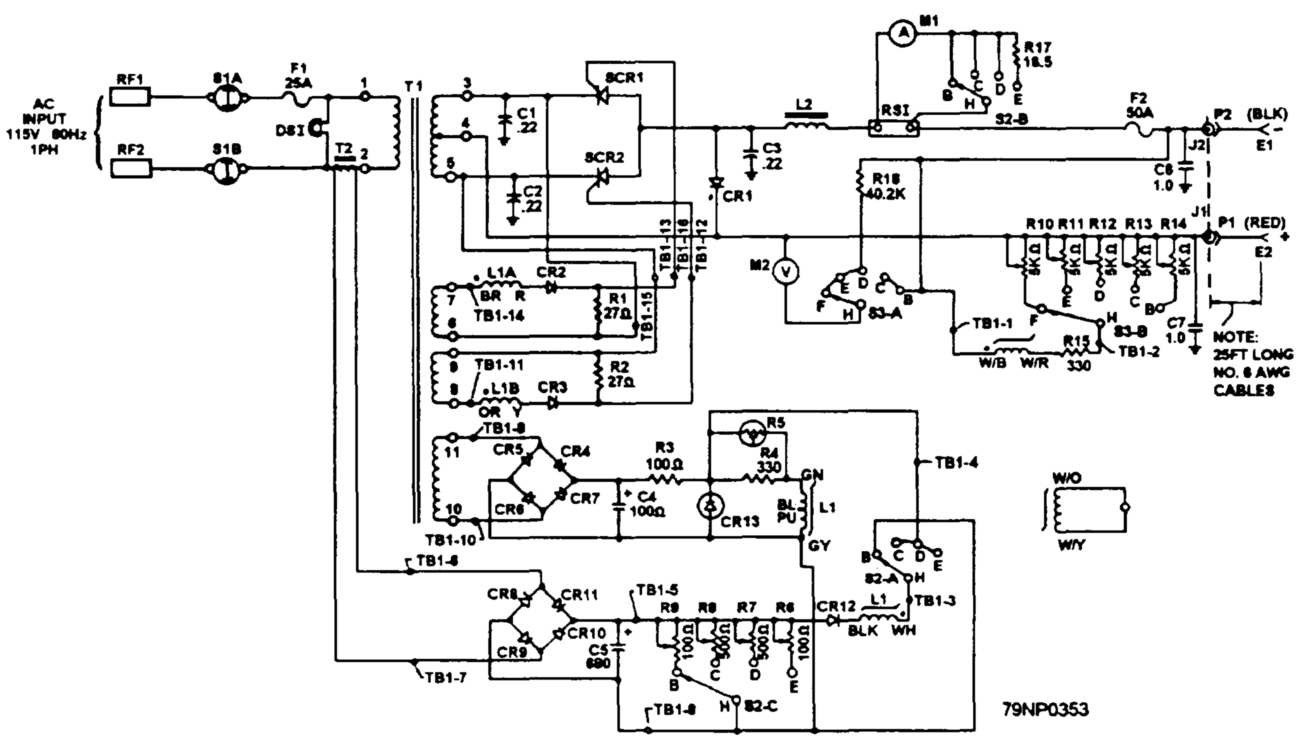


Figure 5-4—Battery charger wiring diagram.

(S2) in the respective position (2, 8, 15, or 30 amperes).

Energize the battery charger by placing the selector switch (S1) in the ON position. This will cause the SCRs to conduct during a portion of the input cycle of the step-down transformer (T1). The amount of conduction of the SCRs is controlled by the feedback signals fed from the magnetic amplifier (L1). This will establish a fixed voltage reference across the Zener diode (CR13) through the control coil (L1), the linear resistor (R4), and the temperature compensating resistor (R5). The R5 resistor serves to change the preset output voltage during temperature changes by changing the current through the L1 control coil. The negative feedback is fed to the L1 coil through the resistors (R10 through R15) and the selector switch (S3B). The current transformer (T2) output is determined by the resistors (R6 through R9) through the selector switch (S2), which will determine the voltage across the capacitor (C5) and the current through transformer T2. When the output current exceeds the selected breakover voltage of the reference Zener diode (CR13), the current flowing through the control coil of L1 from the black to white leads is in such a direction as to oppose the reference voltage. 'Ibis will lower the output voltage until the excess current of the transformer (T2) is accepted by the battery on charge and starts to recharge.

The shorted winding of the reactor (L1) connected to leads white/orange and white/yellow allows for the circulation of the harmonic currents and slows the respoonse time of the output of the magnetic amplifier to changes in the control signals. This increases stability against transient signals generated by the ac supply and the firing of the SCRs.

The choke filter (L2) reduces the ripple of the dc output caused when the SCRs fire.

The battery chargers in use today must meet specification MIL-C-24095B. These battery chargers can charge 1 to 18 cells and have a maximum current limit of 45 amperes.

SUMMARY

The discussion about the model 24-302-BN-1 battery charger introduced you to the various components that make up the battery charger. Also covered was the functions of the charger. Maintenance on this equipment should be accomplished according to the prescribed instructions from the manufacturer and installed PMS procedures.

SMALL CRAFT ELECTRICAL SYSTEMS

Small craft perform an important function in the daily routines of all naval vessels. When their parent ships are at sea, they serve as duty lifeboats and also as troop carriers or assault boats. In port, they are used for transporting stores and liberty parties and for conducting other ship's business. Most small craft are driven by a diesel engine.

The electrical system covered here is representative of those found on a large number of ship's boats and small craft. The electrical system consists of the engine starting system and the battery charging system.

ENGINE STARTING SYSTEM

The engine starting system on small boats is equipped with storage batteries (previously discussed), a starting motor, and control circuitry.

Starting Motor

The starting, or cranking, motor is slow-voltage, dc series motor used to start internal combustion engines by rotating the crankshafts. It is flange-mounted on the engine flywheel housing and is supplied with current from the battery. All starting motors are similar in design and consist essentially of a frame, armature, brushes, field windings, and drive mechanism. The armature shaft is supported on bronze bearings equipped with wick oilers. The number of field poles and brushes varies according to the cranking requirements and the operating voltage.

The starting motor has low resistance; it is designed to operate under heavy load with relatively high horsepower for short periods of time. The high horsepower is accompanied by a high current that creates considerable heat and, if operated for any considerable length of time, will result in failure of the motor due to overheating. Hence the starting motor must be operated for not more than 30 seconds at a time and at about 2-minute intervals to allow the heat to dissipate. The starting current on most small boats is over 600 amperes.

The starting motor is equipped with an overrunning clutch drive mechanism (fig. 5-5) that transmits the power from the motor to the engine. The drive mechanism performs the following functions:

1. Engages the drive pinion with the flywheel for cranking the engine. When the starting motor is operated, the drive mechanism causes the drive pinion to mesh with the teeth of the flywheel ring gear, thereby cranking the engine.
2. Provides a gear reduction between the drive pinion and the flywheel. The gear reduction is necessary because the starting motor must rotate at a relatively high speed with respect to the engine cranking speed to produce sufficient output power to crank the engine. Thus a gear reduction ratio of 15 to 1 will permit the starting motor to rotate at 1,500 rpm while cranking the engine at 100 rpm.
3. Disengages the drive pinion and the flywheel after the engine is started As soon as the engine is started, the drive mechanism causes the drive pinion to disengage from the flywheel. The engine speed increases immediately and may soon attain speeds up to 1,000 rpm. If the drive pinion is allowed to remain in mesh with the flywheel, the engine would drive the starting motor at speeds up to 15,000 rpm, resulting in serious damage to the motor.

The overrunning clutch drive starting motor provides positive engaging and disengaging of the starting motor drive pinion and the flywheel ring gear. This drive mechanism uses a shift lever that slides the clutch and drive pinion assembly along the armature shaft so that it can be engaged and disengaged with the flywheel ring gear. The clutch transmits cranking torque from the starting motor to the engine flywheel but permits the pinion to overrun the armature after the engine starts. Thus power can be transmitted through the overrunning clutch in only one direction. This action protects the starting motor from excessive speed during the brief interval that the drive pinion remains with the flywheel ring gear after the engine has started.

When the shift lever is operated, the clutch assembly is moved along the armature shaft until the pinion engages with the flywheel ring gear. The starting-motor contacts are closed when the movement of the shift lever is completed, causing the armature to rotate, and thereby cranking the engine.

Once the engine has started the speed of rotation of the engine flywheel causes the pinion to spin faster than the armature of the starting motor. This action causes the pinion to spin independently or overrun. When the starting-motor switch is opened, the shift lever releases, causing the drive spring to pull the overrunning clutch drive pinion out of engagement with the engine flywheel ring gear.

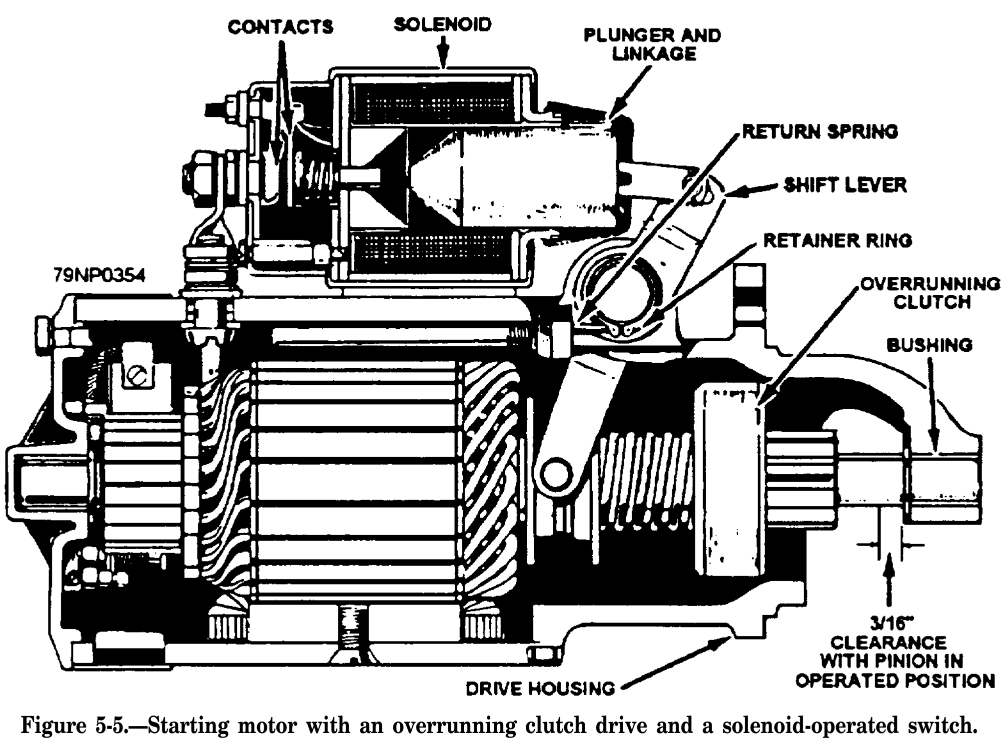


Figure 5-5.—Starting motor with an overrunning clutch drive and a solenoid-operated switch.

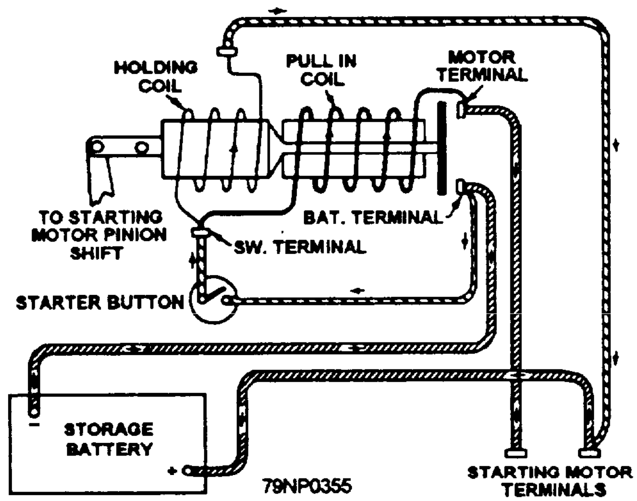


Figure 5-6.—Solenoid switch diagram.

Control Circuitry

The solenoid shown in figures 5-5 and 5-6 is used on some starting motors equipped with overrunning clutch drives to close the circuit to the starting motor and also to engage the pinion with the flywheel ring gear. It is mounted on the motor frame, as shown in figure 5-5, and has a pull-in coil and a holding coil provided with a spring-loaded plunger. A heavy contact disk is attached to one end of the plunger, and the other end is connected by linkage to the shift lever. Both coils are connected in series with a starter switch located on the instrument panel (fig. 5-6). When the starter switch is operated, both coils are energized (from the battery) and the plunger is pulled so that the pinion engages with the flywheel ring gear. The pull-in coil draws a comparatively heavy current necessary to complete the plunger movement. The holding coil aids the pull-in coil. Continuation of the plunger movement closes the switch contacts, permitting the starter motor to crank the engine. As soon as the solenoid switch is closed (and the pinion shifted), the pull-in coil is shorted by the switch contacts in the starting-motor circuit so that only the holding coil is energized to retain the plunger in the operated position.

When the starter switch is released, the tension of the return spring in the drive assembly actuates the plunger to open the circuit to the starting motor.

BATTERY CHARGING SYSTEM

For you to maintain the battery in a fully charged condition, the discharge current must be balanced by a charging current supplied from an external source, such as a battery-charging alternator. If the discharge current exceeds the charging current for an appreciable period, the battery will gradually lose its charge. It will not be able to supply the necessary current to the electrical system.

A belt-driven alternator is used on small boats and service crafts. The alternator has several advantages over the dc generator. It is smaller in size, requires less maintenance, and supplies charging current at idling speed.

A typical alternator electrical system wiring diagram is shown in figure 5-7. The three-phase ac

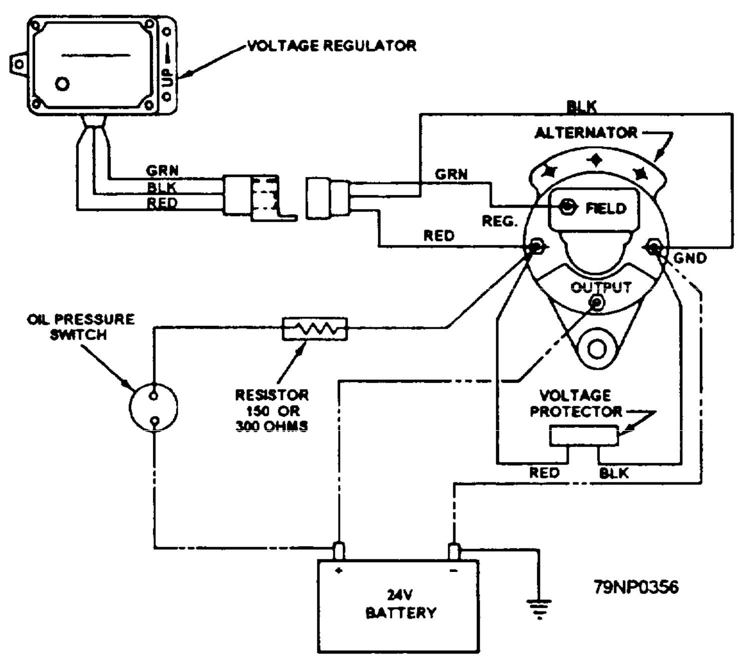


Figure 5-7.—A typical alternator electrical system wiring diagram.

output of the stator is fed to a rectifier bridge consisting of six silicon diodes, which are normally located in the end bell of the alternator. The rotor of the alternator has one coil and two 6-finger rotor halves. In effect, it is a 12-pole rotor. Direct current (for field excitation) is supplied to the rotor coil through a pair of brushes and slip rings. The rectifying diodes will pass current from the alternator to the battery or load but will not pass current from the batter y to the alternator.

The voltage regulator is the only device used with the alternator. It can either be built into the case or externally mounted away from the alternator. The voltage regulator uses no mechanical contacts. It uses only a solid-state circuitry, is a sealed unit, and does not require adjustments.

The electrical equipment is designed to operate at a specific voltage irrespective of the speed of the prime mover (engine) and the alternator.

SUMMARY

Small craft are exposed to the most extreme of weather conditions and must, therefore, receive a great deal of attention. Using the information given in the previous section, you should have no problem taking care of the normal maintenance requirements necessary to keep the small craft aboard ship operational.

AIR COMPRESSORS

There are many uses for compressd air aboard ship. Some of these include operating pneumatic tools, ejecting gas from guns, starting diesel engines, charging and firing torpedoes, and operating automatic combustion control systems. Compressed air is supplied to the various systems by low-pressure (LP—150psi or below), medium-pressure (151 to 1,000 psi), or high-pressure (HP—1,000 psi and above) air compressors.

LP AIR COMPRESSOR

Most of the air compressors aboard ship operate on the same principles, electrical requirements, and controls. Therefore, the model discussed is typical of most units installed aboard ship.

The air compressor (fig. 5-8) supplies the air for the ship's LP air system. The air compressor is direct-driven by an electric motor through a flexible coupling. It has a manual and two automatic operating modes (either at the low or high range), an automatic safety shutdown, an on-off control, and local and remote indicators.

The following is a brief description of the compressor controls and indicators shown on figure 5-8.

OIL PRESSURE GAUGE— Measures oil pressure at the oil pump discharge.

WATER INJECTION PRESSURE GAUGE— Indicates the freshwater pressure in the water system manifold downstream of the freshwater falter.

AIR DISCHARGE PRESSURE GAUGE— Indicates the air pressure in the compressed air receiver downstream of the compressor and the dehydrator.

DEW POINT SAMPLING CONNECTION— A suitable instrument can be attached to this connection to measure the moisture content of the compressed air discharging from the dehydrator into the air receiver periodically.

LOCAL/REMOTE/RESET-EMER SHUT-DOWN SELECTOR SWITCH— Gives remote emergent y stop control to the auxiliary control console (ACC) when in the normal REMOTE position. The RESET position is used to reset the control circuitry after a remote shutdown to permit restarting the compressor. The is a spring return from the RESET to LOCAL setting. It is mounted on the controller door.

MANUAL/AUTOMATIC-125 PSIG/AUTO-MATIC-120 PSIG SELECTOR SWITCH— This operating mode selector switch is located on the controller door.

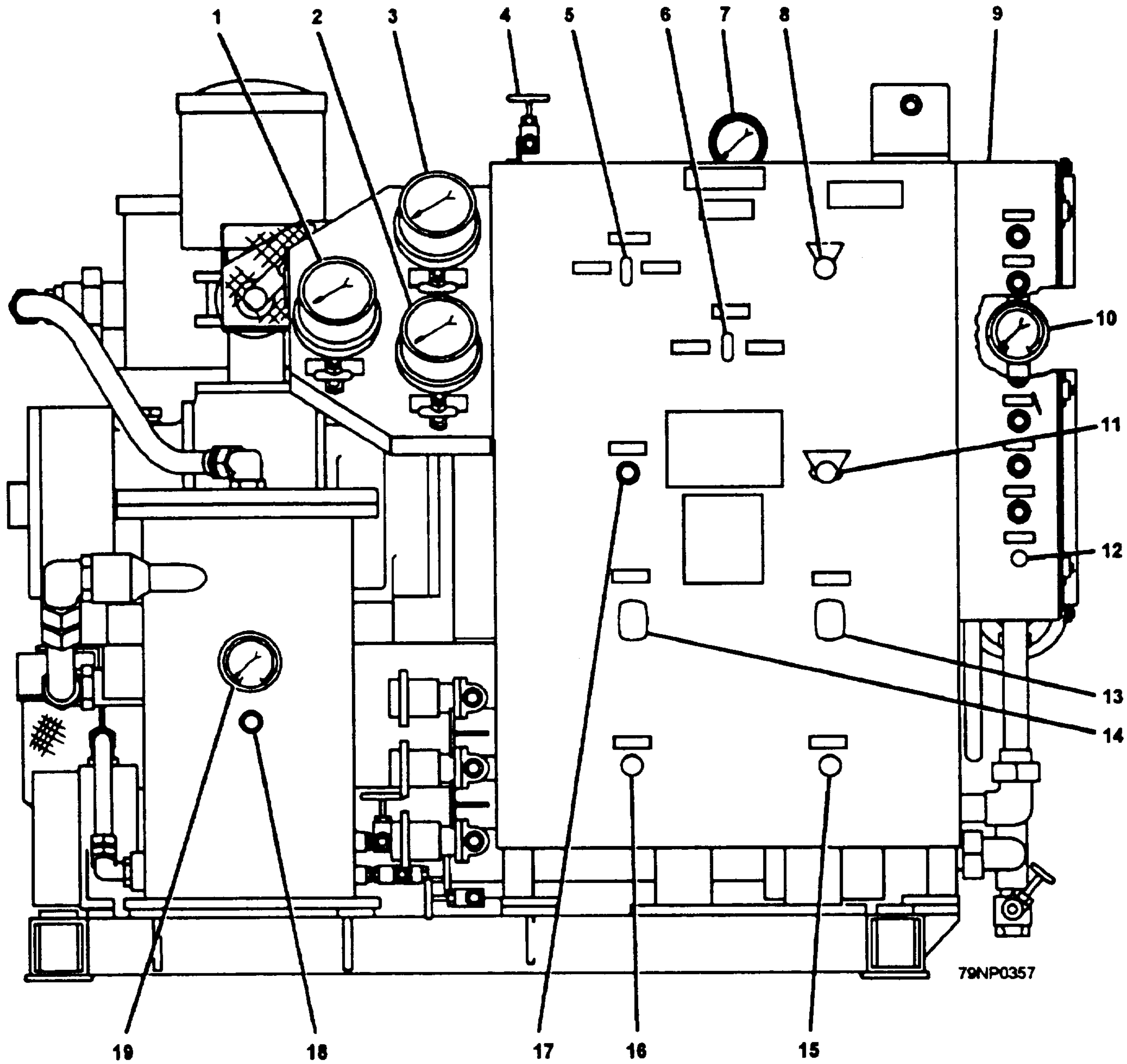
AIR DISCHARGE THERMOMETER— Indicates the compressed air temperature in the air receiver. It is mounted on top of the receiver.

OFF/ON SELECTOR SWITCH— Provides manual start-stop control of the compressor. It is mounted on the controller door.

ANNUNCIATOR PANEL— Shows causes of automatic safety shutdowns using shutdown alarm lamps.

SEAWATER THERMOMETER— Indicates the temperature of the seawater discharging from the compressor cooling system.

SAFETY SHUTDOWN RESET PUSH BUTTON— Resets the control circuitry after an automatic shutdown is initiated by any of the compressor safety devices. If not pressed to reset, the compressor cannot be restarted.



LEGEND

1. OIL PRESSURE GAUGE
2. WATER INJECTION PRESSURE GAUGE
3. AIR DISCHARGE PRESSURE GAUGE
4. DEW POINT SAMPLING CONNECTION
5. LOCAL/ REMOTE/ RESET-EMER SHUTDOWN SELECTOR SWITCH
6. OPERATING MODE SELECTOR SWITCH
7. AIR DISCHARGE THERMOMETER
8. OFF/ ON SELECTOR SWITCH
9. ANNUNCIATOR PANEL
10. SEAWATER THERMOMETER
11. SAFETY SHUTDOWN RESET PUSH BUTTON
12. LAMP TEST PUSH BUTTON
13. LOADED RUNNING TIME METER
14. TOTAL RUNNING TIME METER
15. ENABLE RUNNING LAMP (WHITE)
16. MOTOR RUNNING LAMP (GREEN)
17. OVERLOAD RESET PUSH BUTTON
18. FRESHWATER LEVEL SIGHT HOLE (PLUGGED)
19. COMPRESSOR DISCHARGE THERMOMETER

Figure 5-6.—A typical low pressure air compressor.

LAMP TEST PUSH BUTTON— Checks for burned-out fault indicator lamps. It is located on the annunciator panel.

LOADED RUNNING TIME METER— Records the time in hours that the compressor is operated in a loaded condition.

TOTAL RUNNING TIME METER— Records the total compressor operating time in hours for both loaded and unloaded operating conditions.

ENABLE RUNNING LAMP (WHITE)— Indicates that the compressor is in an operative condition, whether or not the machine is actually running. It is located on the controller door.

MOTOR RUNNING LAMP (GREEN)— Indicates that the compressor is running in either a loaded or unloaded condition. It is located on the controller door.

OVERLOAD RESET PUSH BUTTON— Resets the controller overload relay after an automatic shutdown is caused by a motor overload. If not pressed to reset, the compressor cannot be restarted.

FRESHWATER LEVEL SIGHT HOLE— Allows checks to be made to ensure sufficient water is in the holding tank to permit starting the compressor. The compressor must be shut down and repressurized before the sight hole plug can be removed. It is located in front of the separator-holding tank.

COMPRESSOR DISCHARGE THERMOMETER— Indicates the temperature of the air discharging from the compressor. It is mounted on the separator-holding tank and indicates the air temperature in the separator.

As you read this section, look at the air compressor schematic diagram (fig. 5-9), as the sequence of the manual and automatic modes of operation of the LP air compressor, the injection water level control, the condensate drain control, and the shutdown system are discussed. The numbers/letters in parentheses correspond to the electrical components on the schematic.

Manual Operation

The operator places the controller in the manual mode of operation by positioning the selector switch (1SEL) to the MANUAL position and turning the selector switch (3SEL) to the ON position. This initiates the following sequence:

1. The control relay (SCR) in the low-voltage circuit is energized. The SCR contacts in the high-voltage circuit close, energizing the undervoltage relay (UV). The UV contacts close, lighting the remote ENABLE RUNNING lamp, making power available to the safety shutdown circuits and to the contractors, the relays, the switches, and the solenoids in the high-voltage circuit.

2. When the UV contacts close, the motor contactor (M) is energized. This closes the M contacts in the high-voltage circuit to start the motor. the M contacts in the low-voltage circuit close at the same time, energizing the LOADED RUNNING TIME meter (LHM), the TOTAL RUNNING TIME meter (ETM), both local and remote MOTOR RUNNING lamps, and the dehydrator refrigeration pump motor.

3. The injection water solenoid valve (SV1) and the two timing relays (4TR and 6TR) are energized at the same time as the motor contactor.

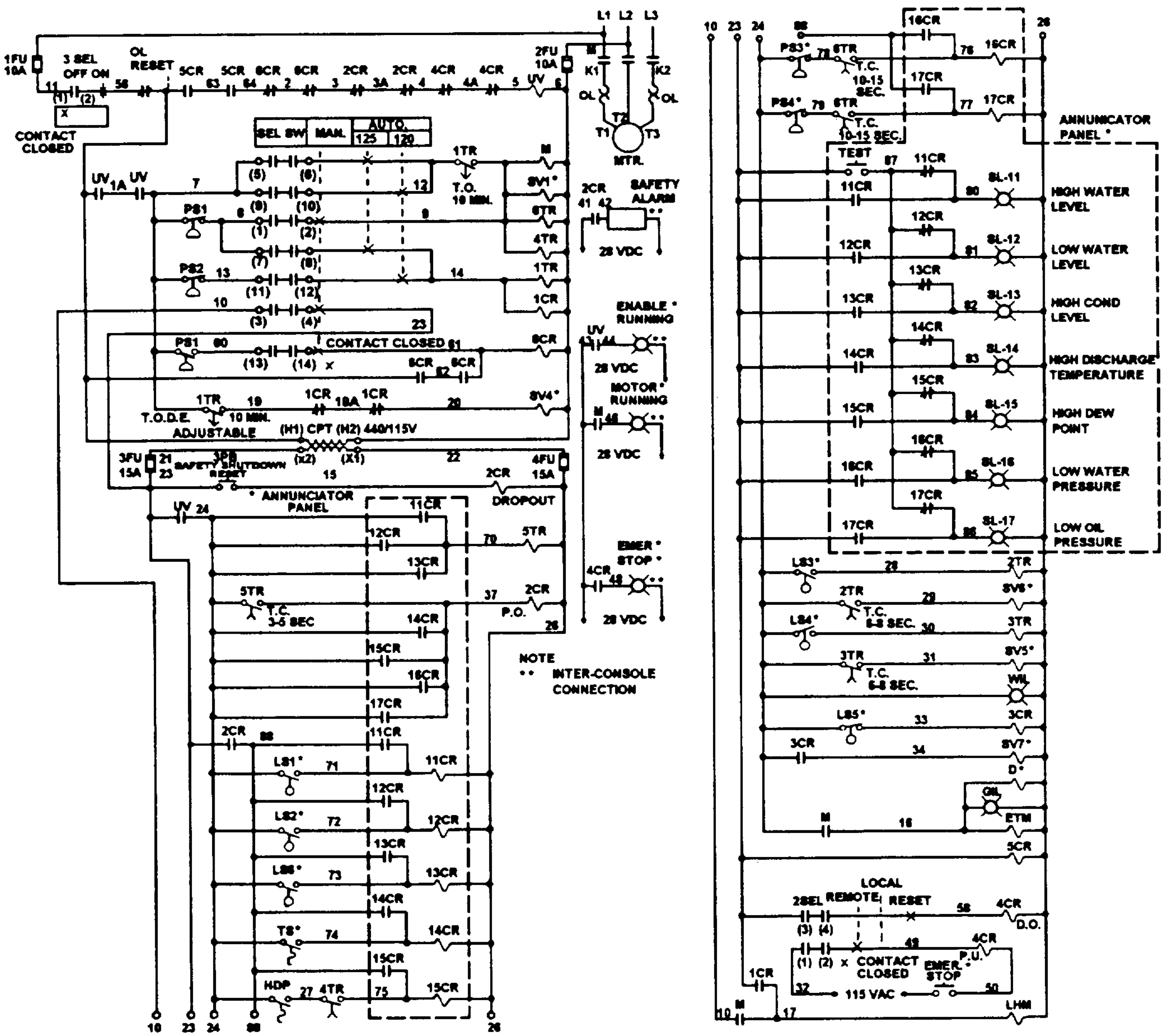
4. Actuation of SV1 opens the valve to permit the flow of injection water. Relay 4TR is a timed-to-close (on-delay) relay that closes 2 minutes after it is energized to make the high dew point temperature switch (HDP) operative in the safety shutdown circuit. Relay 6TR is a timed-to close (on-delay) relay that closes 12 to 15 seconds after it is energized to make the oil pressure and injection water pressure switches (PS4 and PS3) operative in the safety shutdown circuit. (This permits start-up by preventing safety shutdown while the lubricating oil and injection water system pressures build up to normal values.)

5. The compressor is now running fully loaded under control of the receiver air-pressure switch (PS1) and with all control and shutdown circuits operative.

NOTE: The motor will not start when the selector switch (3SEL) is turned ON unless the pressure switch (PS1) is closed and the air discharge temperature switch level control, the condensate drain control, and the shutdown system are de-energized. The numbers/letters in parentheses correspond to the electrical components on the wiring diagram.

The compressor is stopped in the MANUAL mode of operation by one of the following actions:

- The high receiver air-pressure switch (PSI) opening at 125 psig rising pressure



LEGEND

79NP0403

CPT – CONTROL POWER TRANSFORMER
CR – CONTROL RELAY
D – DRYER
ETM – TOTAL RUNNING TIME METER
FU – CONTROL FUSE
GIL – COMPRESSOR MOTOR RUNNING LIGHT (GREEN)
HDP – HIGH DEW POINT SHUTDOWN SWITCH (SET TO CLOSE AT 85°F RISING)
LHM – LOADED RUNNING TIME METER

LS1 – LEVEL SWITCH; HIGH INJECTION WATER SHUTDOWN
LS2 – LEVEL SWITCH; LOW INJECTION WATER SHUTDOWN
LS3 – LEVEL SWITCH; INJECTION WATER DRAIN
LS4 – LEVEL SWITCH; INJECTION WATER ADD
LS5 – LEVEL SWITCH; CONDENSATE DRAIN
LS6 – LEVEL SWITCH; HIGH CONDENSATE SHUTDOWN

M – MOTOR CONTACTOR
OL – OVERLOAD RELAY
PS1 – PRESSURE SWITCH (SET AT 125 PSIG RISING; 110 PSIG FALLING)
PS2 – PRESSURE SWITCH (SET AT 120 PSIG RISING; 105 PSIG FALLING)
PS3 – PRESSURE SWITCH (SET AT 35 PSIG FALLING)
PS4 – PRESSURE SWITCH (SET AT 7 PSIG FALLING)

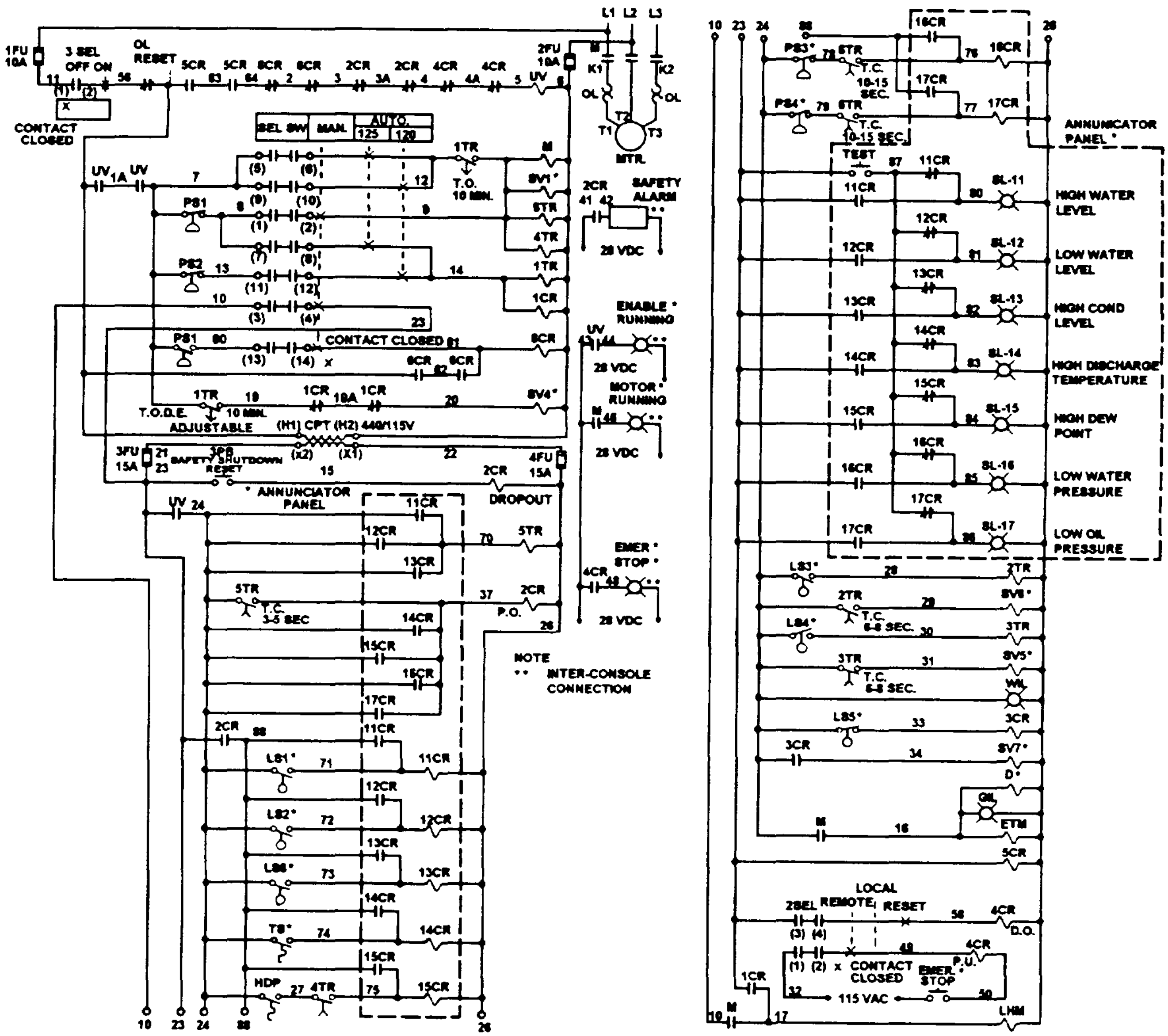
1SEL – SELECTOR SWITCH ("MANUAL "/" AUTOMATIC-125 PSIG "/" AUTOMATIC-120 PSIG")
2SEL – SELECTOR SWITCH ("REMOTE "/" LOCAL "/" RESET")
3SEL – SELECTOR SWITCH ("OFF "/" ON")

SV1 – SOLENOID VALVE; INJECTION WATER
SV4 – SOLENOID VALVE; UNLOADER CONTROL
SV5 – SOLENOID VALVE; INJECTION WATER ADD
SV6 – SOLENOID VALVE; INJECTION WATER DRAIN
SV7 – SOLENOID VALVE; CONDENSATE DRAIN

1TR – TIMING RELAY (TIMES OPEN IN 10 MINUTES)
2TR – TIMING RELAY (TIMES CLOSED IN 6 TO 8 SECONDS)
3TR – TIMING RELAY (TIMES CLOSED IN 6 TO 8 SECONDS)
4TR – TIMING RELAY (TIMES CLOSED IN 2 MINUTES)
5TR – TIMING RELAY (TIMES CLOSED IN 3 TO 5 SECONDS)
6TR – TIMING RELAY (TIMES CLOSED IN 10 TO 15 SECONDS)

TS – TEMPERATURE SWITCH (SET TO CLOSE AT 160° ± 5°F)
UV – UNDER VOLTAGE RELAY
WIL – COMPRESSOR ENABLE RUNNING LIGHT (WHITE)
* – REMOTE MOUNTED (OFF CONTROLLER BOX)
(R) – REMOTE MOUNTED (OFF COMPRESSOR PACKAGE)

Figure 5-9.—Air compressor schematic diagram.



LEGEND 79NP0403

CPT – CONTROL POWER TRANSFORMER
CR – CONTROL RELAY
D – DRYER
ETM – TOTAL RUNNING TIME METER
FU – CONTROL FUSE
GIL – COMPRESSOR MOTOR RUNNING LIGHT (GREEN)
HDP – HIGH DEW POINT SHUTDOWN SWITCH (SET TO CLOSE AT 85°F RISING)
LHM – LOADED RUNNING TIME METER

LS1 – LEVEL SWITCH; HIGH INJECTION WATER SHUTDOWN
LS2 – LEVEL SWITCH; LOW INJECTION WATER SHUTDOWN
LS3 – LEVEL SWITCH; INJECTION WATER DRAIN
LS4 – LEVEL SWITCH; INJECTION WATER ADD
LS5 – LEVEL SWITCH; CONDENSATE DRAIN
LS6 – LEVEL SWITCH; HIGH CONDENSATE SHUTDOWN

M – MOTOR CONTACTOR
OL – OVERLOAD RELAY
PS1 – PRESSURE SWITCH (SET AT 125 PSIG RISING; 110 PSIG FALLING)
PS2 – PRESSURE SWITCH (SET AT 120 PSIG RISING; 105 PSIG FALLING)
PS3 – PRESSURE SWITCH (SET AT 35 PSIG FALLING)
PS4 – PRESSURE SWITCH (SET AT 7 PSIG FALLING)

1SEL – SELECTOR SWITCH ("MANUAL "/" AUTOMATIC-125 PSIG "/" AUTOMATIC-120 PSIG")
2SEL – SELECTOR SWITCH ("REMOTE "/" LOCAL "/" RESET")
3SEL – SELECTOR SWITCH ("OFF "/" ON")

SV1 – SOLENOID VALVE; INJECTION WATER
SV4 – SOLENOID VALVE; UNLOADER CONTROL
SV5 – SOLENOID VALVE; INJECTION WATER ADD
SV6 – SOLENOID VALVE; INJECTION WATER DRAIN
SV7 – SOLENOID VALVE; CONDENSATE DRAIN

1TR – TIMING RELAY (TIMES OPEN IN 10 MINUTES)
2TR – TIMING RELAY (TIMES CLOSED IN 6 TO 8 SECONDS)
3TR – TIMING RELAY (TIMES CLOSED IN 6 TO 8 SECONDS)
4TR – TIMING RELAY (TIMES CLOSED IN 2 MINUTES)
5TR – TIMING RELAY (TIMES CLOSED IN 3 TO 5 SECONDS)
6TR – TIMING RELAY (TIMES CLOSED IN 10 TO 15 SECONDS)

TS – TEMPERATURE SWITCH (SET TO CLOSE AT 180° ± 5°F)
UV – UNDER VOLTAGE RELAY
WIL – COMPRESSOR ENABLE RUNNING LIGHT (WHITE)
* – REMOTE MOUNTED (OFF CONTROLLER BOX)
(R) – REMOTE MOUNTED (OFF COMPRESSOR PACKAGE)

Figure 5-9.—Air compressor schematic diagram.

- The high air temperature switch (TS) closing
- The high injection water level switch (LS1) closing
- The low oil pressure switch (PS4) closing after the timing relay (6TR) has timed closed
- The low injection water pressure switch (PS3) closing after the timing relay (6TR) has timed closed
- The low injection water level switch (LS2) closing
- The high condensate sump water level switch (LS6) closing
- The high dew point temperature switch (HDP) in the dehydrator closing after the timing relay (4TR) has timed closed
- The undervoltage relay (UV) contacts opening
- The motor overload (OL) contacts opening
- A fuse (1FU, 2FU, 3FU, or 4FU) failing
- The operator turning the selector switch (3SEL) to the OFF position
- The operator pressing the remote EMER STOP push button, provied the selector switch (2SEL) is in the REMOTE position

NOTE: If an automatic safety shutdown occurs, the remote SAFETY ALARM will be energized by the control relay (2CR). If a manual shutdown occurs, the remote EMER STOP lamp will be lit. If any shutdown occurs in the MANUAL operating mode, both remote and local ENABLE RUNNING and MOTOR RUNNING lamps will be extinguished

Automatic Operation

Figure 5-9 is a schematic diagram of the air compressor control system. Please follow figure 5-9 as the step-by-step operation of the automatic operation is discussed. The controller is placed in the automatic mode of operation by the selector switch (1SEL) (table 5-2) being placed in either the AUTOMATIC-125 PSIG or AUTOMATIC-120 PSIG position.

Table 5-2.—Automatic Mode Settings of a Typical LP Air Compressor

Switch Setting	Controlling Switch	Switch Setting
Automatic-120	PS2	Open at 120 PSIG rising Close at 105 PSIG falling
Automatic-125	PS1	Open at 125 PSIG rising Close at 110 PSIG falling

Turning the selector switch (3SEL) to the ON position initiates the following sequence:

NOTE: The following operating sequence describes control functions with the selector switch (1SEL) in the AUTOMATIC-125 PSIG position under control of the pressure switch (PS1). With the selector switch in the AUTOMATIC- 120 PSIG position, control functions are the same but are under the control of the pressure switch (PS2).

1. The control relay (5CR) in the low-voltage circuit is energized. The 5CR contacts in the high-voltage circuit close to energize the undervoltage relay (W). The white ENABLE RUNNING light (WIL) is-lit on the controller door.

2. The UV interlocks close to provide power to other parts of the control system and energize the remote ENABLE RUNNING light.

3. The timing relay (1TR) and control relay (1CR) are energized and the following actions occur simultaneously:

- One set of timed-to-open (off-delay) relay 1TR contacts close to energize the motor contactor (M), which closes the M contacts in the motor wiring leads to start the motor. The M contacts in the low-voltage circuit also close to energize the TOTAL RUNNING TIME meter (ETM) and the local and remote MOTOR RUNNING lights.

- A second set of 1TR contacts closes at the same time as the control relay (1CR). Normally closed (NC) contacts open in the circuit to the unloader solenoid valve (SV4) to prevent operation of the valve. Other 1CR normally open (NO) contacts close to energize the LOADED RUNNING TIME meter (LHM).

- Also energized simultaneously are the injection water solenoid valve (SV1) and two timing relays (4TR and 6TR). The SV1 valve opens, permitting flow of injection water. The 4TR begins a 2-minute timed-to-close (on-delay) time out. The 6TR begins a 12- to 15-second on-delay time out.

- The timing relay (6TR) contacts close in 12 to 15 seconds, making the oil pressure and the injection water pressure switches (PS4 and PS3) operative in the safety shutdown circuitry.

- The timing relay (4TR) contacts are timed to close in 2 minutes, making the high dew point temperature switch (HDP) effective in the safety shutdown circuitry.

- The compressor is now running fully loaded under control of the receiver air-pressure switch (PS1) and with all control and shutdown circuits operative.

NOTE: The motor will not start when the selector switch (3SEL) is turned ON unless the pressure switch (PS1) is closed and the air discharge temperature switch (TS) is open. This prevents the compressor from starting when there is adequate receiver air pressure or when an abnormal temperature condition exists.

The compressor is stopped in the AUTOMATIC-125 psig mode of operation by one of the following actions:

- The high receiver pressure switch (PS1) opening, which de-energizes the control relay (1CR) and off-delay timing relay (1TR). The 1TR contacts time open in 10 minutes; this allows the compressor to run for 10 minutes in an unloaded condition before automatically stopping.
- The high air temperature switch (TS) closing.
- The high injection water level switch (LS1) closing.
- The low injection water level switch (LS2) closing.
- The high condensate sump water level switch (LS6) closing.
- The high dew point temperature switch (HDP) in the dehydrator closing after the timing relay (4TR) has timed closed.
- The low oil pressure switch (PS4) closing after the timing relay (6TR) has timed closed
- The low injection water pressure switch (PS3) closing after the timing relay (6TR) has timed closed.
- The undervoltage relay (UV) contacts opening.
- The motor overload (OL) contacts opening.
- A fuse (1FU, 2FU, 3FU, or 4FU) failing.
- Turning of the selector switch (3SEL) to the OFF position.
- Pressing of the remote EMER STOP pushbutton, provided the selector switch (2SEL) is in the REMOTE position.

NOTE: If an automatic safety shutdown occurs, the remote SAFETY ALARM will be energized by the control relay (2CR). If a manual emergency shutdown occurs, the remote EMER STOP lamp will be lit. When the unit is shut down, both remote and local ENABLE RUNNING and MOTOR RUNNING lamps will be extinguished Both of these lamps will remain lit during the 10-minute unloaded run as a result of high air pressure. Should the compressor not reload and it stops after the 10-minute time out, the MOTOR RUNNING lamp will be extinguished, but the ENABLE RUNNING lamp will remain lit.

Injection Water Level Control

The level of injection (fresh) water level in the separator-holding tank is controlled by the operation of float switches (LS3 and LS4) and solenoid valves (SV5 and SV6).

If the injection water rises to the high-level switch setting, the switch (LS3) closes, energizing the on-delay timing relay (2TR). When the 2TR relay times closed in 6 to 8 seconds, provided LS3 remains closed, the solenoid valve (SV6) is energized to drain the tank

If the water level in the separator-holding tank drops low enough to close the low-level switch (LS4), the timing relay 3TR is energized. If the 3TR contacts are allowed to time closed (6 to 8 seconds), provided LS4 remains closed, the solenoid valve (SV5) is energized to add water from the freshwater supply to the injection water system.

Condensate Drain Control

The dehydrator condensate sump is drained by the solenoid valve (SV7) under control of the normally closed level switch (LS5). When the liquid level in the condensate sump reaches the high-level setting of LS5, the switch opens to de-energize the control relay (3CR). This opens the 3CR contacts, which, in turn, de-energizes the SV7 solenoid. The normally open solenoid valve opens to drain the condensate sump. When the liquid level drops to the low-level setting of LS5, the switch closes to energize 3CR and SV7. This shuts the drain valve.

Shutdown System

Automatic shutdown of the compressor occurs when one or more of the following conditions exist:

- High air receiver pressure
- High air discharge temperature
- High dew point temperature at the dehydrator
- High or low injection (fresh) water levels
- Low lube oil pressure
- Low injection water pressure
- High condensate sump level

HIGH AIR RECEIVER PRESSURE.— When the compressed air pressure at the receiver exceeds the rising pressure setting of the pressure switch (PS1 or PS2), one of the following shutdown sequences is initiated:

The selector switch (1SEL) is in the MANUAL mode of operation. The compressor will be automatically y stopped by the pressure switch (PS1) tripping at 125 psig rising pressure. This will de-energize the main motor contactor (M), which opens the M contacts in the motor leads.

The selector switch (1SEL) is in the AUTOMATIC-125 psig operating position. The compressor is under control of the normally closed contact of the pressure switch (PS1). When a rising pressure of 125 psig causes PS1 to open, compressor shutdown is delayed for 10 minutes by the timing relay (1TR). The control relay (1CR) is de-energized by the opening of PS1. This initiates closing of the air intake butterfly valve (solenoid SV4 energized) and opening of the air bypass line. The compressor runs unloaded with discharge air recycling back to the compressor inlet. After 10 minutes (provided PS1 remains open), the 1TR contacts time open to stop the compressor drive motor by de-energizing the motor contactor (M). During the 10-minute time out, excessive air pressure protection is provided by the safety relief valve on the receiver.

The selector switch (1SEL) is set for AUTOMATIC-120 psig operation. Shutdown control is the same except that the shutdown sequence is initiated by the opening of the pressure switch (PS2) at a rising air pressure of 120 psig.

HIGH AIR DISCHARGE TEMPERATURE.— Abnormally high air temperature at the compressor discharge closes the temperature switch (TS), energizing the control relay (14CR). The 14CR contacts close to light the HIGH AIR DISCHARGE TEMPERATURE light on the annunciator panel and to energize the latching relay (2CR). Normally closed 2CR contacts in the high-voltage circuit open to de-energize UV, which de-energizes M. This stops the motor. Other 2CR contacts close to sound the remote safety shutdown alarm and to maintain power to 14CR. This keeps the HIGH AIR DISCHARGE TEMPERATURE light illuminated even if TS opens after the compressor has shut down, allowing operators to determine the cause of the shutdown.

HIGH DEW POINT TEMPERATURE.— Abnormally high dew point temperature in the dehydrator will close the temperature switch (HDP), and if the relay (4TR) has closed, energize the relay (15CR). The 15CR contacts close to light the HIGH DEW POINT lamp on the annunciator panel and to energize 2CR. This functions to stop the compressor, sound the alarm, and maintain the indication (through 15CR).

HIGH WATER LEVEL.— An excessively high water level in the separator-holding tank will close the level switch (LS1), energizing the relay (11CR). The 11CR contacts close to light the HIGH SEP/HLDG TANK LEVEL lamp on the annunciator panel and energize the on-delay (timed-to-close) timing relay (STR). The 5TR contacts close in 3 to 5 seconds to energize 2CR (if LS1 has remained closed). The 2CR contacts actuate to shut down the motor, sound the shutdown alarm, and maintain the indication (through 11CR).

LOW WATER LEVEL.— An excessively low water level in the separator will close the level switch (LS2) and energize the relay (12CR). The 12CR contacts affect 5TR and 2CR. They also light the LOW SEP/HLDG TANK LEVEL lamp on the annunciator panel.

LOW OIL PRESSURE.— An abnormally low oil pressure will close the pressure switch (PS4) and, after the relay (6TR) has closed, energize the relay (17CR). The 17CR contacts close, illuminating the LOW OIL PRESSURE light on the annunciator panel and energizing 2CR. The 2CR contacts initiate a safety shutdown and maintain the indication through 17CR.

LOW INJECTION WATER PRESSURE.— An abnormally low injection water pressure will close the pressure switch (PS3) and, if 6TR has closed, energize the relay (16CR). The 16CR contacts close, illuminating the LOW INJECTION WATER PRESSURE light on the annunciator panel and energizing 2CR. The 2CR initiates a safety shutdown and maintains the indication through 16CR.

HIGH CONDENSATE LEVEL.— An excessively high condensate level in the dehydrator sump causes the level switch (LS6) to close, energizing 13CR and lighting the HIGH CONDENSATE LEVEL light on the annunciator panel. The 13CR also energizes STR, which will time closed to energize 2CR and initiate a safety shutdown.

Whenever the compressor drive motor is shut down by the de-energizing and opening of the motor contactor (M), the solenoid valves (SV1 and SV7) are simultaneously de-energized.

- Solenoid valve SV1 closes in the injection (fresh) water supply line to stop the flow of injection water to the compressor intake.
- Solenoid valve SV7 opens in the condensate drain line to drain the condensate sump and repressurize the compressor.

MAINTENANCE

Scheduled maintenance should be performed according to the Planned Maintenance System (PMS).

SUMMARY

The air compressor discussed in this section contains information on the basic operating principles of most compressors seen in the Fleet. While the compressor aboard your ship may not be this type, the principles discussed here should prove valuable to you in maintaining those found aboard any ship.

REFRIGERATION AND AIR-CONDITIONING SYSTEMS

As an EM, you must have a knowledge of the refrigeration and air-conditioning systems. In this section, you will learn about starting, operating, and stopping some types of refrigeration systems.

REFRIGERATION SYSTEM

The function of the ship's stores refrigeration system is to provide refrigeration in the freeze and chill storerooms to preserve perishable foods. The refrigerant is supplied by two refrigeration plants. The plants can be operated singly or together.

Plant Components

Each plant consists of a 1. l-ton reciprocating compressor assembly, motor controller, condenser, receiver, dehydrator, heat exchanger, gauge board, and associated controls. The refrigeration plants supply refrigerant (R-12) to the cooling coils located in the three storage spaces. The storage spaces are the freeze storeroom and two chill storerooms. The freeze storeroom is maintained at 0°F. The chill storerooms are normally maintained at 33°F.

Table 5-3 contains a list of the safety control switches, the magnetic relays, the contractors, and the indicating devices of the 1.1 -ton refrigeration compressor assembly. It shows the location, functions, and settings of the individual units.

Plant Operation

The compressor can only be energized from the motor controller, which is located in the auxiliary machinery room or reefer flats. Besides providing start/stop operation of the plant, the controller has a two-position selector switch labeled LOCAL and NORMAL. The difference in plant operation between the two positions is that in the NORMAL position the plant can be shut down from either the remote or local location.

To help you understand the refrigeration plant operation, refer to the wiring diagram in

Table 5-3.—Switches, Relays, Contactors, and Indicating Devices of Refrigeration Equipment

TEMPERATURE or PRESSURE SENSITIVE CONTROL SWITCHES			
INSTRUMENT	**LOCATION**	**FUNCTION**	**SETTING**
Discharge pressure (DP)	Instrument board	Stops compressor when discharge pressure is excessive	Opens at 150 psig Closes at 125 psig
Suction pressure (SP)	Instrument board	Controls pump down cycle	Opens at 5" Hg Vac. Closes at 8 psig
Water failure (WF)	Instrument board	Stops compressor when condenser water flow is inadequate	Opens at 15 psig Closes at 30 psig
Oil failure (OP)	Compressor	Stops compressor when oil pressure is inadequate	Opens at 10 psid Closes at 16 psid
Thermostat, freeze rm	Outside room	Starts refrigerant flow to room when temp. is high	Opens at -5°F Closes at 0°F

MAGNETIC RELAYS and CONTACTORS		
INSTRUMENT	**LOCATION**	**FUNCTION**
Undervoltage relay (UV)	Motor controller	Contact UV1 holds UV relay energized Contact UV2 energizes M contactor Contactor UV4 energizes alarms
Timing relay (TR)	Motor controller	Contact TR-2 opens after 10 seconds to de-energize UV if OP is not closed
Control relay (IR)	Motor controller	Contact IR-1 holds IR relay energized
Main contactor (M)	Motor controller	Contacts 1M, 2M, and 3M close to put motor on line voltage Contact 4M de-energizes crankcase heater Contact 5M energizes UNIT ON indicator
Emergency stop (1ES)	Motor controller	Contact 1ES-1 energizes 2ES relay
(2ES)	Motor controller	Contact 2ES-1 de-energizes the UV relay Contact 2ES-2 holds 2ES relay energized Contact 2ES-3 energizes EMERGENCY STOP indicator

MANUAL SWITCHES		
INSTRUMENT	**LOCATION**	**FUNCTION**
STOP	Motor controller	Interrupts holding circuit to stop the compressor
START	Motor controller	Initiates start-run sequence
SP BYPASS	Motor controller	Pressing button bypasses SP switch for manual control of the compressor
EMER. STOP	Remote console	Energizes 1ES relay
MANUAL SWITCHES		
INSTRUMENT	**LOCATION**	**FUNCTION**
ENABLED (ind. light)	Motor controller	Indicates unit is in operating mode
ELAPSED TIME METER (ETM)	Motor controller	Indicates accumulation of compressor operational time
EMER. STOP (Light)	Remote console	Indicates emergency stop via ES relay

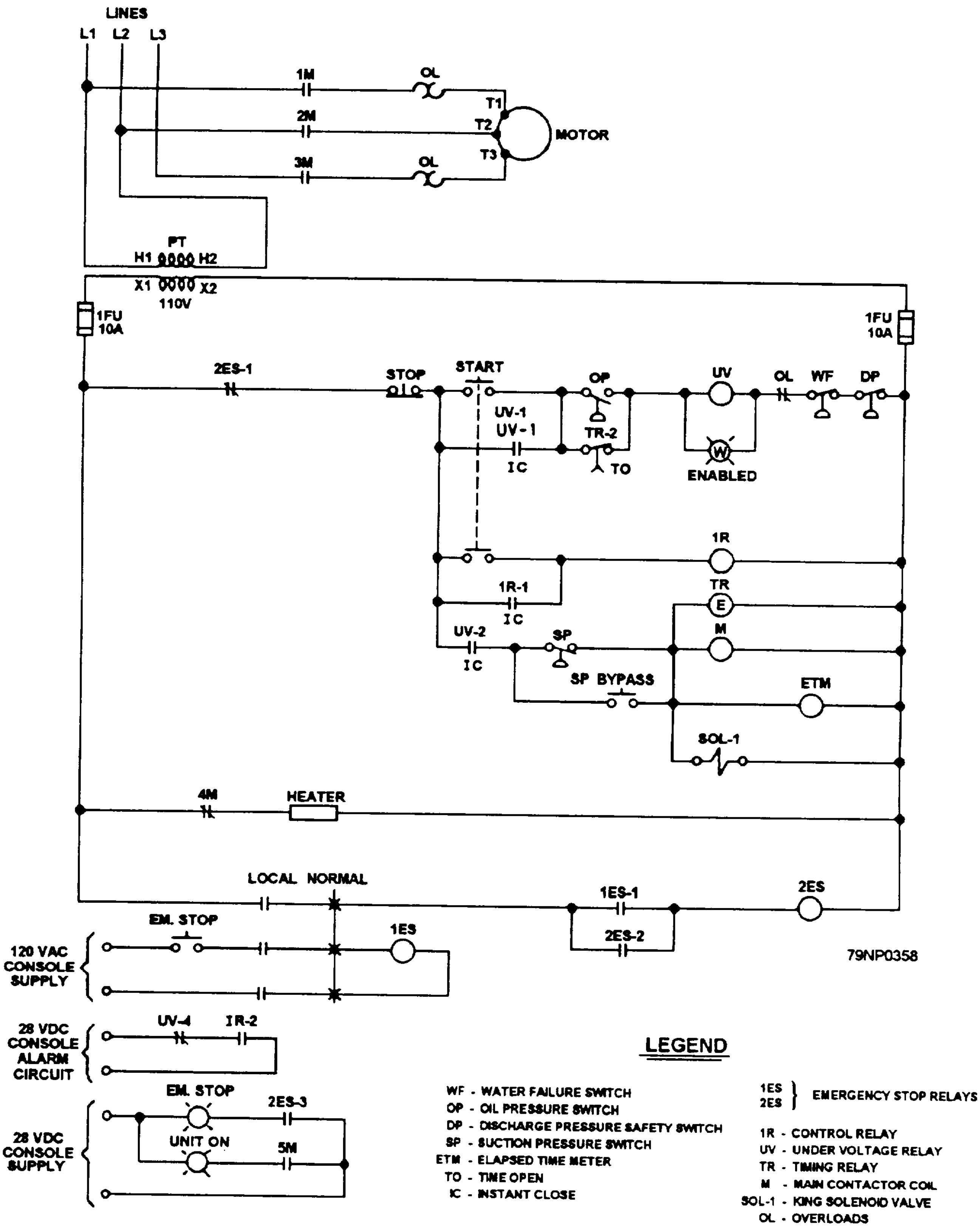


Figure 5-10.—Refrigeration plant wiring diagram.

figure 5-10. To start the compressor, turn the selector switch to LOCAL or NORMAL operation. Then press the start button. Provided the contacts for OL, WF, and DP are closed, the UV relay will be energized and close its UV-1 contacts across the start switch contacts, which will maintain the holding circuit for the UV relay. At the same time, the UV-2 contacts close, causing the main contactor coil (M), the relay (TR), and the elapsed time meter (ETM) to be energized. This causes the M coil to close its contacts (1M, 2M, and 3M), and then the motor should start.

The timing relay (TR) is energized and will open its TR-2 contacts after a 10-second time delay. This should allow the oil pressure enough time to increase and close the oil pressure switch contact (OP). If the oil pressure does not close its OP contacts, the compressor will stop after 10 seconds when the TR-2 contacts open. The ETM will run only as long as the motor is energized or running.

The IR relay is energized at the time the start button is pushed. It is maintained by the IR-1 contact across the start switch contact. You will notice that the contact (4M) is normally closed in the de-energized condition, keeping the oil heater energized This contact is opened by the M coil at the same time that 1M, 2M, and 3M are closed.

The suction pressure switch (SP) is connected in series with the UV-2 contacts. It is used to sense the pressure of the compressor suction line for automatic operation. The switch stops the compressor when the pressure is reduced to a level corresponding to the open setting (5 in. Hg vacuum). The compressor is automatically started again when the SP switch contacts close and the suction line pressure increases to the closed setting (8 psig). The cycle starts over again to maintain the refrigerated rooms at their normal temperatures.

If any of the contacts (WF, DP, OP, or OL) open, the motor will stop and will have to be started manually.

80-TON AIR-CONDITIONING UNITS

The function of the 80-ton air-conditioning units (fig. 5-11) installed on board the FFG-7 class fast frigate

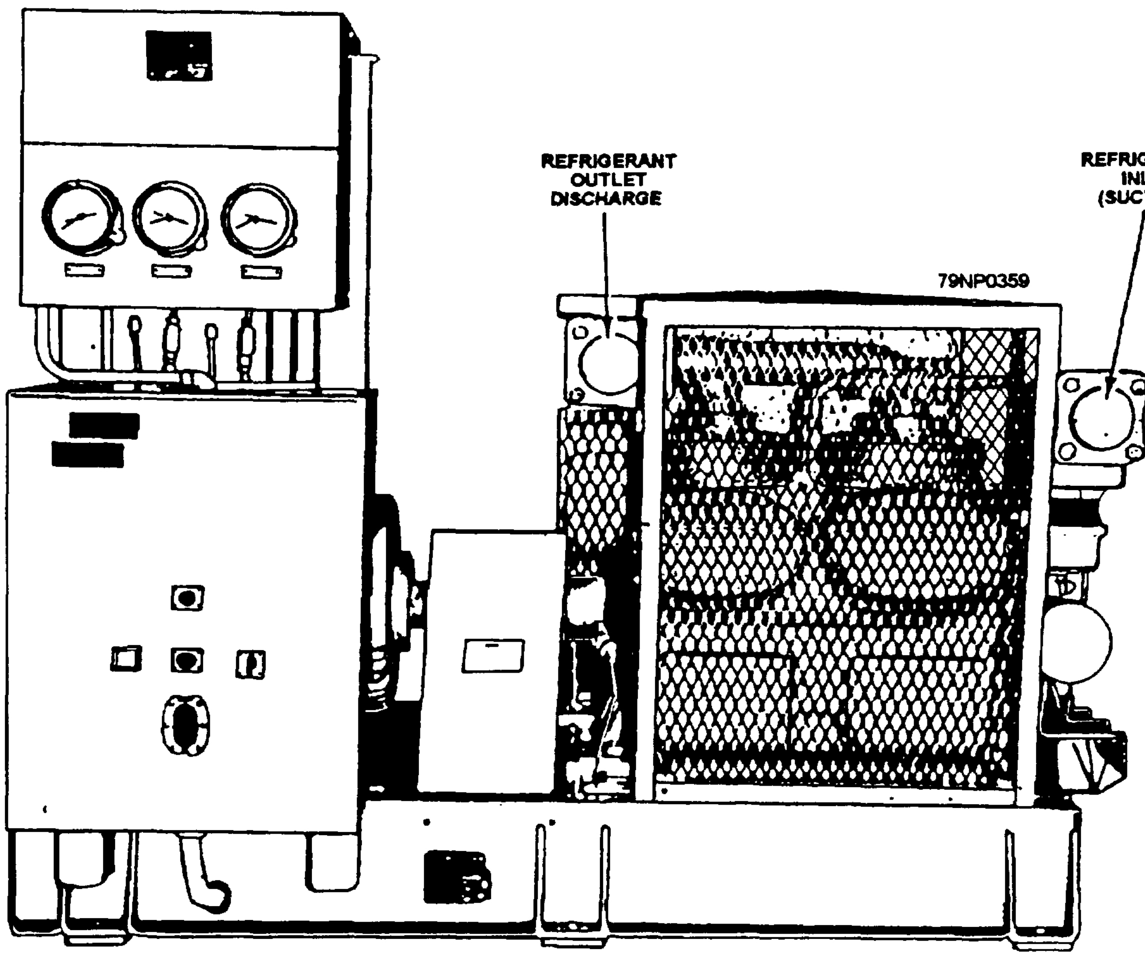


Figure 5-11.—80-ton compressor unit assembly.

is to provide the chilled water for the air-conditioning system throughout the ship. Ships of this class have a minimum of three identical units installed.

The compressor is a reciprocating, single-acting unit. It is equipped with a capacity control system, a pressure relief valve, and an oil pressure failure switch.

Control Devices

The operation and pressure setting of the individual control devices are discussed separately in this section to help you understand the operation of the 80-ton air-conditioning unit.

OIL PRESSURE SAFETY SWITCH.— The oil pressure safety switch protects the compressor in case of insufficient oil pressure. The switch is wired to the compressor motor controller to stop the compressor if one of the following situations exists:

1. The oil pressure drops to 12 psi or less during operation
2. The oil pressure at start-up does not build to a satisfactory minimum of 18 psi.

The oil pressure safety switch is interlocked with a time delay relay in the motor controller to permit a short operating period (10 to 15 seconds) at start-up to allow the oil pressure to develop. The switch is wired so that when the compressor is stopped by the loss of oil pressure action, it must be restarted at the motor controller.

SOLENOID VALVE.— The solenoid valve is a pilot-operated, piston-type valve and is operated by an electric coil. The valve is open when the current is on and closed when the current is secured The solenoid valve is wired to the water chiller operating thermostat for control with the system in operation. The solenoid valve shuts when chilled water reaches the minimum temperature.

HIGH-PRESSURE CONTROL SWITCH.— The high-pressure control switch should be set to open at 160 psig and close at 140 psig.

LOW-PRESSURE SUCTION SWITCH.— The low-pressure suction switch should be set to close at 40 psig and open at 20 psig.

SEAWATER FAILURE SWITCH.— The seawater failure switch should be set to close at 15 psig and open at 5 psig.

FRESHWATER FAILURE SWITCH.—The freshwater failure switch should be set to close at 45 psig and open at 3 psig.

WATER CHILLER OPERATING THERMOSTATS.— The water chiller operating thermostats are set to close when the chilled water reaches 44°F and open when the water temperature reaches 40°F.

LOW-LIMIT THERMOSTATS.— The low-limit thermostats are backup thermostats for the chiller operating thermostat. If the chilled water temperature would decrease below the 40°F level, the low-limit thermostat would open at 36°F. The low-limit thermostat will not close until the chilled water temperature rises to 40°F. The compressor operation would not begin until the chiller operating thermostat contacts close.

Operation

To help you understand the following discussion of the operation of the air-conditioning compressor, refer to the wiring diagram in figure 5-12.

The compressor can only be energized from the motor controller, which is located near the equipment. Besides providing Start/stop operation of the unit, the controller has a two-position selector switch, labeled LOCAL or LOCAL/REMOTE. When in the LOCAL/REMOTE position, the compressor can be stopped remotely by the use of the emergency (EM) stop button located in the control console room.

To start the compressor, turn the selectors witch to the LOCAL or LOCAL/REMOTE position and press the start button. This will energize the UV relay, provided contacts OL, WFS1 and 2, HP, and LT are closed The W relay will close its UV-1 contacts, which are connected across the start switch and is the maintaining circuit for the UV relay. At the same instant, the UV-2 contacts close energizing the 1CR relay, closing its 1CR-1 maintaining contacts. Also, UV-3 contacts will close, energizing the timing relay (TR). This closes the TR-IC contacts, energizing the M-coil contactor. Contacts M-1, M-2, and M-3 will also close, connecting the motor across the line. Contacts M4 close to energize the remote run light in the control console.

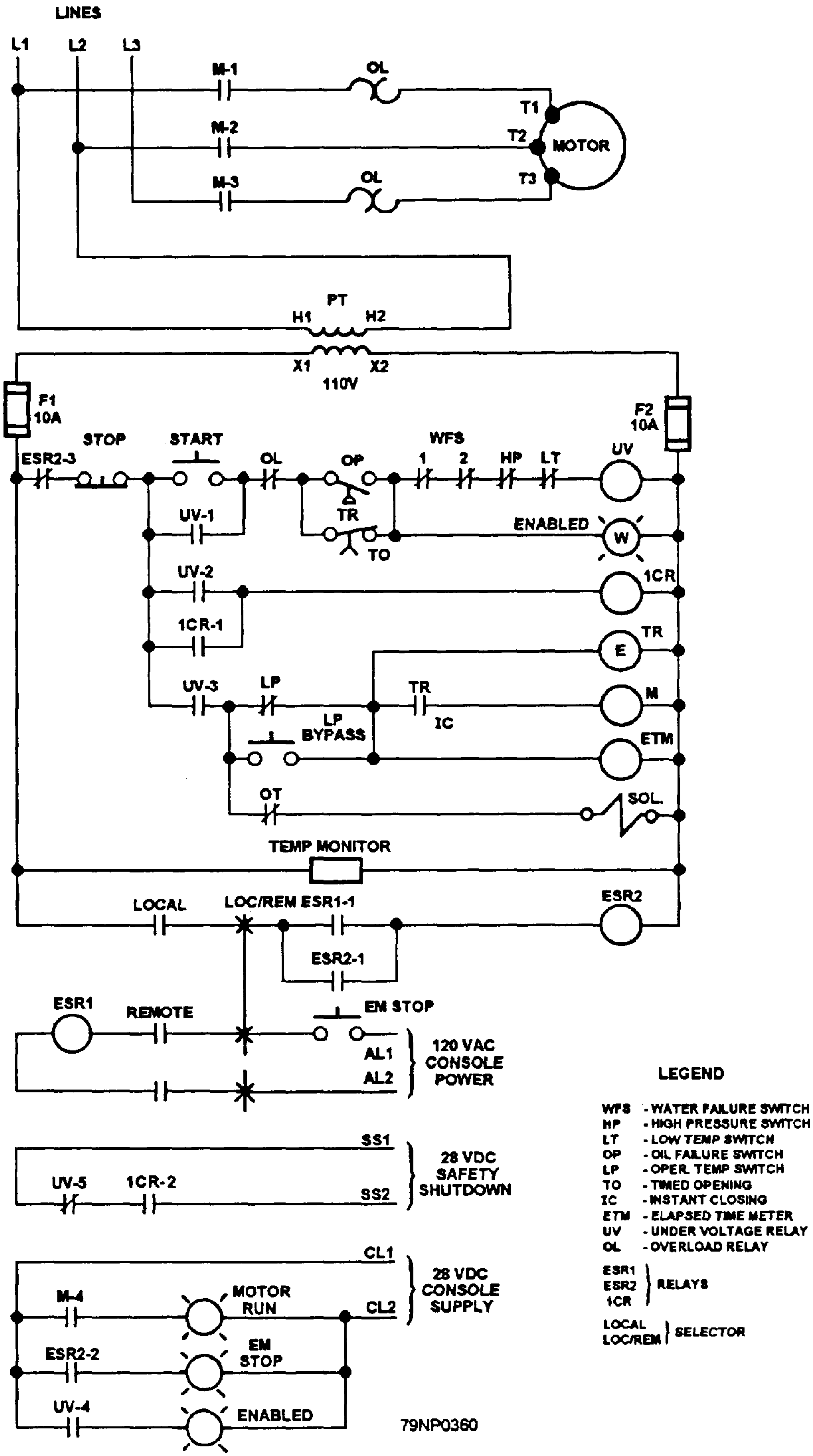


Figure 5-12.—80-ton air-conditioning compressor wiring diagram.

The OP contacts should close before the TR contacts open, which are time opening. The unit should operate normally and will be stopped and started by the LP switch.

During operation, opening the OP, WFS, HP, or LT contacts will cause the W relay to be de-energized, drop out, and stop the motor. The normally closed UV-5 interlock contacts will close and complete the circuit to the safety shutdown alarm.

Loss of voltage for any reason will cause the UV relay and 1CR relays to drop out, stopping the unit. On restoration of the voltage, you need to press the start button to restore the compressor to normal operation. This feature is known as low-voltage protection (LVP).

An overload will cause the OL contacts to open, stop the motor, and energize the alarm. To restore operation, you will have to press the stop-reset button and then the start button.

To stop the compressor manually, all you need to do is press the stop-reset button.

When the selector switch is in the LOCAL/REMOTE position, the emergency (EM-STOP) button in the console is energized. If the EM-STOP button is pressed for any reason, the ESR1 relay will become energized, which will close its contacts ESR1-1. This causes the ESR2 relay to be energized close its maintaining contacts ESR2-1 and ESR2-2, and open contacts ESR2-3. This sequence shuts down the compressor. The ESR2-1 contacts are only maintaining contacts for the ESR2 relay. The ESR2-2 contacts will energize the EM-STOP indicating light in the control console.

The OT and solenoid circuit operates to cut in or cut out the refrigerant to the pilot thermal expansion valve. This causes the main thermal expansion valve to close, cutting off the supply of refrigerant to the water chiller. With the solenoid valve closed and the supply of liquid refrigerant cut off to the chiller, the compressor continues to operate for a short period of time until the suction pressure drops to the cutout setting of the low-pressure control switch. The switch contacts then open and the compressor motor stops.

As soon as the chilled water temperature rises to or above the cut-in setting of the operating thermostat, the solenoid opens and allows liquid refrigerant to flow to the pilot thermal expansion valve. The pilot supplies pressure to the main thermal expansion valve and moves it to the OPEN position. Liquid refrigerant is thus allowed to flow to the chiller. The suction pressure rises, causing the cut-in setting of the low-pressure control switch to close its contacts. This starts the compressor motor.

SUMMARY

In the previous section, the function and the equipment used in air conditioning and refrigeration were described. Also, the operation of air compressors and the refrigeration and air-conditioning systems are covered. It should be apparent that this equipment is very important. If you do not understand a system completely, go back and review before continuing on to the next sections.

PENDULUM WINDOW WIPER

The window wiper (fig. 5-13) is an extremely simple, rugged piece of equipment. The information in the following paragraphs will give you enough information to enable you to operate, troubleshoot, and repair almost any problem that occurs with the wiper.

DESCRIPTION

The pendulum window wiper is a variable-speed, electric motor-driven oscillating arm wiper with a totally enclosed drive unit. The wiper is equipped with a heated arm for operation under icing conditions. The entire unit weighs 20 pounds and is mounted on the bulkhead over the window it serves. The wiper is suitable for use on fixed or hinged windows and can be adjusted to ensure correct blade pressure and travel.

The window wiper runs on dc voltage. It takes 115-volts, single-phase ac power from the ship's service line and rectifies it through a full-wave bridge rectifier.

CONSTRUCTION

The wiper consists of three major components:

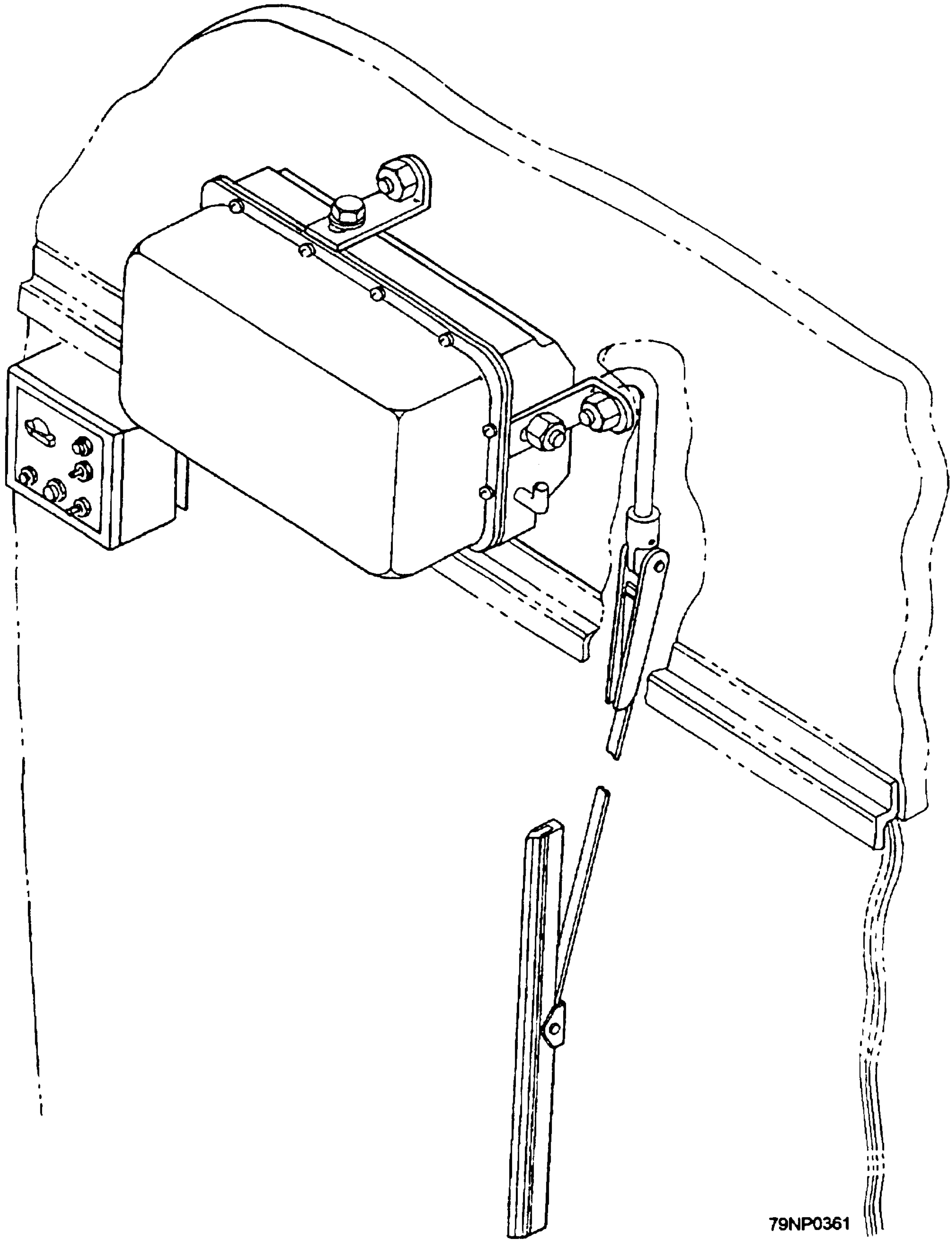


Figure 5-13.—Pendulum window wiper.

1. Control box assembly (fig. 5-14). The control box consists of the three-position wiper switch, the wiper arm heater switch, a light to indicate when the heater is energized, a variable powerstat for wiper control, motor and system overload protectors, and a full-wave bridge rectifier.

2. Drive unit (fig. 5-15). The drive unit consists of a dc motor and a drive mechanism, which converts the rotary motion of the drive motor to a back-and-forth motion necessary for wiper operation.

3. Wiper arm. The wiper arm consists of upper and lower arms and the wiper blade. The upper arm is a stainless steel tube containing a 36-watt heating element. The lower arm is 20 inches long and is bent and cut during installation to suit the particular installation. The wiper blade, attached to the lower arm, is constructed of neoprene rubber and is used to clean the window of water during operation.

OPERATION

Placing the wiper ON/OFF/PARK switch in the ON position completes the circuit from the variable powerstat, through the motor protector, to the bridge rectifier. The ac power is rectified and fed to the drive motor through a fuse and a radio frequency filter.

The motor speed (fig. 5-16) is adjusted through the setting of the variable powerstat in the control box. At full-load speed, the motor shaft turns at 3,600rpm. With the 40 to 1 reduction gear ratio, this means that the wiper blade completes approximately 90 sweeps per minute at high speed. With the wiper switch in the ON position, voltage to the motor is variable through the powerstat from 68 to 115 volts dc. With the switch in the PARK position, voltage is fixed at 40 volts dc.

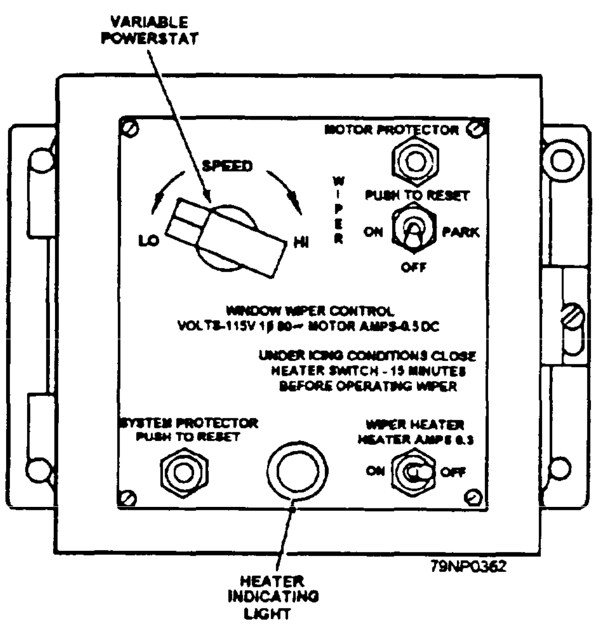


Figure 5-14.—Control box assembly.

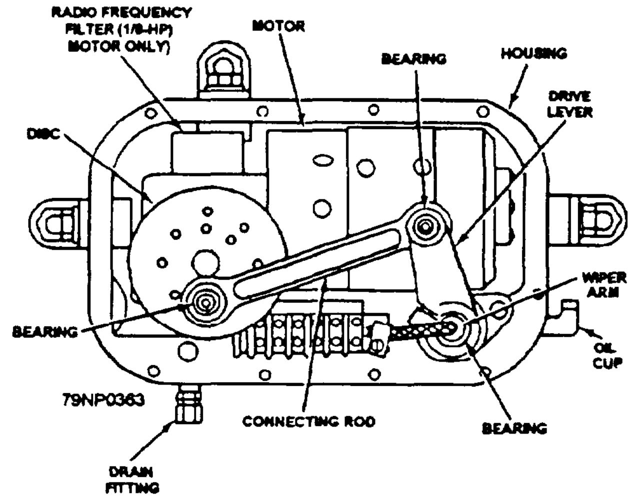


Figure 5-15.—Drive unit.

Placing the wiper switch in the PARK position also completes the circuit to the motor. When the switch is released it springs back to the OFF position. This is convenient for placing the wiper blade out of view when the window wiper is not is use.

MAINTENANCE

Following prescribed preventive maintenance will keep the window wiper operational for extended periods. Refer to NAVSEA S9625-AF-MMA-010 for procedures on adjusting the wiper blade alignment, the travel, and the contact pressure.

SUMMARY

The pendulum window wiper is one of the simplest pieces of equipment the EM will encounter. Since it is needed when the weather is at its worst, good maintenance procedures during good weather periods will preclude having to work outside in the rain.

ULTRASONIC CLEANING MACHINE

Ultrasonic cleaners can be used to clean most items that can be submerged in aqueous solutions. Besides cleaning small parts, the cleaner is especially useful for

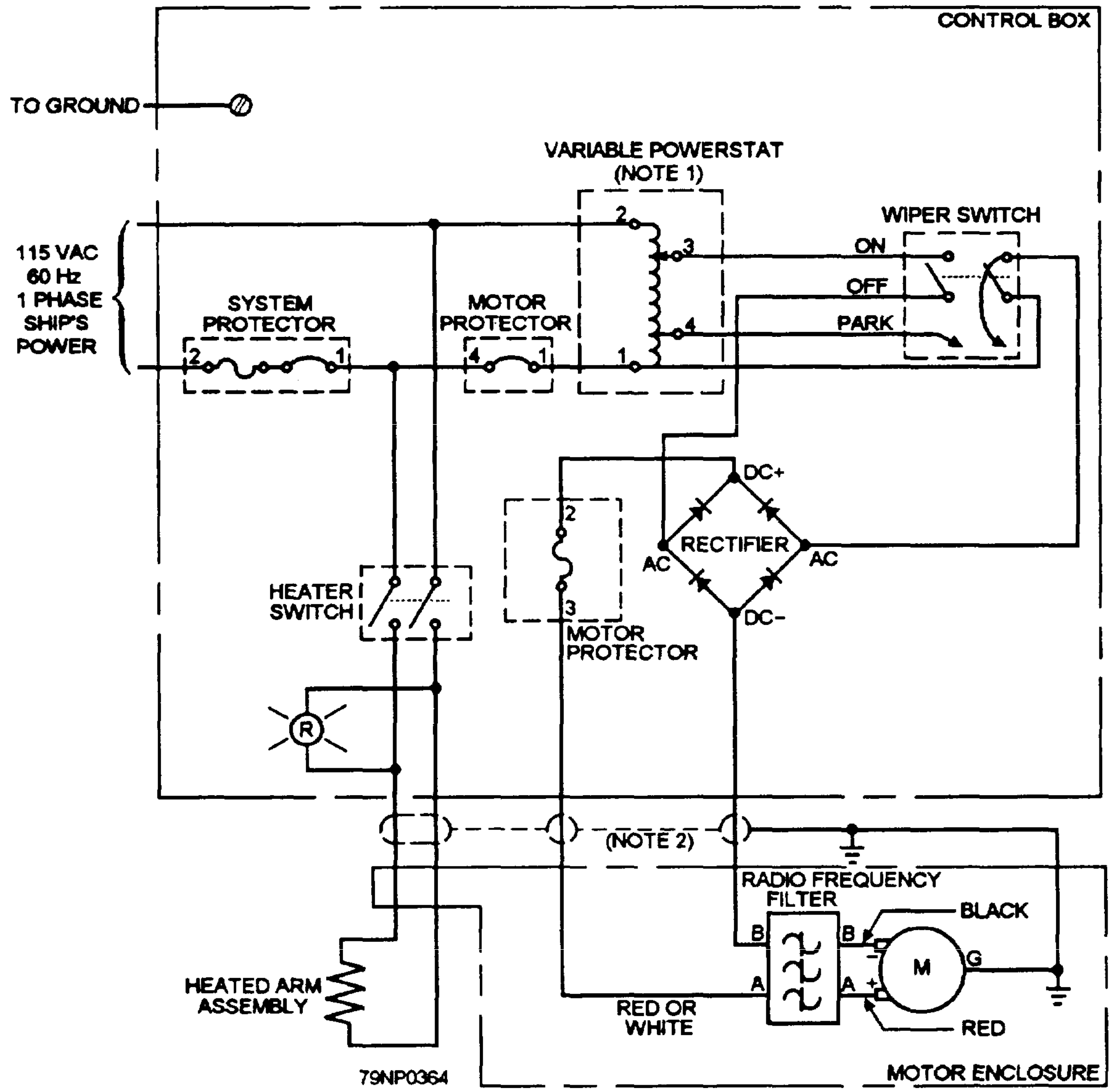


Figure 5-16.—Window wiper schematic.

cleaning items with a mixture of dust, dirt, and grease, such as vent filters.

DESCRIPTION

Ultrasonic cleaners use high-frequency vibrations in an aqueous solution to agitate and "scrub" particles from an item to be cleaned.

The tank of some ultrasonic cleaners is divided into two sections, allowing cleaning in one side and rinsing and drying in the other. Besides a tank for holding the cleaning solution and the part to be cleaned, the cleaner may also be fitted with a spray gun consisting of a hose and nozzle fitting to blast clean hard spots. The cleaning solution can be heated using a 5-Kilowatt electric heater for extra cleaning power. The cleaning solution is circulated through a filter to remove small impurities during the cleaning process, prolonging its life as a useful cleaning agent.

OPERATION

Single-phase, 450-volt, ac power is filtered and fed into a 2 to 1 step-down transformer. In addition to the generator cabinet blower, the cleaning solution circulating pump, and the heat exchanger, the secondary voltage of 220 volts is used to control the operation of a trigger circuit. The trigger causes pulses to be fed to an SCR in both generator circuits. The pulses to the SCRs cause the generators to develop a signal that is fed to the transducers. A frequency adjusting control on the trigger circuit permits adjusting the signal to the generators approximately ±1000 cycles on either side of resonance for the transducers.

Vibrations are generated in the ultrasonic cleaner (fig. 5-17) by transducers. These transducers are welded to plates, called *diaphragms.* When the transducers arc energized, they produce extremely small vibrations in the plates, 1 or 2 thousandths of an inch (0.001 to 0.002 inch) but with strong accelerating forces. As the plates vibrate, they cause whatever medium they are suspended in to assume a similar frequency and transmit that frequency throughout the vessel. The plates are, in effect, a Hi-Fi speaker operating at one frequency.

When the medium through which the waves are transmitted is a liquid, there is good transmission and very little loss of strength since all liquids are relatively incompressible. The physical shock of the vibrations on the item being cleaned cause a "scrubbing" action much better than a brush because the size of the sound waves allows for cleaning of minute holes and crevices that would be impossible for a brush.

MAINTENANCE

The ultrasonic cleaner is extremely rugged and requires little maintenance other than cleaning and oiling. The components should be kept free of dust and dirt accumulations and the air filters in the generator compartment door should be cleaned or replaced periodical y according to PMS requirements. The generator fans and cleaner unit blower should be oiled once a year and the water pump should be oiled every 6 months.

SUMMARY

The ultrasonic cleaner is one of the most essential machines on board when it comes to conducting repairs to other pieces of machinery. Its ability to clean parts and some metallic ventilation filters makes it mandatory that preventive maintenance procedures be strictly followed to ensure it stays operational.

ELECTROSTATIC VENT FOG PRECIPITATOR

The electrostatic vent fog precipitator (fig. 5-18) is mounted in the lube oil system of reduction gears for main engines and generators. The purpose of the vent fog precipitator is to remove entrained oil mist from the vented air of the reduction gears before it is discharged into the engine mom or space.

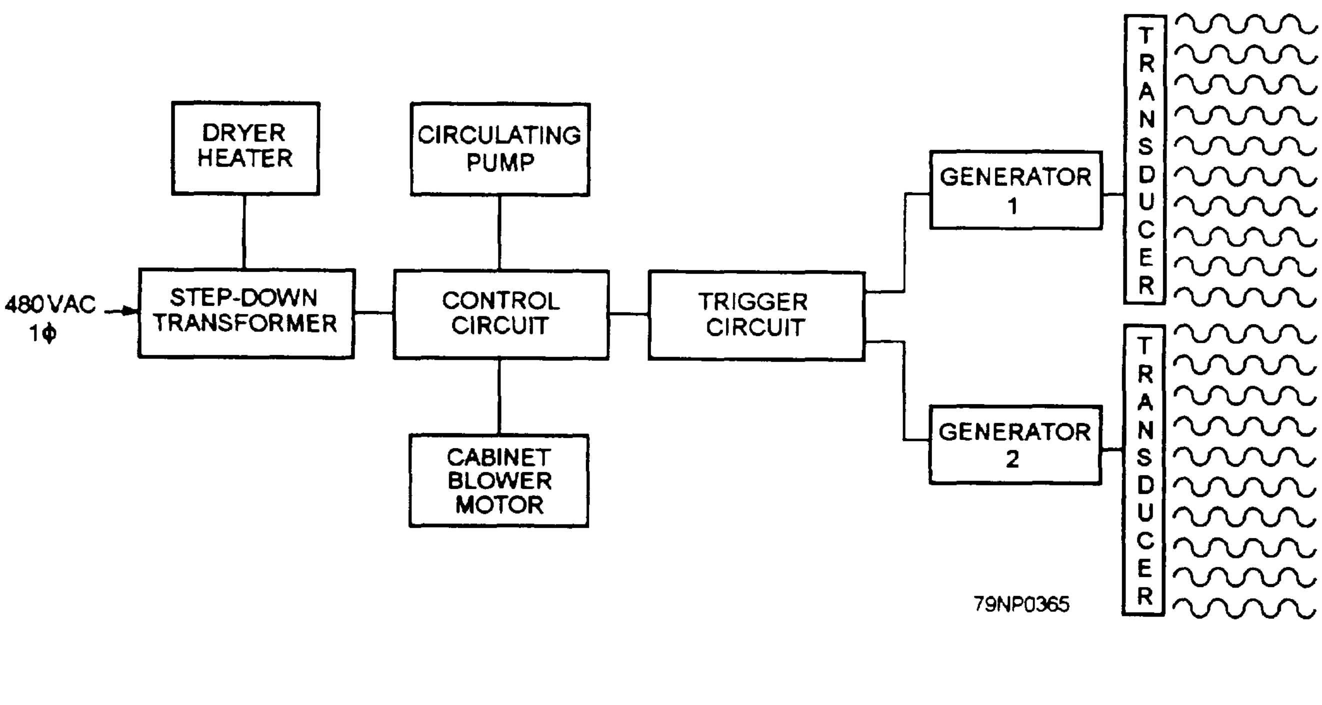


Figure 5-17.—Block diagram of ultrasonic cleaner.

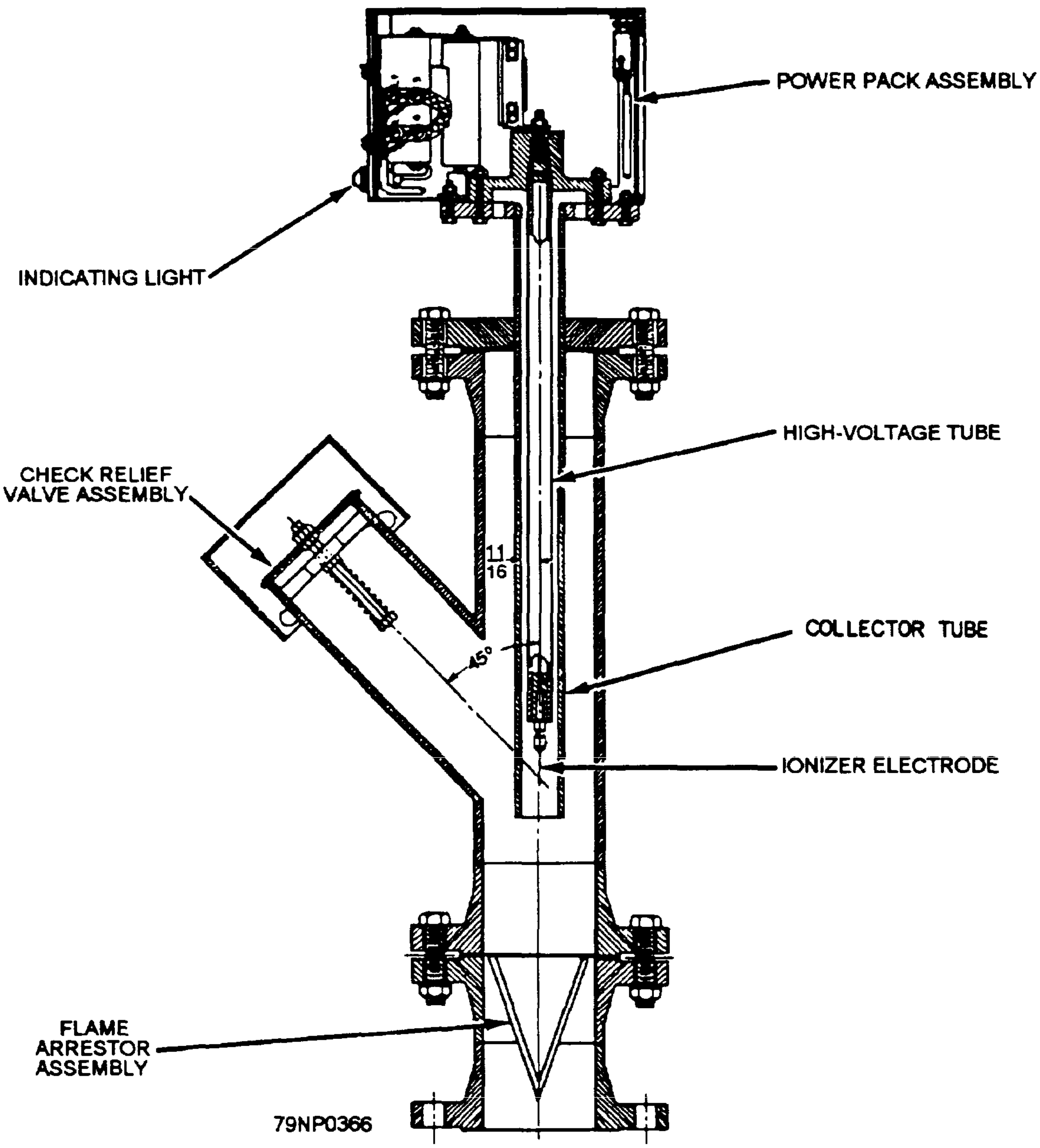


Figure 5-18.—Vent fog precipitator.

The oil mist is caused when the oil gets warm in the gear case and the air space of the entire lubricating system. The larger mist droplets will settle by gravity. The fine mist will continue to rise, borne on air currents.

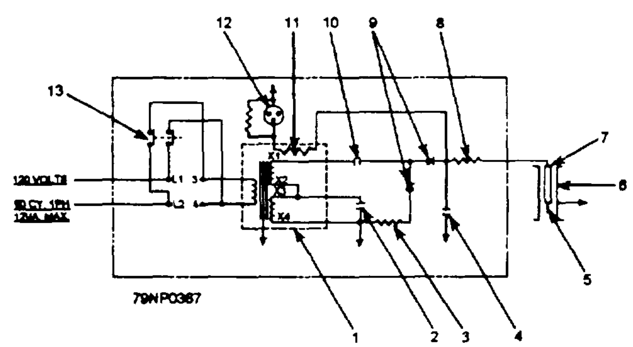
The vent fog precipitator employs the basic phenomenon of electrostatic precipitation. The fine oil mist borne on air currents vented in confined areas of machinery will rise and enter the bottom end of the collector tube through the flame arrester assembly. The droplets are instantly charged by a heavy ion concentration emanating from the ionizer electrode mounted on the end of the high-voltage repelling electrode. As the charged droplets progress up the collector tube, they are subjected to the electrostatic field created between the high-voltage electrode and the grounded collector tube. Since their charge is of the same polarity as the high-voltage tube, the force of the electrostatic field forces them to the wall of the collector tube, which is of opposite polarity. Here the oil is collected and flows back to the machinery reservoir. The oil-free air continues up and is vented to the atmosphere.

The vent fog precipitator operates on 120-volt ac, 60-hertz, single-phase power. The power pack is used to convert the electrical power to high voltage 10,000 volts dc. As you read this section refer to figure 5-19.

The power pack and circuitry are shown in figure 5-19. The circuit is a half-wave voltage doubler, consisting of a high-voltage transformer (1), two selenium rectifiers (9), and two capacitors (4 and 10). The power supply assembly is the self-regulating type commonly known as a constant-voltage transformer. The resonating winding (X3-X4) connected to the resonatiing capacitor (2) serves to hold the power supply voltage at a constant level when the primary input voltage varies. The resonating circuit is designed to help limit the output power.

The high voltage from the power supply is connected to a surge limiting resistor (8), which limits the current of an arc that might occur and provides protection for the capacitors.

The negative output of the power supply is connected to ground through a surge limiting resistor (3). This resistor limits the feedback current due to an arc. It provides additional protection to the capacitors through the ground terminal of the precipitator. The proper operation is indicated by a lamp (12) that is connected to a resistor (11). A portion of the supply output voltage is used for the neon indicating lamp.



1. High-Volume Transformer
2. Capacitor-Resonating
3. Resistor-Surge Limiting
4. Capacitor
5. Ionizer Electrode
6. Collector Tube
7. High-Voltage Tube
8. Resistor-Surge Limiting
9. Selenium Rectifiers
10. Capacitor
11. Lamp Resistor
12. Indicating Lamp and socket
13. Interlock Safety Switch

Figure 5-19.—Vent fog precipitator wiring diagram.

When the operating voltage drops below its minimum requirement the lamp will go out.

The access cover safety switch (13) is an interlock. With the cover removes the contacts are open and de-energize the primary of the power supply.

The components of the precipitator are the ionizer electrode (5) and the electrode chuck and high-voltage tube (7). The assembly is held inside the collector tube (6) by an insulator. The insulator also serves to electrically insulate the high-voltage assembly.

SUMMARY

The vent fog precipitator is a simple, rugged, essential piece of equipment. By following posted maintenance procedures, it will remain a reliable, operational piece of equipment.

PROPULSION SHAFT TORSIONOMETER

The propulsion shaft torsionometer is a device used to measure the torque and (optionally) the rpm of a ship's rotating propulsion shaft accurately. Of the types available in the fleet, the basic principles are the same. By accurately measuring the torsional twisting of a ship's propulsion shaft, you can calculate the load (torque) on the ship's main engine. Using this figure, the load on the shaft can be calculated into shaft horsepower.

DESCRIPTION

Through the use of various sensors and components, the shaft torsionometer detects the slight twisting and (optionally) the rpm of the ship's propulsion shaft. Then the torsionometer produces a proportional signal and uses the signal to drive appropriate indicators located near the ship's engineering console or on the bridge. Shaft horsepower readings may also be displayed at various remote locations, such as the pilothouse or the chief engineer's office, using repeaters or remote displays.

The optional rpm system uses an rpm probe to receive signals from a shaft mounted assembly. The signals are then processed by the rpm conditioner and sent through shipboard cables to the appropriate indicators.

MAINTENANCE

The components of the torque sensor system are surprisingly rugged. Besides keeping the components clean and dry, the only maintenance that should be required from ship's force personnel is preventive maintenance indicated in the ship's PMS system.

SUMMARY

This section has introduced you to the operation of the torsionometer. For a more detailed description of the operation and construction of the system, refer to the manufacturer's technical manual and NAVSEA SN521-AC-MMM-010.

DECK EQUIPMENT

A good deal of the electrician's time aboard ship is spent performing maintenance. Of the items being maintained, deck equipment receives the most wear and tear because of its intended use and location. Deck equipment must be in working condition for the ship to be able to perform its assigned mission effectively.

WINCHES

Winches installed aboard ship are used to heave in on mooring lines, hoist boats, lift booms, and handle cargo. Winches are classified by the drive unit and the type of design, either drum or gypsy. Figure 5-20 shows a simplified representative winch, which is a combination of a drum and gypsy type of winch.

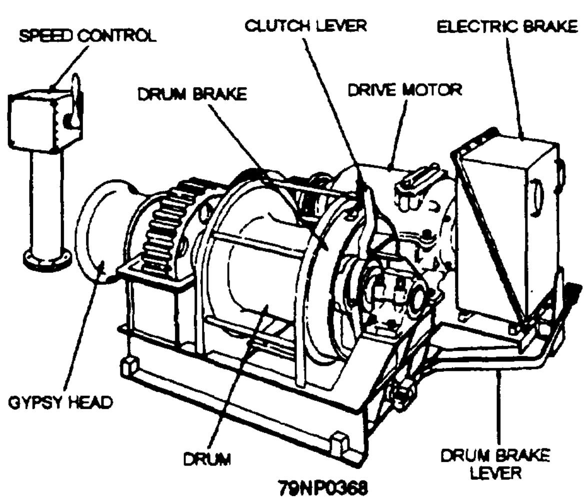


Figure 5-20.—A simplified representative winch.

The drum winch may have from one to four horizontally mounted drums on which wire rope is wound for raising, lowering, or pulling loads. The drum winch may also include one of two gypsy heads. On newer winches with only one gypsy head, the gypsy head can be removed and reassembled on the opposite end of the drum shaft. Drum winches maybe driven by electric motors (ac or dc), an electrohydraulic drive, steam, air, a gasoline engine, or by hand.

The gypsy winch has one or two horizontally mounted gypsy heads around which several turns of line must be taken to prevent slippage when a load is snaked or hoisted. Gypsy winches are driven by electric motors (ac or dc), an electrohydraulic drive, steam, air, a gasoline engine, or by hand.

Winches on numerous auxiliary ships are often referred to as deck winches or cargo winches.

ANCHOR WINDLASSES

Anchor windlasses are installed on board ship primarily for handling the chains used with anchors for anchoring the ship. In addition, most windlasses are provided with capstans or gypsy heads for handling lines and for mooring and warping operations. Anchor windlasses can be of two types—electric or electric-hydraulic.

Electric Anchor Windlasses

Electric windlasses are powered by an electric motor that drives a wildcat(s) and head(s) directly through suitable reduction gearing. The electric power for the motor is either ac or dc.

Cargo ships, transports, and auxiliary ships are generally provided with horizontal shaft, self-contained, electric-driven windlasses with the motor and reduction gearing located on the windlass bedplate on the open deck. These windlasses have combined facilities for anchor handling and warping. They consist of two declutchable wildcats on the main shaft and two warping heads on the shaft ends. These are driven through suitable reduction gearing by the electric motor.

The motors are reversible, variable speed. They are provided with magnetic brakes to hold the load if the power fails or under service conditions. Their dual magnetic controls provide both straight reversing characteristics for warping and dynamic lowering characteristics for anchor handling. Transfer switches allow selection of the proper characteristics. When used for anchor handling, the control usually provides five speeds in each direction with adequate torque in hoist directions and dynamic braking in all lowering points. For warping, the control characteristics are substantially identical in both directions. A single controller master switch is provided and located on the deck adjacent to the windlass.

Electric-Hydraulic Anchor Windlasses

Electric-hydraulic anchor windlasses are particularly adapted for anchor handling because of varying load conditions and their wide range of speed and torque characteristics. The hydraulic drive was developed to overcome all the operating and installation objections inherent with either steam- or direct-electric-driven windlasses. The electric-hydraulic windlass drive is similar to the electric drive with one exception. Instead of having the electric motor coupled directly to the reduction gearing, the power is transmitted from the electric motor through a variable stroke hydraulic transmission. This obtains a wide range of output shaft speed.

The electric motor for a hydraulic windlass is usually a single-speed, squirrel-cage type. Electric control is required only for light starting duty, as the motor is started in a no-load condition. The motor is direct coupled to the pump unit of the hydraulic motor unit, B-end, through piping. The B-end is coupled to a suitable reduction gear that drives the windlass shaft. To determine windlass speed, you vary the stroke of the pump A-end. This is done by control handwheels, located on the weather deck and at the pump. These handwheels also control the direction of rotation of the windlass and are suitably marked. The stroke at which the A-end is set determines the quantity of hydraulic fluid delivered to the B-end, which, in turn, determines the speed at which the B-end rotates.

The power plant of a typical hydraulic windlass installation for large combatant or auxiliary vessels has two units. Each unit comprises a constant-speed, horizontal, squirrel-cage, electric motor driving a variable stroke hydraulic pump through suitable reduction gearing. The electric motors have magnetic brakes designed to hold 150 percent of the motor-rated torque. They are set on loss of power to prevent the anchor dropping. The power units are arranged, port and starboard, in the windlass room. Normally the port unit drives the port windlass half, and the starboard unit, the starboard half. However, transfer valves are provided in the oil lines that, when properly set, allow the port power unit to operate the starboard windlass, and vice versa.

Destroyer Anchor Windlass

The anchor windlass installed aboard destroyers consists of a two-speed motor directly connected through reduction gears to a vertical shaft. A capstan and a wildcat (fig. 5-21) are mounted on the vertical shaft. The capstan and the wildcat are located on the weather deck; the electric motor and the across-the-line starter are located in the windlass room on the next deck below. The windlass is designed to operate in both directions to raise or lower either the starboard or port anchor.

CONSTRUCTION.— The windlass is driven by a two-speed (full speed and one-quarter speed), three-phase, 440-volt, 60-hertz motor connected to the reduction gear by a controlled torque coupling. The controlled torque coupling is provided to prevent undue stresses when the anchor is being housed. When the anchor is housed, the drum master switch must be shifted to the low-speed position before the anchor enters the hawsepipe.

An electric brake is mounted just below the controlled-torque coupling. This brake will release when power is applied. It will set when power is disconnected or fails. If power fails, the electric brake is designed to stop and hold 150 percent of the rated load when the anchor and chain are being lowered at maximum lowering speed.

The wildcat is designed to hoist one anchor and 60 fathoms of 1 1/4-inch dielock chain in not more than 10 minutes on the high-speed connection without exceeding the full-load rating of the motor. On the low-speed connection, the wildcat is designed to hoist the anchor and 60 fathoms of chain without overloading the motor. Also, on the low-speed connection, the wildcat exerts a pull on the chain at least three times that required to hoist the anchor and 60 fathoms of chain.

The capstan is designed to heave a 6-inch circumference manila line at a speed of 50 feet per minute with a line pull corresponding to the full-load motor torque.

The capstan head is keyed directly to the drive shaft, while the wildcat is connected to the drive shaft through a driving head and a locking head. The wildcat is keyed to the driving head, and the locking head is keyed to the drive shaft. Vertical blocks sliding in slots in the locking head are raised (by the locking handwheel) into slots in the driving head to connect the two heads. The mechanism is called the *locking gear.* The wildcat and sleeve run free on the same shaft until connected to the

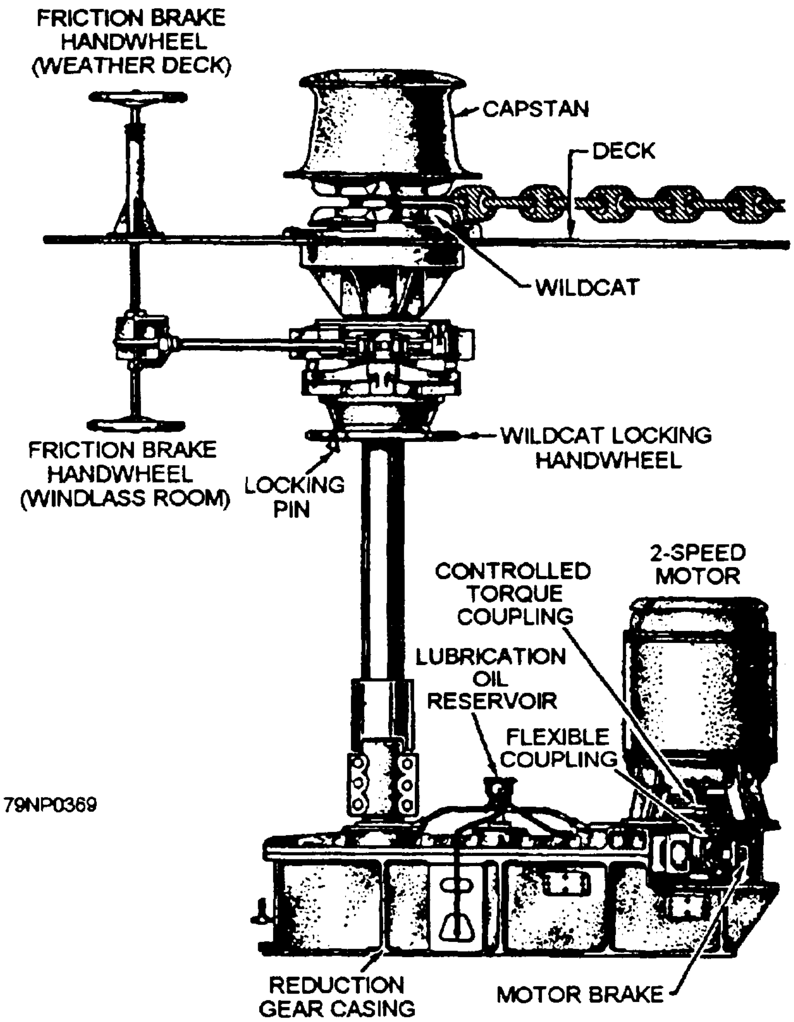


Figure 5-21.—Anchor windlass.

shaft by a locking head located below the weather deck. You can run the capstan independently for warping by disconnecting the locking head and holding the wildcat by the brake band on the brake drum. You can pin the handwheel in the LOCKED or UNLOCKED positions. Ensure it is always fully locked or fully unlocked to prevent unnecessary wear on the brake.

There is a hand brake on the wildcat shaft to control the anchor handling. It is designed to operate in either direction of rotation of the wildcat and to stop and hold the anchor when dropped into a depth of 45 to 60 fathoms. The brake is operated by a handwheel located on the weather deck or by a duplicate handwheel in the windlass room.

OPERATION.— The windlass is operated by a drum master switch on the weather deck and a duplicate switch in the windlass room. It is important to remember that if the windlass is run with the locking handwheel in the LOCKED position, the wildcat will revolve. In this case, if the chain is engaged in the whelps on the wildcat, the chain should be free to run. Be careful to select the proper direction of rotation and be sure that the windlass is properly lubricated.

You can operate the motor from either master switch No. 1 (on the weather deck) or from master switch No. 2 (in the windlass room). Master switch No. 1 predominates. When the associated on-off switch located on master switch No. 1 is operated in the ON position, master switch No. 1 takes over the control from master switch No. 2 (if both switches are operated simultaneously).

The anchor windlass is used alternately to handle either the starboard or the port anchors. The windlass is operated by a reversible motor in either of two directions. These directions may be hoist for the starboard anchor (lower for the port anchor) and hoist for the port anchor (lower for the starboard anchor). However, only one anchor can be handled at a time.

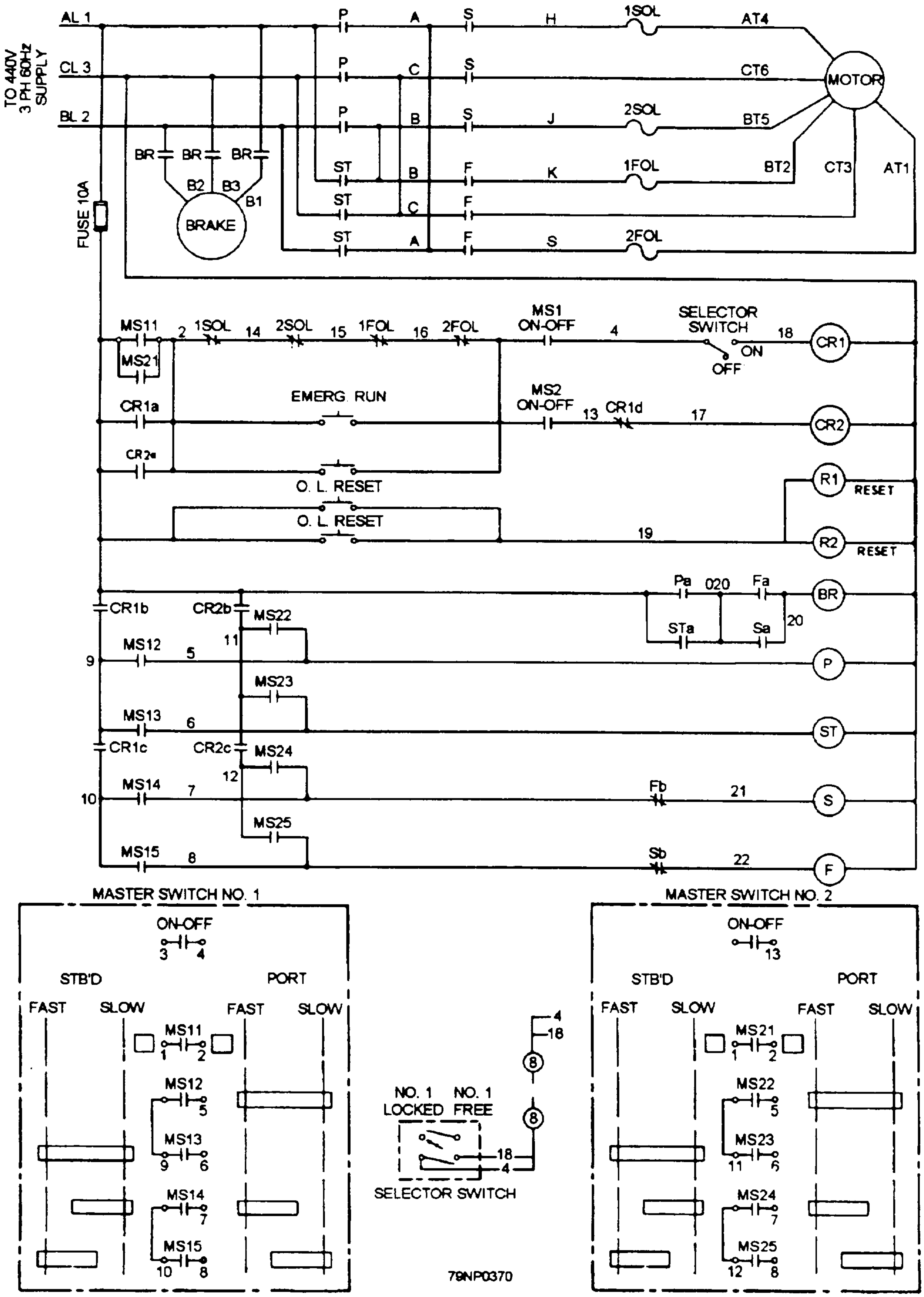


Figure 5-22.—Reversing across-the-line starter for a two-speed anchor windlass.

The motor starter (fig. 5-22) is equipped with four thermal overload relays to protect the motor against overloads. Overload relays 1FOL and 2FOL are in the fast-speed motor circuit. If an overload occurs in the slow-speed or fast-speed circuit, the SOL or the FOL relays will operate to trip the slow-speed or the fast-speed contractors, respectively. You can operate the motor in an emergency by holding either of the EMERG-RUN push buttons down and operating the master switch in the usual manner. To reset the overload relays, press the OVERLOAD RESET push buttons if an overload or voltage failure occurs. Return the master switch to the OFF position to restart the motor.

To start the motor in the port (hoist) direction for slow speed using master switch No. 1, take the following actions:

STEP	ACTION	RESULT
1.	Turn the associated on-off switch to the ON position and move the controller handle to the SLOW PORT (hoist) position.	Contact MS11 momentarily closes to energize the operating coil of relay CR1 which closes contact CR1a to provide a holding circuit for relay CR1.
		Contacts CR1b and CR1c close to prepare the circuit to controller contacts MS12, MS13, MS14, and MS15.
		Normally closed contact CR1d opens to prevent operation of relay CR2.
2.	When the controller handle is moved further toward the SLOW PORT position.	Contacts MS11 open; controller contacts MS12 close to energize the operating coil P and close the port contactor in the motor starter.
		Contacts Pa close to provide the circuit to the motor brake relay BR.
		Controller contacts MS14 close to energize the operating coil S and close the slow-speed contactor in the motor starter.
		Contacts Sa close to energize the brake relay BR and close its contacts to release the motor brake.
		Normally closed contacts Sb (in the circuit to the operating coil F of the fast-speed contactor) open.

The motor is now connected for hoisting the port anchor at slow speed.

When the controller handle is moved further to the FAST-PORT position:

STEP	ACTION	RESULT
1.	The controller handle is moved further to the FAST-PORT position.	Contacts MS15 close before contacts MS14 open so that the operating coil S is kept energized through normally closed contacts Fb.
2.	Contacts MS14 open.	The operating coil S de-energizes and closes contacts Sb to energize the operating coil F.
3.	Contacts Fb open to de-energize the operating coil S and open the slow-speed contactor.	Contacts Sb close to complete the circuit to the fast-speed contactor in the motor starter.

The motor is now connected for hoisting the port anchor at fast speed. The same sequence occurs to hoist the starboard anchor. However, controller contacts MS13 energize the operating coil sr to close the starboard contactor instead of controller contacts MS12 energizing the operating coil to close the port contactor.

If you operate the motor by master switch No. 2, operate the associated ON-OFF switch to the ON position and move the controller handle to the PORT or STARBOARD SLOW position. This action closes contacts MS21 momentarily y to energize the operating coil of relay CR2 (if relay CR1 is not energized). The sequence of operation for master switch No. 2 is almost the same as that for master switch No. 1. However, contractors P, ST, S, and Fare energized through the CR2 contacts instead of through the CR1 contacts. You can lock out master switch No. 1 by turning the selector switch to the No. 1 LOCKED position. In this position the selector switch opens the circuit to relay CR1 and prevents its operation.

Operating instructions and system diagrams are normally posted near the anchor windlass controls. The diagrams describe the various procedures and lineups.

MAINTENANCE.— General maintenance of anchor windlasses should follow the PMS installed aboard ship.

SUMMARY

The information covered on winches and windlasses is only an introduction. More information on the specific type and size of equipment aboard your ship is available in the manufacturer's technical manuals and *NSTMs* available in your technical library or legroom.

ELEVATORS

The elevator installations aboard aircraft carriers usually consist of hydraulic or electric types for airplane elevators and electrohydraulic or electromechanical types for freight, mine, bomb, torpedo, and ammunition elevators. This section contains a discussion about the electric and electrohydraulic elevators and the electronic control system of some elevators.

ELECTRIC (ELECTROMECHANICAL) ELEVATORS

The platform on electric elevators is raised and lowered by groups of cables that pass over sheaves and then to the hoisting machinery drums. The hoisting drums, coupled together, are driven through a reduction gear unit by an electric motor.

The motor is of the two-speed type. The control arrangements are such that the elevator starts and runs on the high-speed connection. The low speed is used for deceleration as the elevator approaches the upper or lower limit of travel.

The two-speed electric motor is controlled through a system of contractors, relays, limit switches, and selector switches. Automatic operation is obtained by selecting the levels between which the platform is to run. The start pushbutton can then be used to close contractors through safety switches to operate the elevator at high speed. Just before reaching the desired level, the control transfers the motor to the low-speed winding through the action of cam-operated limit switches. On reaching the desired level, the control circuit is disconnected by a cam-operated stop switch, releasing the contractors and setting the brake to stop the platform.

For safety in operation, all doors at each level are interlocked to prevent operation unless they are closed. Also, all hatch covers are interlocked to prevent elevator operation unless they are fully opened.

The following protective features are incorporated in the control:

- Slack-cable switches. These switches prevent operation of the elevator if any cable should become slack.
- Emergency stop switches at each level served. These switches allow operators at any level to stop the elevator should a malfunction occur.
- Overtravel switches. These switches stop the elevator if it should fail to stop at the uppermost level.
- Overload protection. This feature prevents damage to the system from an overload condition.

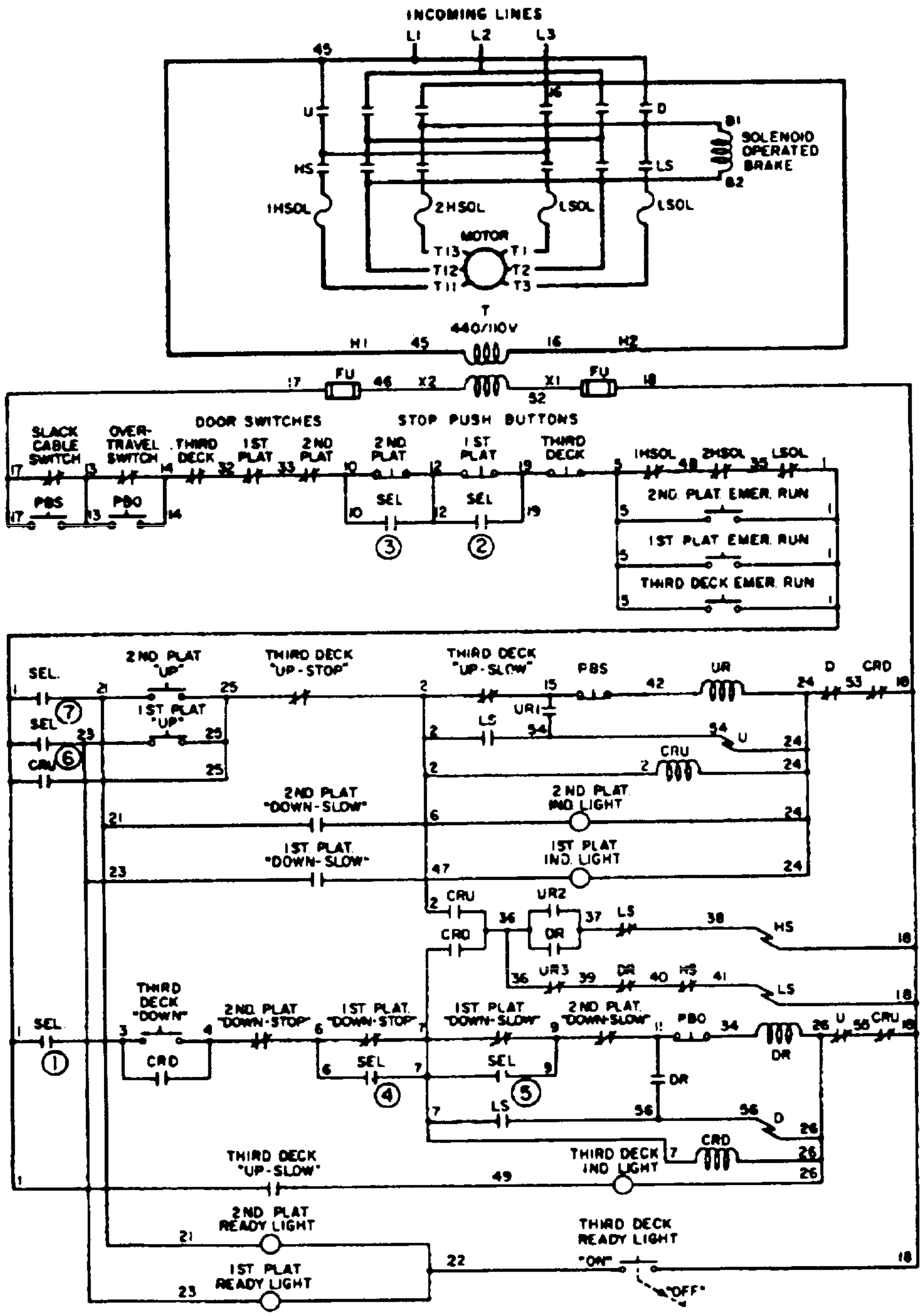
Elevator controllers are designed with a double-break feature that prevents improper operation if any one contactor, relay, or switch should fail to function properly. Pushbuttons are interlocked to prevent operation of the elevator unless the platform is at the same level as the pushbutton. Some elevators are equipped with hatchway door mechanical interlocks to prevent opening the door unless the platform is at the same level.

A governor-actuated safety device is provided under the platform to grip the guide rails and stop the platform if there is an overspeed in the DOWN direction. Also, spring bumpers are provided at the bottom of the hatchway to prevent mechanical damage to the hull or platform due to overtravel in the DOWN direction.

The operation of the elevator depends on the position of the selector switch. The selector switch determines which decks the elevator will run between. This switch also makes all master switches inoperative, except those pertaining to the selected levels.

Suppose the selector switch is set in the second platform to the third deck position (fig. 5-23). Refer to figure 5-23 as you read the sequence of events which follow:

ACTION	RESULT
The selector switch is set in the second platform to the third deck position.	In this position the control is set up for the elevator to operate between the second platform and the third deck. The following sequence occurs: 1. Contacts 1, 2, 4, 5, and 7 close. 2. Contact 2 shorts out the first platform pushbutton. 3. Contact 1 places the third deck pushbutton station in the circuit. 4. Contacts 4 and 5 short out the first platform DOWN-STOP switches, respectively. 5. Contact 7 places the second platform pushbutton station in the circuit. If the overtravel, slack cable, door switches stop pushbuttons, and overload relay contacts are in their normally closed positions, the control circuit is energized and set up for operation.
The second platform UP pushbutton (fig. 5-23) is momentarily pressed; the UP auxiliary relay UR and the UP control relay CRU are energized.	The following are the result of this action: 1. Contacts CRU and UR1 close energizing the up contactor U in the across-the-line starter. 2. UP auxiliary relay UR closes contacts UR2 and opens UR3, which energizes the high-speed contactor HS. 3. Contactor HS applies voltage to the motor and energizes the brake-release solenoid. 4. The elevator moves up until it mechanically operates the UP-SLOW limit switch on the third deck. 5. The limit switch de-energizes the up auxiliary relay UR. 6. This action closes contact UR3 and energizes the LS coil (the motor is transferred from the HS to the LS contactor). 7. The elevator continues up at low speed until it mechanically operates the UP-STOP limit switch on the third deck. 8. The limit switch de-energizes up contactor U, de-energizing the brake-release solenoid and operates the motor brake, stopping the motor. 9. An indicating light shows when the elevator reaches the selected deck.
To stop the elevator—	Press the STOP lever at the push-button station located on the selected level (the third deck in this case). To restart the elevator, press the UP pushbutton lever at the second platform or the DOWN lever at the third deck.
If there is an overload—	1. One of the overload relays opens the control circuit, sets the motor brake, and de-energizes the motor. 2. For normal operation, reset the overload relay by pressing the reset button that projects through the door of the controller enclosure.



	SELECTOR SWITCH		
	CONTACT NOS. HANDLE END OFF	2ND PLATFORM TO THIRD DECK	1ST PLATFORM TO THIRD DECK
A	① ⊣⊢	X	X
	⊣⊢ ②	X	
B	③ ⊣⊢		X
	⊣⊢ ④	X	
C	⑤ ⊣⊢	X	
	⊣⊢ ⑥		X
D	⑦ ⊣⊢	X	
X - INDICATES CONTACTS CLOSED			

NOMENCLATURE

U - UP CONTACTOR
D - DOWN CONTACTOR
HS - HIGH SPEED CONTACTOR
LS - LOW SPEED CONTACTOR
UR - AUXILIARY UP RELAY
DR - AUXILIARY DOWN RELAY
T - CONTROL TRANSFORMER 440/110V
LSOL - LOW SPEED OVERLOAD RELAY
FU - CONTROL FUSE - 10 AMP.
PBO - OVER TRAVEL BY-PASS SWITCH
SEL - SELECTOR SWITCH. FOR CONTACTOR SEQUENCE SEE ABOVE SCHEMATIC
PBS - SLACK CABLE BY-PASS SW
1HSOL, 2HSOL - HIGH SPEED OVERLOAD RELAYS
CRU & CRD - CONTROL RELAYS - UP & DOWN

MOTOR CONNECTION TABLE

SPEED	L1	L2	L3	OPEN	DIRECTION
LOW	T1	T2	T3	T11, T12, T13	UP
HIGH	T11	T12	T13	T1, T2, T3	
LOW	T3	T2	T1	T11, T12, T13	DOWN
HIGH	T13	T12	T11	T1, T2, T3	

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Figure 5-23.—Schematic diagram of electric elevator automatic control selective from one station.

As already mentioned, additional protection is provided through a system of series-connected interlocks in the control circuit. These interlocks consist of door, slack cable, and overtravel switches. The following table lists some of the means of elevator operation during malfunctions:

ACTION	RESULT
If a cable becomes slack or the elevator overtravels—	1. Operate the elevator by holding in the SLACK CABLE bypass button PBS (located inside the controller). 2. When this pushbutton is operated, the elevator will travel in low speed only.
If an overload occurs—	1. Operate the elevator (in case of an emergency) in the usual manner by depressing the EMERG-RUN lever of either pushbutton station.
If other relays or contactors malfunction—	Proper operation is ensured by the up and down current control relays CRU and CRD, respectively.

ELECTROHYDRAULIC ELEVATOR

The electrohydraulic elevators use hoisting cables and drums in much the same manner as the electric elevator. In this system, however, the cable drums are driven through reduction gears by a hydraulic motor. Raising, lowering, or speed changes are accomplished by varying the stroke of the variable delivery hydraulic pump through differential gearing. Figure 5-24 shows a typical arrangement scheme for operation of the electrohydraulic bomb elevators.

The elevators use a follow-up type control system so that the pump is put on stroke by a pilot motor and the stroke is taken off by the motion of the platform working on the follow-up control.

On some elevators, the pilot motor is started by depressing an operating pushbutton. The pilot motor moves the pump control piston to the ON-STROKE position, and the elevator accelerates to full speed. Upon approaching the selected level, a platform mounted cam trips a slow-down switch that de-energizes the pilot motor. Movement of the platform then returns the stroke of the pump to the NEUTRAL position. On reaching the selected level, a stop switch de-energizes the brake solenoid to set the brake and stop

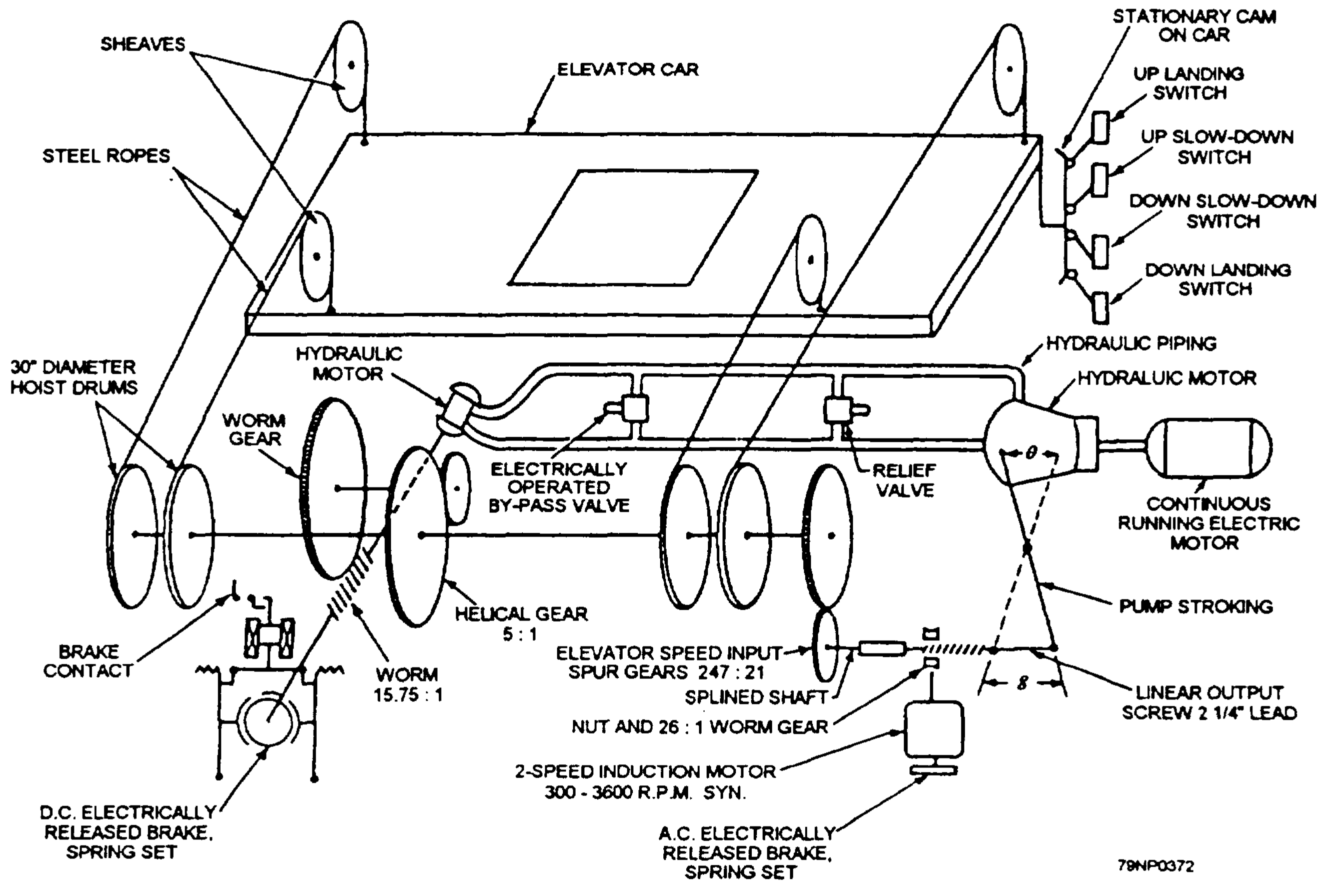


Figure 5-24.—Bomb elevator power plant and control scheme.

the elevator. Reversing the direction of rotation of the pilot motor reverses the direction of movement of the control piston of the pump. This allows the elevator to be moved in the opposite direction.

In another electric-hydraulic system, the pilot motor is a dc motor. The speed of the motor is varied by a rheostat-type control that gives an infinite number of platform speeds. These speeds range from approximately 3 to 90 feet per minute. In installations of this type, a rheostat control is provided on the platform, and a duplicate control is provided in the elevator machinery room.

Several methods are used for stroking the pump for emergency operation two of which are as follows:

1. Declutching the "follow-up" control system from the control stroking unit and manually holding in a pushbutton. This action releases the electric motor brake to free the machinery. A handwheel maybe used to stroke the pump.

2. Rotate the pilot motor armature by attaching a handwheel to an extension on the armature shaft, thus stroking the pump.

ELECTRONIC CONTROLLED ELEVATORS

Elevators installed on some new naval ships use static controls (no meting parts). In these elevators, electronic devices perform the functions of relays, contractors, and limit switches.

The electronic controlled elevator system components (fig. 5-25) include the elevator cam target, the sensing heads, the static logic panels, the motor (magnetic) controller, and a three-phase drive motor. These system components function as follows:

The elevator cam targets are steel cams or vanes, mounted on the elevator platform to actuate the sensing heads.

The sensing heads are mounted up and down the elevator trunk bulkhead. They are used for many elevator functions, such as slowing and stopping, high-speed up and down stops, governing overspeed, preventing overtravel, and door interlock functions.

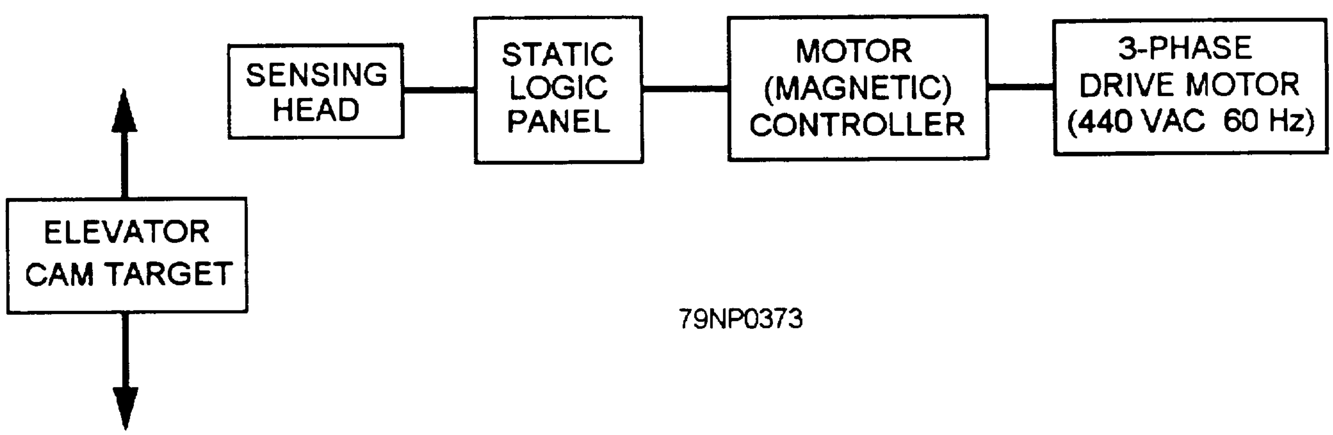


Figure 5-25.—Block diagram of electronic controlled elevator system.

The static logic panel is a solid-state, low-power system that performs functions normally associated. with limit switches, relays, and contactors (fig. 5-26). The logic modules consist of proximity switches, signal converters, retentive memories, reset memories, shift registers, duo-delay timers, and pulses with appropriate logic elements and circuitry.

The motor controller (fig. 5-27) energizes appropriate contractors to control the speed and rotation of the motor.

The three-phase, 400-volt, 60-hertz motor drives the elevator

PROXIMITY LIMIT SWITCHES

Proximity limit switches (electronic limit switches) are used extensively to control elevator movement. Basically, the proximity switch consists of a remotely located sensing head and a logic module that amplifies the sensing head voltage to a positive 10-volt level used

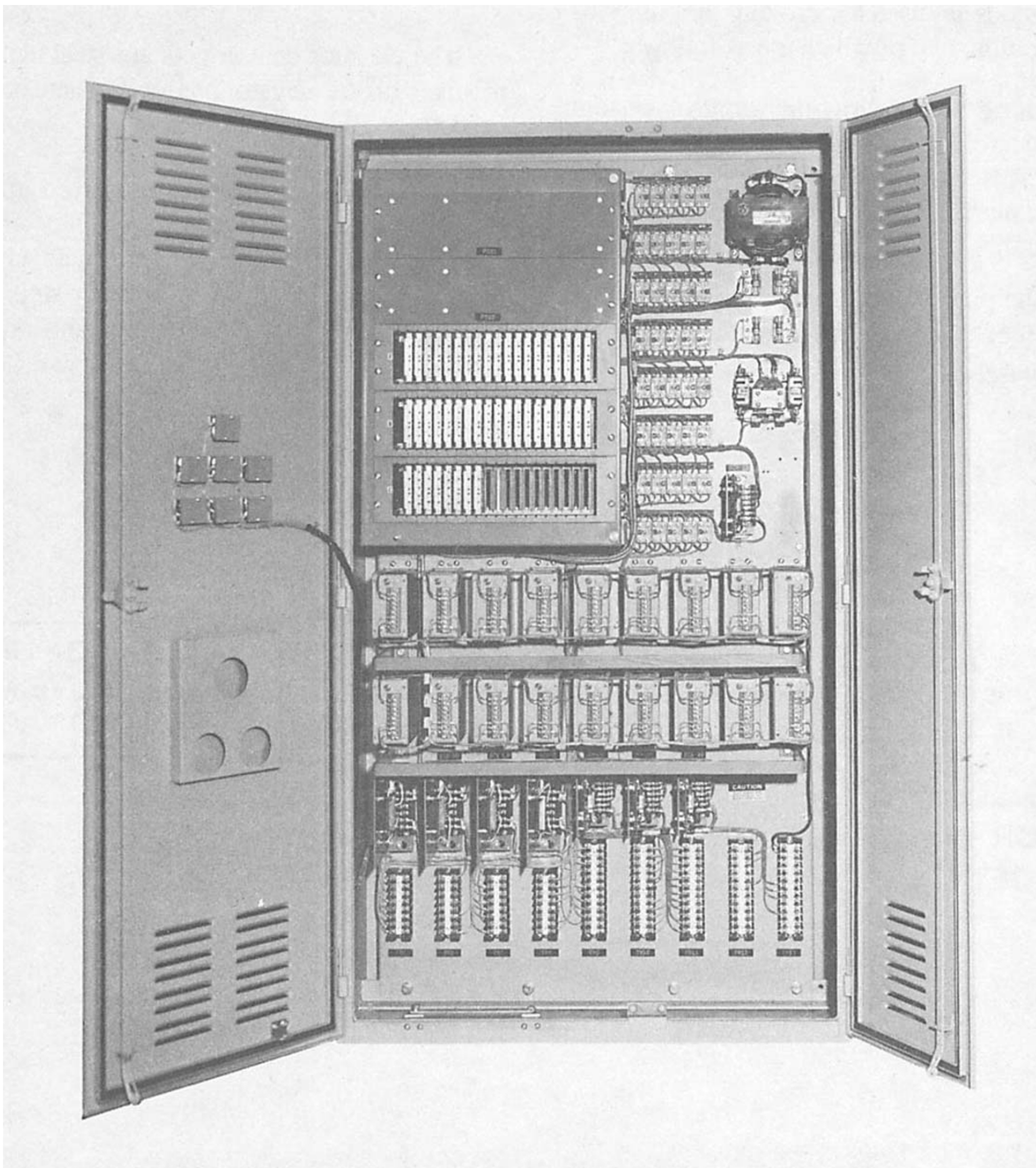


Figure 5-26.—A static logic panel at the sixth level for a cargo elevator.

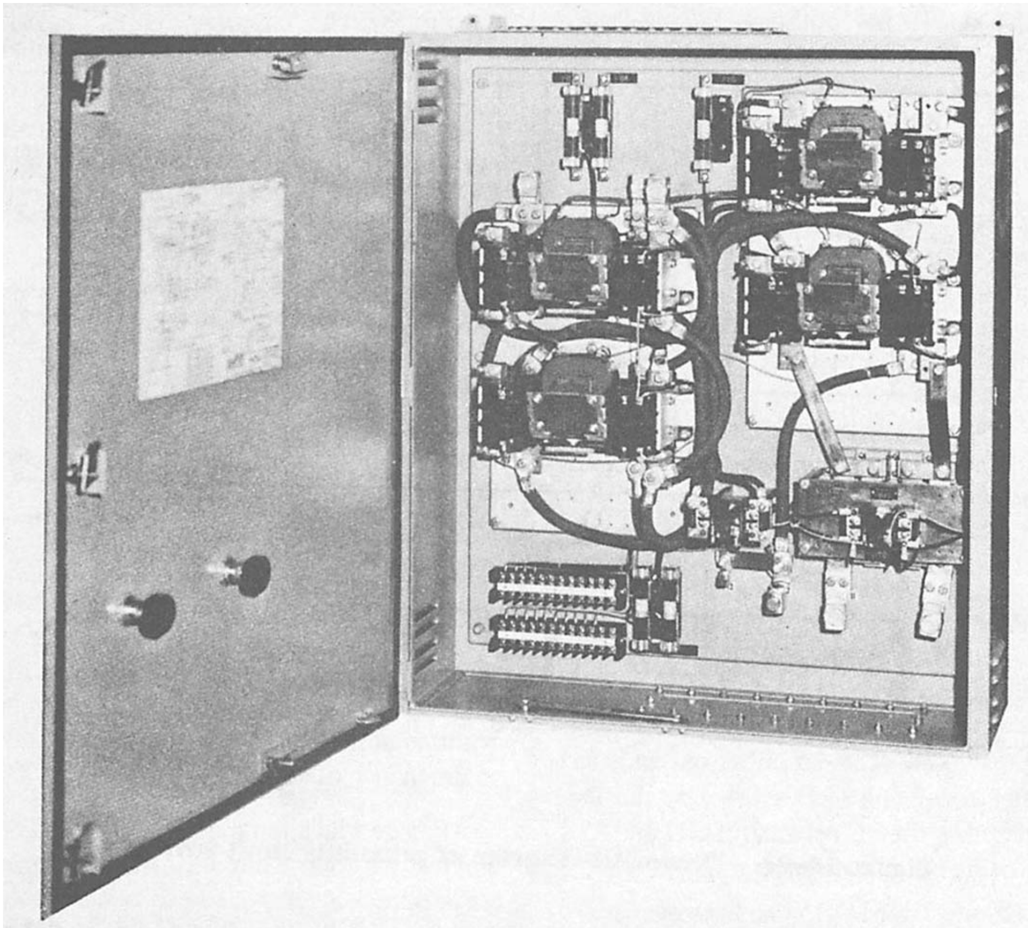


Figure 5-27.—AC magnetic reversing controller for a two-speed, two-winding motor for a cargo elevator.

by the static logic control system. The voltage output is +10 volts when the cam target on the elevator car is moved in front of the sensing head mounted on the elevator shaft. The voltage output is zero when the cam is moved away from the sensing head (deactuated). The metallic elevator target to be sensed must enter the sensing zone to create a signal. The signal strength depends primarily on the distance between the face of the sensing head and the target.

Operation of a proximity limit switch maybe best explained by examining the following basic circuits and components:

The power supply (fig. 5-28), consisting of the 115/15 volt transformer, D1, D2, C1, R1, and R2.

The voltage across D2 used to bias the succeeding amplifier stages.

The Zener diode (D2) has a breakdown voltage of 12 volts, which protects the following stages from overvoltage.

Sensing Heads

The sensing heads (fig. 5-28) consist of two coils connected in series opposition, which, when energized by mutual inductance from a third coil, are balanced by means of a tuning slug. A resistor, connected in parallel with the top sensing coil, is used for positioning the sensing heads. An output voltage is produced by the sensing head when an elevator cam target enters the field, resulting in an output to terminals 3 and 5.

AC Amplifier

The input to the ac amplifier is supplied by the sensing head at terminals 3 and 5 (fig. 5-28). The sensing head signal is amplified by three cascaded amplifier stages consisting of Q1, Q2, and Q3 with suitable biasing networks. The amplifier output is fed through a rectifier consisting of D3, D4, D5, and D6. This signal is filtered by the RC network of C11 and R18 to drive the following Schmitt-trigger.

Schmitt-Trigger

The Schmitt-trigger, consisting of Q4 and Q5, presents a voltage across R23, which is used to bias the output switch transistor Q6 to its ON a OFF state.

Output Switch

The proximity switch supplies only the switching power. Proximity limit switch terminals 6 and 8 connect to a 10-Volt, dc static logic power source. This power source is supplied at terminals 7 and 8 and the proximity light is lit when Q6 switches to the ON state.

When the target is in the sensing zone, the sensing head has an output that is amplified rectified, and filtered, switching the output of the Schmitt-trigger off. This turns the output switch Q6 (fig. 5-28) to its ON position. Therefore, when the target is in the sensing zone, there is an output and the status light L1 is on.

MAINTENANCE

As with all electrical and electronic equipment, preventive maintenance must be performed on a routine basis and according to the PMS and the manufacturer's instruction manuals. Good housekeeping practices and routine adjustments play an important part in the maintenance of elevator controllers.

Pay special attention to the proximity switches. **Do not** test the control circuitry with a megger because the

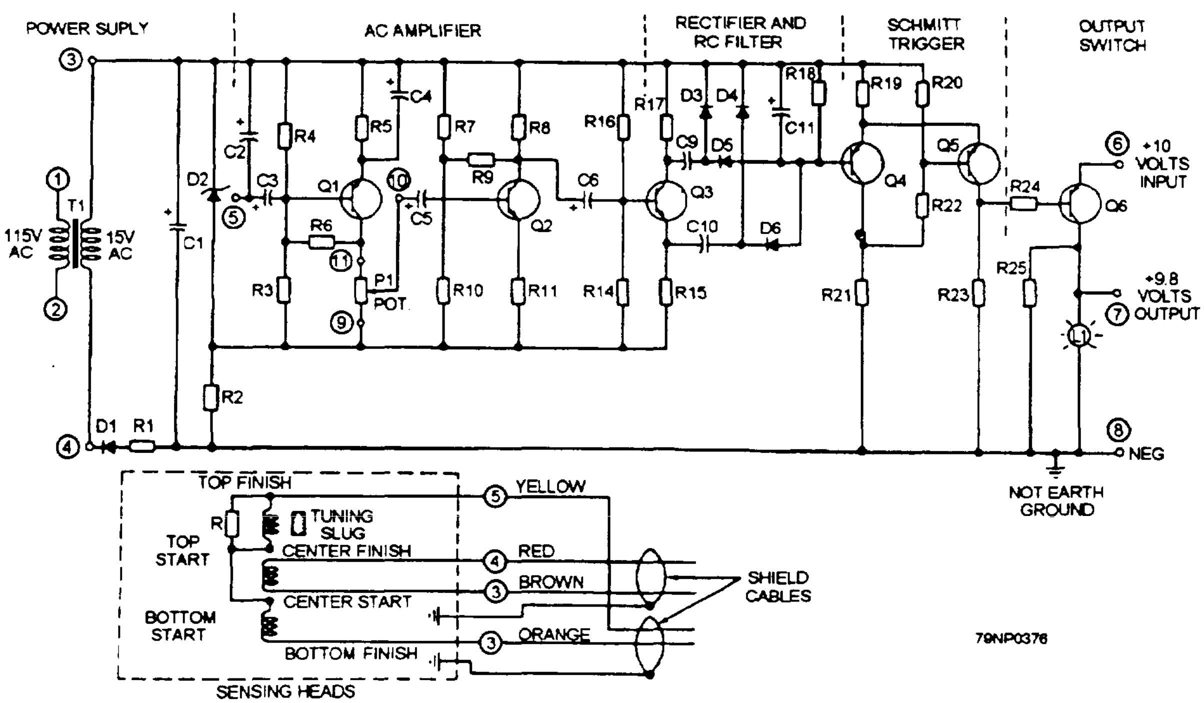


Figure 5-28.—Schematic diagram of a proximity limit switch.

high voltage generated by a megger can easily damage electronic components. If a proximity switch doesn't pick up or drop out properly, make the following checks on the amplifier at the panel:

1. Check the indicating lamp for operation
2. Measure voltage and frequency input and output at the T1 transformer (take all measurements with high impedance meters greater than 1 megohm).
3. Measure drop-out voltages between terminals #3 and #5 of the proximity switch (with and without the cam target at the pick-up point). See the manufacturer's manual for proper tolerance values.

IF any of the above measurements are out of tolerance, you should first check for metal, other than the metal target in the sensing field

The null point of the sensing head may need adjusting. To adjust the null point, remove the soft plug in the tuning slug hole of the sensing head and turning the slug with an Allen wrench. Remove the wrench when checking the null point.

The amplifier sensitivity is adjusted by removing the plug button on the top right of the amplifier and adjusting the potentiometer (Pi) screw. Be careful when inserting the screwdriver. Clockwise rotation reduces pick-up voltage, while counterclockwise rotation will increase the pick-up voltage. This adjustment is very sensitive and must be executed cautiously.

Drop-out voltage cannot be adjusted and depends on the tolerance of resistors in the Schmitt-trigger circuit. If drop-out voltage is not within tolerance, check the values of resistors R19 through R23.

If the above checks and adjustments do not correct the trouble, the problem must be internal to the amplifier. In this case, the amplifier should be removed from the panel for servicing.

SUMMARY

Elevators have become one of the mainstays of equipment aboard ship. While they present a great convenience when moving stores and equipment, they are also one of the most hazardous pieces of gear to operate. When dealing with the elevators aboard ship, you should be sure safety is always the number one priority. Sailors and shipyard workers are killed almost every year due to improper work and maintenance practices. Refer to the applicable technical manuals and training material aboard ship for safety precautions to be observed when operating or maintaining the elevators aboard your ship.

UNDERWAY REPLENISHMENT SYSTEM

The underway replenishment (UNREP) system is a high-speed, heavy weather, day or night method of transferring missiles and other loads between a noncombatant supply ship and a combatant ship while underway. The system shown in figure 5-29 is made up

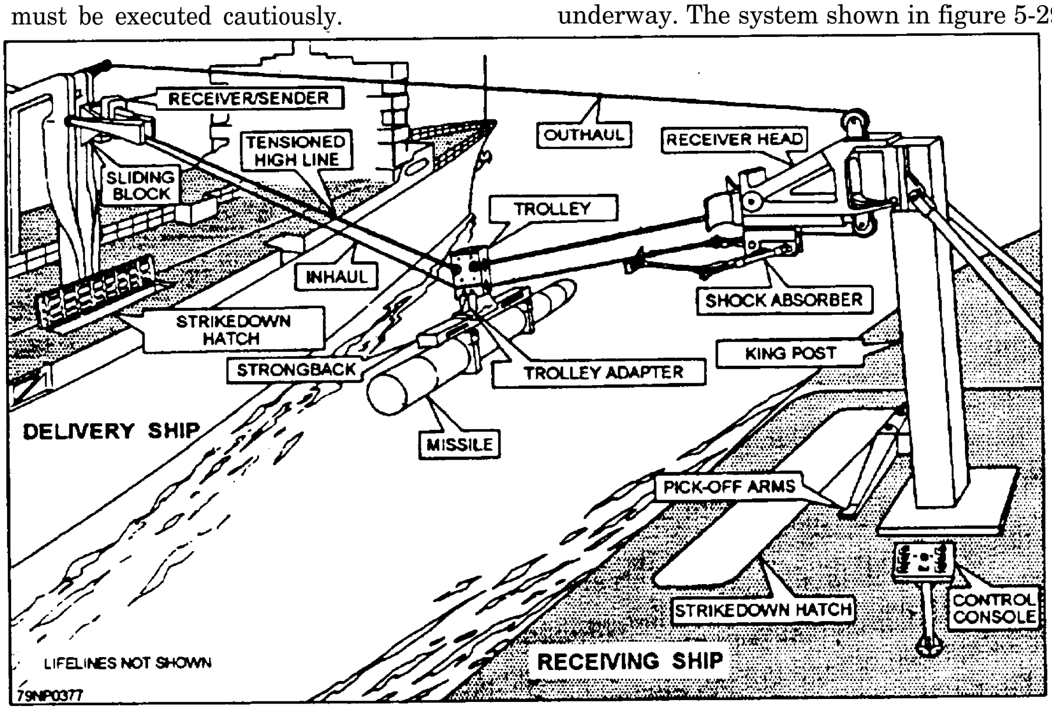


Figure 5-29.—UNREP system.

of two major units-the SENDING UNIT, located on the delivery ship, and the RECEIVING UNIT, located on the receiving ship.

In operation, the sending and receiving units are connected through a ram tensioner by a l-inch-diameter wire rope (highline) to form an integral system. A fast trolley is pulled back and forth along the highline between the ships by the electrohydraulic, winch-tensioned inhaul and outhaul lines. These lines are supplied by the delivery ship. The receiving unit can function to return missiles or other loads back to the supply ship.

Since it is not possible to cover all types of UNREP systems, the ammunition ship (AE) UNREP system is used as a representative system for explanation purposes.

DELIVERY SHIP

The delivery (supply) ship has the missiles racked below deck with the necessary facilities to deliver a missile to the receiving ship. Figure 5-30 shows an AE UNREP delivery system with the steps the missile goes through during the move and the names of the equipment that moves the missile.

Centerline Elevators

The centerline elevators are used in the system to move missiles from the lower deck storage to the second deck. When missiles are stored at the second deck instead of a lower level, the centerline elevator is not used. The second deck has the overhead hi-rail tracks and necessary equipment for delivery of the missile to topside. A strongback is manually connected to the missile when it reaches the second deck to facilitate the careful handling of the missile, as it moves through the system.

Bridge Crane

The bridge crane moves the hi-rail hoist into the centerline elevator. Here, the hi-rail hoist mates with the strongback and lifts the missile from its storage cradle to a LOCK-ON position on the hi-rail hoist. The bridge crane then pulls the hi-rail hoist from the elevator area to the hi-rail track.

Bi-rail Hoist

The bi-rail hoist is an air-driven car that rolls along an overhead track on the second deck. The hi-rail hoist transports the missile to the component lift.

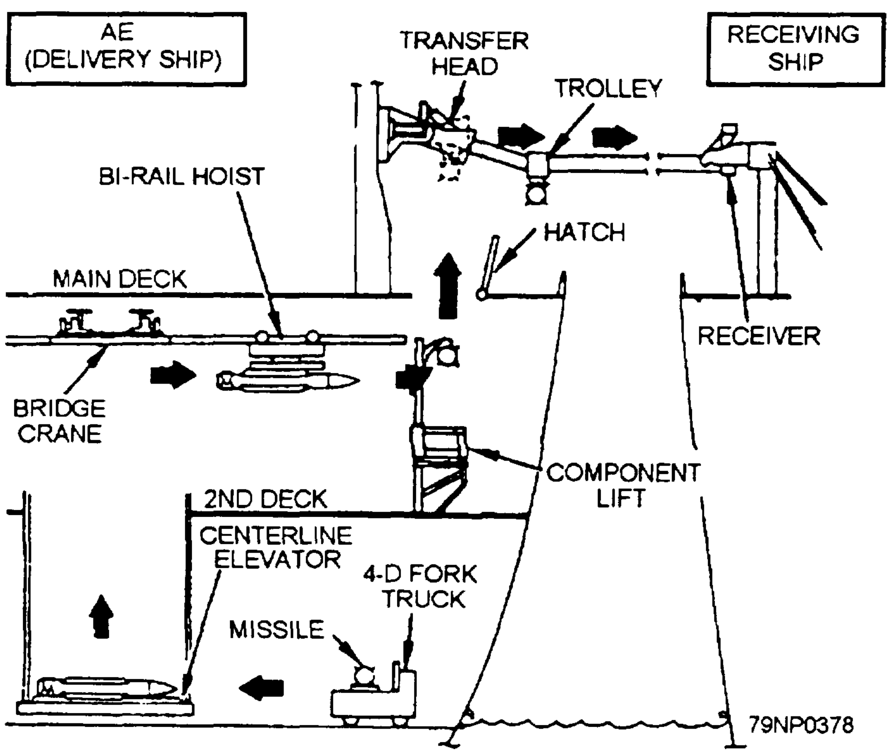


Figure 5-30.—UNREP system equipment used to move a missile from storage to the receiving ship.

The bi-rail hoist lowers a spider to mate with the strongback that raises the missile from the centerline elevator. After the strongback is raised and secured to the hi-rail hoist, the hoist is moved to align with the hi-rail tracks. At this point the bi-rail hoist can turn the missile around (180°), if necessary. The need for turning the missile depends on the receiver ship's strikedown equipment.

Component Lift

When the hi-rail hoist has the missile centered over the component lift, the component lift arms swing out and mates with the strongback. The bi-rail hoist unlatches and returns for the next missile. The component lift raises through the hatch to the main deck and onto the transfer head where the strongback is then connected to the trolley for transporting. The abovedeck equipment on the delivery ship is comprised of a kingpost, a transfer head, a tensioned highline, and the ram tensioner.

Highline Winch and Ram Tensioner

The trolley travels between the delivery and the receiving ship on a tensioned wire rope, called the *highline* (fig. 5-31). The highline is tensioned at 18,000 to 20,000 pounds during ship-to-ship replenishment operations to hold the weight of a load of about 5,000 pounds. The highline stays tensioned even when the distance between the two ships changes and when the ships roll toward or away from each other.

The highline winch (fig. 5-31) has a 200-horsepower electric motor. The motor operates at 440-volt, three-phase, 60-hertz power, and 180 amperes when working at a full load.

A hydraulically operated antibirdcager is installed to keep the wire rope from tangling during operation of the UNREP winches. This unit keeps a steady tension on the wire rope at the winches.

The ram tensioner (fig. 5-31) is a unit that helps the highline winch operator keep the highline tight. When the ram tensioner cannot haul in or pay out the highline fast enough to keep the correct tension, the highline winch operator hauls in or pays out the highline to help the ram tensioner maintain the correct tension.

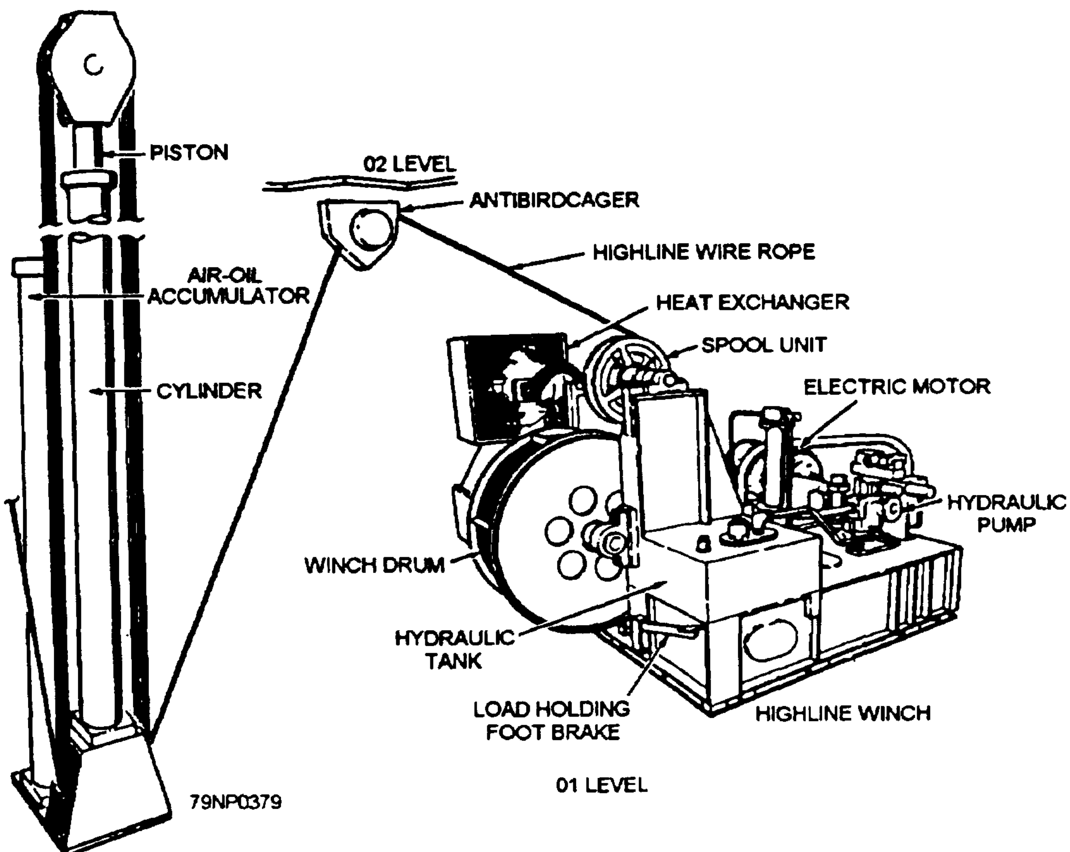


Figure 5-31.—Highline winch.

Inhaul and Outhaul Winches

Wire ropes from two winches (figs. 5-32 and 5-33) control the missile transfer during ship-to-ship transfer operation. The outhaul winch pulls the trolley, which is holding the missile and riding on the tensioned (outhaul) highline to the receiving ship. After the missile has been delivered, the inhaul winch returns the empty trolley by pulling it back to the delivery ship with a wire rope.

The highline winch and the inhaul/outhaul winches (figs. 5-31 and 5-32) all have the same electrical, mechanical, and hydraulic system. The electric motors on the winches drive three pumps—the servo pump, the main pump, and the makeup pump.

RECEIVING SHIP

The UNREP receiving (combatant) ship receives the missile with the receiving unit (fig. 5-34). The receiving unit consists of a kingpost, a receiving head, an elevator, a carriage return hydraulic power unit, and a remote control console. The receiving head is supported by the kingpost, and the elevator operates vertically on the kingpost. The trolley is captured by the receiving head On the other head are shock absorbers (called *jackknifes)* that slow the trolley and arms that steady it while the missile is being removed by the elevator.

The elevator takes the strongback and load from the trolley and deposits them on the strikdown elevator. Lateral orientation of the elevator arms is controlled by the swing of the receiving head. Regardless of roll, pitch, height of the load and station alignment, the arms assume the correct position to receive the strongback supporting the load. A quick-acting mechanism in the trolley (called *pick-off probes*) releases the strongback when the elevator arms are fully closed and locked in slots in the strongback.

The UNREP gear varies from ship to ship. For example, one type may be stationary, while another must be stowed like a crane boom to keep it from interfering with the ship's armament. One type will service only one strikedown elevator, whereas another may have the capability of swinging around to service both port and starboard elevators.

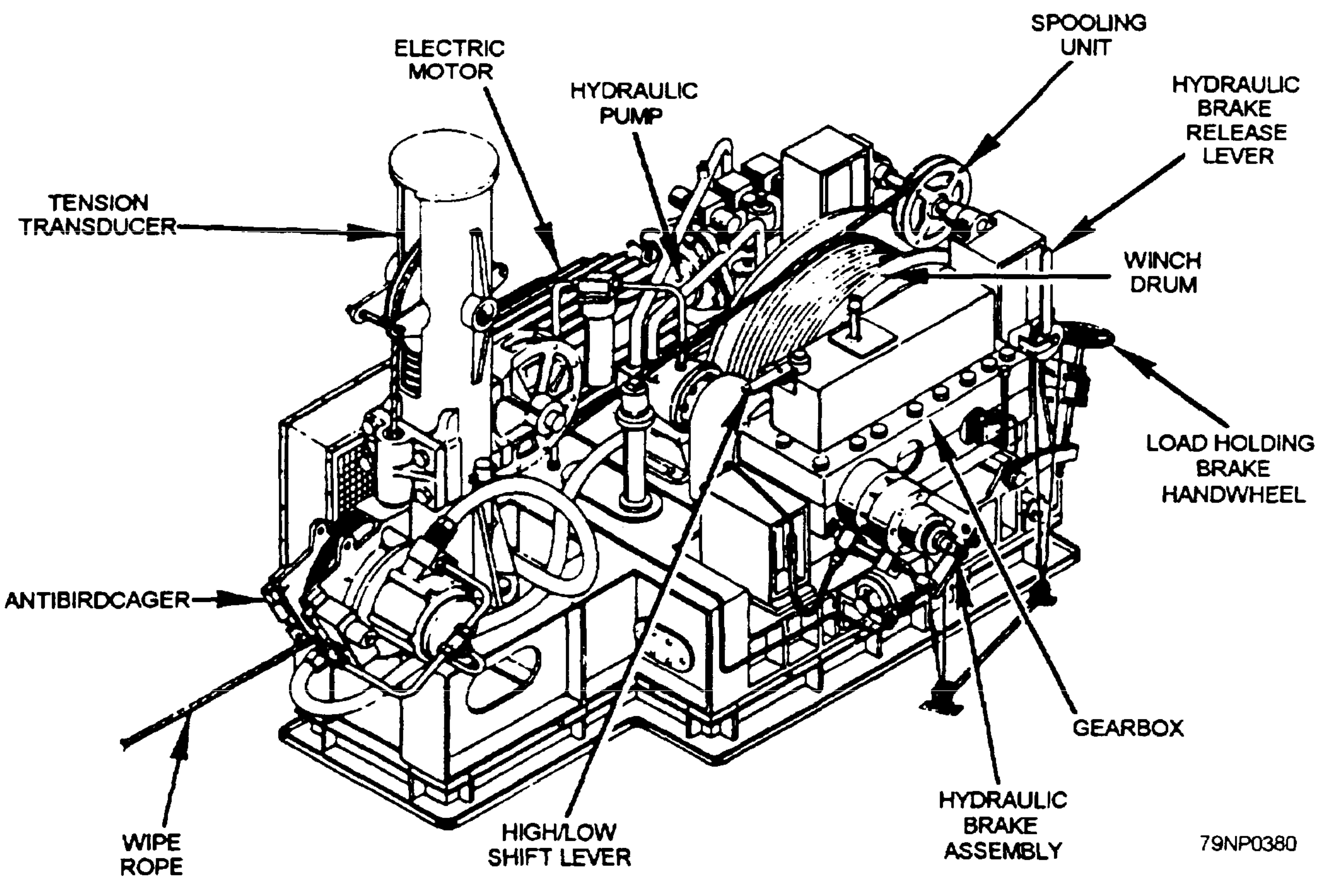


Figure 5-32.—Parts of the inhaul/outhaul winch.

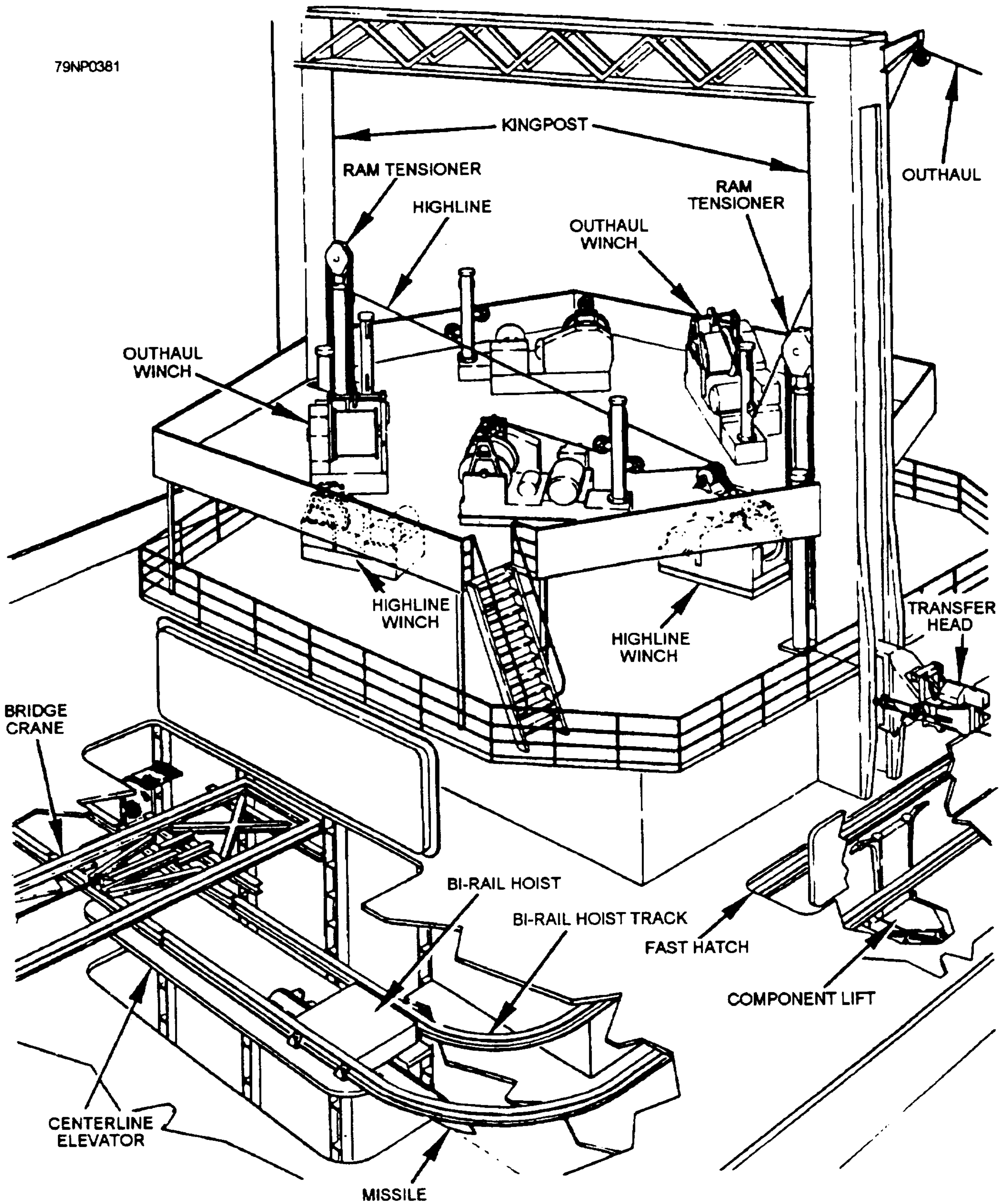


Figure 5-33.—Top view of AE UNREP system (view looking aft).

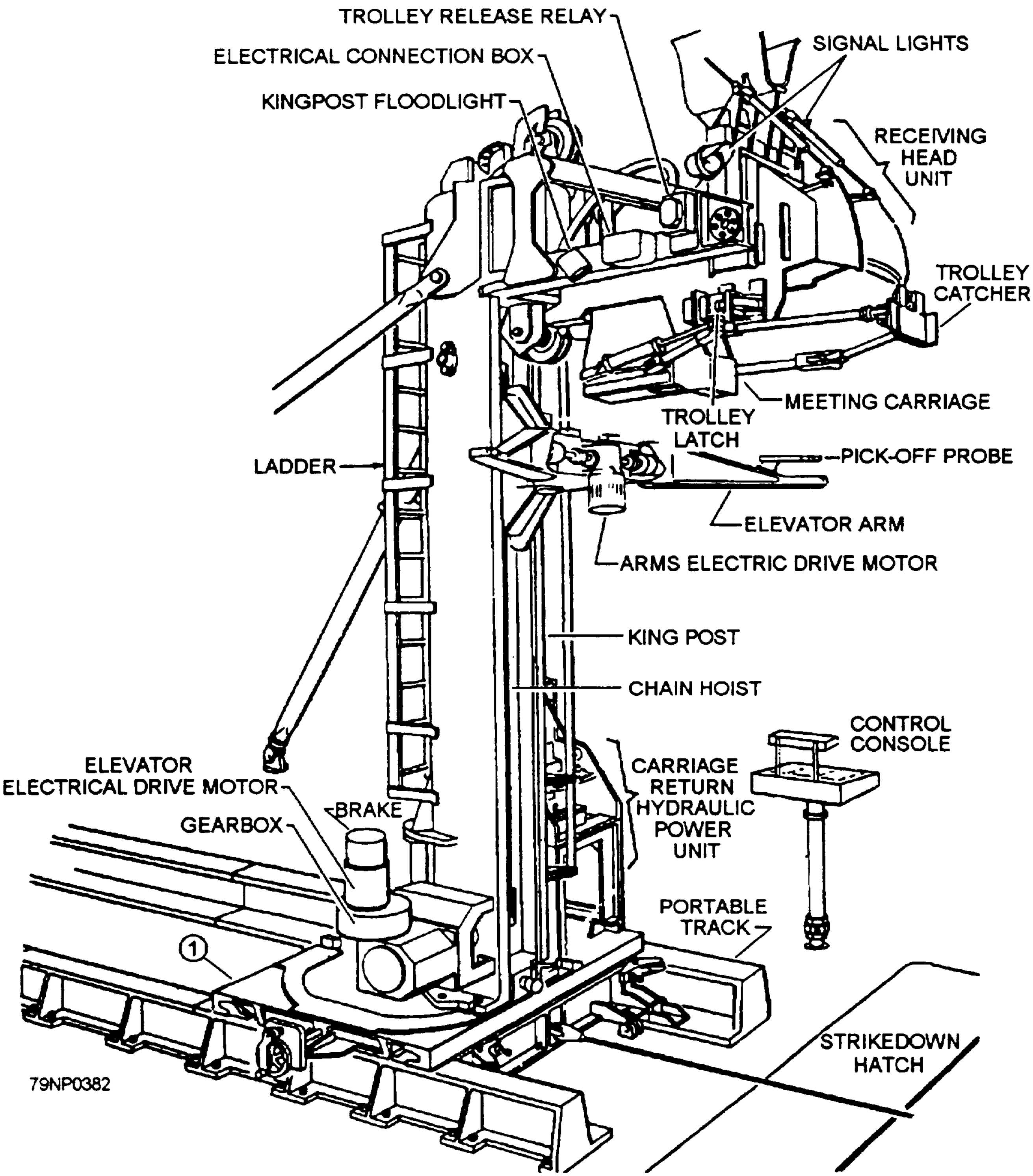


Figure 5-34.—Reciving unit.

The specific operations of the elevator are controlled by the console operator by pushbutton switches on the remote control console.

Remote Control Console

The electrical system provides the controls and signals necessary to operate the receiving unit from a remote control console. Figure 5-34 shows the control console mounted on a pedestal near the receiving unit. The control console is a portable aluminum box housing with control switches and indicator lights installed. The switches on the console are grouped by their control function (fig. 5-35). The power switch is in the upper right-hand corner of the control console and connects and disconnects the 440-volt, ac ship's power supply to all the electrical components of the receiving unit. The main electrical operations of the receiving unit are as follows:

1. Raising and lowering the elevator
2. Opening and closing the elevator arms
3. Immobilizing the meeting carriage when receiving and stowing the missile
4. Releasing the trolley latch
5. Operating the transfer signal holdup light

An ultraviolet night-light is installed above the console to illuminate the switch panel during night operations. When not in use, the control console is stowed within the console stowage box.

Elevator Drive Control System

The elevator drive control system raises and lowers the elevator. The elevator mechanism is supported by the kingpost. A chain hoist, located within the kingpost, is attached to the elevator and is driven by a bidirectional electric motor for elevator operation. The motor is mounted on the side of the kingpost near the base (fig. 5-34). The 5-horsepower motor operates on 440-volt ac, three-phase, 60-hertz power at 1,800 rpm. It is a watertight motor and drives the elevator through a worm gear type of speed reducer. A solenoid-operated disk brake, installed on top of the elevator drive motor, performs fast action in stopping and starting the motor. This permits the swift and accurate positioning required by the system. The operator at the console can stop the elevator at any position along the kingpost.

Electrical circuits provide the means to raise the elevator with the arms open and unloaded or with the arms closed and loaded. These circuits also allow

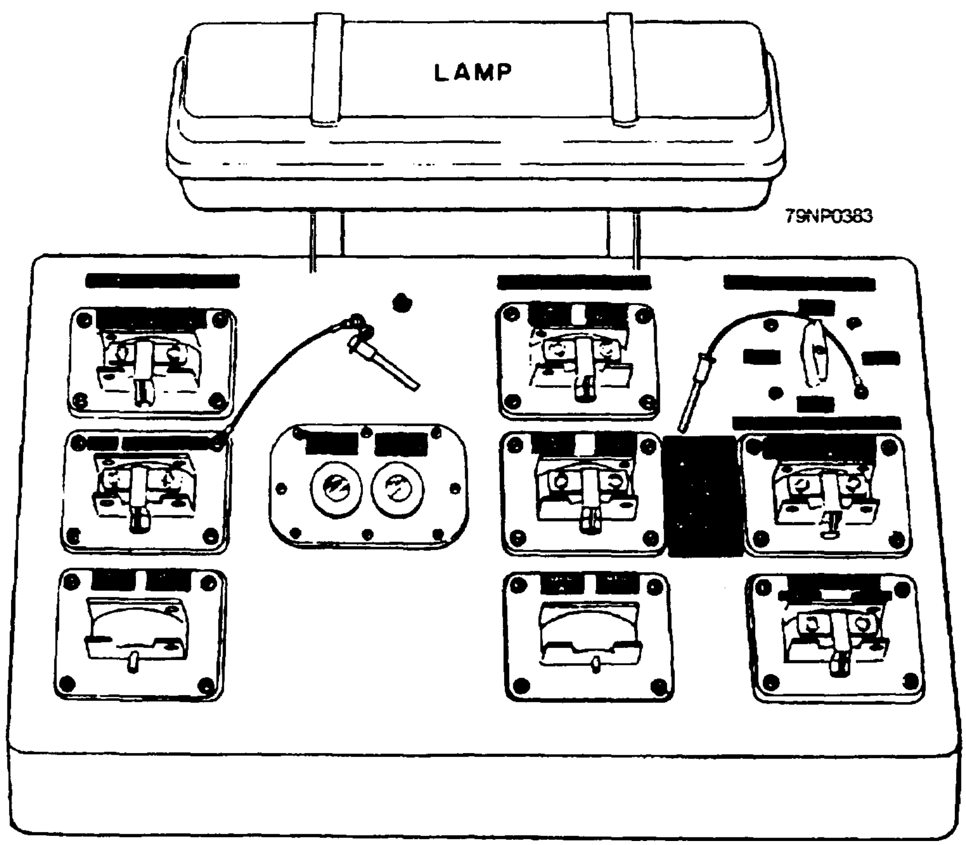


Figure 5-35.—Control console on a receiving ship.

lowering if the elevator with the arms open and unloaded or with the arms closed and loaded Emergency circuits bypass the normal control switches to provide a built-in safety for emergency operation. They should never be used unless an emergency arises.

ARMS ROTATION CONTROL SYSTEM.— The arms rotation control system controls the opening and closing of the elevator arms for both normal and emergency operations. The arms system consists of an electric motor (fig. 5-34), a speed reduction gearbox, and a cross-shaft, worm gear mechanism. The 1 1/2-horsepower electric motor is bidirectional and is watertight. It operates on 440-volt ac, three-phase, 60-hertz power at 1,800 rpm. The components, as a unit and with the necessary control circuitry, function to open and close the arms of the elevator.

MEETING CARRIAGE CONTROL SYSTEM.— The meeting carriage (fig. 5-34) receives and cushions the incoming missile with the trolley catcher and jackknife units. The meeting carriage is pushed back horizontal y about 20 inches, moving from the fully extended RECEIVED position to the fully compressed INDEXED position. The carriage is held in the INDEXED position by the trolley, which is retained by the trolley latch When the trolley latch is released the trolley is pulled from the receiving head. Hydraulic pressure is automatically supplied to the carriage return cylinder, which extends the cylinder and moves the meeting carriage to the RECEIVED position.

During operation when the trolley enters the receiving head, the jackknife folds back and mechanically operates an electrical limit switch. This action automatically energizes the carriage return solenoid valve (fig. 5-36, view B) and allows the hydraulic fluid within the carriage return cylinder to bleed off into the reservoir (fig. 5-36, view A). As the trolley moves all the way into the receiving head, the meeting carriage is pushed back into the INDEXED position and the cylinder is collapsed. When the meeting carriage solenoid valve is de-energized, the supply port to the cylinder is open, and hydraulic pressure pushes the meeting carriage into the RECEIVED position. Upon trolley release, the jackknife and limit switch also return to their normal operating positions.

An electric motor mounted vertically on top of the reservoir (fig. 5-36, view A) operates a positive displacement gear type of hydraulic pump located inside the reservoir, The motor is a three-phase, 440-volt ac, 60-hertz, waterproof motor with a rating of 1 1/2 horsepower at 3,600 rpm. Operation of the hydraulic pump motor is automatic and maintains the hydraulic fluid supply pressure at about 1,000 psi. During operation, whenever the supply pressure within the accumulator is below 950 psi, the oil pressure switch (fig. 5-36, view A) will close electrical contacts and start the pump motor operating. As the pressure inside the accumulator reaches 1,000 psi, the oil pressure switch electrical contacts open and stop the motor. The console operator can override the automatic controls at anytime.

TROLLEY LATCH RELEASE.— The trolley latch (fig. 5-34) consists primarily of a latch pin and trunnion assembly, a locking arm, a solenoid, two limit

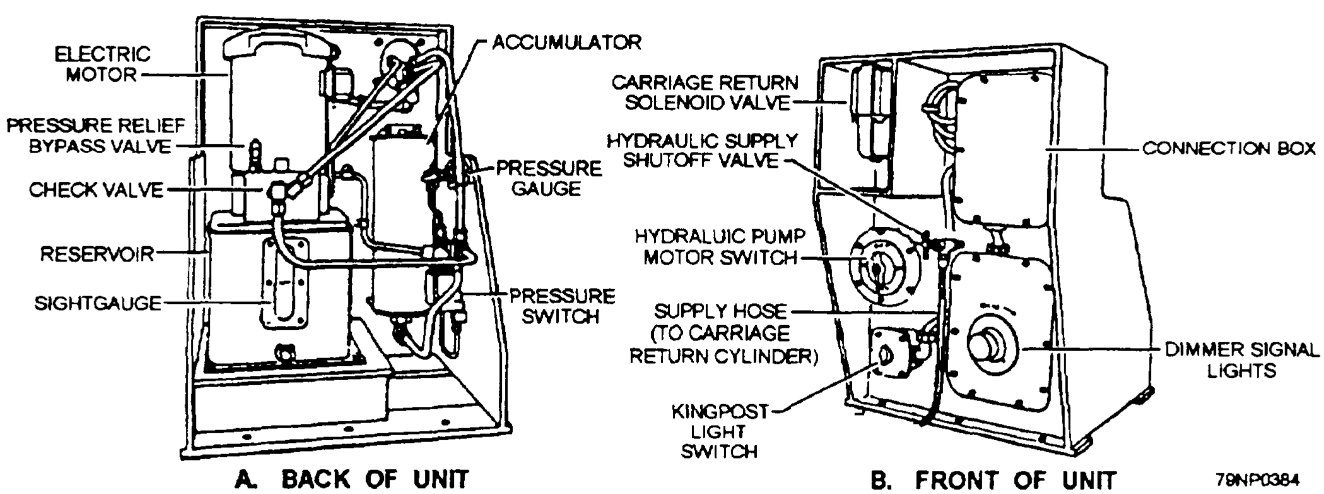


Figure 5-36.—Carriage return hydraulic power unit: A. Back of unit: B. Front of unit.

switches, and a manually operated release lever. The latch will automatically fall into the latch hole in the side of the trolley when the trolley has been pulled into the receiving head enough to push the meeting carriage into the INDEXED position.

The trolley latch release system has a blue signal light (not shown) located on the opposite side of the receiving head unit and a blue indicator light lusted at the control console (fig. 5-35). The purpose of the electrical circuit is to provide the winch operator on the supply ship and the console operator on the receiving ship with a visual indication that the trolley is latched. When the trolley is latched the blue trolley latched lights are illuminated and are extinguished when the trolley is released.

The trolley latch signal light circuit receives 110-volt ac power from the 440/120-volt transformer. The 440-volt ac power to the transformer is controlled by the power switch located on the control console.

The operator can manually control the automatic trolley latch system. The operator does this by releasing the latch. The latch can be released in two ways-by energizing the trolley release solenoid from the control console or by manually pulling the release handle on the side of the kingpost.

Transfer Signal Holdup Light

The transfer signal holdup light circuit has an amber signal (fig. 5-34) located on the receiving head unit. An amber indication light is located on the control console. The purpose of the electrical circuit is to give the winch operator on the supply ship and the console operator on the receiving ship a visual indication when the ships are becoming too far off station. Whenever the receiving head trains more than 30 degrees off station, the lights are illuminated This light circuit also lets the console operator signal the winch operator to temporarily y stop operation.

The holdup transfer signal light circuit receives 120-volt ac power from the 440/120-volt transformer. The 440-volt ac power to the transformer is controlled by the power switch located on the control console.

SUMMARY

The UNREP system is a complicated system consisting of many components working together to perform an important function at sea. While the information given above may not match all the types of equipment found aboard your ship, it is representative of the types of UNREP equipment you will encounter. Since there are so many pieces of equipment and the amount of maintenance needed to keep it functional is so great, most ships have EMs dedicated to the deck department to devote the needed time to the equipment.

ELECTRIC FORKLIFT TRUCK

Electric forklift trucks are primarily used for handling, transporting, and warehousing materials in confined areas where engine exhaust times cannot be tolerated. Figure 5-37 shows two of the electric forklifts most commonly used. The larger vehicles are electric powered, front-wheel drive, rear-wheel power-steering

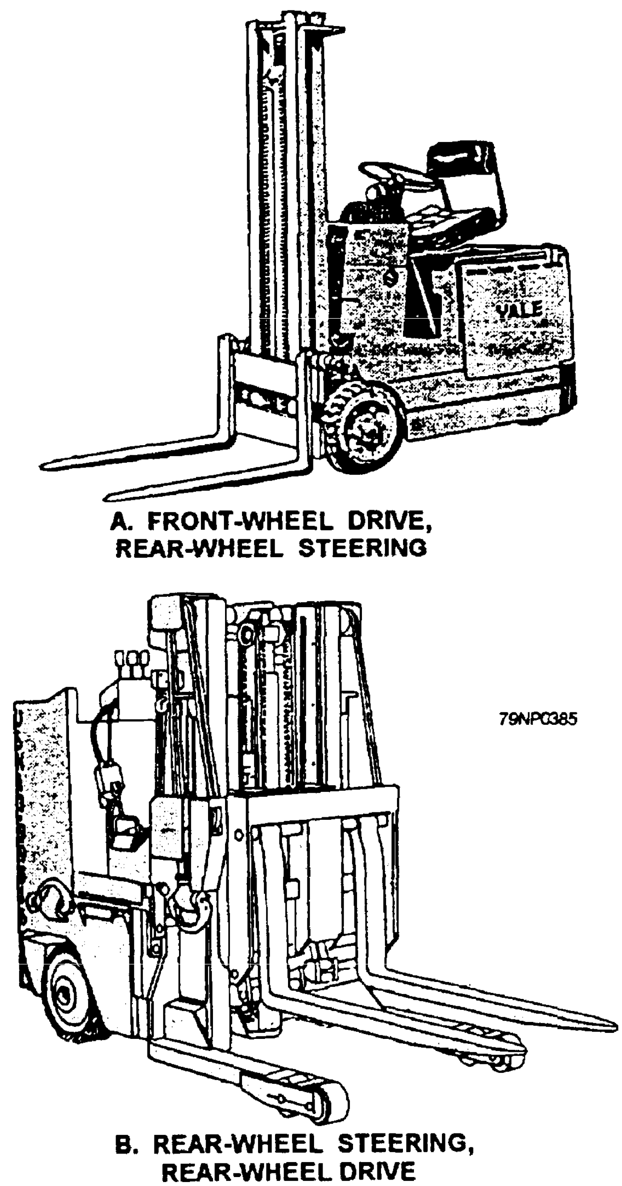


Figure 5-37.—Electric forklift trucks.

forklift trucks (fig. 5-37, view A). Figure 5-37, view B, shows a smaller electric forklift that has both steering and drive provided by the rear wheels. A 36- or 24-volt storage battery is required to furnish power for the traveling, the lifting, and the steering mechanism.

The drive mechanism includes an electric drive (traaction) motor, coupling, power axle assembly, and control. Control of the travel circuit provides one automatic accelerating speed plus four forward and four reverse controlled speeds.

The lifting mechanism includes an electric motor, hydraulic pump, hydraulic fluid reservoir, hoist, tilt, side shift cylinders, directional control valve, forks, and controls.

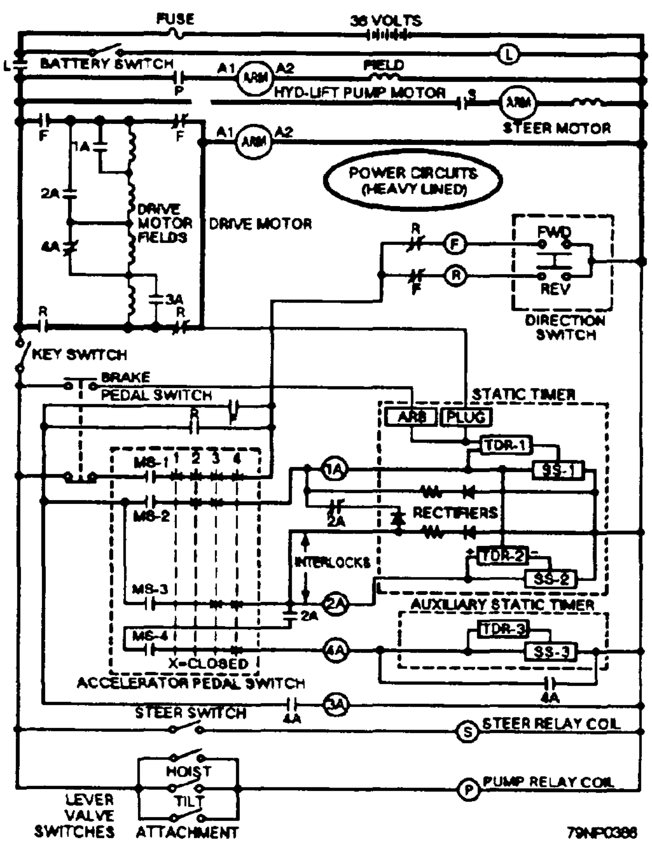
The vehicle steering system consists of a steering motor, pump, steering gear assembly, power steering unit, trailing axle, and controls.

The brake system consists of a master cylinder, mechanical parking brake, and hydraulic service brakes.

The operator controls the truck speed by depressing the accelerator pedal, which determines the amount of power to the drive motor over a given period of time. Most forklifts have speed controls that are incremental type of controllers. In incremental controllers, a bank of resistors is inserted into or shorted out of the circuit to obtain speed control. The stepless type in the newest forklift trucks uses SCR control circuitry. The incremental type of truck control is similar to a car with a standard shift, and the stepless type of control is similar to a car with an automatic transmission that provides for smooth control of the speed.

Many of today's shipboard requirements for material-handling operations necessitate very smooth acceleration of the electric truck. Smooth acceleration for a major portion of the speed range is highly desirable and permits accurate maneuvering of the truck for spotting loads in congested areas.

The electrical system of an electric forklift maybe logically divided into a power circuit and a control circuit. These two circuits comprise the circuitry for the hydraulic pump motor, the steer motor, and the drive motor. Figure 5-38 shows the wiring diagram of an electric forklift. Please refer to this figure as you read



- LEGEND -

1A TO 4A - SPEED-CHANGING POWER RELAYS
ARB - ANTIROLL BACK
F - FORWARD RELAY
L - LINE RELAY
MS - MASTER SWITCH CONTACT
P - PUMP RELAY
R - REVERSE RELAY
S - STEER RELAY
SS - STATIC SWITCH
TDR - TIME DELAY RELAY

Figure 5-38.—Wiring diagram of an electric forklift.

about the operation of the pump motor, the steer motor, and the drive motor and controller.

PUMP MOTOR

The hydraulic-lift pump motor power circuit consists of the pump motor and contacts of the pump relay coil P. The pump motor control circuit consists of the pump relay coil P and lever valve switches that are actuated by a hydraulic control valve.

To operate the lift system of the truck, you must close the battery switch and turn on the key switch. The movement of one of the lever valve switches starts the hydraulic-lift pump motor. When the levers are returned to neutral, the pump motor stops.

STEER MOTOR

The steer motor power circuit consists of the steer motor and contacts of the steer relay coil S. The steer motor control circuit has a relay coil S and, on the seated-type forklifts, a steer switch that is closed when the operator is seated. On this type of forklift the motor is in continuous operation while the operator is seated. This permits power steering even though the truck is not moving.

DRIVE MOTOR AND CONTROLLER

The drive motor controller regulates the speed of the series drive motor by solid-state control circuitry integrated with magnetically operated devices. This circuitry enables the generator to handle heavy loads at low speeds with very little battery current. This results in extra hours of operation. For full-speed cruising, the solid-state system is removed from the control circuit. This connects the drive motor across the battery supply.

The drive motor power circuit (fig. 5-38) consists of the drive motor with its series fields; speed-changing relay contacts 1A, 2A, 3A, and 4A; and the forward and reversing relay contacts F and R. The functions of the components in the drive motor control circuit are as follows:

- The accelerator pedal switches. Provides the four accelerating speeds by controlling the series fields of the drive motor.
- The speed-changing power relay coils (1A, 2A, 3A, and 4A).
- The directional relay coils (F and R).
- The static timer. Provides an adjustable time delay between first and second speed, and one between second and third speed, as well as a fixed time delay between third and fourth speed.
- The brake switch Operated by the brake pedal, interrupts the drive control circuit whenever the brake pedal is depressed It also provides power for starting on a grade by the antirollback (ARB) connection of the static timer.
- The static timer. Provides for controlled plugging.
- The control fuses (not shown). Protects the drive motor and the static timer against electrical faults.
- The thermal switches (not shown). Opens the drive and steer motor circuits in case motor frame temperatures reach 225°F.

The master accelerating switch used for controlling truck speed is a manually operated pilot device to control magnetic contractors. These magnetic contractors control the drive motor of the vehicle. An OFF position and four speeds are provided. The switch is operated by an accelerator pedal.

The directional master switch determines the direction the vehicle operates. The switch is a three-position, manually operated, two-circuit pilot device. It is designed for handling coil circuits of directional magnetic contractors that must be energized to initiate movement of the truck.

The heart of a solid-state speed control system is the SCR. Essentially, the SCR is nothing but a rectifier, except that a control element (commonly referred to as agate) has been introduced. As applied in stepless truck control systems, the SCR is nothing but a switch.

As you read about the sequence that takes place in normal operation when the directional control handle is moved to forward or reverse and the accelerator pedal is slowly depressed, refer to figure 5-38 and table 5-4.

Table 5-4.—Drive Motor Field Connections

SPEEDS	POWER TIPS	MOTOR FIELDS
First Speed	All open	All fields energized
Second Speed	1A closed	Three fields energized
Third Speed	1A, 2A closed	Two fields energized
Fourth Speed	1A, 2A, 3A closed	One field energized

- FIRST SPEED, When the accelerator pedal is depressed to the first speed contact MS-1 closes, the direction handle is placed in the forward position, the F contactor picks up, and the drive motor is energized.

- SECOND SPEED. The pedal is depressed to the second speed point to close contact MS-2, a positive voltage appears at TDR-1, SS-1 anode, and TDR-2 on the static timer. The positive voltage appears at these points because of the low-resistance path through the 1A coil. The very small currents needed to operate the time-delay circuitry is about 1/100 of that needed to operate the coil; therefore, only a small voltage is dropped across the coil. Now TDR-1 cannot operate until a positive voltage also appears from either ARB or the plug. A positive voltage could only come from ARB when the brake pedal is depressed. However, a small positive voltage comes through the plugging section due to the voltage developed across the armature of the drive motor. Now TDR-1 does operate, fires SS-1, and picks up 1A coil, which provides the second speed.

- THIRD SPEED. The pedal is depressed to the third speed point to close MS-3, and a positive voltage appears at TDR-2 and SS-2. Since 1A has already picked up, a negative voltage is at the top input to TDR-2; and after a time delay, SS-2 operates and 2A coil picks up, which provides the third speed. Now the 2A interlock leading to contact MS-4 closes, providing a positive voltage to the left of contact MS-4 to ready the control of the fourth speed.

- FOURTH SPEED. The pedal is depressed to the fourth speed point to close contact MS-4 and to open contact MS-2, which de-energizes relay 1A. In a manner similar to the previous steps, the auxiliary static timer gives a time delay to the pickup of 4A. After 4A energizes, both normally open 4A interlock contacts close. One shorts out the auxiliary static timer and turns it off. The other interlock lets coil 3A pick up to shunt the field. However, relay 1A has opened; therefore, afield is still present. The 4A coil picks up before the 3A coil so that any arc that might be present when the normally closed 4A contacts open will be extinguished before 3A coil picks up. Otherwise, a direct short may occur. This provides the fourth speed.

SUMMARY

You should now know about the major deck equipment that is installed for winching operations, anchoring the ship, elevator operations, and replenishment at sea. If you do not understand the sequence of operation of this equipment, before continuing on, review these sections. Extensive step-by-step operational methods were described, and it is essential that you know how to operate, troubleshoot, and repair this equipment properly. Having learned this information thoroughly, you should be able to maintain the equipment in a reliable condition.

ELECTROHYDRAULIC STEERING GEAR

Ships have been in use almost as long as man has been actively exploring the earth and defending his territory. In that time, ship's steering has evolved from a simple rudder of wood attached to the stem of the ship to today's modern electrohydraulic systems.

The modern or industrial era saw steering systems evolve in definite stages from steam driven to electromechanical and finally the electrohydraulic systems of today. Electrohydraulic steering gear was developed to meet the power requirements of naval vessels having large displacements and high speeds with attendant increase in rudder torques.

The steering gear is one of the most vital auxiliaries aboard ship. It must be dependable and have sufficient capacity for maximum maneuverability. The ship steering control system for the modem ships is an integrated group of electrical, mechanical, and hydraulic subsystems, equipment, and components interconnected to provide rapid and flexible control of the ship's course and maneuverability under all conditions of ship readiness. The ship is equipped with two separate steering gear systems—one for each rudder. The steering control system coordinates operation of the steering gear system as rudder commands constantly vary.

The ship steering control system provides steering control from a fixed station in the pilot house, from either bridge wing using portable steering equipment, or from the aft emergency steering station in the steering gear room.

CONSTRUCTION

The movement of the two rudders is controlled by two mechanically independent steering gears located in the steering gear room (fig. 5-39). Each steering gear is

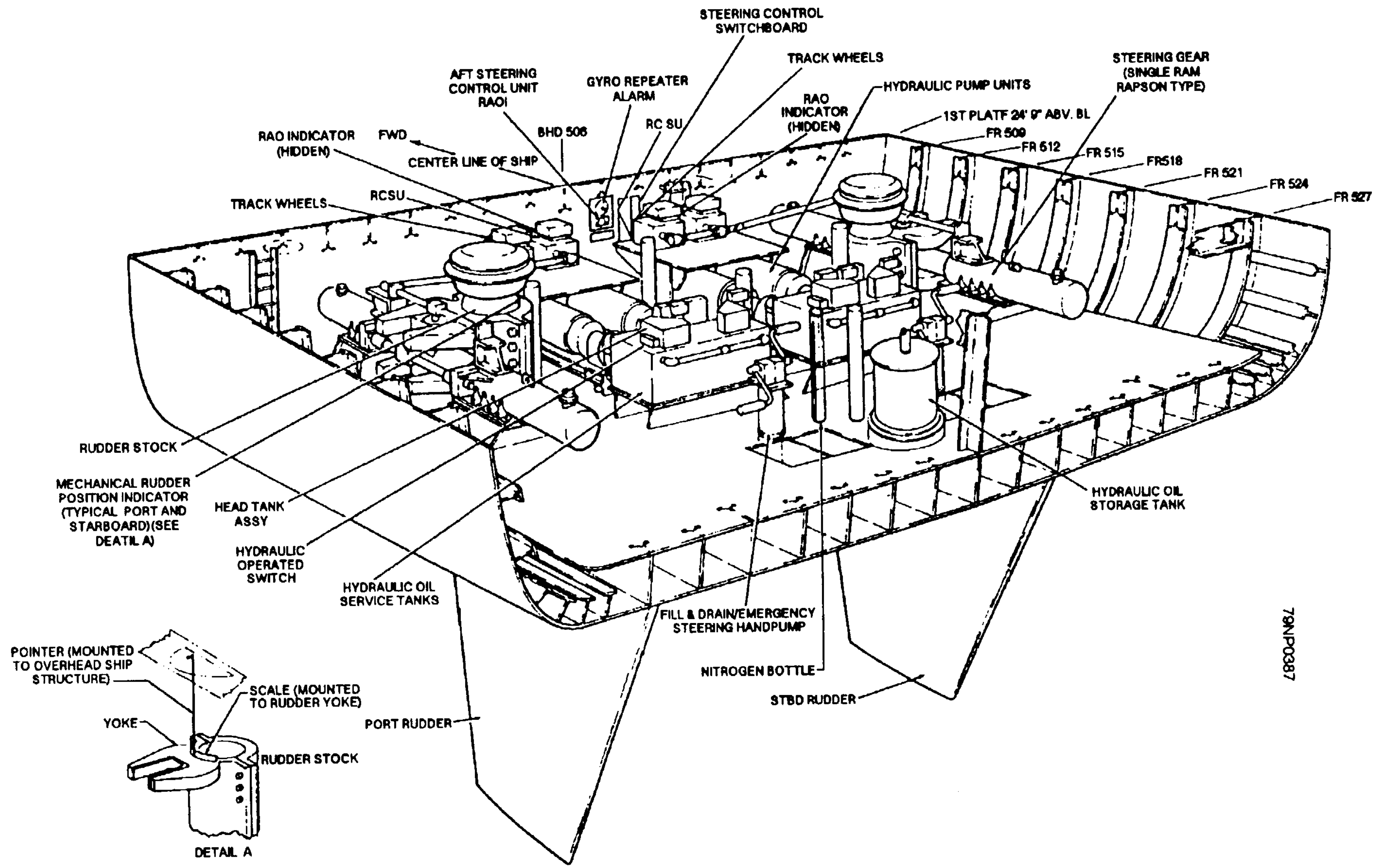


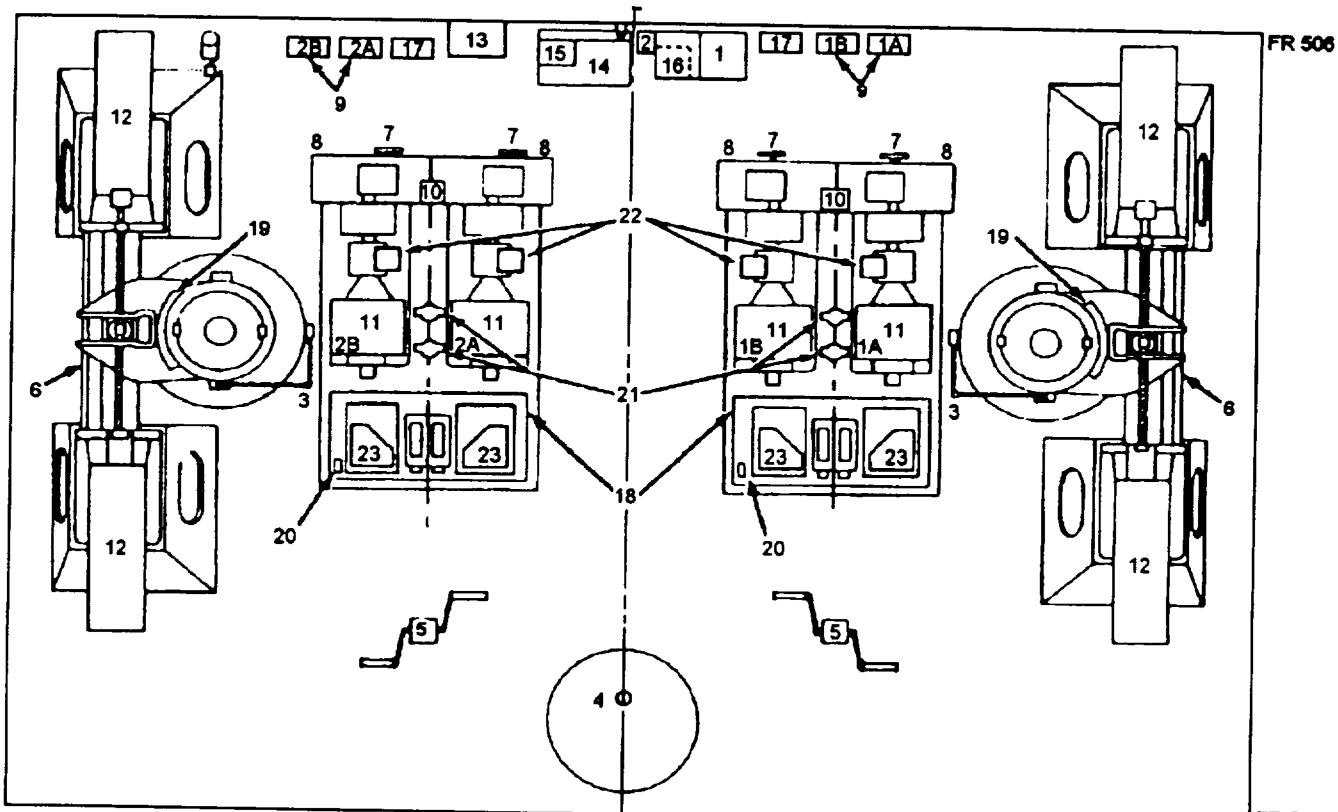
Figure 5-39.—Steering gear room (perspective view).

operated by a separate hydraulic system that has an on-line power unit operating and a standby power unit as a backup.

A total steering gear system has two independent sets of pump units and either set can operate the sliding rams to cause rudder movement, while the other power unit set is offline. Each of the steering gear assemblies operates through the function of the following systems and components (fig. 5-40):

Ship Control Console (SCC)

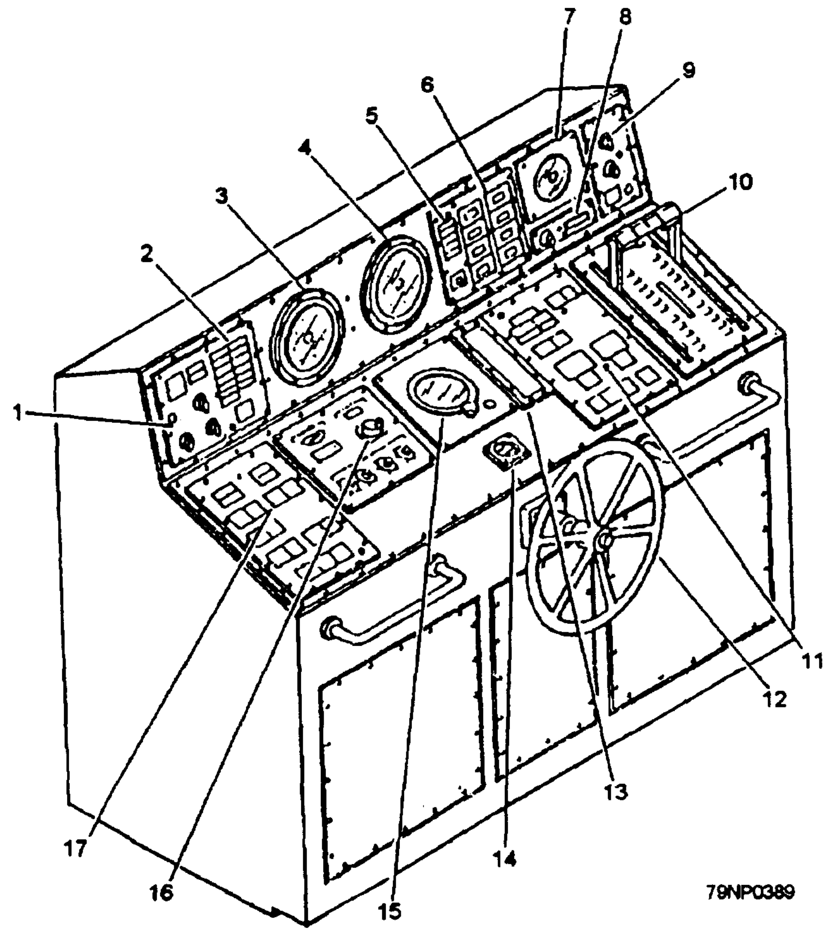
The SCC (fig. 5-41) operates, along with other equipment, to control ship speed and heading and speed lights, and it provides a display of ship performance and alarms status. The SCC can detect and indicate a failure for approximately 90% of the console electronics, indicated on the console malfunction, power supply malfunction, EOT/display alarm, or autopilot alarm indicators.



EQUIPMENT LEGEND

NO.	NAME	NO.	NAME
1.	STEERING CONTROL SWITCHBOARD	13.	LOUDSPEAKER
2.	SHIP COURSE INDICATOR	14.	LOG DESK
3.	RUDDER ANGLE TRANSMITTER	15.	DIAL PHONE
4.	HYDRAULIC OIL STORAGE TANK	16.	AFT STEERING CONTROL UNIT
5.	EMERGENCY STEERING HAND PUMP	17.	STEERING GEAR POWER PANEL
6.	MANUAL POSITIONING ASSEMBLY	18.	HYDRAULIC OIL SERVICE TANK
7.	TRICK WHEEL	19.	RUDDER POSITION INDICATOR SCALE (POINTER MOUNTED TO OVERHEAD)
8.	RUDDER COMMAND SERVO UNITS (RCSU)	20.	HYDRAULIC OPERATED SWITCH
9.	MOTOR CONTROLLERS	21.	ACCUMULATOR (MOUNTED OVHD)
10.	RUDDER ANGLE ORDER INDICATOR	22.	SUBPLATE VALVE SERVO (MOUNTED OVHD)
11.	HYDRAULIC POWER UNIT	23.	HEAD TANK ASSEMBLY
12.	STEERING GEAR RAM & FOLLOW UP ASSY		

Figure 5-40.—Steering gear room (plan view).



1. Steering control console power
2. Steering alarms
3. Course-to-steer indicator
4. Ship's course indicator
5. Propulsion alarms
6. Shaft performance display
7. Ship's speed indicator
8. Dummy log control
9. Speed light control*
10. Throttle controls
11. Propulsion controls
12. Helm wheel
13. Speed calibration placard
14. Helm position indicator
15. Rudder angle/RAO indicator
16. Autopilot
17. Steering control unit

* Speed lights have been disconnected on DD 997

Figure 5-41.—Ship control console (front view).

Operational capability of the SCC permits connection to a portable steering control unit (PSCU) for alternate position steering at either bridge wing. It can also be used with the aft steering control unit (ASCU) for emergency steering operations from the steering gear room.

Portable Steering Control Unit (PSCU)

The PSCU provides the option of steering from either the port or starboard bridge wing. This can be useful if lateral visibility is of paramount importance during steering operations.

Aft Steering Control Unit (ASCU)

The ASCU, along with the steering control switchboard and other equipment in the after steering gear room, permits local control of the steering gear for emergency steering or manual hydraulic positioning of the rudders if there is a loss of steering control from the pilot house.

Steering Control System

The steering control system provides rudder command inputs to the mechanical differentials which provide a mechanical rudder position command input to each hydraulic system.

Rudder Angle Display System

The rudder angle display system provides rudder position information to those personnel concerned with the ship conning tasks.

Rudder Angle Order System

The rudder angle order system provides a nonverbal means of communicating rudder commands from the pilot house SCC to the steering gear room ASCU and trick wheels.

Helm Wheel Angle Indicator

The helm wheel angle indicator provides a mechanical indication of the rudder command position of the helm wheel or knob.

Ram and Follow-up Assembly

The ram and follow-up assembly is a mechanical arrangement of components connected to the rudder stock crosshead. The assembly reacts to hydraulic pressure developed by the power units, causing radial movement of the rudders.

Hydraulic Power Unit Control System

The hydraulic power unit control system remotely and locally controls and monitors the operation of the four hydraulic power units. Each power unit consists of an electric motor directly coupled to a variable delivery hydraulic pump. Each power units electric motor is individually controlled by an associated 440-volt ac, three-phase, bulkhead-mounted motor controller.

Magnetic Controllers

Four motor controllers, one for each steering pump motor, are mounted on the forward bulkhead of the steering gear room. Control of the steering motors may be switched at its controller from OFF to LOCAL or REMOTE.

Each controller may be setup to act as an LVR- or LVP-type controller. Through the operation of a hydraulic-operated switch, the active steering controller of the unit acts as an LVR type, while the backup unit is set to operate as an LVP type. This results in the automatic restarting of the active unit after recovering from a loss of power. Should the active unit fail to restart, the steering watch stander can manually start the backup unit.

OPERATION

The basic force used to operate the rudders is the pressure of the hydraulic fluid from the steering pumps. The array of valves, piping, sensors, and controls is used to send this fluid under pressure to the appropriate point to achieve the desired change in rudder position. What follows is the means by which this is accomplished.

Description of Operation

Movement of twin rudders is provided through movement of port and starboard single-ram, mechanical] y independent, slide-type steering gears located in the steering gear room. Each hydraulic system is controlled by a mechanical differential which provides a summing function to operate the hydraulic pump stroking mechanism.

Each power unit hydraulic pump and electric pump is mechanically mated by a keyed coupling joining the respective shafts. The command module, differential control assembly, and remote control servo units (RCSUs) are clustered on a support bracket which is mounted to the ship's foundation and positioned at the forward end and above the power unit electric motors. A rudder angle order signal from the SCC drives a gear train and cam assembly in the RSCU to position the mechanical differential output shaft. The output shaft is linked to a pump control module which positions the control valve which "strokes" the pump.

As you read this section, refer to the block diagram shown in figure 5-42. Once a rudder command is initiated from the steering control console, a signal is generated by the synchro transmitters. This signal is transmitted to the RCSU. The RCSU, which has its own internal control loop, drives its servo motor to the proper position to set the cam of the steering gear mechanical differential so that the steering gear is ordered to move the rudder in the desired position. As the cam of the mechanical differential is moved, it puts the variable delivery pump "on stroke." The on stroke pump provides hydraulic pressure through the automatic transfer valve to the appropriate side of the ram cylinder, which moves the ram in the desired direction.

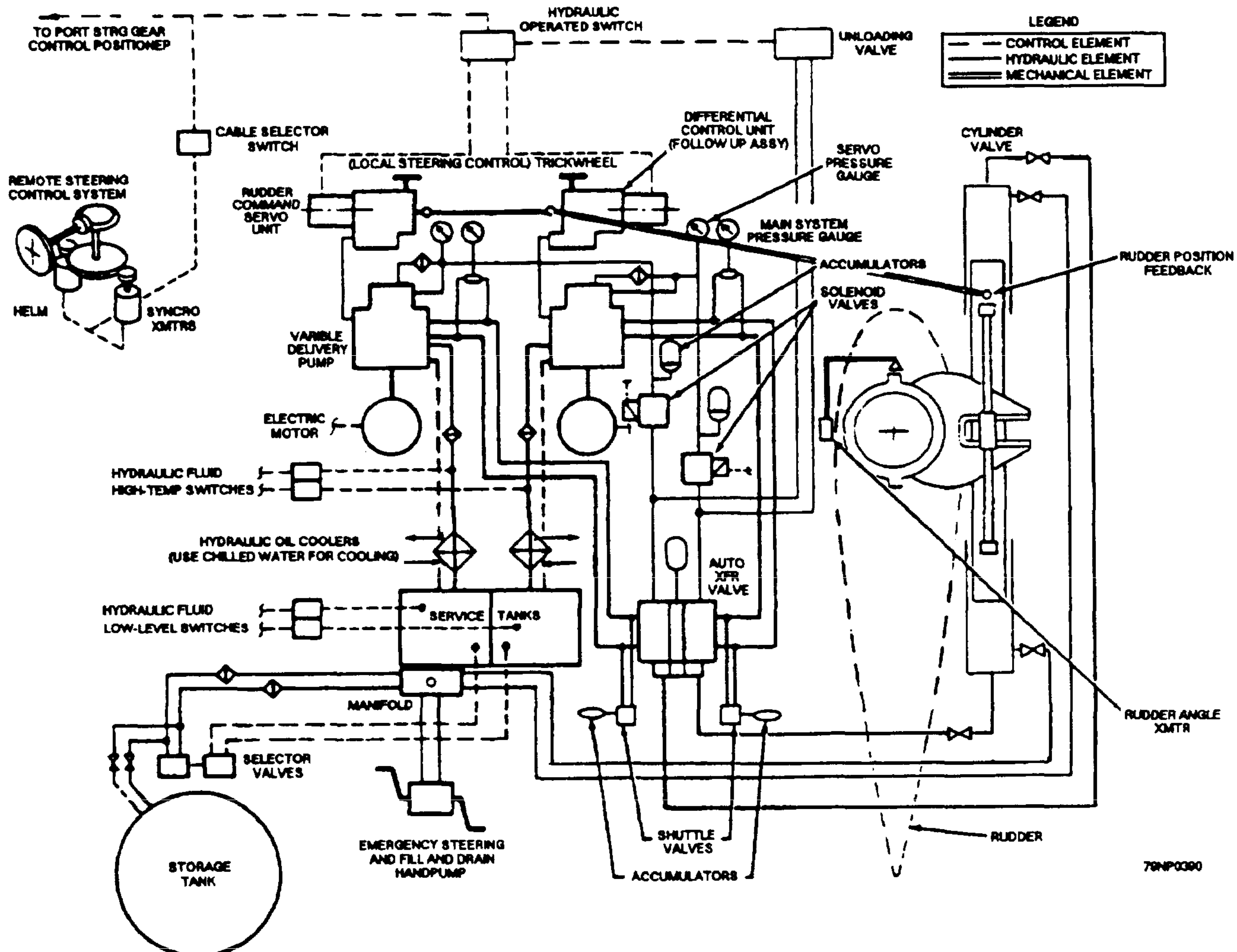


Figure 5-42.—Steering gear functional block diagram.

Movement of the ram moves the rudders and drives a feedback mechanism to the differential control to cancel out the rudder angle order (RAO) input signal when the rudder reaches the ordered angle, taking the pump off stroke.

Power for each steering gear is provided by one of two hydraulic pumps. The steering control system provides rudder command inputs to mechanical differentials. Differentials then provide a mechanical rudder position command input to each hydraulic system.

The rudders have a maximum working angle of 35" right and 35° left from the midships at rest position. These angles are set by an adjustment in the electronic limit circuit. If there are uncontrolled surges within the hydraulic system severe enough to cause ram overtravel, there are copper crush stops to mechanically engage the tie rod at 37° of rudder angle and steel stops that are engaged at 38° of rudder angle.

Modes of Steering

There are four means of controlling the operation of the steering gear. Three modes (autopilot, hand electric, and emergency) control the movement of the rams by using electric power to position valves to allow hydraulic fluid under pressure from the power units to position the rudders. The fourth mode (manual) is totally manually driven.

AUTOPILOT MODE.— Steering (rudder deflection) commands are generated by the autopilot (part of the SCC) during automatic steering modes. These electrical commands are proportional to the difference between the actual ship heading, as determined by the ships gyrocompass, and the desired or selected ship's heading.

Before the automatic steering mode is selected, the ship must be steered manually (hand electric) to the desired course to prevent uncontrolled turning rates, which may be immediately commanded by the autopilot. The desired heading command is set manually into the autopilot where it is compared with the actual ship heading to produce the automatic rudder commands.

HAND ELECTRIC MODE.— Steering of the Ship is controlled manually by the use of the helm wheel or the controls on the ASCU or the PSCU.

EMERGENCY MODE.— In the emergency steering mode, steering control is accomplished in the steering gear room in response to rudder commands communicated by RAO indicators or orally over the ship interior communications system. The ASCU operates in the hand electric mode and transmits rudder commands through the steering control switchboard to the rudder command servo units.

If the ASCU becomes inoperable, the trick wheels are used to send rudder commands to the command servo units manual] y and thus position the rudders.

MANUAL STEERING MODE.— Manual hydraulic operation of the steering gear rams is affected by positioning the appropriate hydraulic valves and hand cranking the emergency steering fill and drain hand pumps as described below.

- Manual positioning of the rudder is made possible by hand operation of the emergency steering/fall and drain pumps. An emergency hydraulic system consists of hand pumps, a hydraulic oil storage tank, and valves and piping interconnected to the hydraulic steering system. When properly lined up, hydraulic fluid is applied to the ram cylinders to drive the rudders to the desired position.

- Hand pumps are operated by the normally stowed 15-inch handles. Either low or high volume fluid flow may be selected by appropriately positioning a gear selector lever located on the hand pumps. Pressure relief valves control system pressure at 650 psi.

- The hydraulic oil storage tank provides a 93-gallon capacity for operation of the emergency (manual) steering hydraulic system. Normal operating level (system lines full) is maintained at 31 gallons. High-level caution is monitored at 82 gallons. In addition to the emergency steering function, stored hydraulic fluid may be used to add makeup oil to the steering gear hydraulic ram cylinders.

MAINTENANCE

The most common cause of failure of any hydraulic system is dirt. Because hydraulic system clearances are so precise, any amount of dirt or sludge introduced into the system will eventually lead to problems in operation. A differential pressure indicator is mounted across a hydraulic filter in the servo system in the auxiliary pump discharge. Replace the filter element if the pressure drop across the filter exceeds 12 psig. If fluid flow is impeded, a red indicator rod rises from the differential pressure unit to visually warn personnel of the degree of filter blockage. If the red indicator rises, the filter element should be replaced. The filter element should be replaced every 3 months, regardless of the pressure drop across the filter.

SUMMARY

Steering is an essential element of any ship. To keep steering dependable under all service conditions, you must maintain and operate the steering gear and associated equipment according to posted instructions and manuals.

ELECTRIC GALLEY EQUIPMENT

Electric galley equipment comprises the heavy-duty rooking and baking equipment installed aboard naval vessels. This equipment consists essential y of ranges, griddles, deep fat fryers, roasting ovens, and baking ovens. Electric galley equipment is supplemented by electric pantry equipment, which includes coffee urns, coffee makers, griddles, hotplates, and toasters. The number and capacity of the units comprising a galley installation depends on the size and type of ship. Galley equipment is normally designed for operating on 115-volt or 230-volt ac/dc or for operation on 115-volt or 230-volt ac/dc or 440-volt, three-phase, 60-hertz, ac power.

RANGES

Electric galley ranges are provided in type A (36 inch), type B (20 inch), and type C (30 inch). The ranges consist of a range-top section and an oven section assembled as a single unit and a separate switchbox designed for overhead or bulkhead mounting. Figure 5-43 shows a type-A range. This range is provided with three 6-kilowatt surface units and an oven section with two 3-kilowatt enclosed heating units.

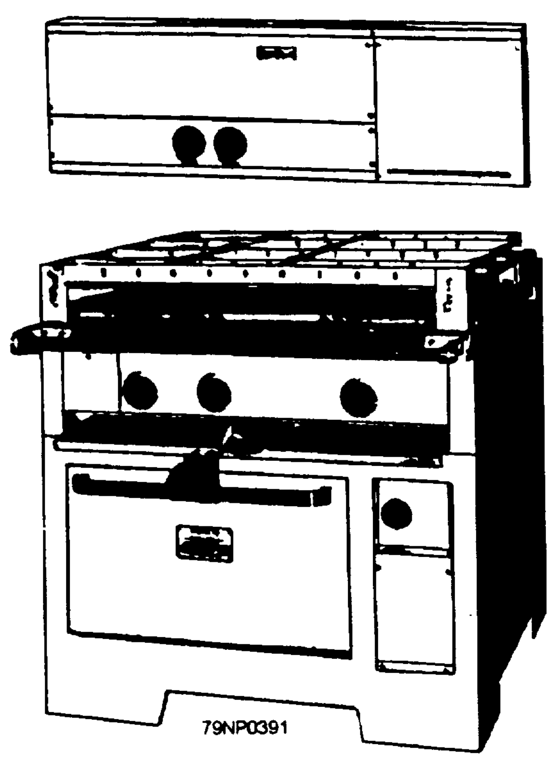


Figure 5-43.—Type-A range.

TYPE-60 OVEN

A type-60 oven is shown in figure 5-44. Type-60 and type-125 ovens are sectional ovens. They have either two or three sections mounted one above the other. Each section constitutes a separate oven that is thermally insulated and operated independently of the other section(s). The ovens have a separately mounted switchbox that contains the fuses, the contractors, and the three-heat switches for each section.

The heating elements are located at the top and bottom of the oven. Each heating element is controlled by individual three-heat switches located in a switchbox enclosure mounted on the right-hand side of the oven.

M-SERIES CONVECTION OVEN

The M-series convection oven (fig. 5-45) is the most common type of oven being installed aboard naval vessels. This oven can be used individually, or more than one oven can be stacked one on top of the other. The construction of the ovens is rugged and has many useful features. These features include a positive door latch, ventical split doors, a main power light, a main power switch, a blower motor, a thermostat, oven chamber lights, an oven ready light, an interior light switch, and a door interlock switch.

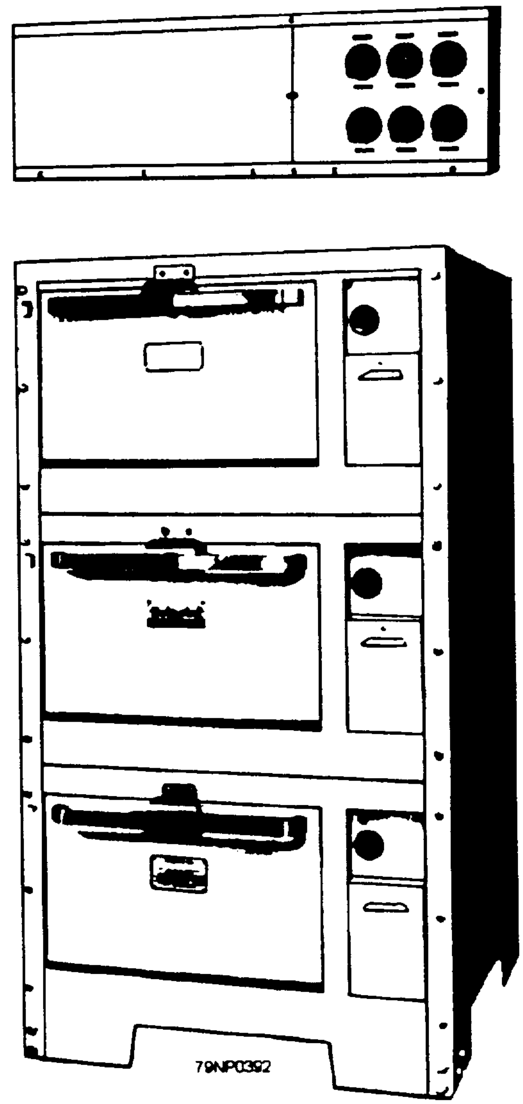


Figure 5-44.—Type-60 oven.

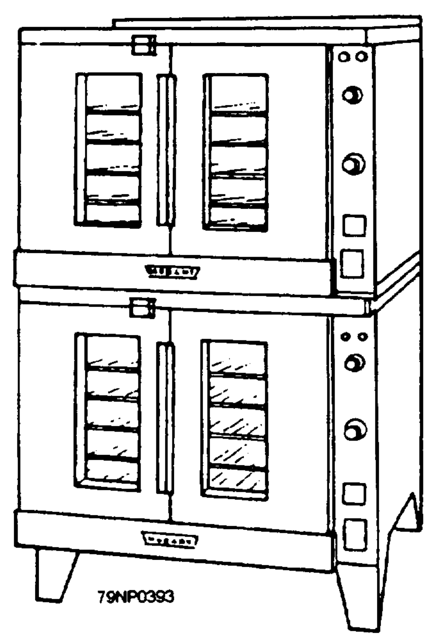


Figure 5-45.—M-series convection oven.

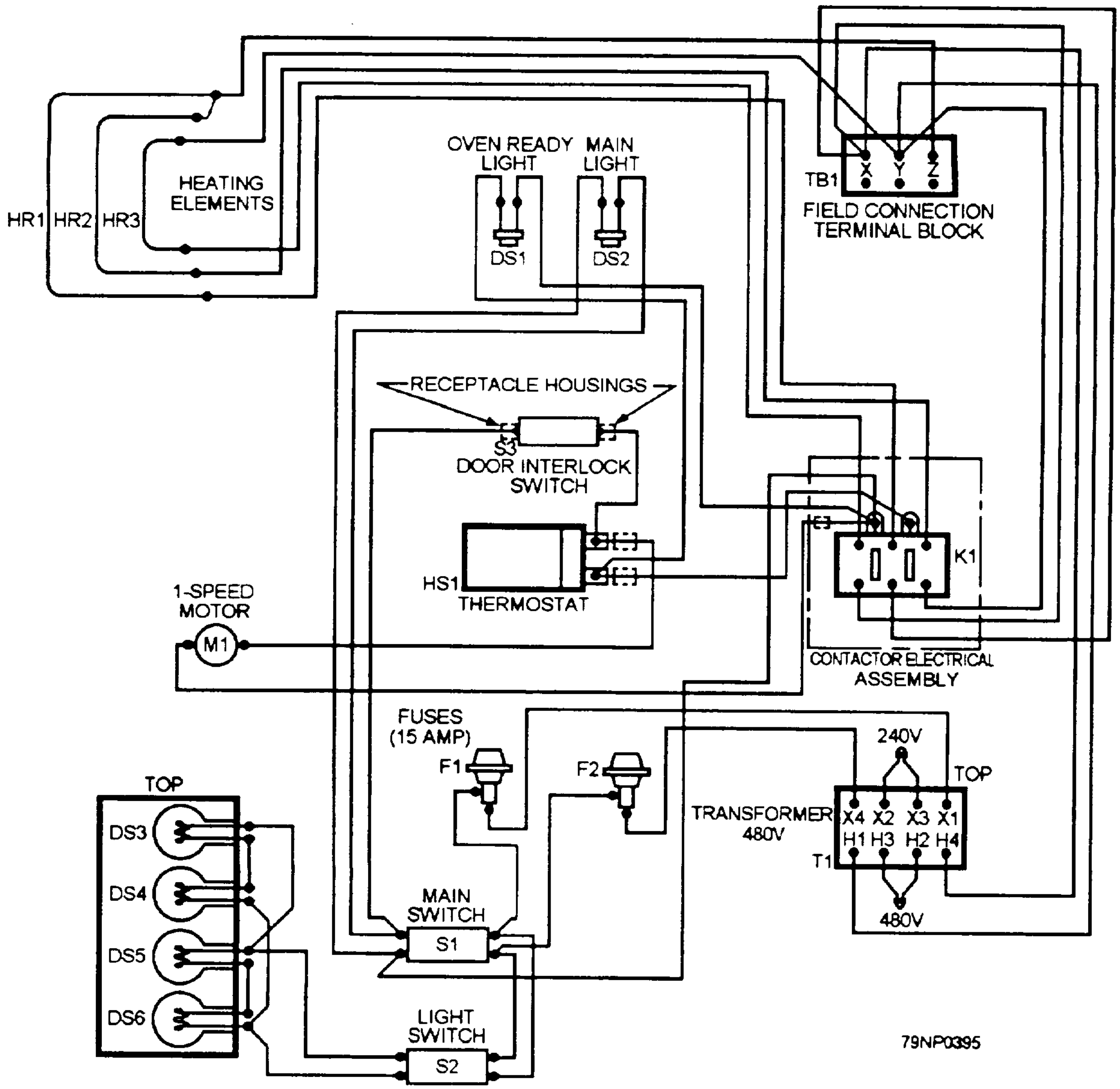


Figure 5-46.—Wiring diagram of M-series oven.

The principle of operation of the convection oven is different from that of a standard oven. In the convection oven the air is forced around the chamber by the motor/fan located at the rear of the oven. The convection oven heating elements are also at the rear of the oven and are controlled by a thermostat switch with a range of 175°F to 450°F. When the doors are opened, the fan motor and heating elements will be de-energized because the door interlock switch opens.

The step-down transformer is 240/480 volts ac and is used for the control circuit only. Figure 5-46 shows a simplified wiring diagram of the M-series oven.

ELECTRIC GRIDDLE

Electric griddles are designed to be installed into metal fixtures or fabricated tops. The tops must be rigid enough to support the equipment weight without warping. Figure 5-47 shows a self-heating griddle. The electric griddle operates on 208-, 230-, and 460-volt ac, 60-hertz, single- or three-phase power. It is thermostatically controlled and has a heating range of 200°F to 450°F±10°F. The thermostat is used to control

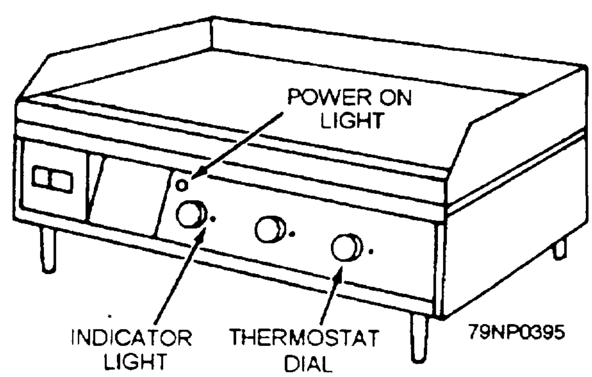


Figure 5-47.—Self-heating griddle.

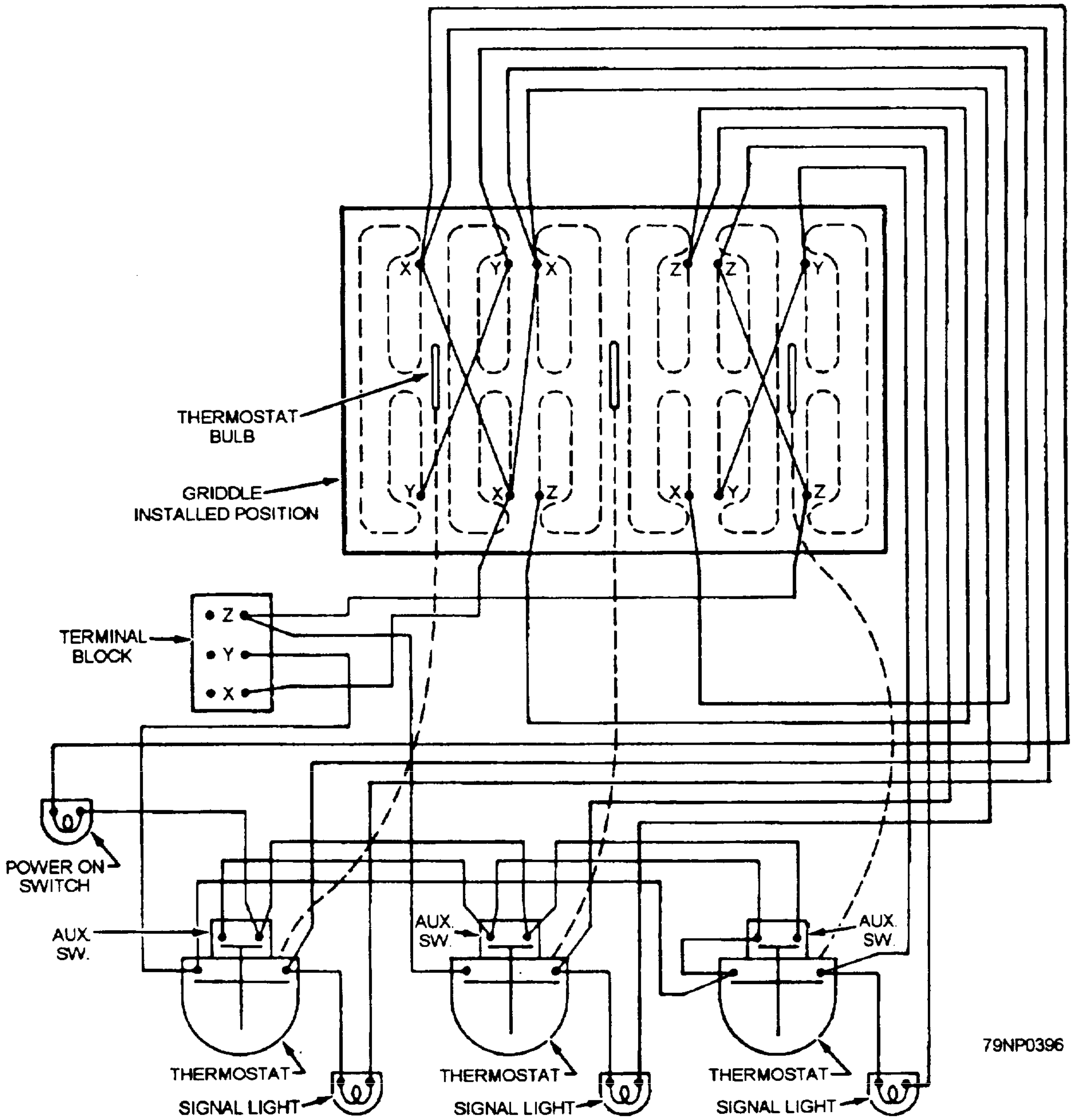


Figure 5-48.—Electric griddle wiring diagram.

the griddle heating unit. When one heating unit is energized the power on light and the heating unit signal light illuminates.

The controls are usually located in the base of the griddle below the heated surface. Figure 5-48 shows a wiring diagram of the electric griddle.

ELECTRIC DEEP FAT FRYER

There are various models and styles of electric deep fat fryers. A representative model, Mk 721, is shown in figure 5-49. Deep fat fryers can be connected to 208-volt ac, 230-volt ac/dc, or 460-volt ac power, depending on the model and voltage requirements.

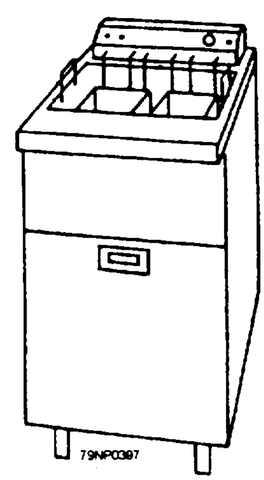


Figure 5-49.—A deep fat fryer.

They can be connected in either single-phase or three-phase configuration.

The deep fat fryer must not be fused, but connected to an external circuit breaker equipped with a shunt trip element. The shunt trip element is connected to the (backup) upper limit thermostat. The backup thermostat functions when the normal thermostat does not operate properly. When the temperature rises to 460°F, the backup thermostat will operate and trip the external circuit breaker to disconnect the deep fat fryer from the power source.

The heating unit is an enclosed type of element and is immersed directly into the fat to ensure maximum efficiency. The heating unit is hinged to the back of the fryer for ease of cleaning or for changing the liquid fat.

The pilot light is energized at all times to indicate that power is available to the deep fat fryer. The power on light is only energized when the heating unit is energized and the unit is heating the liquid fat.

The controls are located inside the deep fat fryer enclosure. Figure 5-50 is a simplified wiring diagram of the Mk 721 deep fat fryer.

MAINTENANCE

NOTE: Before starting any service work on electric galley equipment, ensure the equipment power supply is secured and properly tagged out.

Refer to the manufacturers' technical manuals for instructions concerning the servicing of the electric galley equipment installed aboard your ship. These manuals also include the methods you should use to remove and replace various heating units, thermostats, switches, contractors, and other components of electric cooking equipment.

Galley equipment is normally trouble-free. The most frequent trouble with electric ranges, ovens, and deep fat fryers is burnt contacts. As the operating temperature is met on the thermostat, the contactor will open under a heavy load, causing its contact(s) to arc and burn. Another common problem is corroded connections due to prolonged exposure to heat and grease. You should make a concentrated effort to follow the prescribed planned maintenance, and when necessary, perform corrective maintenance.

SUMMARY

The information in the preceding paragraphs is very basic. There is no standard for the type of galley

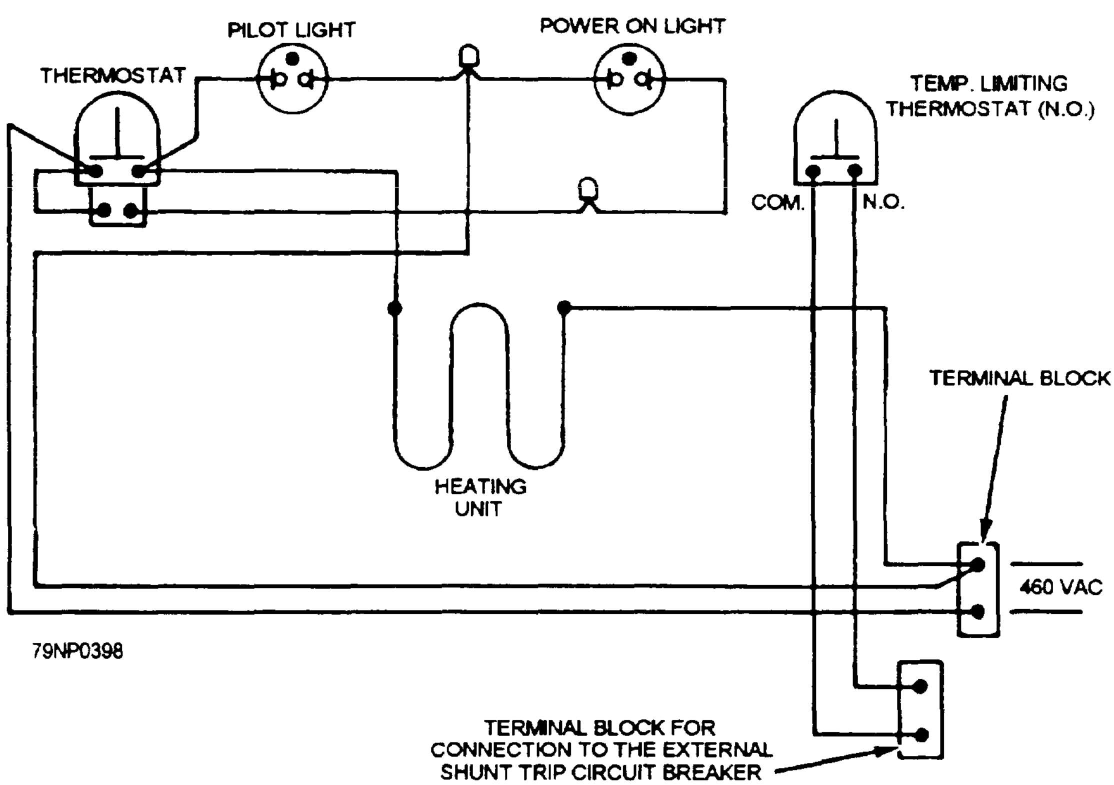


Figure 5-50.—Wiring diagram of the Mk 721 deep fat fryer.

equipment used aboard ship, and there are hundreds of different brands and models of equipment in use. You can determine the basic operation of any electrical galley equipment by using manufacturer's manuals, bulletins, and wiring diagrams usually found on the equipment itself.

LAUNDRY EQUIPMENT

Laundry equipment aboard ship includes washers, extractors, dryers, dry-cleaning machines, and presses. This equipment may be used as separate components or in combination (such as a washer-extractor). The washer-extractor will be the only laundry equipment discussed in this chapter.

WASHER-EXTRACTOR

The washer-extractor is a front-loading, self-balancing, general-purpose piece of equipment. Figure 5-51 shows a front and rear view of a washer-extractor. It is rigidly mounted to the deck in the ship's laundry. The washer-extractor uses ship's electrical power, low-pressure air, saturated steam, and fresh water. The washer can perform all cycles of the wash operation in formula (automatic) or manual (operator-controlled) mode. The washer is capable of washing loads up to 60 pounds of dry weight. The washer-extractor has nine interrelated systems. The washer components are grouped into systems by the major functions performed. These systems are power distribution, function control, air distribution, water distribution, temperature control, drive train, balance, supply injection, and drain.

Power Distribution System

The power distribution system is 440-volt ac, three-phase, 60-hertz. It is routed to the washer through a circuit breaker on the laundry power panel. The 440-volt ac provides power to the four motors in the washer/drive train. It is reduced through a step-down transformer to 120-volt ac, single-phase, 60-hertz power for use in the washer control circuitry. The 120-volt ac power is reduced through another step-down transformer to 24-volt ac, single-phase, 60-hertz power for use in the washer command circuitry.

CONTROL CIRCUITRY.— The control circuity energizes the washer and controls operation through the action of switches, relays, motor solenoids, and electrically operated solenoid valves. When the control circuit receives the proper command signal, the following washer functions can occur:

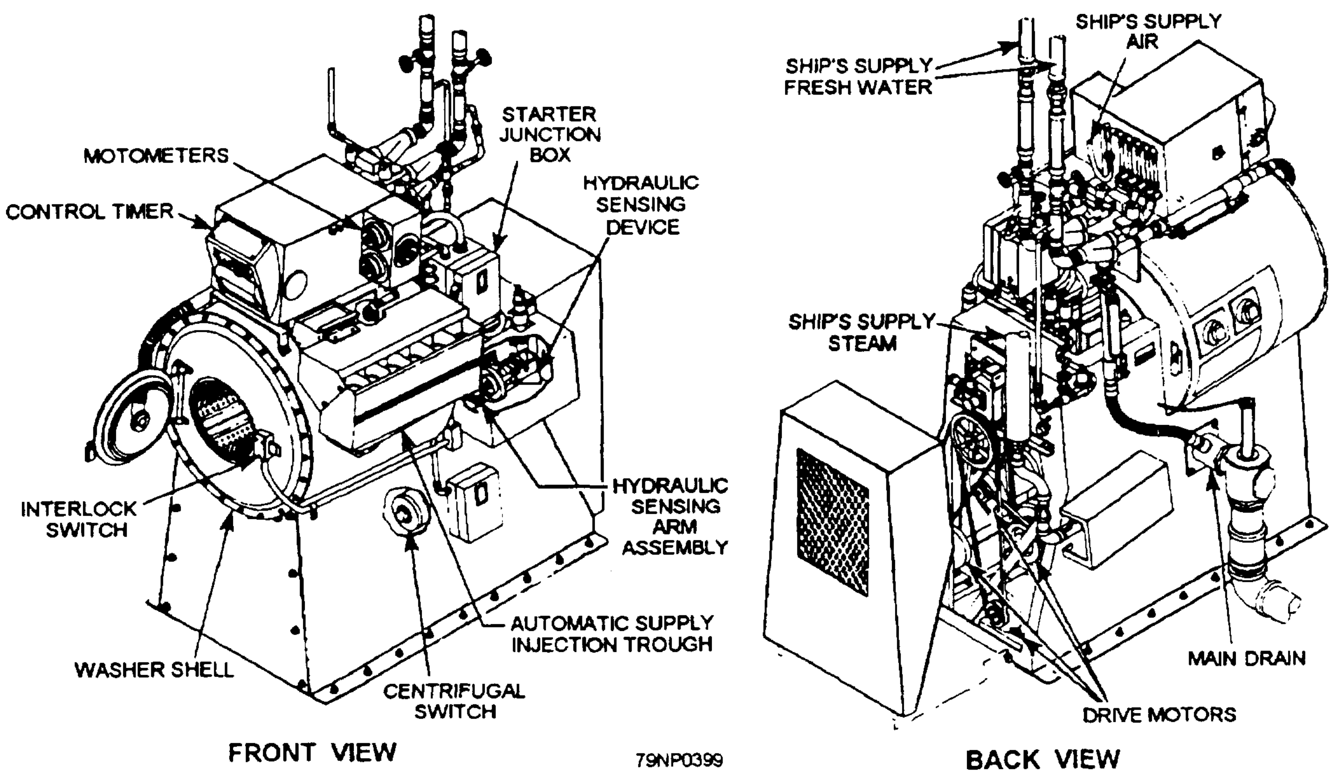


Figure 5-51.—A typical washer-extractor installation.

- The air brake can be set or released.
- The air clutch can be engaged or disengaged
- The proper drive motor can be energized or de-energized
- The chart motor can advance the formula chart (formula mode).
- The washer balance system can operate.
- The washer door can be opened.

COMMAND CIRCUITRY.— The 24-volt ac command circuit generates command signals through the action of finger contacts and/or toggle switches. The command signals are routed throughout the washer to open and/or close relays and solenoid valves. The relays and solenoid valves sequence and control the duration of functions and/or cycles during a wash operation.

Function Control

The automatic control timer (fig. 5-52) is the function control system for the washer-extractor. Command and control signals are routed by finger contacts and/or switches in the control timer to sequence functions and cycles within an operation during formula or manual mode.

FORMULA MODE.— A programmed formula chart (fig. 5-53) is mounted on the rotating drum/copper screen inside the control timer. During the formula mode, the drum rotates and finger contacts press against the chart. As a finger contact passes over a slot in the chart, it touches the copper screen. This completes an electrical circuit and generates a command signal. Each finger contact controls a different command signal. The chart can control the wash operation by programming the time and duration of finger contact on the screen.

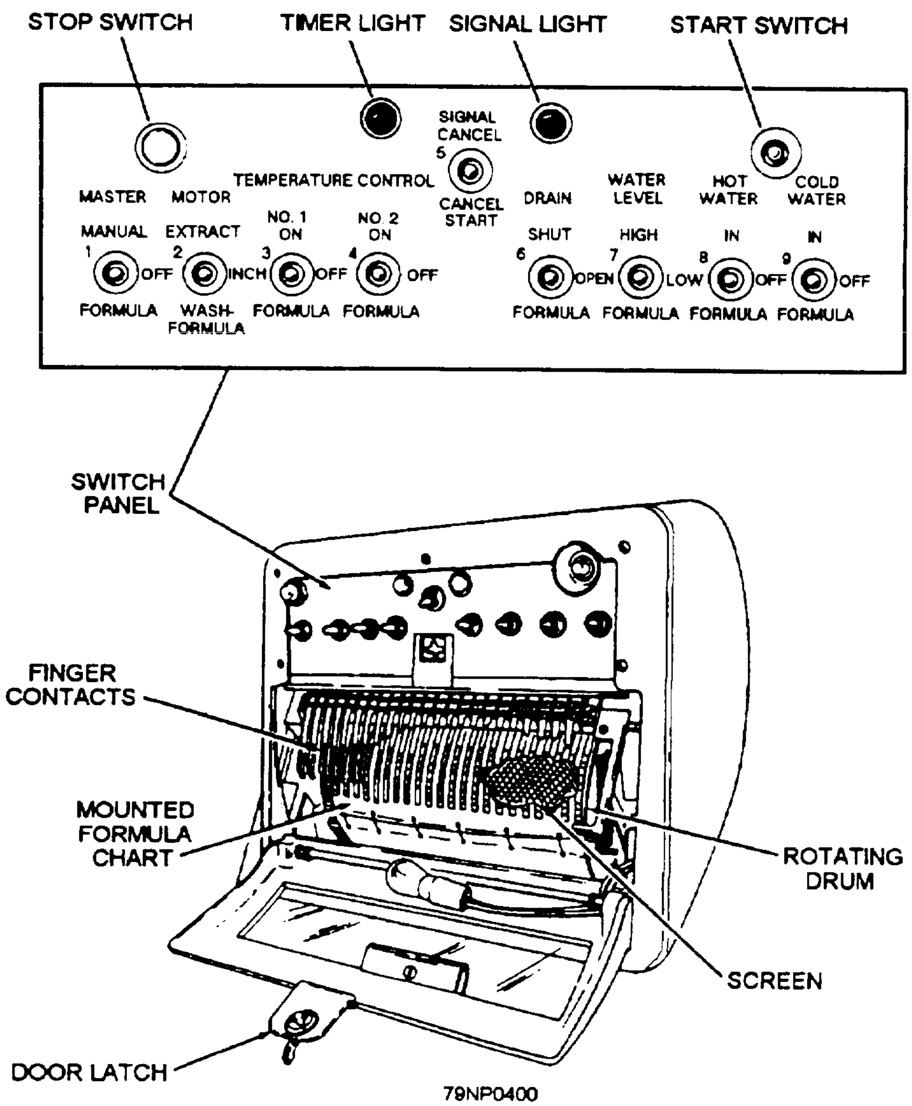


Figure 5-52.—A typical automatic control timer.

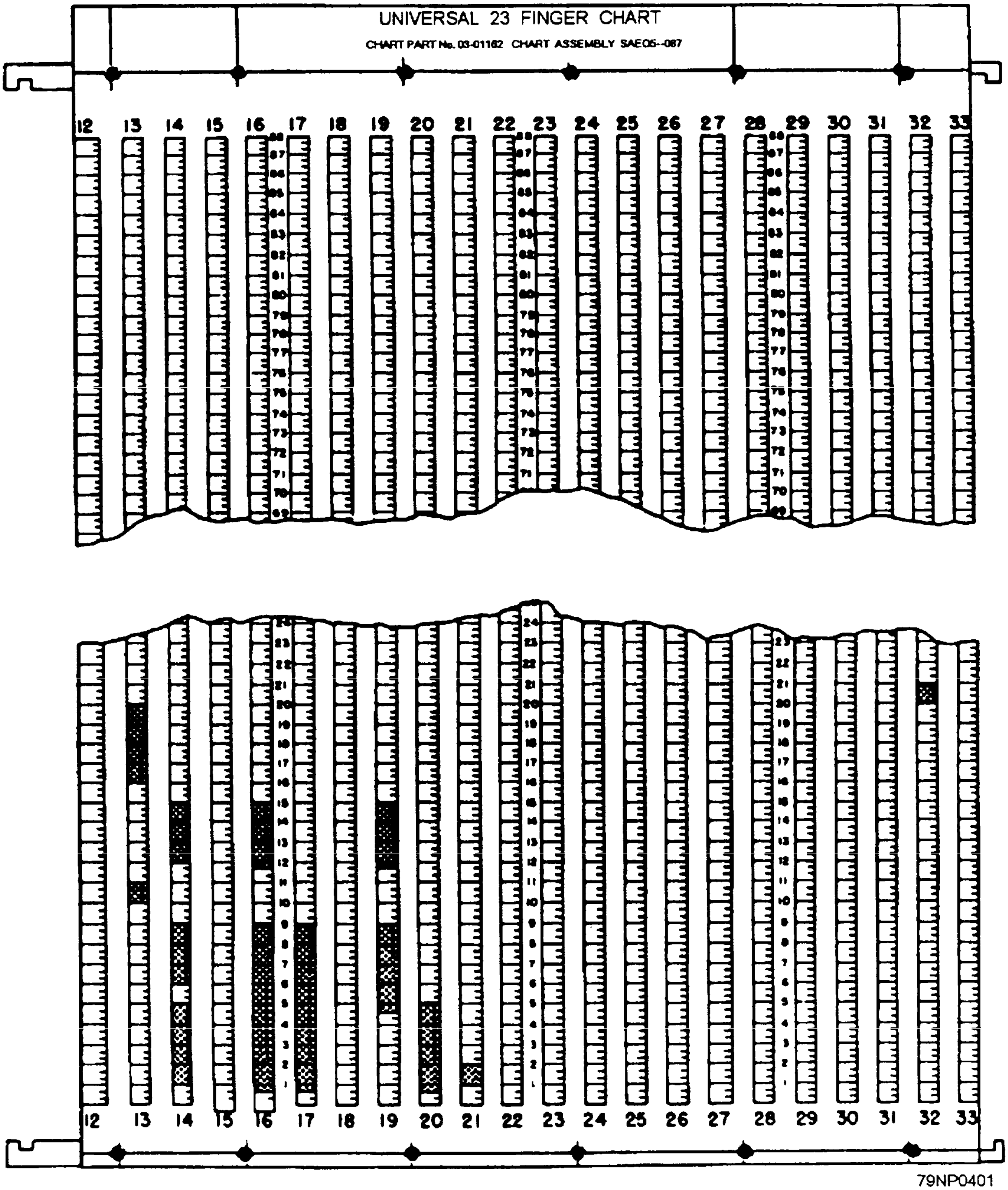


Figure 5-53.—Programmed formula chart.

MANUAL MODE.— In the manual mode the command signals are generated by toggle switches. An operator positions these switches for specific functions and/or cycles. The function and/or cycle is ended by returning the appropriate toggle switch to OFF.

Air Distribution

The air distribution system uses ship's service compressed air to operate the brake and clutch assemblies. Electrically controlled solenoid valves connected to the air manifold distribute the compressed air as signaled by the command or control circuits. The air operates valves controlling the washer drain, the steam supply, and the bottom fill valve. The air also actuates the air brake and the air clutch.

Freshwater Distribution

The freshwater distribution system is used for washing and rinsing. Some fresh water is also used by the temperature control system, the balance system, and the supply injection system.

Temperature Control

Three motometers comprise the temperature control system. Motometers are combination thermometers and thermostats. Each motometer has three indicator pointers-one for indicating existing temperature and two for setting desired temperatures. Water and/or steam are automatically injected to bring the temperature to the preset value.

Drive Train

Figure 5-54 shows the washer drive train. Each drive motor provides a different rotational speed to the washer cylinder and is used during separate cycles. During wash or drain cycles, the drive is from the appropriate motor through a V-belt coupling to the gear reducer and clutch. The inflated (engaged) clutch causes the drive shaft and the washer cylinder to rotate at the wash or drain speed. During low-speed or high-speed extract cycles, the drive is from the appropriate motor through a V-belt coupling directly to the clutch/brake drum pulley. The pulley, connected to

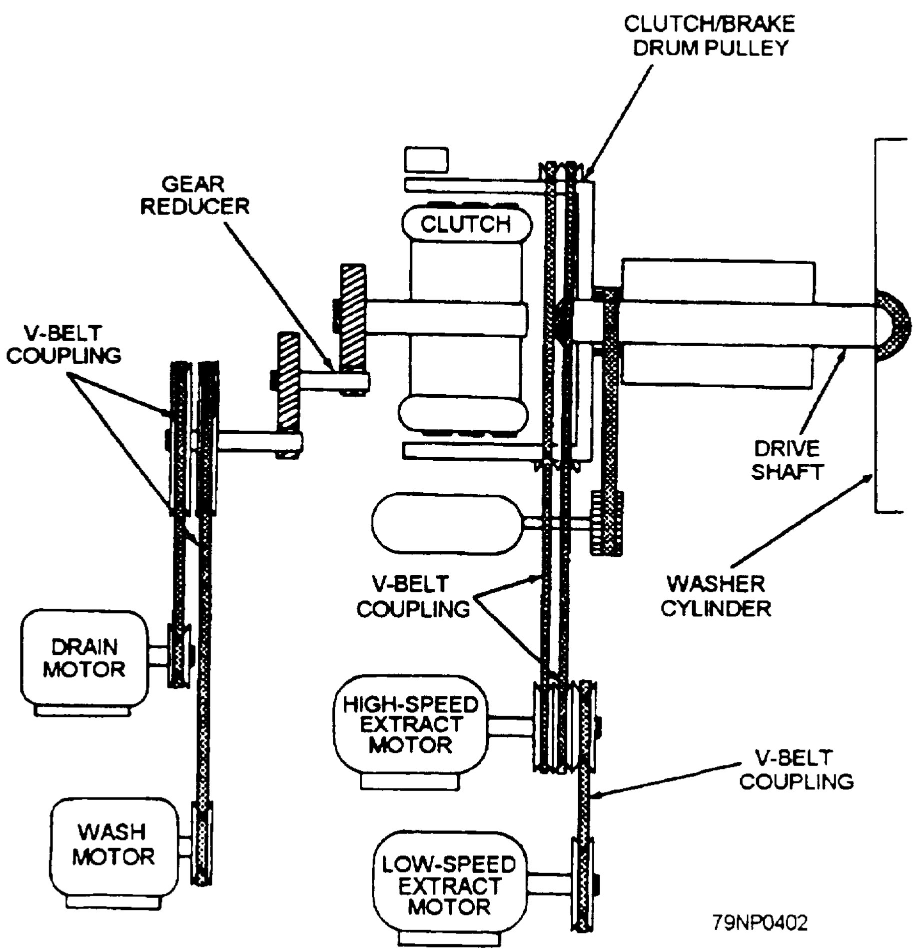


Figure 5-54.—Wash drive train.

the drive shaft, rotates the washer cylinder at low or high speed. The clutch is not engaged during extract cycles.

Balance

The balance system automatically corrects imbalances that occur during extract cycles in either formula or manual mode operation. An imbalance causes washer vibrations that are transmitted through a rigidly mounted arm to a hydraulic sensor unit. The unit converts the vibrations to electric impulse signals that operate electric balance solenoid valves. When a solenoid valve opens, hot water from the water distribution system is injected into a cylinder rib opposite the point of imbalance.

Supply Injection

You can use the manual supply chute in either operational mode. Supplies, such as soap, bleach, conditioner, and so forth, are poured directly into the chute. The automatic injection system is used only during formula mode operations. Initial soap is placed in the manual supply chute, and additional laundry supplies are loaded into the appropriate compartment at the start of wash operations. When the programmed formula chart calls for a supply injection, a command signal is generated by a finger contact in the control timer. The signal opens a solenoid valve, and then water from the water distribution system enters the appropriate supply compartment and flushes the contents into the washer.

Drain

The washer main drain is mounted directly onto the bottom of the washer shell. The main drain valve is controlled by a solenoid valve in the air distribution system manifold.

SAFETY

Never exceed the dry weight cylinder capacity (60 pounds); however, **loading the cylinder to capacity** is recommended Lighter loads may fail to distribute clothes properly. This will cause the machine to vibrate excessively. Before performing maintenance on the machine, ensure it is de-energized and tagged out according to your ship's tag-out program.

For additional information on the operation, the troubleshooting, and the repair of the washer-extractor installed aboard your ship, refer to the manufacturer's technical manual.

OTHER LAUNDRY EQUIPMENT

For other laundry equipment, such as dry-cleaning machines, dryers, and presses, refer to the appropriate manufacturer's instruction manual for operational procedures, troubleshooting, and repairs.

SUMMARY

In this chapter you have been introduced to information on various components of electrical equipment. These components include small craft electrical systems, the ship's air compressors, the refrigeration and air-conditioning plants, the electrostatic vent fog precipitators, the electrohydraulic steering gear, and the ship's deck equipment. Some of the smaller auxiliary equipment components that have been discussed include battery chargers and storage batteries and components. We also described various deck equipment, including winches, anchor windlasses, elevators, and UNREP systems. Some galley and laundry equipment were also described and explained.

The installations aboard your ship may differ, but the information given is basic in nature and should be of some use in determining the proper course of action when operating and maintaining the vast amount of auxiliary electrical equipment aboard ship.

CHAPTER 6

MOTOR CONTROLLERS

Controllers are commonly used for starting motors aboard ship. They can be designed to limit the amount of current applied when starting motors by slowly incrementing the starting process, allow the user to select the speed at which the motor will operate, allow the operator to reverse the direction of rotation of a motor, remove the motor from service if conditions exist which may damage the motor or other connected equipment, allow the user to operate the motor under adverse conditions in an emergency, and so forth. In all cases, the basic function of motor controllers is to govern the operation of and protect the motors they serve.

LEARNING OBJECTIVES

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

1. *Identify the different types of electric controllers.*
2. *Recognize the principle of operation of various types of motor controllers.*
3. *Identify the procedures for troubleshooting motor controllers.*
4. *Identify the procedures to use when performing corrective maintenance on motor controllers.*

In this chapter, you will learn the characteristics, the uses, and the operating principles of the various kinds of shipboard motor controllers, including their relays and switches. The techniques for maintaining and troubleshooting motor controllers are also discussed.

TYPES OF MOTOR CONTROLLERS

Motor controllers are classified as manual or automatic (magnetic). They are further classified b y the methods by which they are started-across-the-line and reduced voltage.

- Across-the-line motors are started with full-line voltage being immediate] y applied to the motor.
- Reduced voltage motors are started by applying line voltage to the motor in increments to allow for acceleration of the motor to avoid high starting current.

MANUAL

A manual (nonautomatic) controller is operated by hand directly through a mechanical system. The operator closes and opens the contacts that normally energize and de-energize the connected load.

MAGNETIC

In a magnetic controller, the contacts are closed or opened by electromechanical devices operated by local or remote master switches. Norman y, all the functions of a semiautomatic magnetic controller are governed by one or more manual master switches. Automatic controller functions are governed by one or more automatic master switches after the motor has been initially energized by a manual master switch. All magnetic controllers can be operated in either mode, depending on the mode of operation selected.

ACROSS-THE-LINE CONTROLLER

An across-the-line controller (fig. 6-1) throws the connected load directly across the main supply line. The across-the-line controller may be either manual or magnetic, depending on the rated horsepower of the motor. Norman y, across-the-line dc controllers are used to start small (fractional horsepower) motors. However, they may be used to start average-sized, squirrel-cage induction motors without any damage because these

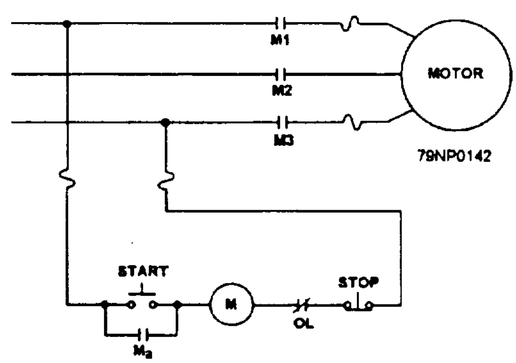


Figure 6-1.—Schematic of a simple across-the-line controller.

motors can withstand the high starting currents caused by starting with full-line voltage applied. Most squirrel-cage motors drive pumps, compressors, fans, lathes, and other auxiliaries. They can be started "across the line" without producing excessive line-voltage drop or mechanical shock to a motor or auxiliary.

AC PRIMARY RESISTOR CONTROLLER

In an ac primary resistor controller, resistors are inserted in the primary circuit of an ac motor for both starting and speed control. Some of these controllers only limit the starting currents of large motors; others control the speed of small motors, as well as limiting the starting current.

Figure 6-2 illustrates the use of resistors to limit the amount of starting current.

AC SECONDARY RESISTOR CONTROLLER

In an ac secondary resistor controller (fig. 6-3), resistors are inserted in the secondary circuit of a wound-rotor ac motor for starting or speed control. Although sometimes they are used to limit starting currents, secondary resistor controllers usually function to regulate the speeds of large ac motors.

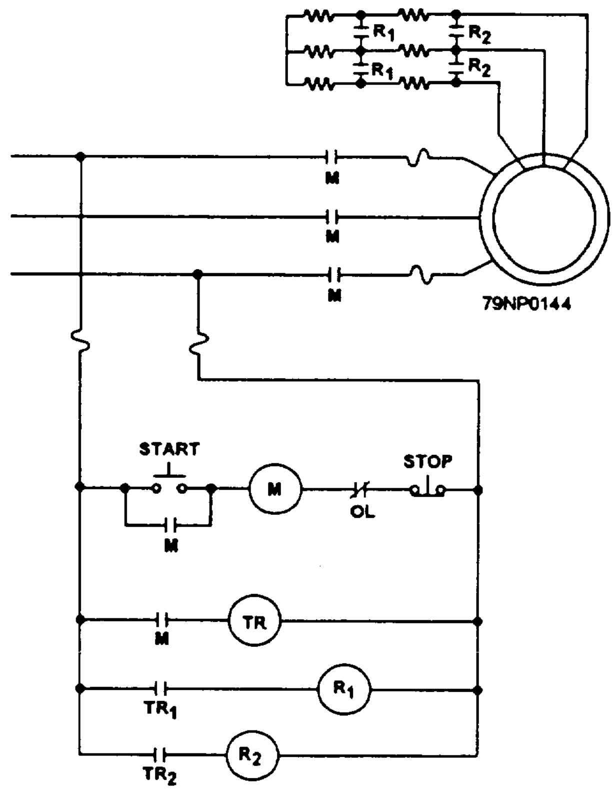


Figure 6-3.—Schematic of an ac secondary resistor controller.

AUTOTRANSFORMER CONTROLLER

The autotransformer controller (or compensator) is an ac motor controller. The autotransformer controller (fig. 6-4) starts the motor at a reduced voltage through an autotransformer and then connects the motor to line voltage after the motor accelerates. There are two types of compensators—open transition and closed transition.

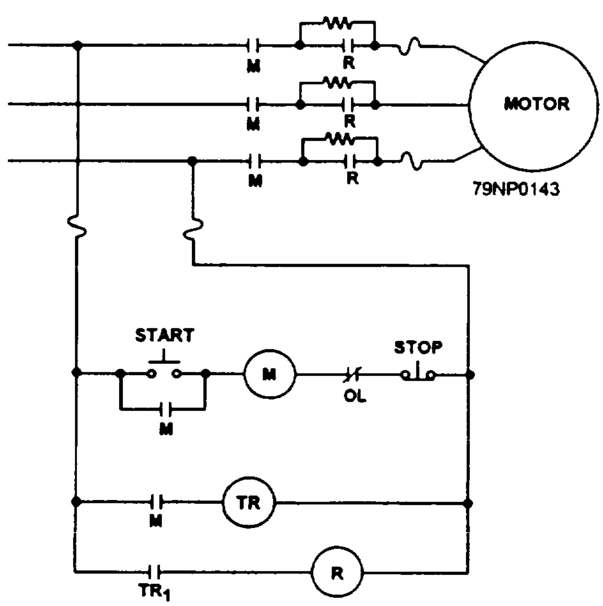


Figure 6-2.—Schematic of an ac primary resistor controller.

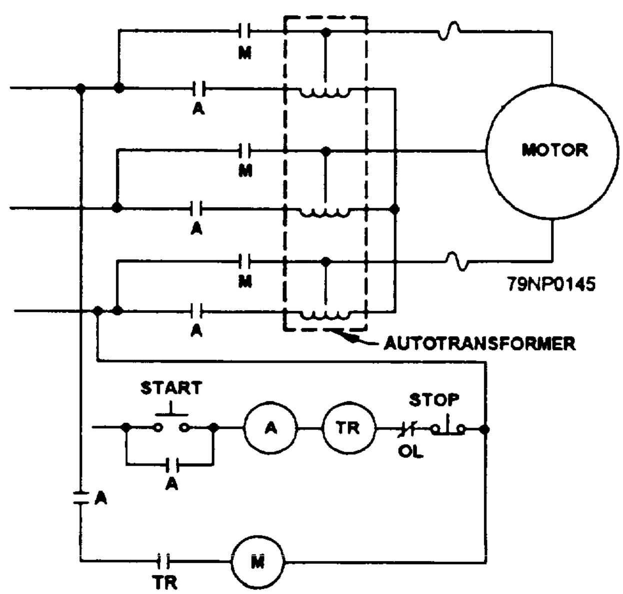


Figure 6-4.—Schematic of an autotransformer controller.

Open-Transition Autotransformer

The open-transition compensator cuts off power to the motor during the time (transition period) that the motor connection is shifted from the autotransformer to the supply line. In this short transition period, it is possible for the motor to coast and slip out of phase with the power supply. After the motor is connected directly to the supply line, the resulting transition current may be high enough to cause circuit breakers to open.

Closed-Transition Autotransformer

The closed-transition compensator keeps the motor connected to the supply line during the entire transition period. In this method, the motor cannot slip out of phase and no high transition current can develop.

REACTOR CONTROLLER

A reactor controller (fig. 6-5) inserts a reactor in the primary circuit of an ac motor during starts and later short-circuits the reactor to apply line voltage to the motor. The reactor controller is not widely used for starting large ac motors. It is smaller than the closed-transition compensator and does not have the high transition currents that develop in the open-transition compensator.

REVERSING CONTROLLER

Reversing controllers act to change line connections to the motors under control causing the direction of rotation to reverse. Three-phase ac motors are reversed by interchanging any two of the three lines providing power to the motor. Look at figure 6-6. Standard practice when reversing three-phase ac motors is to interchange L1 and L3.

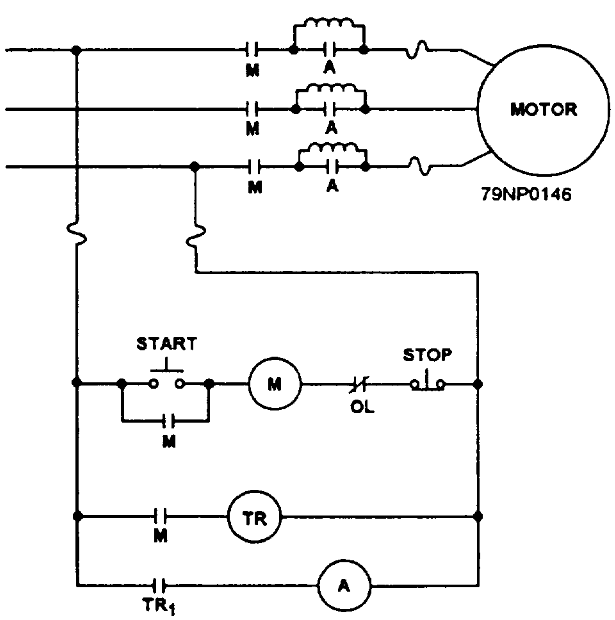


Figure 6-5.—Schematic of a reactor controller.

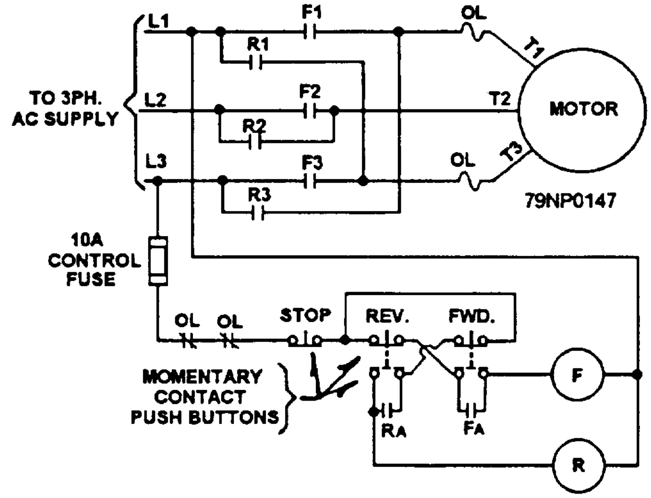


Figure 6-6.—Schematic of a reversing ac controller.

DC motors are reversed by reversing the connections to the armature. DC controllers accomplish this through the use of drum switches.

VARIABLE-SPEED CONTROLLER

A motor static variable-speed controller consists of solid-state and other devices that regulate motor speeds in indefinite increments through a predetermined range. Speed is controlled by either manual adjustment or actuation of a sensing device that converts a system parameter, such as temperature, into an electric signal. This signal sets the motor speed automatically.

DC RESISTOR CONTROLLER

In a dc resistor motor controller (fig. 6-7), a resistor in series with the armature circuit of the dc motor limits the amount of current during starts, thereby preventing

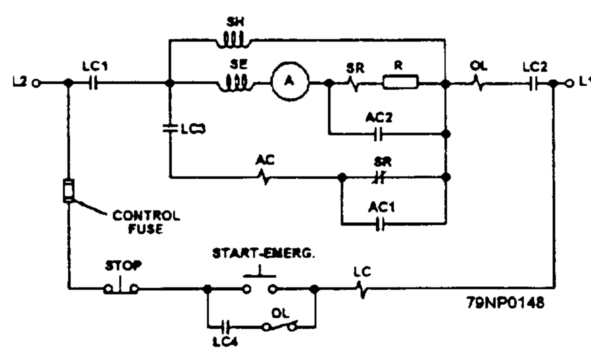


Figure 6-7.—Schematic of a dc resistor controller with one stage of acceleration.

motor damage and overloading the power system. In some resistor controllers, the same resistor also helps regulate the speed of the motor after it is started. Other dc controllers use a rheostat in the motor shunt field circuit for speed control.

LOGIC CONTROLLERS

Some of the controlled equipment that you will see uses logic systems for circuit control. For additional information in this area, the Navy Electricity and Electronics Training Series (NEETS), Module 13, NAVEDTRA B72-13-00-86, *Introduction to Number Systems and Logic Circuits,* is an excellent basic reference.

CONSTRUCTION

In this section of the TRAMAN, you will learn how controllers are constructed.

SIZE DESIGNATION

Controllers are sized numerically according to the maximum horsepower rating of their connected loads. Generally, the numbers zero to five (0-5) are used; however, in special circumstances, controllers as large as 6, 7, or 8 may be used. AC controllers that are connected to two-speed motors have two numbers separated by a slash. The larger number indicates the rating of the controller at motor fast speed, while the smaller number indicates the rating at motor slow speed.

The controller sizes given in table 6-1 apply to both ac and dc controllers.

Table 6-1.—AC and DC Controller Sizes

Maximum Horsepower Rating		
Size	450-Volt Three Phase	230-Volt, DC (nominal)
0	5	1
1	10	5
2	25	10
3	50	25
4	100	40
5	200	75
6	400	150
7	600	225
8	—	350

ENCLOSURES

The components of the controller are housed within an enclosure suitable to its location, atmospheric condition, or presence of explosive vapors or liquids. Enclosures provide mechanical and electrical protection for both the operator and the motor starter. Controller enclosures can be classified in the following ways:

- Open. Open enclosures provide the least amount of protection from dust and moisture. Provides maximum ventilation to internals.
- Dripproof. Dripproff enclosures are the most common type found aboard ship. They are constructed so that liquid or solid particles can't enter the enclosure when striking at an angle of 0° to 15° from the downward vertical.
- Spraytight. Spraytight enclosures provide more than usual protection from casual water. They are constructed to prevent entry of water from spray at any angle not greater than 100° from the vertical.
- Watertight. Watertight enclosures are constructed so that water sprayed from any angle will be unable to enter the enclosure.
- Submersible. Submersible enclosures are constructed so that water can't enter when the unit is submerged underwater. Provides least amount of ventilation to internal components.
- Explosionproof. Explosionproof enclosures are constructed so that no gas vapor can penetrate except through vents or piping provided for the purpose.

MASTER SWITCHES

A master switch is a device, such as a pressure or a thermostatic switch, that governs the electrical operation of a motor controller. The master switch (fig. 6-8) can be manually or automatically actuated. Drum, selector, and push-button switches are examples of a manual master switch. The automatic switch is actuated by a physical force, not an operator. Examples of automatic master switches include float, limit, or pressure switches.

Depending on where it is mounted, a master switch is said to be either local or remote. A local switch is mounted in the controller enclosure, while a remote switch is mounted near the watchstation or work area where the motor is to be controlled from.

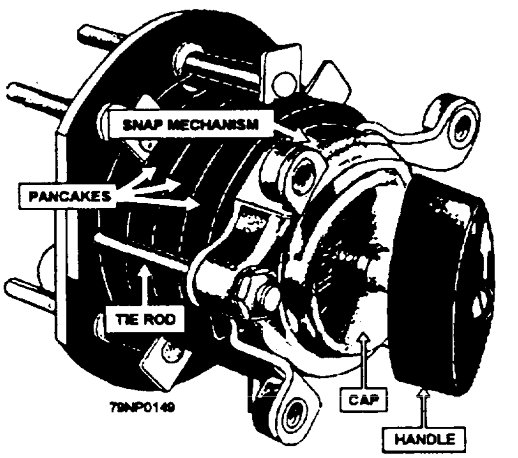


Figure 6-8.—Rotary snap switch.

Master switches may start a series of operations when their contacts are either closed or opened. In a momentary contact master switch, the contact is closed (or opened) momentarily; it then returns to its original condition. In the maintaining contact master switch, the contact does not return to its original condition after closing (or opening) until it is again actuated. The position of a normally open or normally closed contact in a master switch is open or closed, respectively, when the switch is de-energized. The de-energized condition of a manual controller is considered to be in the OFF position

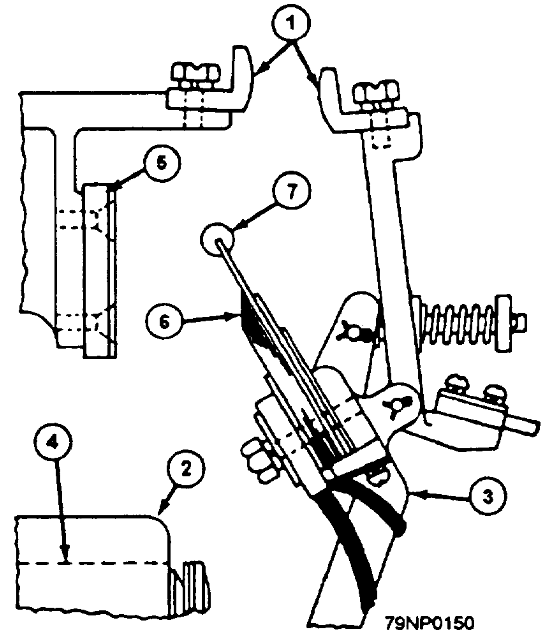
CONTRACTORS

Contractors are the heart of any controller. They operate to open and close the contacts that energize and de-energize connected loads.

DC Contractors

A dc contactor is composed of an operating magnet energized by either switches or relays, fixed contacts, and moving contacts. It maybe used to handle the load of an entire bus or a single circuit or device. Larger contacts must be used when heavy currents are to be interrupted. These contacts must snap open or closed to reduce contact arcing and burning. In addition to these, other arc-quenching means are used.

ARCING CONTACTS.— The shunt contactor shown in figure 6-9 uses a second set of contacts (1) to reduce the amount of arcing across the main contacts (5 and 6) when closing. The numbers that are in parentheses are indicated on the figure. Shunt-type contractors will handle up to 600 amperes at 230 volts.



1. Arcing contacts
2. M-coil
3. Moveable armature
4. M-coil core
5. Stationary main contacts
6. Moveable main contacts
7. Silver brush arcing tips

Figure 6-9.—Detailed view of arcing contacts.

The blowout shield has been removed in this detailed view. As you read this section refer to figure 6-9.

The arcing contacts (1) are made of rolled copper with a heavy protective coating of cadmium. These contacts are self-cleaning because of the sliding or wiping action following the initial contact. The wiping action keeps the surface bright and clean, and thus maintains a low contact resistance.

The contactor is operated by connecting the coil (2) directly across a source of dc voltage. When the coil is energized, the movable armature (3) is pulled toward the stationary magnet core (4). This action causes the contacts that carry current (5, 6, 7, and 1) to close with a sliding action

The main contacts (5 and 6), called *brush contacts,* are made of thin leaves of copper that are backed by several layers of phosphor bronze spring metal. A silver brush arcing tip (7) is attached to the copper leaves and makes contact slightly before the leaf contact closes. The stationary contact (5) consists of a brass plate, which has a silver-plated surface. Since the plating lowers the surface resistance, the contact surfaces should never be filed or oiled. If excessive current causes high spots on the contact, the high places maybe smoothed down by careful use of a fine ignition-type file.

You can check the operation and contact spacing by manually closing the contactor (be sure the power is off). The lowest leaf of brush contact 6 should just barely touch contact 5. If the lower leaf hits the plate too soon, bend the entire brush assembly upward slightly. The contact dimensions should be measured with the contactor in the OPEN position.

Refer to the manufacturer's instruction book when making these adjustments.

BLOWOUT COILS.— When a circuit carrying a high current is interrupted, the collapse of the flux linking the circuit will induce a voltage, which will cause an arc. If the spacing between the open contacts is small, the arc will continue once it is started. If the arc continues long enough, it will either melt the contacts or weld them together. Magnetic blowout coils overcome this condition by providing a magnetic field that pushes the arc away from the contact area.

The magnetic blowout operation is shown in figure 6-10. It is important that the fluxes remain in the proper relationship. Otherwise, if the direction of the current is changed, the direction of the blowout flux will be reversed, and the arc will actually be pulled into the space between the contacts.

When the direction of electron flow and flux is as shown in figure 6-10, the blowout force is upward. The blowout effect varies with the magnitude of the current and with the blowout flux. The blowout coil should be chosen to match the current so that the correct amount of flux may be obtained. The blowout flux across the arc gap is concentrated by the magnetic path provided by the steel core in the blowout coil and by the steel pole pieces extending from the core to either side of the gap.

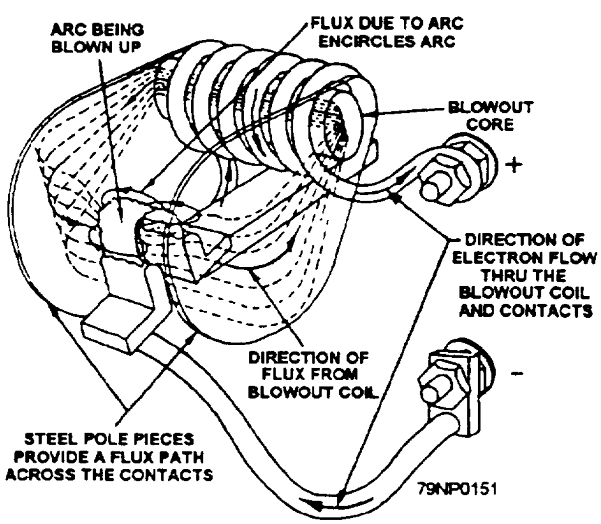


Figure 6-10.—Action of a magnetic blowout coil.

AC Contractors

AC contractors (fig. 6-11) and control relays differ from DC contractors and control relays in three general areas:

1. For heavy currents, ac contractors generally use an air gap alone to quench the arc created by opening energized contacts while dc contractors use blowout coils.
2. AC contractors are noisier than dc contractors. Shading bands are sometimes used on ac contactor cores to reduce noise and produce smoother operation.
3. The coil of an ac contactor contains fewer turns of wire than a dc contactor for the same voltage; therefore, it depends on inductive reactance to produce counterelectromotive force (cemf) to limit current flow in the coil. If an ac contactor fails to close completely, an air gap will exist in the magnetic circuit. This air gap reduces the amount of cemf produced which reduces the ability of the coil to protect itself and may lead to burnout of the coil.

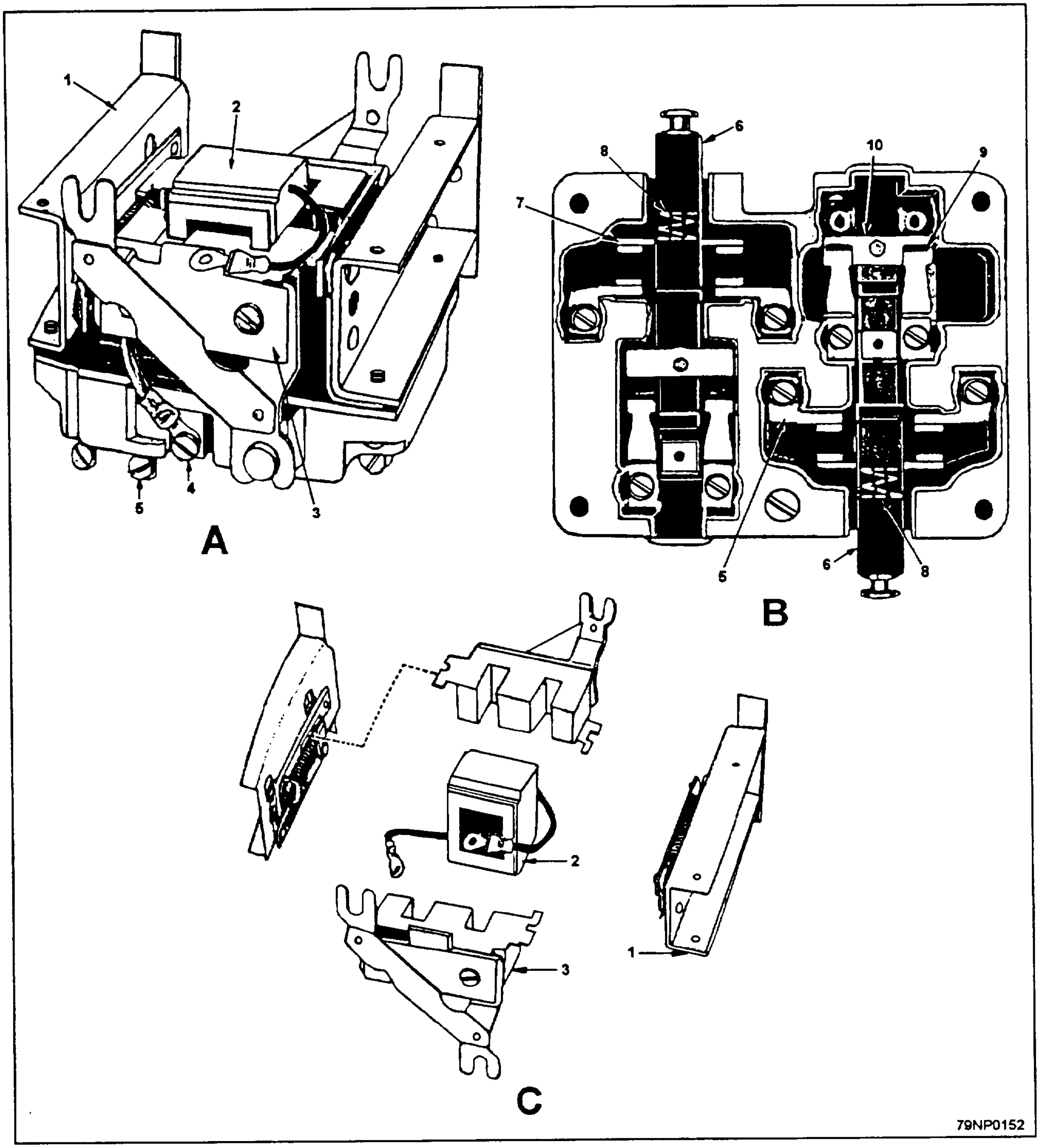
The operating parts of the contactor must be kept clean and free to operate to prevent burnout of the coils. A regular maintenance routine of cleaning and circuit testing according to prescribed PMS will keep contractors free of trouble for years of operation.

CONTROLLER OPERATION

The operation of the various types of controllers is discussed in this section of the TRAMAN.

MAGNETIC ACROSS-THE-LINE CONTROLLERS

Across-the-line controllers are the most common motor controllers you will encounter aboard ship. Of the three types (LVP, LVR, and LVRE), LVPs are most often used aboard ship to control/protect motors.



1. Mounting Bracket
2. Operating Coil
3. Armatures
4. Coil Lead Terminal
5. Main Contact Terminal
6. Contact Bars
7. Main Contact (movable)
8. Main Contact Spring
9. Electrical Interlock (stationary contact)
10. Electrical Interlock (movable contact)

Figure 6-11.—AC contactor.

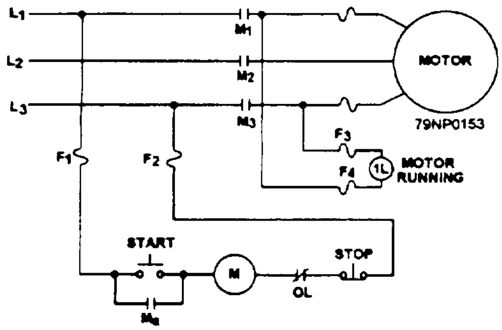


Figure 6-12.—Schematic of a simple LVP controller.

Low-Voltage Protection (LVP)

An elementary or schematic diagram of an LVP magnetic controller is shown in figure 6-12. Table 6-2 describes the sequence of operation in starting the motor:

Table 6-2.—Operation of a Simple LVP Controller

STEP	ACTION
1. The start button is pushed	The circuit is completed from L_1 through the control fuse F_1, the start button, the contactor coil M, the overload relay contacts OL, the stop button, through control fuse F_2, and on to L_3.
2. Current through the M coil causes the relay to energize and close its contacts.	This causes: 1. Contact M_a to close forming the maintaining circuit to keep the motor energized when the start button is let go (opened). 2. Line contacts M_1, M_2, and M_3 to close to connect the full-line voltage to the motor.

The motor will continue to run until the contactor coil is de-energized by the stop push button, failure of the line voltage, or tripping of the overload relay, OL.

Low-Voltage Release (LVR)

The LVR controller (fig. 6-13) operates in basically the same way as the LVP controller, except that its start switch is a maintaining-type switch, such as a snap switch. This makes the use of a maintaining circuit, through an auxiliary contact in parallel with the start switch, unnecessary.

If power is lost to a motor supplied by an LVR contactor while it is operating, the motor will stop just as if it had been turned off. Once power is restored, the motor will restart since the start circuit was maintained through the maintaining-type start switch. For this reason, motors that drive loads requiring some setup by the operator before being energized are normally controlled by LVP controllers.

Low-Voltage Release Effect (LVRE)

The LVRE controller is actually a simple switch. It operates in the same way as the LVR controller, except that it doesn't have a coil in its circuit to operate contacts. The main contacts are operated by the operator manually opening and closing the start switch. A household light switch is an example of an LVRE controller.

SPEED SELECTION CONTROLLERS

Both ac and dc motors maybe designed to operate at more than one speed. In each case, controllers are used to select the desired operating speed and protect the motor.

The most common type of motor in the fleet is the ac, squirrel-cage induction motor. The speed of this

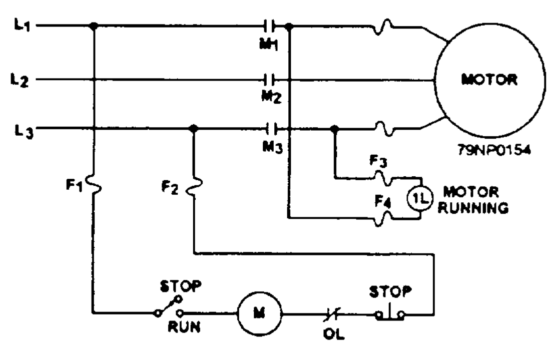


Figure 6-13.—Schematic of simple LVR controller.

motors depends on the speed of the rotating magnetic field (also known as the *synchronous speed).* The synchronous speed depends on the following factors:

1. The number of magnetic poles in the motor, and
2. The frequency of the power supplied to it

This can be expressed mathematically as:

$$f = \frac{NP}{120}$$

or

$$N = \frac{120 \times f}{P}$$

where: f= frequency of the voltage supplied to the motor

N = synchronous speed

P= number of magnetic poles in the stator

Since it isn't desirable to change the frequency throughout the ship to change motor speed, the speed of ac motors is changed by altering the number of magnetic poles. The number of magnetic poles in ac motors is varied by changing connections to the motor through the controller.

The speed of dc motors can be controlled by varying the voltage to the motor. An arrangement of resistors is used along with the controller to operate the motor at the desired speed.

AC Speed Selection

An ac induction motor designed for two-speed operation may have either a single set of windings or two separate sets of windings, one for each speed. Figure 6-14 is a schematic diagram of the ac controller for a two-speed, two-winding induction motor. The low-speed winding is connected to terminals T_1, T_2, and T_3. The high-speed winding is connected to terminals T_{11}, T_{12}, and T_{13}. Overload protection is provided by the LOL coils and contacts for the low-speed winding and the HOL contacts and coils for the high-speed winding. The LOL and HOL contacts are connected in series in the maintaining circuit, and both contacts must be closed before the motor will operate at either speed.

The control push buttons are the momentary-contact type. High-speed operation of the controller in figure 6-14 is shown in table 6-3.

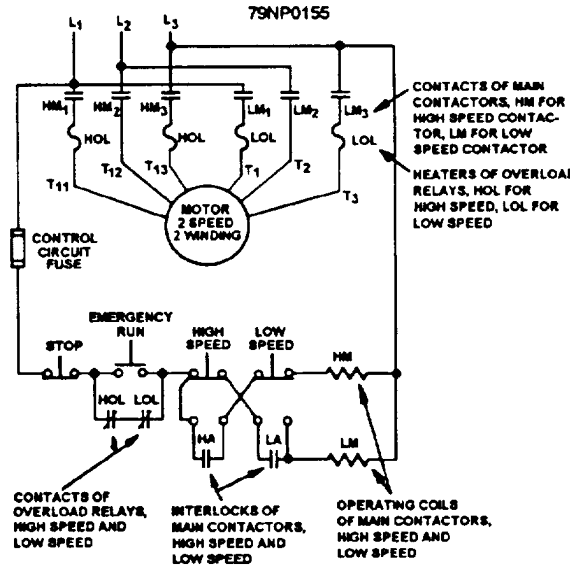


Figure 6-14.—Two-speed, ac controller.

Table 6-3.—High-Speed Operation of a Two-speed AC Motor

STEP	ACTION
1.	Pressing the high-speed push button closes the high-speed contactor by energizing coil HM.
2.	The coil remains energized after the push button is released, closing holding contacts HA.
3.	The coil, HM, also closes main line contacts HM_1, HM_2, and HM_3, applying full-line voltage to the motor high-speed winding.

The motor will run at high speed until coil HM is de-energized either by opening the stop switch, a power failure, or an overload.

The Low-Speed operation of the controller is shown in table 6-4.

Table 6-4.—Low-Speed Operation of a Two-Speed AC Motor

STEP	ACTION
1.	Pressing the low-speed push button closes the low-speed contactor by energizing coil LM.
2.	The coil remains energized after the button is released, through the holding coil contacts LA.
3.	The coil (LM) also closes the main line contacts LM_1, LM_2, and LM_3, which apply the full-line voltage to the low-speed motor winding.

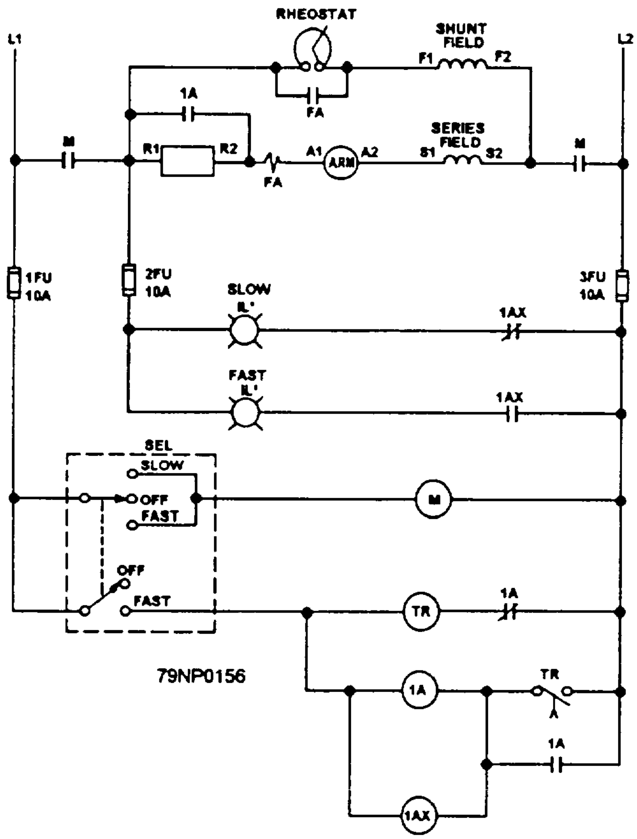


Figure 6-15.—A two-speed de controller with shunt field rheostat.

The motor will run at low speed until coil LM is de-energized. The LM and HM contractors are mechanically interlocked to prevent both from closing at the same time.

DC Speed Selection

The speed of dc motors is determined by the amount of current flowing through both the field winding and the armature winding. If resistance is added in series with the shunt field (fig. 6-15), the current through the shunt field winding will be decreased. The decreased field strength will momentarily decrease the amount of cemf produced, and the motor will sped up. Once the motor speeds up the amount of cemf will rise and again limit the armature current.

In a similar manner, a decrease in resistance increases the current flow through the field windings, momentarily increases the production of cemf, and slows the motor down.

The operation of the slow-speed circuit is shown in table 6-5.

Table 6-5.—Operation of slow-speed circuit

STEP	ACTION
1.	Placing the start switch in the slow position completes the circuit from L1 through the 10 A line fuse, through the selector switch, through the main contactor M, through the other 10 A line fuse, and back to L2.
2.	The M contactor closes its contacts forming the circuit from L1, through the M contact, through the starting resistance R, through relay FA, through the armature, the series field, the other M contact, and back to L2.
3.	Relay FA is energized to close its contact and bypass the shunt field rheostat.
4.	The motor begins to turn with the current through the armature being limited by the resistance R.
5.	As the motor builds up speed current through the armature will decrease because of the growing amount of cemf developed by the armature. Once the motor is up to speed, the current through the armature circuit will decrease to the point that relay FA will drop allowing its contact to open and place the rheostat in series with the shunt field.
6.	The rheostat can now be used to alter the strength of the shunt field and thus the speed of the motor.

Setting the start switch to high speed causes steps 1 to 5 above to be repeated. This is followed by the sequence of events listed in table 6-6.

Table 6-6.—Operation of High-Speed Circuit

STEP	ACTION
7.	The sequence of operations for slow-speed is duplicated through the upper arm of the start switch.
8.	Through the lower arm of the start switch, timing relay TR is energized from L1, through the 10 A line fuse, through the selector switch, through the timing relay, through the other 10 A line fuse, through the normally closed contact 1A, and back to L2.
9.	The timing relay operates after a delay that has been set to allow the motor to build up speed and thus cemf. The TR operates to energize coils 1A and 1AX.
10.	Coil 1A energizes to remove the timing relay from the circuit and to close the contact in parallel with the starting resistance, thus removing the resistance from the armature circuit and allowing the motor to operate at high speed.

REVERSING CONTROLLERS

Certain applications call for the ability to reverse the direction of rotation of installed motors aboard ship. Whether the motor is ac or dc, the method used to reverse the direction of rotation is to change the connections of the motor to the line. Motor controller controllers make this a quick, simple process.

AC Motors

The rotation of a three-phase induction motor is reversed by interchanging any two of the three leads to the motor. The connections for an ac reversing controller are shown in figure 6-16. The stop, reverse, and forward push-button controls are all momentary contact switches. Note the connections to the reverse and forward switch contacts. (Their contacts close or open momentarily, then return to their original closed or opened condition.)

The operation of the reversing ac motor controller in the forward position is shown in table 6-7. After the forward push button is pressed:

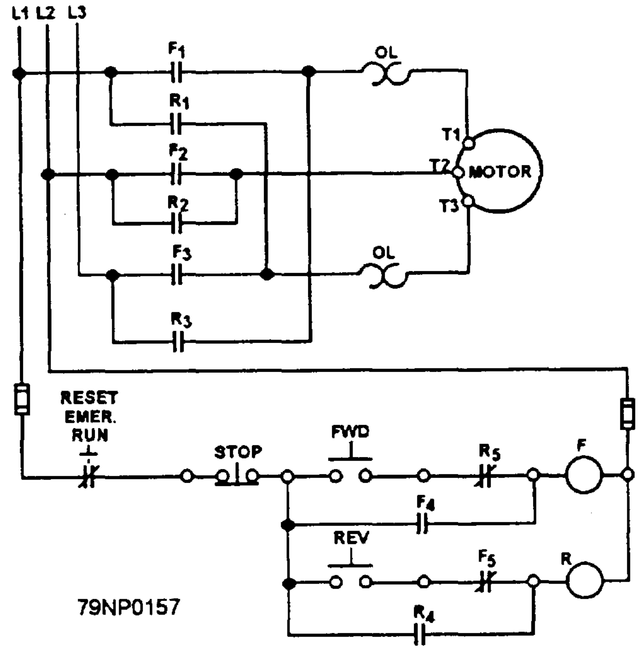


Figure 6-16.—Reversing ac controller.

Table 6-7.—Forward Operation of a Reversing AC Controller

STEP	ACTION
1.	Coil F will be energized through normally closed contact R_5 and will close its holding contact F_4. This contact will remain closed as long as coil F is energized.
2.	Line contacts F_1, F_2, and F_3, are closed applying full-line voltage to the motor.
3.	The motor then runs in a forward direction.
4.	Normally closed contact F_5 will open to act as an electrical interlock to prevent energizing the reverse coil (R) while in the forward direction.

If either the stop button or the reverse button is pressed, the circuit to the F contactor coil is broken, and the coil releases and opens line contacts F_1, F_2, and F_3, and maintaining contact F_4.

The operation of the reversing motor in the reverse position is shown in table 6-8. After the reverse push button is pressed (solid to dotted position):

Table 6-8—Reverse Operation of a Reversing AC Controller

STEP	ACTION
1.	Coil R is energized, through normally closed contact F5, and closes holding contact R4 and line contacts R1, R2, and R3.
2.	Contacts R1 and R3 reverse the connections of lines 1 and 3 to motor terminals T1 and T3.
3.	The motor will now rotate in the reverse direction.

The F and R contractors are both mechanically and electrically interlocked to prevent both being closed at the same time.

Momentary contact push buttons provide low-voltage protection with manual restart in the circuit shown in figure 6-16. If either the F or R operating coil is de-energized, the contactor will not reclose and start the motor when voltage is restored unless either the forward or reverse push button is pressed. The circuit arrangement of the normally closed contacts F_5 and R_5 provides an electrical interlock that prevents the energizing of both coils at the same time.

DC Motors

In most applications, the direction in which a dc motor turns is reversed by reversing the connections of the armature with respect to the field. The reversal of connections can be done in the motor controller by adding two electrically and mechanically interlocked contractors.

A dc motor reversing connection is shown in figure 6-17. Note that there are two start buttons—one marked START-EMERG FORWARD and the other marked START-EMERG REVERSE. These buttons serve as master switches, and you can get the desired motor rotation by pressing the proper switch.

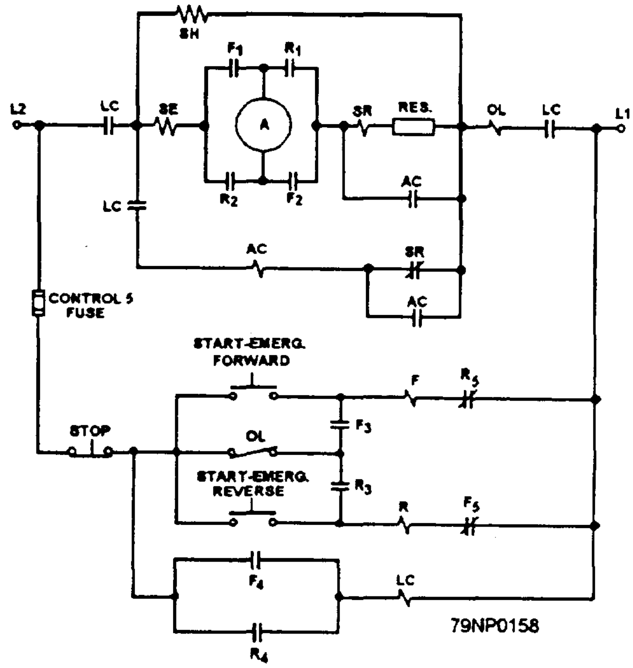


Figure 6-17.—Reversing dc controller.

The forward operation of the reversing dc controller is given in table 6-9.

Table 6-9.—Forward Operation of a DC Controller

STEP	ACTION
1.	Pressing the forward button causes line voltage to be applied through the button to the forward contactor coil (F).
2.	This pulls in the armature and closes the normally open contacts: 1. (F1 and F2) in the motor armature circuit, 2. the forward contactor holding circuit contacts (F3), and 3. the line contactor circuit contacts (F4).
3.	The normally closed contacts (F5) of the reverse contactor circuit are opened.
4.	The normally closed contacts (F5) are electrically interlocked open when the forward contactor (F) coil is energized to prevent the operation of the reverse coil R at the same time.

After the line contactor is energized, acceleration is accomplished in the reamer described previously.

Operating the reverse button duplicates the steps for the forward button described in table 6-9 with the exception of the F_1 and F_2 contacts. The R_1 and R_2 contacts are closed to reverse the direction of current through the armature and thus the direction of rotation.

AUTOTRANSFORMER CONTROLLERS

A single-phase autotransformer has a tapped winding on a laminated core. Normally, only one coil is used on a core, but it is possible to have two autotransformer coils on the same core. Figure 6-18 shows the connections for a single-phase autotransformer being used to step down voltage. ‘he winding between A and B is common to both the primary and the secondary windings and carries a current that is equal to the difference between the load current and the supply current.

Any voltage applied to terminals A and C will be uniformly distributed across the winding in proportion to the number of turns. Therefore, any voltage that is less than the source voltage can be obtained by tapping the proper point on the winding between terminals A and c .

Some autotransformers are designed so that a knob-controlled slider makes contact with wires of the winding in order to vary the load voltage.

The directions for current flow through the line, transformer winding, and load are shown by the arrows in figure 6-18. Note that the line current is 2.22 amperes and that this current also flows through the part of the winding between B and C. In the part of the winding that is between A and B, the load current of 7 amperes is opposed by the line current of 2.22 amperes. Therefore, the current through this section is equal to the difference between the load current and the line current. If you subtract 2.22 amperes from 7 amperes, you will find the secondary current is 4.78 amperes.

Autotransformers are commonly used to start three-phase induction and synchronous motors and to furnish variable voltage for test panels. Figure 6-19 shows an autotransformer motor starter, which incorporates starting and running magnetic contractors, an autotransformer, a thermal overload relay, and a mercury timer to control the duration of the starting cycle.

ONE-STAGE ACCELERATION CONTROLLERS

Figure 6-20 shows a typical dc controller. The connections for this motor controller with one stage of

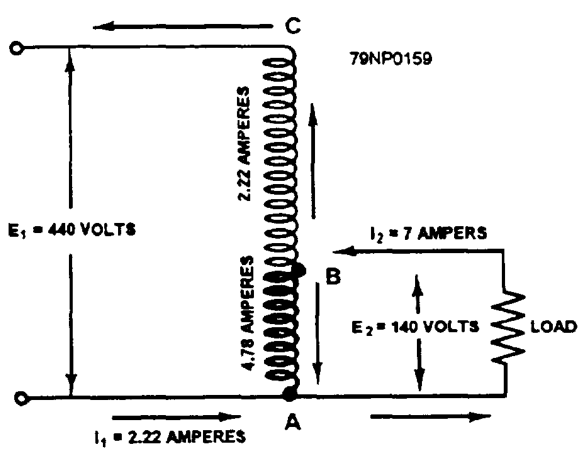


Figure 6-18.—Single-phase autotransformer.

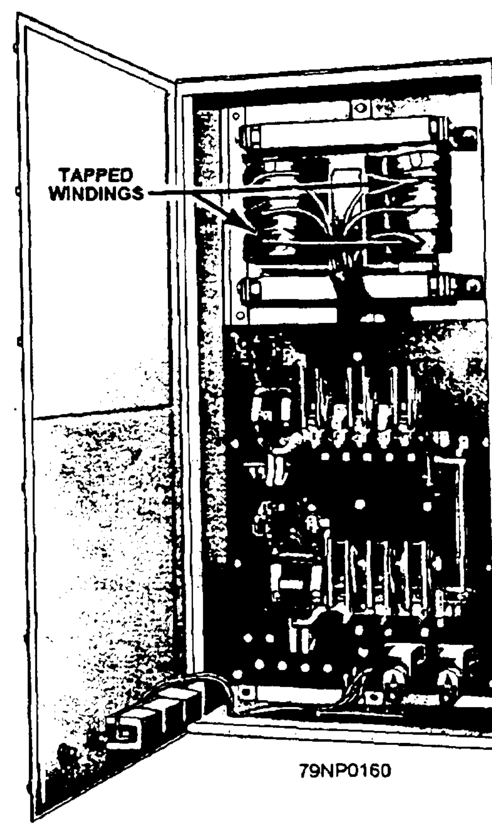


Figure 6-19.—Autotransformer controller.

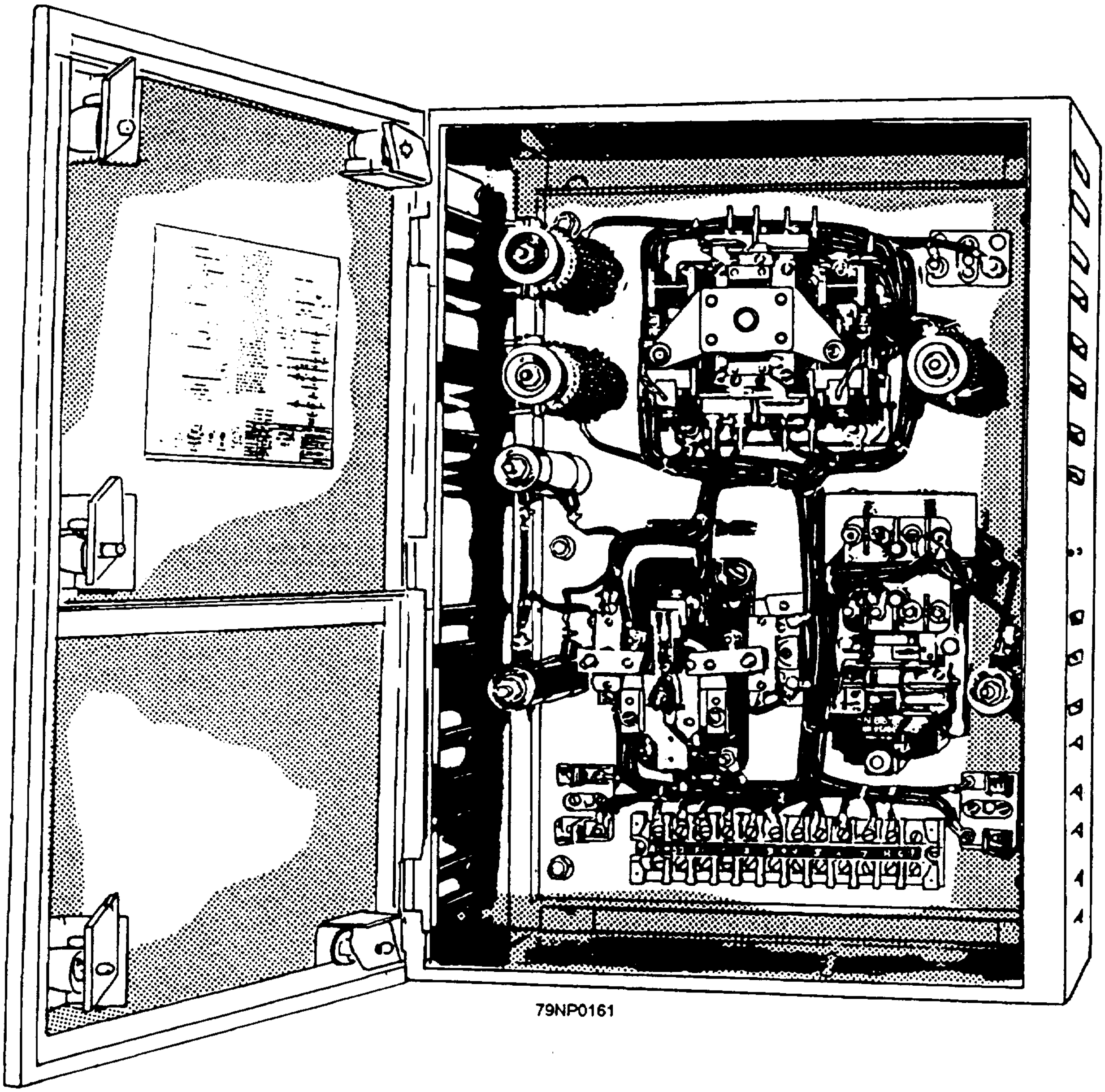


Figure 6-20.—A typical dc controller.

acceleration are shown in figure 6-21. The letters that are in parentheses are indicated in figure 6-21. When the start button is pressed, the path for current is from the line terminal (L2) through the control fuse, the stop button, the start button, and the line contactor coil (LC), to the line terminal (L1). Current flowing through the contactor coil causes the armature to pull in and close the line contacts (LC1, LC2, LC3, and LC4).

When contacts LC1 and LC2 close, motor-starting current flows through the series field (SE), the armature (A), the series relay coil (SR), the starting resistor (R), and the overload relay coil (OL). At the same time, the

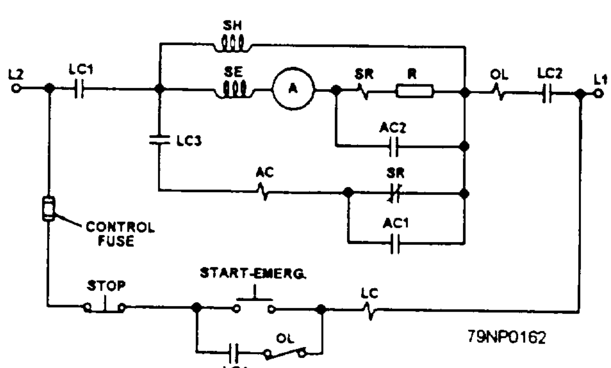


Figure 6-21.—A dc controller with one stage of acceleration.

shunt field winding (SH) is connected across the line and establishes normal shunt field strength. Contacts LC3 close and prepare the circuit for the accelerating contactor coil (AC). Contacts LC4 close the holding circuit for the line contactor coil (LC).

The motor armature current flowing through the series relay coil causes its armature to pull in, opening the normally closed contacts (SR). As the motor speed picks up, the armature current drawn from the line decreases. At approximately 110 percent of normal running current, the series relay current is not strong enough to hold the armature in; therefore, it drops out and closes its contacts (SR). These contacts are in series with the accelerating relay coil (AC), and cause it to pick up its armature, closing contacts AC1 and AC2.

Auxiliary contacts (AC1) on the accelerating relay keep the circuit to the relay coil closed while the main contacts (AC2) short out the starting resistor and the series relay coil. The motor is then connected directly across the line, and the connection is maintained until the STOP button is pressed.

If the motor becomes overloaded, the excessive current through the overload coil (OL) (at the top right of fig. 6-21) will open the overload contacts (OL) (at the bottom of fig. 6-21), disconnecting the motor from the line

If the main contactor drops out because of an excessive drop in line voltage or a power failure, the motor will remain disconnected from the line until an operator restarts it with the START push button. This prevents automatic restarting of equipment when normal power is restored.

LOGIC CONTROLLERS

The basic concept of logic circuits is shown in figures 6-22 and 6-23. As you read this section, refer to these figures.

In figure 6-22, view A, an AND symbol is shown. The AND symbol can be compared to the electrical circuit in figure 6-22, view B. (**NOTE:** Both switches A *AND* B must be closed to energize the lamp.)

In figure 6-23, view A, an OR symbol is shown. The OR symbol can be compared to the electrical circuit in figure 6-23, view B. (**NOTE:** Either switch A *OR* B needs to be closed to energize the lamp.)

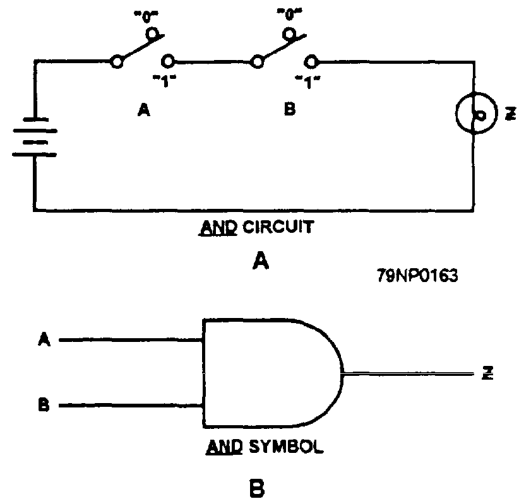


Figure 6-22.—AND symbol and circuit.

AND and OR logic circuits are used in logic controllers. Their use is discussed in this section of the TRAMAN.

One common application of logic control that is being incorporated on newer ships is the elevator system. Since this system is large and consists of many symbols, only a small portion of this system is discussed.

Assume that the elevator platform is on the third deck and that you require it on the main deck. Refer to

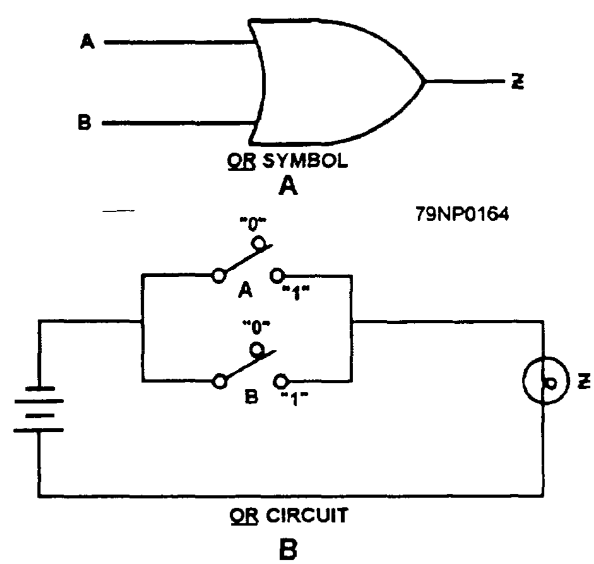


Figure 6-23.—OR symbol and circuit.

figure 6-24. Three conditions (detected by electronic sensors usually associated with the driven component) must be met before the elevator can be safely moved.

CONDITION	RESPONSE
1. The platform must be on EITHER the second or third deck (on a certain deck as opposed to somewhere in between).	The OR symbol will have an input, and since only one input is needed, the OR symbol will also have an output.
2. The locking devices must be engaged.	If the sensors are energized for these conditions 2 and 3, the AND symbol will have the three inputs necessary to produce an output. This output will then set up a starting circuit, allowing the motor to be started at your final command.
3. The access doors must be shut.	

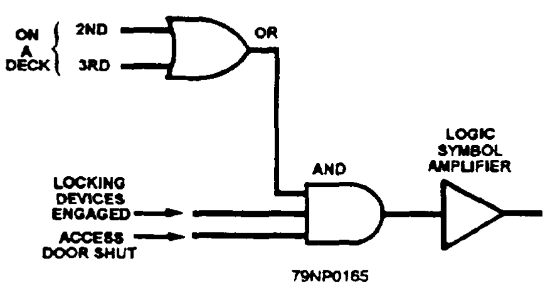


Figure 6-24.—Basic logic circuit.

The advantages of these electronic switches over mechanical switches are low power consumption, no moving parts, less maintenance, quicker response, and less space requirements. A typical static logic panel found aboard ship is shown in figure 6-25.

Although there are more logic symbols than AND and OR, they all incorporate solid-state devices. For more information, see NEETS, Module 7, NAVEDTRA B72-07-00-92, *Introduction to Solid-State Devices and Power Supplies.*

PROTECTIVE FEATURES

As its name implies, the primary purpose of motor controllers is to control the operation of the motor connected. In accomplishing this function, it is imperative that the controller be able to operate as well as protect the motor being controlled. The following section describes the various means of protection available to motors by the controller used.

VOLTAGE PROTECTION

A drop in voltage supplied to a motor under load could severely damage the motor windings. If allowed to remain on the line, the current through the windings could become excessive and cause damage to the motor.

Low voltage type controllers (LVP, LVR, and LVRE) are designed to remove a motor from the line upon a drop in line voltage. Once line voltage drops to a predetermined level, the main contactor coil (or an undervoltage coil controlling it) will dropout. This will function to open its contacts and remove the motor from the line.

Once line voltage has been restored, the motor may be restarted normally.

OVERLOAD PROTECTION

Nearly all shipboard motor controllers provide overload protection when motor current is excessive. This protection is provided by either thermal or magnetic overload relays, which disconnect the motor from its power supply, thereby preventing the motor from overheating.

Overload relays in magnetic controllers have a normally closed contact that is opened by a mechanical device, which is tripped by an overload current. The opening of the overload relay contact de-energizes the circuit through the operating coil of the main contactor, causing the main contactor to open, and secures power to the motor.

Overload relays for naval shipboard use can usually be adjusted to trip at the correct current to protect the motor. If the rated tripping current of the relay does not fit the motor it is intended to protect, it can be reset after tripping so the motor can be operated again with overload protection. Some controllers feature an emergent y-run button that enables the motor to be run without overload protection during an emergency.

Thermal Overload Relays

The thermal overload relay has a heat-sensitive element and an overload heater that is connected in series with the motor load circuit. When the motor current is excessive, heat from the heater causes the heat-sensitive element to open the overload relay contact. This action breaks the circuit through the

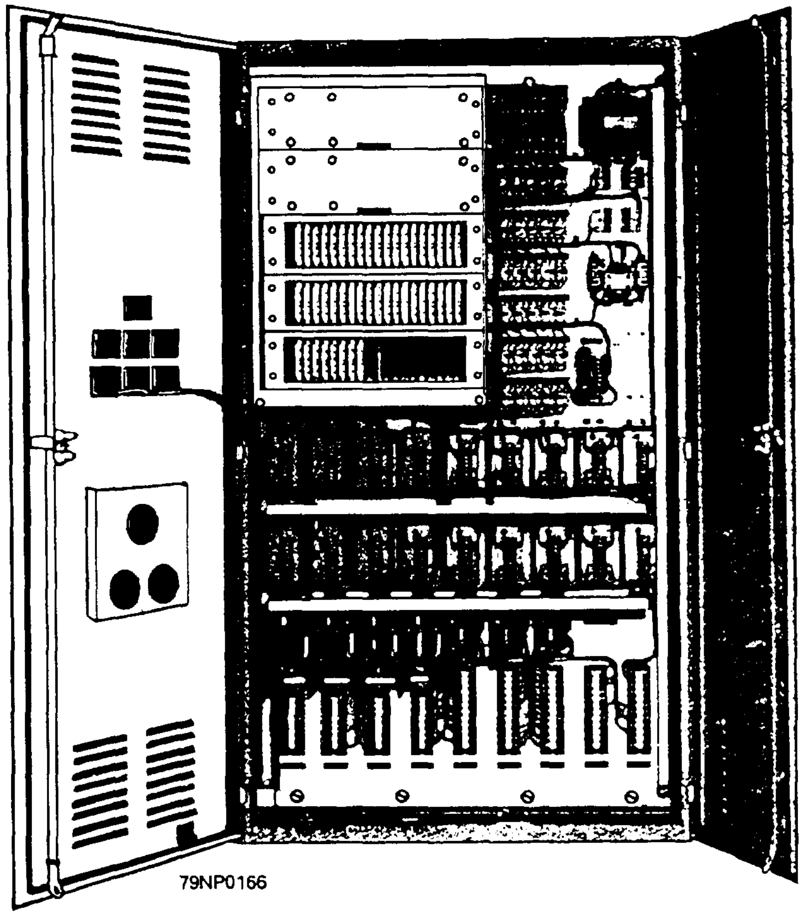


Figure 6-25.—A static logic panel for a cargo elevator.

operating coil of the main contactor and disconnects the motor from the power supply. Since it takes time for the parts to heat up, the thermal overload relay has an inherent time delay, which allows the motor to draw excessive current at start without tripping the motor.

You can make a coarse adjustment of the tripping current of thermal overload relays as follows:

- Change the heater element.
- Change the distance between the heater and the heat-sensitive element to make a fine adjustment. An increase in this distance increases the tripping current. (NOTE: Making fine adjustments depends on the type of overload relay.)
- Change the distance the bimetal strip has to move before the overload relay contact is opened.

Check the related technical manual for additional information and adjustments.

Thermal overload relays must be compensated; that is, they are constructed so the tripping current is unaffected by variations in the ambient (room) temperature. Different compensation methods are used for different types of thermal overload relays. Refer to the technical manual furnished with the equipment on which the controller is used for information on the particular form of compensation provided. There are four types of thermal overload relays—solder pot, bimetal, single metal, and induction.

SOLDER POT THERMAL OVERLOAD RELAY.— The heat-sensitive element of a solder-pot relay consists of a cylinder inside a hollow tube. The cylinder and tube are normally held together by a film of solder. In case of an overload, the heater melts the solder (thereby breaking the bond between the cylinder and tube) and releases the tripping device of the relay. After the relay trips, the solder cools and solidifies. The relay can then be reset.

BIMETAL THERMAL OVERLOAD RELAY.— In the bimetal relay, the heat-sensitive element is a strip or coil of two different metals fused together along one side. When heated, the strip or coil deflects because one metal expands more than the other. The deflection causes the overload relay contact to open.

SINGLE-METAL THERMAL OVERLOAD RELAY.— The heat-sensitive element of the single-metal relay is a tube around the heater. The tube lengthens when heated and opens the overload relay contact.

INDUCTION THERMAL OVERLOAD RELAY.— The heater in the induction relay consists of a coil in the motor circuit and a copper tube inside the coil. The tube acts as the short-circuited secondary of a transformer and is heated by the current induced in it. The heat-sensitive element is usually a bimetal strip or coil. Unlike the other three types of thermal overload relays that may be used with either ac or dc, the induction type is manufactured for ac use only.

Magnetic Overload Relays

The magnetic overload relay has a coil connected in series with the motor circuit and a tripping armature or plunger. When the normal motor current exceeds the tripping current, the contacts open the overload relay. Though limited in application, one type of magnetic overload relay is the instantaneous overload relay. This type operates instantly when the motor current exceeds the tripping current. It must be set at a higher tripping current than the motor starting current because the relay would trip each time you start the motor. Instantaneous magnetic overload relays are used in motor controllers for reduced voltage starting where the starting current peaks are less than the stalled rotor current.

The second type of magnetic overload relay is time-delay magnetic overload relay. It delays a short time when the motor current exceeds the tripping current. This type of relay is essential y the same as the instantaneous relay except for the time-delay device. This is usually an oil dashpot with a piston attached to the tripping armature of the relay. Oil passes through a hole in the piston when the tripping armature is moved by an overload current. The size of the hole can be adjusted to change the speed at which the piston moves for a given pull on the tripping armature. For a given size hole, the larger the current, the faster the operation. Therefore, the motor is allowed to carry a small overload current. The relay can be set to trip at a current well below the stalled rotor current because the time delay gives the motor time to accelerate to full speed before the relay operates. By this time the current will have dropped to full-load current, which is well below the relay trip setting.

In either the instantaneous or time-delay magnetic overload relays, you can adjust the tripping currents by changing the distance between the series coil and the tripping armature. More current is needed to move the armature when the distance is increased. Compensation for changes in ambient temperature is not needed for magnetic relays because they are practically unaffected by changes in temperature.

Overload Relay Resets

After an overload relay has operated to stop a motor, it must be reset before the motor can be started again. Magnetic overload relays can be reset immediately after tripping. Thermal overload relays must Cool a minute or longer before they can be reset. The type of overload reset may be manual, automatic, or electric.

The manual, or hand, reset is usually located in the controller enclosure, which contains the overload relay. This type of reset usually has a hand-operated rod, lever, or button that returns the relay tripping mechanism to its original position, resetting interlocks as well, so that the motor can be run again with overload protection. (An interlock is a mechanical or electrical device in which the operation of one part or mechanism automatically brings about or prevents the operation of another.)

The automatic type of reset usually has a spring- or gravity-operated device, resetting the overload relay without the help of an operator. The electric reset is actuated by an electromagnet controlled by a push button. This form of overload reset is used when it is desired to reset an overload relay from a remote operating point.

EMERGENCY RUN FEATURE

Motor controllers having emergency-run features are used with auxiliaries that cannot be stopped safely in the midst of an operating cycle. This type of feature allows the operator of the equipment to keep it running with the motor overloaded until a standby unit can take over, the operating cycle is completed, or the emergency passes

> **CAUTION**
>
> **USE THIS FEATURE IN AN EMERGENCY ONLY. DO NOT USE IT OTHERWISE.**

There are three methods of providing an emergency run in magnetic controllers-an emergency run push button, a reset-emergency run lever, or a start-emergency run pushbutton. In each of these types, the lever or push button must be held closed manually during the entire emergency.

Figure 6-26 is a schematic diagram of a controller showing a separate EMERGENCY RUN push button with normally open contacts in parallel with the normally closed contact of the overload relay. (NOTE: Like all schematics, this one uses standard symbols to show the electrical location and operating sequence of the individual elements or devices, and it does not indicate their relative physical location.) For emergency run operation, the operator must hold down this push button and press the START button to start the motor. While the emergency run push button is depressed, the motor cannot be stopped by opening the overload relay contact.

A RESET-EMERGENCY RUN lever is shown in figure 6-27. As long as the lever or rod is held down, the overload relay contact is closed. The start button must be momentarily closed to start the motor. Figure 6-28 shows a START-EMERGENCY RUN push button. The motor starts when the button is pushed and continues to run without overload protection as long as it is held down. For this reason, push buttons that are marked start-emergency run should not be kept closed for more than a second or two unless the emergency run operation is desired.

Manual controllers may also be provided with an emergency run feature. The usual means is a start-emergency run push button or lever, which keeps the main contactor coil energized despite the tripping action of the overload relay mechanism.

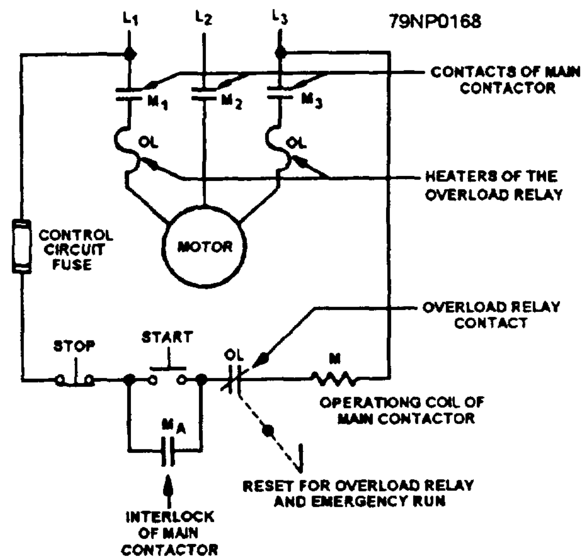


Figure 6-27.—Schematic of controller with reset-emergency lever or rod.

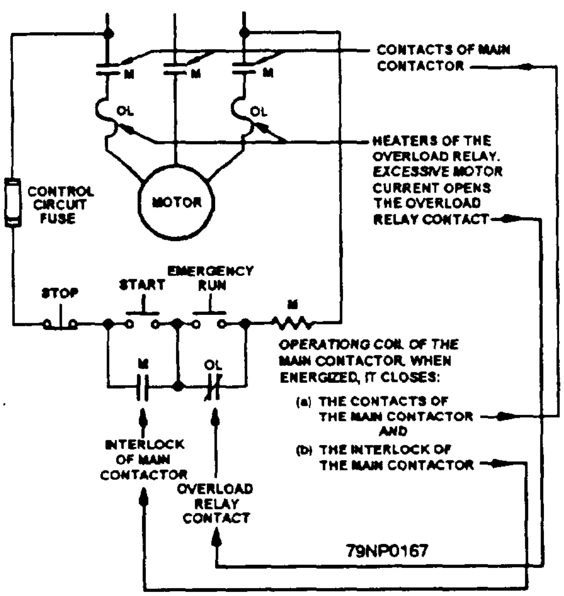


Figure 6-26.—Schematic of controller with emergency run push button.

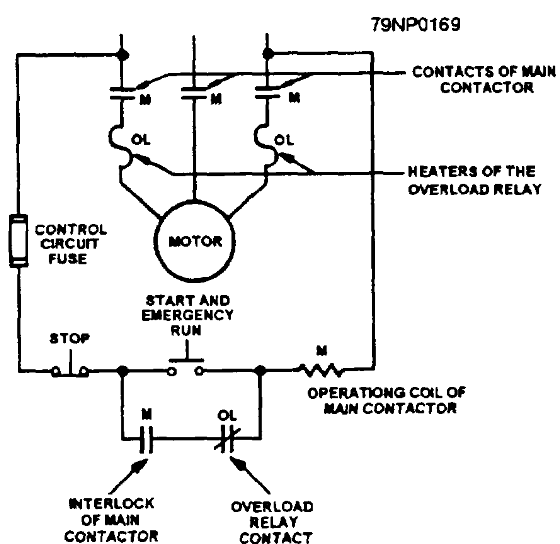


Figure 6-28.—Schematic of controller with start-emergency run push button.

SHORT-CIRCUIT PROTECTION

Overload relays and contractors are usually not designed to protect motors from currents greater than about six times the normal rated current of ac motors or four times normal rated current of dc motors. Since short-circuited currents are much higher, protection against short circuits in motor controllers is obtained through other devices. To protect against short circuits, circuit breakers are installed in the power supply system, thereby protecting the controller, motor, and cables. Short-circuit protection is provided in controllers where it is not provided by the power distribution system. Also, short-circuit protection isn't provided where two or more motors are supplied power, but the circuit breaker rating is too high to protect each motor separate] y. Short-circuit protection for control circuits is provided by fuses in the controller enclosure, which provides protection for remote push buttons and pressure switches.

FULL-FIELD PROTECTION

Full-field protection is required when a shunt field rheostat or a resistor is used to alter a dc motor field and obtain different motor speeds. Full-field protection is provided automatically by a relay that shunts out the shunt field rheostat for the initial acceleration of the motor, and then cuts it into the motor field circuit. In this way, the motor first accelerates to 100 percent or full-field speed, and then further accelerates to the weakened-field speed determined by the rheostat settings.

JAMMING (STEP BACK) PROTECTION

The controller for an anchor windlass motor provides stepback protection by automatically cutting back motor speed when needed to relieve the motor of excessive load.

CONTROLLER MAINTENANCE

Controllers only operate correctly when serviced by a planned program of periodic maintenance and inspection. Since controllers frequently operate several times a day, they should be inspected and serviced regularly so that normal repairs or replacement of parts can be accomplished before a failure occurs.

CLEANING

Dust should not be allowed to accumulate inside the controller. An excessive amount of dust can cause mechanical parts to stick and, if allowed to go unchecked, can lead to a short circuit between contacts.

The controller should be cleaned periodically, per PMS requirements, to remove dust and dirt from the enclosure. Contact surfaces should be kept free of dirt, grease, and grime. Seating surfaces of magnetic cores and armatures should be kept free of grease and scale to ensure quiet operation and a good seal of magnetic parts.

Use of compressed air in cleaning is not recommended since it could blow metallic dust particles with such force as to pierce insulation or cause short circuits.

INSULATION

Insulation of the contractors, wiring, switches, and so forth, should be inspected periodical y to ensure there is no danger of fire or electric shock. A convenient way to schedule the maintenance is to accomplish the checks at the same time as the maintenance checks for the motor it serves. Doing a check in this way prevents the need to de-energize the motor and controller more than once, which allows the system to stay on line with as few interruptions as possible.

LUBRICATION

The only lubrication that might be necessary is the application of light oil to hinge pivots of contractors that don't operate freely and mechanical interlock mechanisms.

CONTROLLER TROUBLESHOOTING

Although the Navy maintains a policy of preventive maintenance, sometimes trouble is unavoidable. In general, when a controller fails to operate or signs of trouble (such as heat, smoke, smell of burning insulation) occur, the cause of the trouble can be found by conducting an examination that consists of nothing more than using the sense of feel, sight, and sound. On other occasions, however, locating the cause of the problem will involve more detailed actions.

Troubles tend to gather around mechanical moving parts and where electrical systems are interrupted by the making and breaking of contacts. Center your attention in these areas. See table 6-10 for a list of common troubles, their causes, and corrective actions.

When a motor-controller system has failed and pressing the start button will not start the system, press

Table 6-10.—Troubleshooting Chart

Contacts

Trouble	Probable cause	Remedy
Contact chatter............	Poor contact in control relay......	Clean relay contact.
	Broken shading coil................	Replace.
	Excessive jogging..................	Caution operator to avoid excessive jogging.
Overheated contact tips....	Dirty contact tips.................	Clean and dress, if necessary, in accordance with chapter 300 or manufacturer's instructions.
	Sustained overloads................	Find and remedy the cause of the overloads.
	Insufficient tip pressure..........	Clean and adjust.
	Loose connections..................	Clean and tighten.
Weak tip pressure..........	Wear allowance gone................	Replace contacts and adjust.
	Poor tip adjustment................	Adjust "gap" and "wipe."
	Low voltage which prevents magnet sealing..........................	Correct voltage condition.
Short tip life.............	Excessive filing or dressing.......	Follow manufacturer's instructions.
	Excessive jogging..................	Instruct operator in correct operation.
Welding or fusing..........	Abnormal starting currents.........	Operate manual controllers slower. Check automatic controllers for correct starting resistors and proper functioning of timing devices or accelerating relays.
	Rapid jogging......................	Instruct operator in correct operation.
	Short-circuit currents on contacts.	Find and remedy causes of short circuit. Check feeder fuses for proper size and replace, if necessary.
Failure of the flexible conductors between fixed and moving parts of contactor................	Improper installation..............	See manufacturer's instructions.
	Worn out mechanically by large number of operations.............	Replace.
	Moisture or corrosive atmosphere...	Replace with flexible conductors suitable for application.
	Burned by arcing or overheating from loose, oxidized, or corroded connections................	Clean and tighten connections.

Coils

Trouble	Probable cause	Remedy
Coil failure: (a) Not overheated.......	Moisture, corrosive atmosphere.....	Use correctly insulated coils.
	Mechanical damage..................	Avoid handling coils by the leads.
	Vibration or shock damage..........	Secure coils properly.
(b) Overheated...........	Overvoltage or high ambient temp...	Check current and application.
	Wrong coil.........................	Use only the manufacturer's recommended coil.
	Too frequent use or rapid jogging..	Use correct operating procedure.
	Undervoltage, failure of magnet to seal in..........................	Check circuit and correct cause of low voltage.
	Used above current rating..........	Install correct coil for the application
	Loose connections to coil or corrossion or oxidation of connection surfaces....................	Clean and tighten connection.
	Improper installation..............	See manufacturer's instructions.

Table 6-10.—Troubleshooting Chart-Continued

Overload relays

Trouble	Probable cause	Remedy
Magnetic, instantaneous type: High or low trip.........	Wrong coil........................	Install correct coil.
	Mechanical binding, dirt, corrosion	Clean with approved solvent, and adjust.
	Shorted turns (High trip)..........	Test coil, and replace if defective.
	Assembled incorrectly..............	Refer to manufacturer's instructions for correct assembly.
	Wrong calibration..................	Replace.
Magnetic, inverse time delay type: Slow trip...............	Fluid dirty, gummy, etc...........	Change fluid and fill to correct level.
	Mechanical binding, corrosion, etc.	Clean with approved solvent, and adjust.
	Worn or broken parts...............	Replace and adjust.
	Fluid too low......................	Drain and refill to correct level.
Thermal type: Failure to trip..........	Wrong size heater..................	Install correct size.
	Mechanical binding, dirt, corrosion	Clean with approved solvent, and adjust.
	Relay damaged by a previous short..	Replace.
Trips at too low temperature................	Wrong size heater..................	Install correct size.
	Assembled incorrectly..............	See technical manual for correct assembly.
	Wrong calibration..................	Replace.
Failure to reset.........	Broken mechanism or worn parts.....	Replace.
	Corrosion, dirt, etc...............	Clean and adjust.
Burning and welding of control contacts.........	Short circuits in control circuits with fuses that are too large....	Correct causes of short circuits and make sure that fuses are right size.
Turning relays, flux decay type: Too short time...........	Dirt in air gap....................	Clean.
	Shim to thick......................	Replace with thinner shim.
	Too much spring or tip pressure....	Adjust in accordance with technical manual.
	Misalignment.......................	Correct alinement, and remedy cause of misalignment.
Too long time............	Shim worn too thin.................	Replace with thicker shim.
	Weak spring and tip pressure.......	Adjust in accordance with technical manual.
	Gummy substance on magnet face or mechanical binding.	Clean with approved solvent and adjust.

Magnets and mechanical parts

Trouble	Probable cause	Remedy
Worn or broken parts.......	Heavy slamming caused by overvoltage or wrong coil............	Replace part and correct cause.
	Chattering caused by broken shading coil or poor contact in control circuit..........................	
	Excessive jogging..................	
	Mechanical abuse...................	
Noisy magnet...............	Broken shading coil................	Replace.
	Magnet faces not true, result of mounting strain..................	Correct mounting.
	Dirt or rust on magnet face........	Clean.
	Low voltage........................	Check system voltage and correct if wrong.
	Improper adjustment, magnet overload............................	Check and adjust according to manufacturer's instructions.
Broken shading coil........	Heavy slamming caused by overvoltage, magnet underloaded, weak tip pressure................	Replace coil and correct the cause.
Failure to drop out........	Gummy substances on magnet faces...	Clean with approved solvent.
	Worn bearings......................	Replace.
	Nonmagnetic gap in magnet circuit..	Replace magnet.
	Voltage not removed................	Check coil voltage.
	Not enough mechanical load on magnet, improper adjustment.........	Adjust according to the manufacturer's instructions.

the overload relay reset push button. Then attempt to start the motor. If the motor operation is restored, no further checks are required. However, if you hear the controller contacts close but the motor fails to start, then check the motor circuit continuity. If the main contacts don't close, then check the control circuit for continuity. An example of troubleshooting a motor-controller electrical system is given in a sequence of steps that may be used in locating a fault:

1. Symptom recognition-recognize the normal operation of the equipment
2. Symptom elaboration-recognize/observe the faulty operation of the equipment
3. Listing of probable faulty functions-develop a list of possible causes for the malfunction
4. Localizing the fault-determine the most likely areas of failure to create the symptoms noted
5. Localizing the trouble to the circuit-using test equipment, isolate the malfunction down to the most likely component(s)
6. Failure analysis-verify the component(s) is/are faulty

Let's start by analyzing the power circuit.

POWER CIRCUIT ANALYSIS

When no visual signs of failure can be located and an electrical failure is indicated in the power circuit, you must first check to see if power is available and the line fuses are good. See if the supply source is available by checking that the feeder breaker is shut and other equipment receiving power from that breaker is operational. Only under extremely rare situation would there be a break in the cabling going to the line fuses. Taking applicable electrical safety precautions according to NSTM, Chapter 300, remove the line fuses and check the continuity of the fuses. While removing the fuses, check for lose fuse clips which could give a faulty connection to the line fuse. If power is available and the line fuses are good, then the problem is in either the control circuit, the motor line leads, or the motor itself.

CONTROL CIRCUIT ANALYSIS

Taking applicable electrical safety precautions according to NSTM, chapter 300, remove the control fuse and check the fuse continuity. If the fuse is bad, replace the fuse with a fuse of proper size and rating and retest the controller. If the control fuse is good, the controller circuit must be checked for possible fault. As you read this section, refer to figures 6-29 and 6-30.

Remove the controller line fuses or verify that the fuses are removed. Danger tag the controller line fuses that have been removed and taking the applicable electrical safety precautions according to NSTM, chapter 300, check the controller de-energized.

Using an ohmmeter, check the continuity of the control circuit between the L1 and the L3 connection points (point A and B of fig. 6-30) in the controller while holding the start button in the START position. If the control circuit is good, the ohmmeter should read a resistance equivalent to the resistance value of the contactor coil. Depending on the size of the coil, this value could be anywhere from a couple hundred ohms to a couple thousand ohms. If the ohmmeter reading is infinite, the problem is in the control circuit.

To isolate the fault in the control circuit, leave one of the ohmmeter leads on the L1 control circuit connection point (point A) and move the other lead of the ohmmeter to the other side of the contactor coil in the controller (point C). If while holding the start button in the ON position the ohmmeter reads infinite, the fault is between point A and C in the control circuit. If the

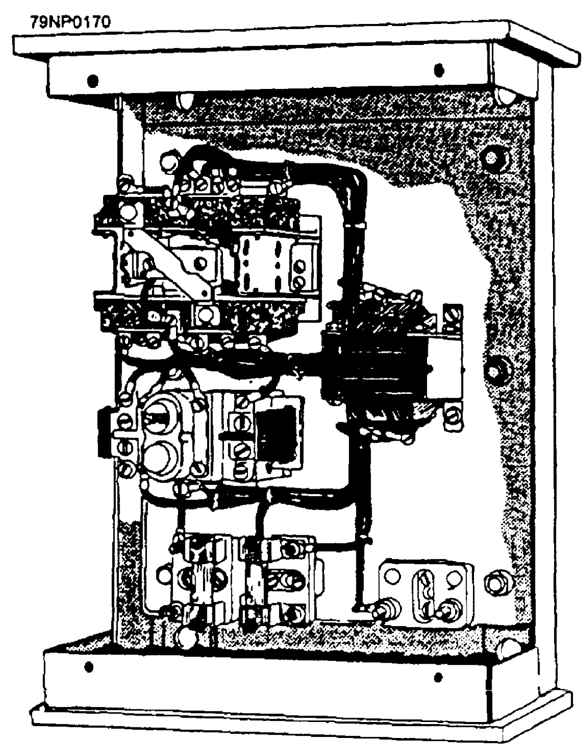


Figure 6-29.—Typical three-phase controller.

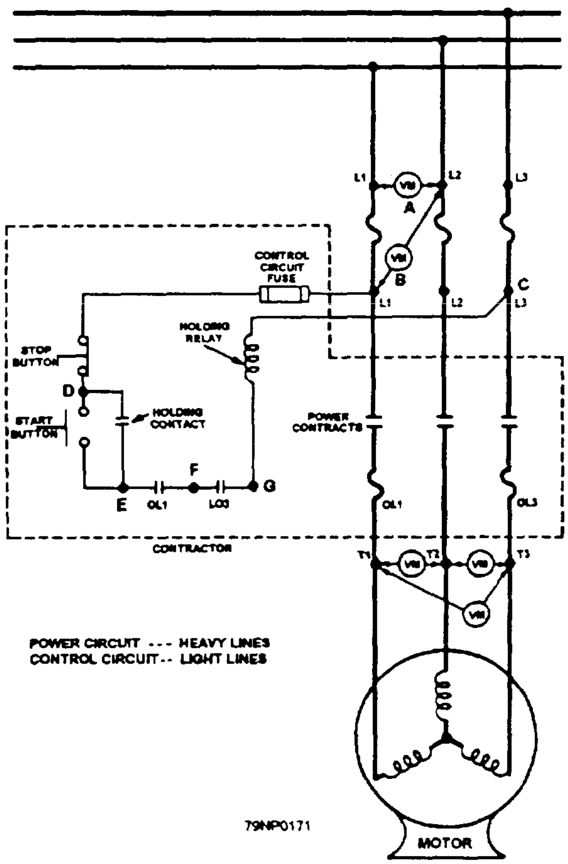


Figure 6-30.—Troubleshooting a thee-phase magnetic line starter.

ohmmeter reads close to zero, the fault is in the contactor coil.

By maintaining the one ohmmeter lead on the L1 control circuit connection point in the controller (point A) and moving the other ohmmeter lead along the control circuit (points D then E then F) towards the first ohmmeter lead, you will localize the fault to a faulty component or lead.

If the control circuit continuity check was of a satisfactory value, the problem is in either the lines to the motor, the motor, or the main contacts of the contactor. Check the main contacts of the contactor by manually operating the contactor and reading the continuity across the main contacts.

If the main contacts of the contactor read good, check the lines leading to the motor and the motor windings themselves. You do this by measuring the motor winding resistance between the T1 and T2 and T3 points in the controller. If there is a high or infinite reading at this point, isolate the fault to the motor or lines leading to the motor by reading the motor winding resistance in the terminal connection box on the motor. A good resistance value indicates the fault in the lines to the motor. A high or inifinite value indicates the fault is in the motor.

When starting a three-phase motor and the motor fails to start and makes a loud hum, you should stop the motor immediately by pushing the stop button. These symptoms usually mean that one of the phases to the motor is not energized. You can assume that the control circuit is good since the main contactor has operated and the maintaining contacts are holding the main operating contactor in. Look for trouble in the power circuit (controller line fuses, main contacts, overload heaters, cable, and motor).

SUMMARY

In this chapter you were introduced to the fundamentals of the various ac and dc motor and circuit control devices to enable you to maintain, troubleshoot, and repair the equipment successfully. Almost all equipment installed will have a manufacturer's technical manual that should be used to adjust and repair the equipment following the recommended specifications. The NSTM, chapter 302, will provide additional information of value to you so that your electrical plant will be maintained in the highest state of readiness.

CHAPTER 7

MAINTENANCE AND REPAIR OF ROTATING ELECTRICAL MACHINERY

The main objective of shipboard preventive maintenance is the preventing the breakdown, deterioration or the malfunction of equipment. If this objective is not met, failed equipment must be repaired or replaced. By performing preventive maintenance according to the prescribed procedures, you can ensure proper operation of the equipment in the ship's electric plant. However, despite your best efforts, on occasion corrective action will be required to restore the electric plant to peak operating conditions. This chapter describes maintenance practices and procedures for preventing casualties to, and for diagnosing, repairing, and testing shipboard electric motors and generators. For additional information, refer to *Naval Ships' TechnicalManual* (NSTM), chapters 300, 302, and 310, and Naval Sea Systems Command Technical Manual, 0900-LP-060-2010, "Electric Motor Repair."

LEARNING OBJECTIVES

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

1. *Identify the procedures to be followed in cleaning motors and generators.*
2. *Identify various types of bearings and their proper care.*
3. *Describe the procedures for maintaining and overhauling commutators and collector rings.*
4. *Describe the steps to be followed in overhauling and rewinding dc machines and armatures.*
5. *Describe the methods of overhauling and rewinding ac machines.*
6. *Describe the operation of motor and generator air coolers.*

CLEANING ROTATING ELECTRICAL MACHINERY

One of your most important jobs is to keep all electrical machinery clean. Dust, dirt, and foreign matter (such as carbon, copper, and mica) tend to block ventilation ducts and increase resistance to the dissipation of heat, causing local or general overheating. If the particles form a conducting paste through the absorption of moisture or oil, the motor or generator windings may eventually be short-circuited or grounded.

Additionally, abrasive particles may puncture insulation; iron dust is particularly harmful since the dust is agitated by magnetic pulsations. The acceptable methods of cleaning motors and generators involve the use of wiping rags or cloths, suction, low-pressure air, and solvents. Wiping with a clean, lint-free, dry rag (such as cheesecloth) is effective for removing loose dust or foreign particles from accessible parts of a machine. When wiping, do not neglect the end windings, mica cone extensions at the commutator of dc machines, slip-ring insulation, connecting leads, and terminals.

The use of suction is preferred to the use of compressed air for removing abrasive dust and particles from inaccessible parts of a machine because it lessens the possibility of damage to insulation. If a vacuum cleaner is not available for this purpose, a flexible tube attached to the suction side of a portable blower will make a suitable vacuum cleaner. Always exhaust the blower to a suitable sump or overboard. Whenever possible, remove grit, iron dust, and copper particles by suction methods.

Clean, dry, compressed air is effective in removing dry, loose dust and foreign particles, particularly from inaccessible locations such as air vents in the armature. Air pressure up to 30 pounds per square inch (psi) may be used to blow out motors or generators. Where air lines carry higher pressure than is suitable for blowing out a machine, use a throttling valve to reduce the pressure. Always blow out any accumulation of water in the airlines before directing the airstream on the part or machine to be cleaned.

> **CAUTION**
>
> Be careful when using compressed air, particularly if abrasive particles are present because they may be driven into the insulation and puncture it or be forced beneath the insulating tape. Compressed air should be used only after the equipment has been opened on both ends to allow the air and dust to escape. The use of compressed air will be of little benefit if the dust is not suitably removed from the equipment. The most suitable method to remove dirt-laden air is to place a suction hose on the opposite end of the equipment where compressed air is being used

Whenever possible, avoid the use of solvents for cleaning electrical equipment. However, their use is necessary for removing grease and pasty substances consisting of oil and carbon or dirt. Alcohol will injure most types of insulating varnishes, and it should not be used for cleaning electrical equipment. Because of their high toxicity, solvents containing gasoline, benzene, and carbon tetrachloride must NEVER be used for cleaning purposes. Refer to chapter 1 of this manual and *NSTM,* chapter 300, for detailed information on the use of solvents for cleaning electrical machinery.

Motors, generators, and other electrical equipment that have been wet with salt water should be flushed out with fresh water and dried. Never let the equipment dry before flushing it with fresh water. For complete information on washing and drying procedures, refer to *NSTM,* chapter 300.

BEARINGS

Bearings are designed to allow a rotating armature or rotor to turn freely within a motor or generator housing. Shaft bearings must be properly maintained to reduce the heat caused by friction.

The two common types of bearings found in motors and generators are antifriction bearings and friction bearings.

ANTIFRICTION BEARINGS

There are two types of antifriction bearings—ball and roller. Basically, both types consist of two hardened steel rings, hardened steel rollers or balls, and separators. The annular, ring-shaped ball bearing is the type of roller bearing used most extensively in the construction of electric motors and generators used in the Navy. These bearings are further divided into the following three types (fig. 7-1), depending on the load they are designed to bear:

1. Radial. Radial bearings are capable of supporting combined high radial and thrust loads, but they aren't self-aligning. Therefore, accurate alignment between the shaft and housing is required.
2. Angular contact. Angular contact bearings are designed to take radial and thrust loads where the thrust component may be large.
3. Thrust. Thrust bearings are used when the load is completely axial rather than radial.

The ball bearings on a rotating shaft of an electric motor or generator may be subjected to radial thrust and/or angular forces. While every ball bearing is not subjected to all three forces, any combination of one or more may be found depending on the equipment design. Radial loads are the result of forces applied to the bearing perpendicular to the shaft; thrust loads are the result of forces applied to the bearing parallel to the shaft; and angular loads are the result of a combination of radial and thrust loads. The load carried by the bearings in electric motors and generators is almost entirely due to the weight of the rotating element. For this reason, the method of mounting the unit is a major factor in the selection of the type of bearing installed when they are constructed. In a vertically mounted unit, the thrust bearing is used, while the radial bearing is normally used in most horizontal units.

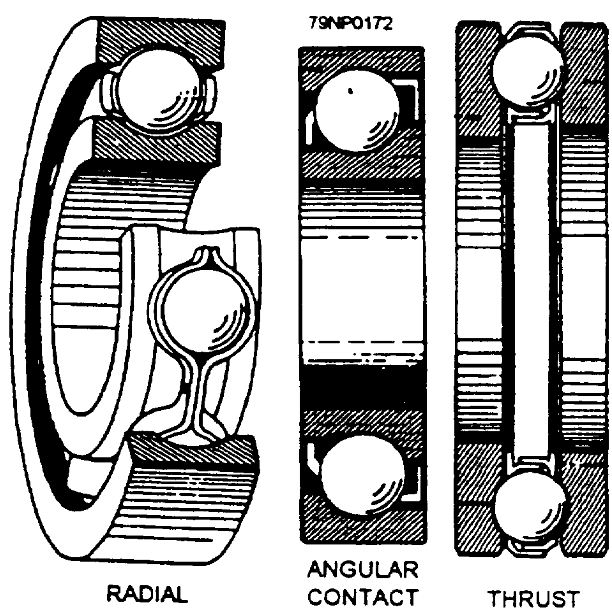


Figure 7-1.—Representative types of ball bearings.

Wear of Bearings

Normally, it is not necessary to measure the air gap on machines with ball bearings because the construction of the machines ensures proper bearing alignment. Additionally, ball bearing wear of sufficient magnitude as to be readily detected by air-gap measurements would be more than enough to cause unsatisfactory operation of the machine.

The easiest way of determining the extent of wear in these bearings is to periodically feel the bearing housing while the machine is running to detect any signs of overheating or excessive vibration, and to listen to the bearing for the presence of unusual noises.

Rapid heating of a bearing maybe an indication of danger. Bearing temperatures that feel uncomfortable to the touch could be a sign of dangerous overheating, but not necessarily. The bearing may be operating properly if it has taken an hour or more to reach that temperature; whereas, serious trouble can be expected if high temperatures are reached within the first 10 or 15 minutes of operation.

The test for excessive vibration relies to a great extent on the experience of the person conducting the test. The person should be thoroughly familiar with the normal vibration of the machines to be able to correctly detect, identify, and interpret any unusual vibrations. Vibration, like heat and sound, is easily telegraphed. A thorough search is generally required to locate the source and determine its cause.

Ball bearings are inherently more noisy in normal operation than sleeve bearings (discussed later). This fact must be kept in mind by personnel testing for the presence of abnormal bearing noise. A common method for sound testing is to place the blade of a screwdriver against the bearing housing and the handle against the ear. If a loud, irregular grinding, clicking, or scraping noise is heard, trouble is indicated. As before, the degree of reliance in the results of this test depends on the experience of the person conducting the test.

Checking the movement of a motor or generator shaft can also give an indication of the amount of bearing wear. If the motor shaft has excessive vertical movement (fig. 7-2, view A), it indicates worn bearings. Figure 7-2, view B, shows how to get a rough approximation of motor or generator end-play movement. You can correct excessive end-play, as described in the applicable technical manual, by adding bearing shims.

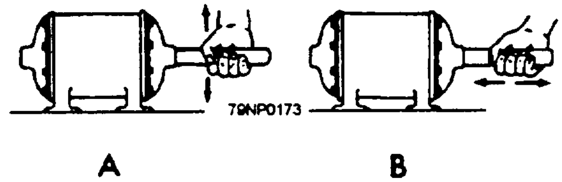


Figure 7-2.—Checking motor or generator shaft. (A) Vertical movements: (B) End-play movement.

Lubrication

A common cause of motor and generator failure is overlubrication. Forcing too much grease into the bearing housing seals and onto the stationary windings and rotating parts of the machine will cause overheating and deterioration of insulation, eventually resulting in electrical grounds and shorts. Overheating will also cause rapid deterioration of the grease and the eventual destruction of a bearing. To avoid overlubrication, add new lubricant only when necessary.

The frequency that new grease must be added depends on the service of the machine and the tightness of the housing seals, and the requirements should be determined for each machine by the engineering officer or PMS requirements. A large quantity of grease coming through the shaft extension end of the housing usually indicates excessive leakage inside the machine.

To prevent greasing by unauthorized personnel, grease cups are removed from motors and generators. Pipe plugs are inserted in place of the grease cups. The pipe plugs are replaced temporarily with grease cups during lubrication (fig. 7-3). (Removable grease cups

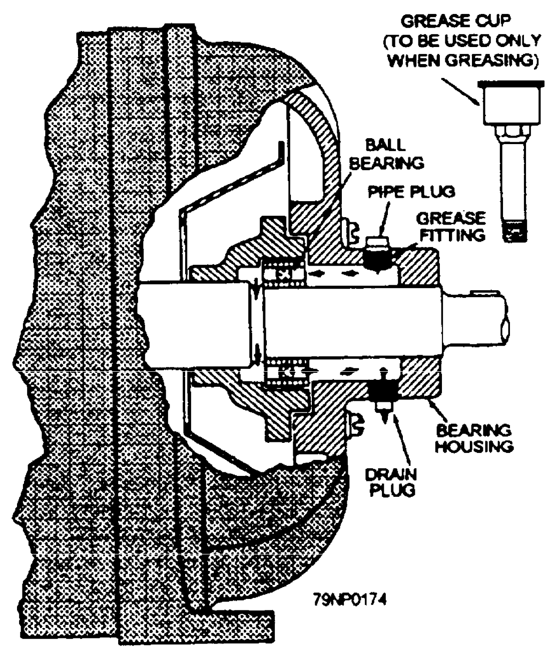


Figure 7-3.—Grease-lubricated ball bearings.

should remain in the custody of the responsible maintenance personnel.) Make sure the grease cups are clean. After the grease is added, clean the pipe plugs before replacing them.

The preferred method of adding grease calls for disassembly of the bearing housing. Although not recommended, renewing the bearing grease without at least partially disassembling the housing may be tried under certain conditions (given later).

RENEWAL OF GREASE BY DISASSEMBLING THE BEARING HOUSING.— The extent of disassembly necessary will depend on the construction of the bearing, Bearings with outer bearing caps should be disassembled as described in table 7-1:

Table 7-1.—Renewal of Grease by Disassembly of the Bearing Housing

STEP	ACTION
1.	Remove the outer bearing cap after thoroughly wiping all exterior surfaces.
2.	Remove the old grease from the housing, and clean it thoroughly. Be careful not to introduce dirt or lint into the bearing housing.
3.	Flush the bearing cap with clean, warm 2190 TEP oil.
4.	Where practical, plug all holes leading into the interior of the machine. Using 2190 TEP oil, flush the bearing housing with the outer bearing cap removed. If the possibility exists that the fluids may leak into the windings, omit this step.
5.	Drain the 2190 TEP oil thoroughly and pack the housing half-full with fresh, clean grease.
6.	Start the machine.
7.	Fill the grease cup with fresh, clean grease and screw it down as far as it will go. KEEP THE MACHINE RUNNING CONTINUOUSLY.
8.	Repeat step 7 until the clean grease begins to emerge from the drain hole.
9.	At this point, stop adding grease and allow the machine to run until no more grease comes out of the drain hole. THIS IS THE MOST IMPORTANT STEP IN LUBRICATION.
10.	Clean and replace the drain pipes that have been removed.
11.	Replace the drain plug.

RENEWAL OF GREASE WITHOUT DISASSEMBLING THE BEARING HOUSING.— Do not try to add new grease without at least partially disassembling the bearing housing unless the following conditions exist:

- The machine is horizontal. There is no adequate means of protecting the windings against displaced lubricant in vertical machines.
- A suitable fitting is provided for admitting grease. If a grease-gun fitting is provided, it should be replaced by a grease cup when you add grease.
- The drain hole on the bearing housing is accessible. Drainpipes do not permit satisfactory escape of displaced grease, and should be removed when renewing grease.
- The machine is running continuously while removing grease. If the machine cannot be run continuously during the greasing period without injuring the driven auxiliary or endangering personnel, the bearing housing must be disassembled to renew the grease.

If one or more of the above conditions exist, renew the grease in assembled bearing housings by the method in table 7-2:

Table 7-2.—Renewal of Grease in Assembled Bearing Housings

STEP	ACTION
1.	Run the machine to warm up the bearings.
2.	Wipe any dirt away from the area around the grease fittings.
3.	Remove the drain plug and drain-pipes from the drain hole in the bearing housing.
4.	With a clean wire, screwdriver, or similar tool, clear the drain hole of all hardened grease.
5.	Remove the grease cup and clear the grease inlet hole of hardened grease.
6.	While the motor is running, pack the grease cup with grease and screw it down all the way.
7.	Repeat step 6 until grease runs out of the drain hole.
8.	Run the motor until the grease stops running from the drain hole.
9.	Replace the pipe plugs.

Oil-Lubricated Ball Bearings

Lubrication charts or special instructions are generally furnished for electric motors and generators equipped with oil-lubricated ball bearings. The oil level inside the bearing housing should be maintained about even with the lowest point of the bearing inner ring. At this level, there will be enough oil to lubricate the bearing for its operating period, but not enough to cause churning or overheating.

One common method by which the oil level is maintained in ball bearings is the wick-fed method In this method, the oil is fed from an oil cup to the inside of the bearing housing through an absorbent wick. This wick also filters the oil and prevents leakage through the cup if momentary pressure is built up within the housing. A typical wick-fed, oil-lubricated ball bearing is shown in figure 7-4.

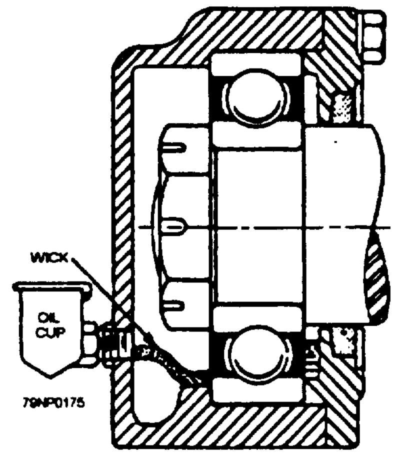


Figure 7-4.—Wkk-fed bell bearings.

Grease-Lubricated Ball Bearings

Preferred Navy bearing greases for shipboard auxiliary machinery are as follows:

1. Bearings operating below 110°C (230°F) in non-noise or noise-critical application should use DOD-G-24508 grease. It is available in a 1-pound can under National Stock Number (NSN) 9150-00-149-1593.

2. Bearings operating near water (for example, rudder stock bearings) should use grease MIL-G-24139. It is available in a 5-pound can under NSN 9150-00-180-6382.

NOTE: Other size containers may be available under other NSNs.

DOUBLE-SHIELDED OR DOUBLE-SEALED BALL BEARINGS SHOULD NEVER BE DISASSEMBLED OR CLEANED. These bearings are prelubricated. Cleaning will remove the lubricant from the bearings or can dilute the lubricant until it no longer possesses its original lubricating qualities.

Permanently lubricated ball bearings require no greasing. You can recognize equipment furnished with these bearings by the absence of grease fittings or the provision for attaching grease fittings. When permanently lubricated bearings become imperative, replace them with bearings of the same kind. If not already provided, attach DO NOT LUBRICATE nameplates to the bearing housing of machines with sealed bearings.

Cleaning Bali Bearings

You can clean an open or a single-sealed ball bearing only in an emergency when a suitable replacement is not available. It is difficult to remove dirt from ball bearings. Unless the cleaning is carefully done, more dirt may get into the bearings than is removed

In cleaning an open, single-shielded or single-sealed bearing, take the bearing off with a bearing puller applied to the inner race of the bearing. Figure 7-5,

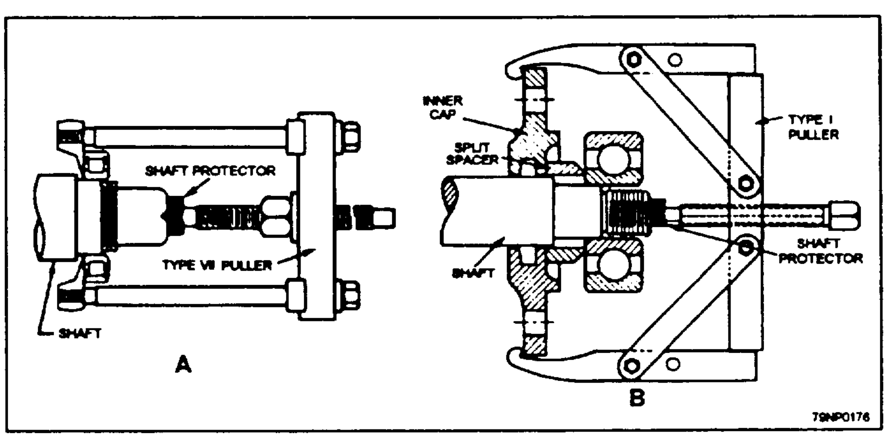


Figure 7-5.—Bearing pullers.

views A and B, shows two types of bearing pullers, both of which apply the pulling pressure to the inner race of the bearing. Removal of bearings by pulling on the outer race tends to make the balls dent the raceway even when the puller is used. If bearings are subjected to high temperatures, the race can be distorted. This can cause the race to shrink to the shaft more tightly. You should be careful not to damage the shaft when removing bearings. Use soft centers (shaft protectors), which are sometimes provided with a bearing removal kit. If not, the soft centers may be made of soft metal, such as zinc or brass.

After removal, thoroughly clean the bearing. The recommended cleaner is standard solvent or clean oil. Soak the bearing in cleaner for as long as necessary to dislodge dirt or caked grease from around the balls and separators. After the bearing is cleaned, wipe it carefully with a dry, lint-free cloth. If compressed air is used for drying, direct the airstream across the bearing so that the bearing does not spin. Because a dry bearing rusts quickly, protect the bearing at once by coating it with clean, low-viscosity lubricating oil.

Rotate the inner ring slowly by hand, and if the bearing feels rough, repeat the cleaning. After the second cleaning, if the bearing still feels rough when turned slowly by hand, renew it.

Removing a Seized Bearing

When a bearing fads on equipment that is running, it is not always possible to secure the equipment immediately. This may cause one or both of the bearings to heat excessively and seize to the shaft. Removal of a seized bearing may be accomplished as follows:

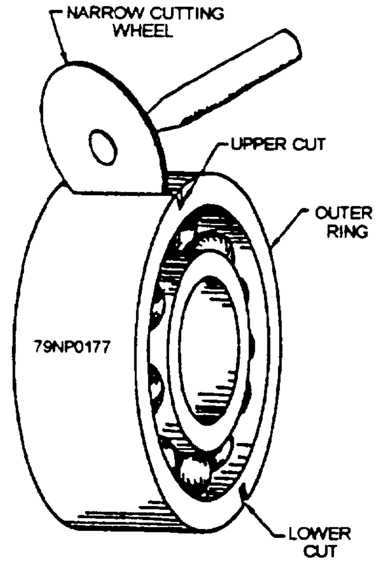


Figure 7-6.—Removing seized outer ring of bearing.

1. Don proper safety equipment (goggles, earmuffs, gloves, etc.)
2. Use clean rags or plastic drapes to protect any equipment nearby from flying bits of debris and metal particles.
3. Using a high-speed grinder with a cutting wheel, cut the outer ring of the seized bearing in two places (fig. 7-6).
4. Remove the outer rings and discard.
5. Cut the cage in two places and remove the cage and balls.
6. Make two cuts to the inner ring at two different points as illustrated in figure 7-7. Be careful to

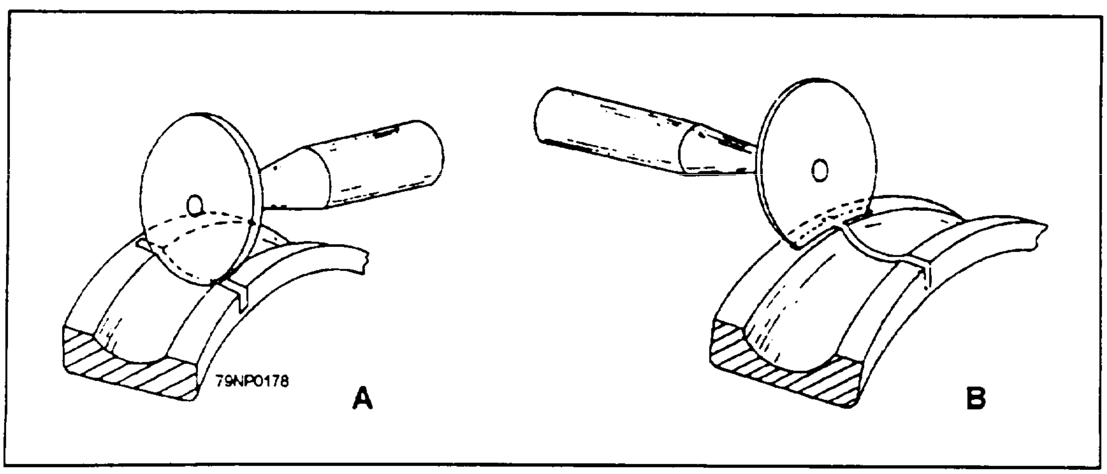


Figure 7-7.—Removing seized inner ring of bearing.

cut only 3/4 of the way through the seized inner ring in order to prevent damage to the shaft.

7. Using the correct size chisel, as shown in figure 7-8, crack the bearing inner ring and remove it.

Bearing Installation

There are two acceptable methods for installing bearings-the arbor press method and the heat method.

ARBOR-PRESS METHOD.— When available and adaptable, you can use an arbor press if you take the proper precautions. Place a pair of flat steel blocks under the inner ring or both rings of the bearing. Never place blocks under the outer ring only. Then, lineup the shaft vertically above the bearing, and place a soft pad between the shaft and press ram. After making sure the shaft is started straight in the bearing, press the shaft into the bearing until the bearing is flush against the shaft or housing shoulder. When pressing a bearing onto a shaft, always apply pressure to the inner ring; when pressing a bearing into a housing, always apply pressure to the outer ring.

HEAT METHOD.— A bearing can be heated in an oven or furnace to expand the inner ring for assembly. This method ensures uniform heating all around the bearing.

Heat the bearing in an infrared oven or a temperature-controlled furnace at a temperature not to exceed 203° ± 10°F (89.4° to 100.6°C). The bearing should be left in the oven or furnace only for enough time to expand the inner race to the desired amount. Prolonged heating could possibly deteriorate the prelubrication grease of the bearing. The bearing may also be heated in oil at 203° ± 10°F (89.4° to 100.6°C) until expanded, and then slipped on the shaft. This method should not be used unless absolutely necessary. The disadvantages of the hot-oil method are the lack of temperature control, the possibility of bearing enlargement and grease deterioration or contamination by dirty oil.

For additional methods of bearing installation, refer to *NSTM,* chapter 244.

FRICTION BEARINGS

Friction bearings are of three types:

1. Right line. In right line friction bearings, motion is parallel to the elements of a sliding surface.
2. Journal. In journal friction bearings, two machine parts rotate relative to each other.
3. Thrust. In thrust bearings, any force acting in the direction of the shaft axis is taken up.

Turbine-driven, ship's service generators and propulsion generators and motors are equipped with journal bearings, commonly called *sleeve* bearings. The bearings may be made of bronze, babbitt, or steel-backed babbitt. Preventive maintenance of sleeve bearings requires periodic inspections of bearing wear and lubrication.

Wear of Bearings

Propulsion generators, motors, and large ship's service generators are sometimes provided with a gage for measuring bearing wear. You can obtain bearing wear on a sleeve-bearing machine not provided with a bearing by measuring the air gap at each end of the machine with a machinist's tapered feeler gage. Use a blade long enough to reach into the air gap without removing the end brackets of the machine. Before

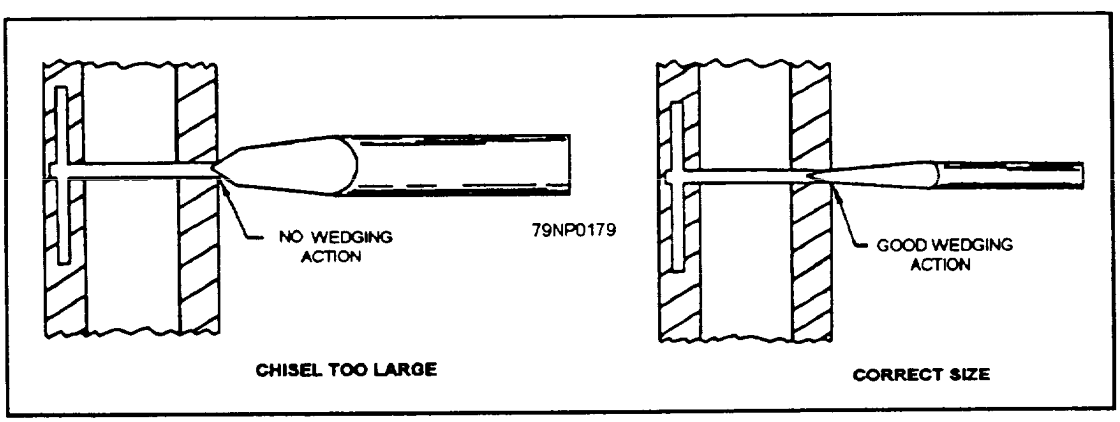


Figure 7-8.—Cracking seized inner ring of bearing.

making the measurements, clean the varnish from a spot on a pole or tooth of the rotor. A spot should also be cleaned at the same relative position on each field pole of a dc machine. For ac machines, clean at least three and preferably four or more spots spaced at equal intervals around the circumferences on the stator. Take the air gap measurement between a cleaned spot on the rotor and a cleaned spot on the stator, turning the rotor to bring the cleaned spot of the rotor in alignment with the cleaned spots on the stator. Compare these readings with the tolerance stated by the manufacturer's instruction book.

Oil Rings and Bearing Surfaces

An opening is provided in the top of the bearing for you to check the condition of the oil rings and bearing surfaces (fig. 7-9). Periodic inspections are necessary to make certain that the oil ring is rotating freely when the machine is running and is not sticking. With the machine stopped, inspect the bearing surfaces for any signs of pitting or scoring.

Trouble Analysis

The earliest indication of sleeve bearing malfunction normally is an increase in the operating temperature of the bearing. Thermometers are usually inserted in the lubricating oil discharge line from the bearing as a means of visually indicating the temperature of the oil as it leaves the bearing. Thermometer readings are taken hourly on running machinery by operating personnel. However, a large number of bearing casualties have occurred in which no temperature rise was detected in thermometer readings; in some cases, discharge oil temperature has actually decreased. Therefore, after checking the temperature at the thermometer, personnel should make a follow-up check by feeling the bearing housing whenever possible. Operating personnel must thoroughly familiarize themselves with the normal operating temperature of each bearing so they will be able to recognize any sudden or sharp changes in bearing oil temperature. Many large generators are provided with bearing temperature alarm contractors, which are incorporated in the ship's alarm system. The contactor is preset to provide an alarm when the bearing temperature exceeds a value detrimental to bearing life. You should secure the affected machinery as soon as possible if a bearing malfunction is indicated. A motor with overheated sleeve bearings should be unloaded, impossible, without stopping the motor. If you stop it immediately, the bearing may seize. The best way to limit bearing damage is to keep the motor running at a light load and supply plenty of cool, clean oil until the bearing cools down

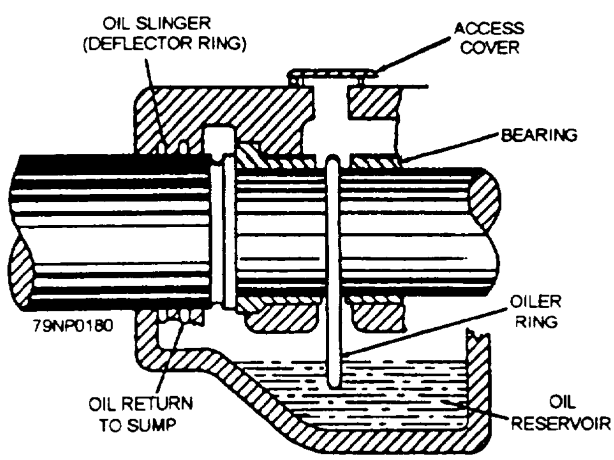


Figure 7-9.—Diagram of an oil-lubricated bearing.

Because the permissible operating temperature is often too high to be estimated by the sense of touch, temperature measurements should be taken to determine whether a bearing is overheated. A thermometer securely fastened to the bearing cover or housing will usually give satisfactory bearing temperature measurements on machines not equipped with bearing temperature measuring devices. **Do not insert a thermometer into a bearing housing,** as it may break and necessitate disassembly of the machinery to remove broken glass and mercury.

Any unusual noise in operating machinery may also indicate bearing malfunction. When a strange noise is heard in the vicinity of operating machinery, make a thorough inspection to determine its cause. Excessive vibration will occur in operating machinery with faulty bearings, and inspections should be made at frequent intervals to detect the problem as soon as possible.

BRUSHES

Carbon brushes used in electric motors and generators are generally constructed of one or more plates of carbon, riding on a commutator, or collector ring (slip ring), to provide a passage for electrical current to an internal or external circuit. The generic term, *carbon brush,* is used b y convention to denote all brush compositions in which carbon is employed in some proportion in one of its many structural forms,

The brushes are held in position by brush holders mounted on studs or brackets attached to the brush-mounting ring, or yoke. The brush holder studs, or brackets, and brush-mounting ring comprise the brush rigging. The brush rigging is insulated from, but attached to, the frame or one end bell of the machine. Flexible leads (pigtails) are used to connect the brushes to the terminals of the external circuit. An adjustable spring is generally provided to maintain proper pressure of the brush on the commutator to effect good commutation. Atypical dc generator brush holder and brush-rigging assembly is shown in figure 7-10.

Brushes are manufactured in different grades to meet the requirements of the varied types of service. The properties of resistance, ampere carrying capacity, coefficient of friction, and hardness of the brush are determined by the maximum allowable speed and load of the machine.

CORRECT BRUSH TYPE

The correct grade of brush and correct brush adjustment are necessary to avoid commutation trouble.

Use the grade of brush shown on the drawing or in the technical manual applicable to the machine, except where Naval Sea Systems Command instructions issued after the date of the drawing or technical manual (such as the instructions for brushes to be used in electric propulsion and magnetic minesweeping equipment dictate otherwise. In such cases, follow the Naval Sea Systems Command instructions. Most of the brushes in shipboard service appear on the Qualified Products List as complying with one of six military grades (S, A, H, D, G, and E). For propulsion and magnetic minesweeping equipment, only one grade of brush specified by the manufacturer is permitted. The restriction on brush interchangeability is due to the vital nature of the machines involved.

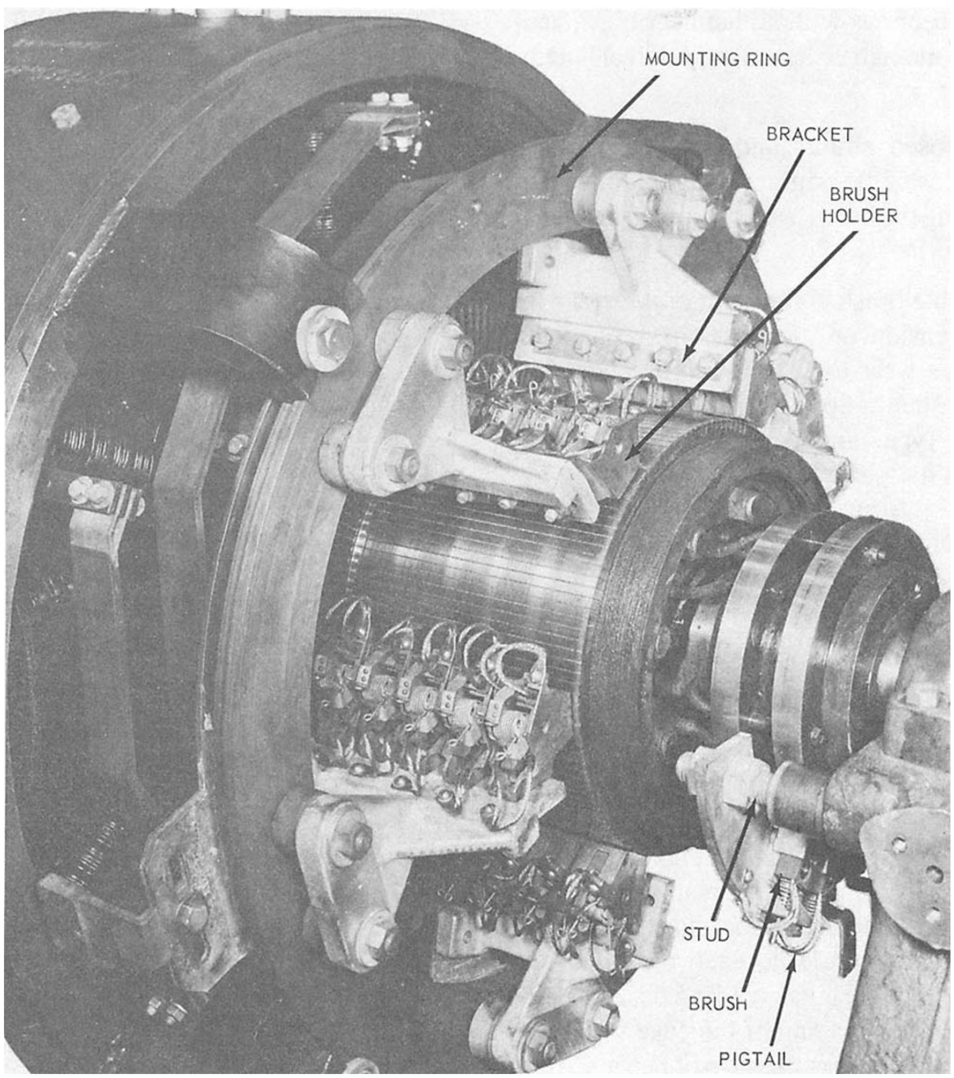


Figure 7-10.—Brush holder and brush rigging assembly.

CARE OF BRUSHES

All brush shunts should be securely connected to the brushes and the brush holders. Brushes should move freely in their holders, but they should not be loose enough to vibrate in the holder. Before replacing a worn brush with a new one, clean all dirt and other foreign material from the brush holder.

Replace old brushes with new brushes when the old brushes meet the following criteria:

worn or chipped so they will not move properly in their holders

damaged shunts, shunt connections, or hammer clips

riveted connections or hammer clips and are worn to within one-eighth inch of the metallic part

tamped connections without hammer clips, and are worn to one-half or less of the original length of the brush; or

spring-enclosed shunts and are worn to 40 percent or less of the original length of the brush (not including the brush head, which fits into one end of the spring).

Where adjustable brush springs are of the positive gradient (torsion, tension, or compression) type, adjust them as the brushes wear to keep the brush pressure approximately constant. Springs of the coiled-band, constant-pressure type, and certain springs of the positive gradient type are not adjustable except by changing springs. Adjust pressure following the manufacturer's technical manual. Pressures as low as 1 1/2 psi of contact area may be specified for large machines and as high as 8 psi of contact area may be specified for small machines. Where technical manuals are not available, a pressure of 2 to 2 1/2 psi of contact area is recommended for integral horsepower and integral kilowatt machines. About twice that pressure is recommended for fractional horsepower and fractional kilowatt machines. To measure the pressure of brushes operating in box-type brush holders, insert one end of a strip of paper between the brush and commutator; use a small brush tension gage (such as the 0- to 5-pound indicating scale) to exert a pull on the brush in the direction of the brush holder axis, as shown in figure 7-11. Note the reading of the gage when the pull is just sufficient to release the strip of paper so that it can be pulled out from between the brush and commutator without offering resistance. This reading

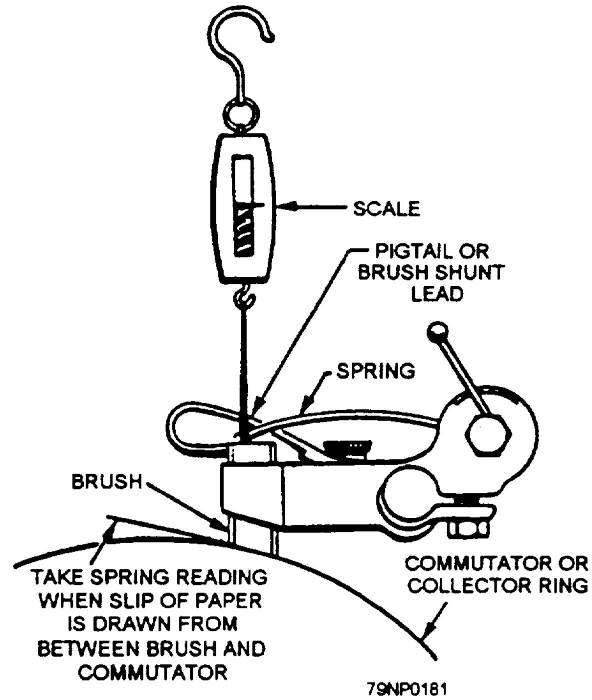


Figure 7-11.—Measuring brush tension.

divided by the contact area maybe considered to be the spring operating pressure.

The toes of all brushes of each brush stud should line up with each other and with the edge of one commutator segment.

The brushes should be evenly spaced around the commutator. To check brush spacing, wrap a strip of paper around the commutator and mark the paper where the paper laps. Remove the paper from the commutator, cut at the lap, and fold or mark the paper into as many equal parts as there are brush studs. Replace the paper on the commutator, and adjust the brush holders so that the toes of the brushes are at the creases or marks.

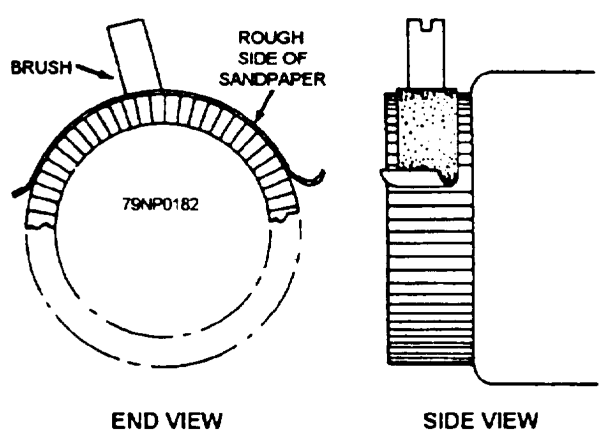


Figure 7-12.—Method of sanding brushes.

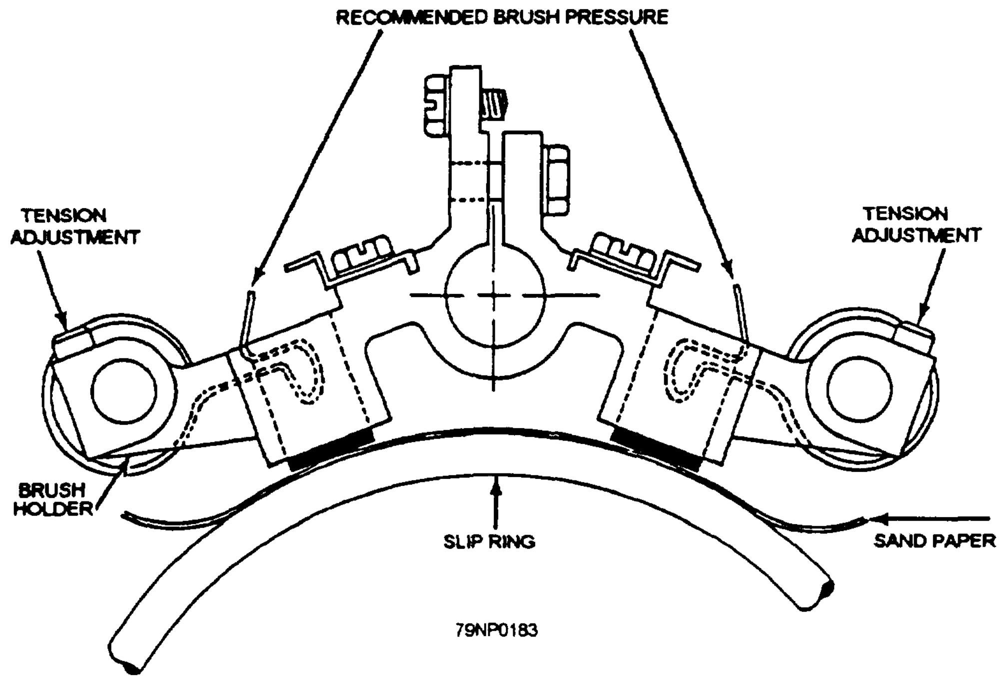


Figure 7-13.—Detail of brush rigging with sandpaper in position.

AU brush holders should be the same distance from the commutator, not more than one-eighth inch, nor less than one-sixteenth inch. A brush holder must be free of all burrs that might interfere with the free movement of the brush in the holder. Burrs are easily removed with a fine tile.

SEATING

Accurate seating of the brushes must be ensured where their surfaces contact the commutator. Sandpaper and a brush seater are the best tools to accomplish a true seat (fig. 7-12).

Disconnect all power from the machine. You must take every precaution to ensure that the machine will not be inadvertently started before using sandpaper to seat the brushes.

Lift the brushes to be fitted and insert (sand side up) a strip of fine sandpaper (No. 1), about the width of the commutator, between the brushes and the commutator. With the sandpaper held tightly against the commutator surface to conform with the curvature and the brushes held down by normal spring pressure, pull the sandpaper in the direction of normal rotation of the machine (fig. 7-13). When returning the sandpaper for another pull, lift the brushes. Repeat this operation until the seat of the brush is accurate. Always finish with a finer grade of sandpaper (No. 0). You need a vacuum cleaner for removing dust while sanding. After sanding, thoroughly clean the commutator and windings to remove all carbon dust.

The use of a brush seater will further improve the fit obtained by sanding. A brush seater consists of a mildly abrasive material loosely bonded into a stick about 5 inches long. To use a brush seater to seat the brushes, install the brushes in the brush holders and start the machine. Press a brush securely against the commutator by using a stick of insulating material or by increasing the brush spring tension to its maximum value. Touch the brush seater lightly to the commutator, exactly at the heel of the brush (fig. 7-14), so that abrasive material worn from the brush seater will be carried under the brush. You must hold the brush seater behind each brush, applying the seater for a second or two, depending on brush size. Do not hold the seater steadily against the commutator because it will wear away too rapidly and produce too much dust. After

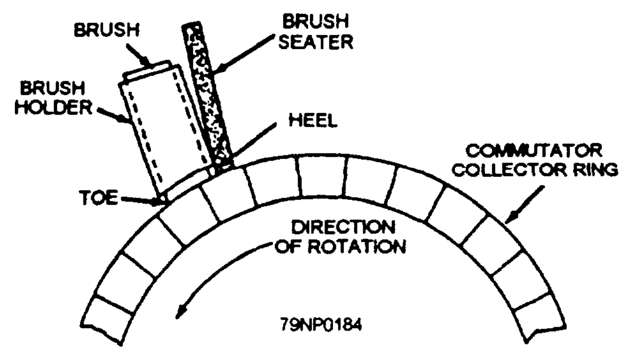


Figure 7-14.—Using the brush seater.

seating one or two brushes, examine them to see if the seater is being applied long enough to give a full seat. After seating the brush, if white dust is plainly visible on the seat, you have applied insufficient pressure to the brush, or applied the brush seater too heavily or too far from the brush. Be careful not to remove the copper oxide film from the commutator surface. If you remove this film, you must restore it, as described later in this chapter.

Use a vacuum cleaner during the seating operation to prevent dust from reaching the machine windings and bearings. After seating all the brushes, blow out the machine with a power blower or completely dry compressed air, or clean thoroughly with a vacuum cleaner.

SETTING ON NEUTRAL

When a machine is running without a load and with only the main pole field windings excited,the point on the commutator at which minimum voltage is induced between adjacent commutator bars is the no-load neutral point. This is the best operating position of the brushes on most commutating-pole machines. Usually, the brush studs are doweled in the proper position. The correct setting is indicated on a stationary part of the machine by a chisel mark or an arrow. In some cases commutation may be improved by shifting the brushes slightly from the marked position.

The three methods to determine the correct neutral position are (1) mechanical, (2) reversed rotation, and (3) the inductive kick.

Mechanical Method

The mechanical method is an approximate method. Turn the armature until the two coil sides of the SAME armature coil are equidistant from the center line of one MAIN field pole. The commutator bars to which the coil is connected give the position of the mechanical neutral.

Reversed Rotation Method

Use of the reversed rotation method is possible only where it is practicable to run a machine in either direction of rotation, with rated load applied. This method differs for motors and generators. For motors, the speed of the motor is accurately measured when the field current becomes constant under full load at line voltage with the motor running in the normal direction. Then, the rotation of the motor is reversed, the full load is applied, and the speed is again measured. When you shift the brushes and the speed of the motor is the same in both directions, the brushes will be in the neutral plain Generators are run at the same field strength and the same speed in both directions, and the brushes are shifted until the full-load terminal voltage is the same for both directions of rotation. To ensure accuracy, you must use a reliable tachometer to measure the speed of the machines.

Inductive Kick Method

The kick method is used only when other methods are inadequate and the conditions are such as to warrant the risks involved. You must now connect sufficient resistance in series with the field coils to reduce the field current to about 10 percent of normal value.

With a lead pencil or other means that will not damage the surface, mark A on a commutator bar under one set of brushes. Mark B on another bar one pole pitch away from the center of the bar marked A. A pole pitch is the angular distance from the center of one main pole to the center of the next main pole. Raise all brushes. Connect bars A and B to a low-range voltmeter having two or three scales (for example, 0 – 0.5, 0 – 1.5, or 0 – 15 volts). Use leads with pointed prongs to connect the bars. Separately excite the shunt field winding from a dc source connected to the winding in series with a high resistance and a quick-break switch. Start with the minimum obtainable value of field current and the high-range scale of the voltmeter.

Close the knife switch and wait for the momentary deflection to disappear; open the knife switch and note the momentary deflection or kick of the voltmeter. If insufficient deflection is observed on the lowest range scale of the voltmeter, decrease the resistance connected in series with the shunt field winding and repeat the procedure until an adequate deflection is obtained on the voltmeter when the switch is opened. Retain this setting of the resistor for the remainder of the test. Turn the armature slightly until the position is found at which the minimum kick is produced when the field current is broken. Bars A and B will then be on neutral. If one pole pitch from the center of bar A does not fall on a bar but on the mica between two bars, mark the bars next to the mica, C and D. Then measure the kick when bar A and bar C are connected to the voltmeter, and again when A and D are connected to the voltmeter. Adjust the position of the armature until these two deflections are equal and opposite. The center line of bar A and the mica between bars C and D will then be on neutral.

COMMUTATORS AND COLLECTOR RINGS (SLIP RINGS)

After being used about 2 weeks, the commutator of a machine should develop a uniform, glazed, dark-brown color on the places where the brushes ride. If a nonuniform or bluish-colored surface appears, improper commutation conditions are indicated. Periodic inspections and proper cleaning practices will keep commutator and collector-ring troubles at a minimum.

CLEANING COMMUTATORS AND COLLECTOR RINGS

One of the most effective ways of cleaning the commutator or collector rings is to apply a canvas wiper while the machine is running. You can make the wiper by wrapping several layers of closely woven canvas over the end of a strong stick between one-fourth and three-eighths inch thick (fig. 7-15, view A). Secure the canvas with rivets, and wrap linen tape over the rivets to prevent the possibility of them coming in contact with the commutator. When the outer layer of canvas becomes worn or dirty, remove it to expose a clean layer. The wiper is most effective when it is used frequently. On ship's service generators, it may be desirable to use the wiper once each watch. When using the wiper, exercise care to keep from fouling moving parts of the machine. The manner of applying the wiper to a commutator is illustrated in figure 7-15, view B.

When the machines are secured, you can use a toothbrush to clean out commutator slots. You can use a clean canvas or lint-free cloth for wiping the commutator and adjacent parts. Besides cleaning by wiping, periodically clean the commutator with a vacuum cleaner or blow it out with clean, dry air.

Do not sandpaper a commutator if it is operating well, even if long service has developed threading, grooving, pits, burn areas between bars, longitudinal irregularities, etc., unless sparking is occurring or the brushes are wearing excessively. In sanding a commutator, use a fine grade of sandpaper (No. 0000 is preferred, but in no case coarser than No. 00). You can use sandpapering to make emergency reduction of high mica or to polish finish a commutator that has been stoned or turned. The sandpaper, attached to a wooden block shaped to fit the curvature of the commutator, is moved slowly back and forth across the surface of the commutator while the machine is running at moderate speed. Rapid movement or the use of coarse sandpaper will cause scratches. Never use emery cloth, emery

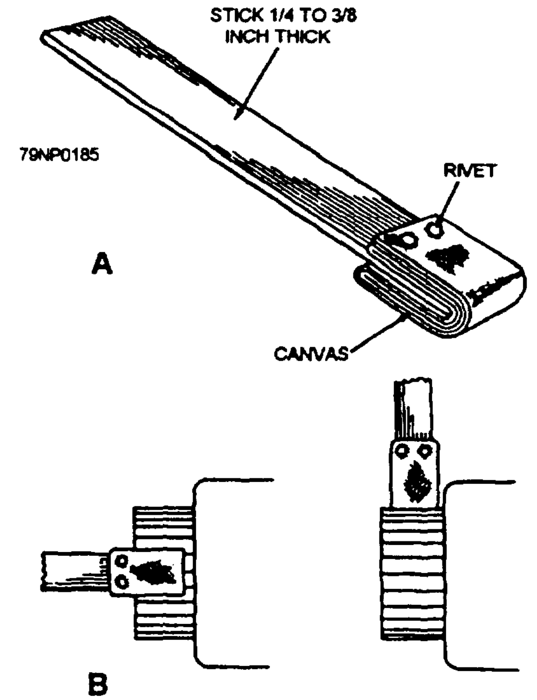


Figure 7-15.—Cleaning commutator or collector rings.

paper, or emery stone on a commutator or collector ring since the danger of causing electrical shorts exists.

TRUING COMMUTATORS AND COLLECTOR RINGS

With proper care and maintenance, commutators and collector rings can be counted on to provide years of carefree service. If not maintained properly, commutators and collector rings may be subject to any number of problems including excessive threading, grooving, copper drag, excessive out-of-roundness, waviness, high bars, high mica, slot or pitch patterns, contaminated surface films, and so forth.

When any of these symptoms is encountered, the most efficient and economical course of action usually is to begin corrective maintenance immediate y, rather than wait for the condition to get worse. It is desirable, however, to know the history of the machine before performing corrective maintenance. For example, light threading, small pits, longitudinal irregularities or wide slots between bars made during undercutting usually indicate a need to resurface a commutator or collector ring in place. However, if there is no sparking, brush wear is normal, and these abnormalities have developed over along period of time, no corrective action need be taken. Often, the best maintenance is to leave a well running machine alone.

Collector Ring Circularity

The maximum total indicated runout (TIR) for collector rings is normally 0.001 inch to 0.002 inch. See table 7-3 for eccentricity limits for various collector ring diameters. Collector ring diameters are typically small in comparison to commutators, and surface irregularities accentuate brush motion more. Larger commutators (18 inches in diameters) have surface/brush interfacing that often allow excessive out-of-roundness conditions without catastrophic failure.

Commutator Circularity

Ideally, commutator surfaces should be smooth and mechanically true. Optimum perfomance is obtained if maximum runout of a commutator surface with respect to its center of rotation does not exceed 0.002 inches. This value is a judgment criterion and is dependent upon the type of irregularity. Maximum allowable runout criteria could vary from less than 0.002 inches for wavy commutator surfaces to 0.005 inches for elliptical surfaces. The type of irregularity and also the degree of brush shunt fraying must be taken into consideration when evaluating the commutator surface condition.

Corrective Action

Do not hue a commutator or collector ring in place unless its condition has become so bad that it cannot wait until the next shop overhaul for reconditioning. Large commutators in the 125- to 850-rpm range, used on most electric propulsion motors and generators, usually operate satisfactorily with runouts up to 0.003 inch. Under no condition should you attempt to true a commutator or collector ring in place unless there is sparking, excessive brush wear, or brush movement sufficient to fray the brush pigtails and wear the hammer plates. Do not confuse brush chatter with brush movement by runout.

Table 7-3.—Collector Ring Eccentricity Limits

Slip Ring Diameter (inches)	Eccentricity (inches)		
	Up to 1200 rpm	1201-3599 rpm	3600+ rpm
3	0.001	0.0008	0.0005
3-6	0.002	0.0015	0.0015
6-10	0.003	0.0025	0.002
10	0.005	0.004	0.003

Sandpapering will not correct flat spots, grooves, eccentricity, or out-of-roundness condition You can correct some or all of these conditions by machine stoning or handstoning, by turning on a lathe, or by grinding with a rigidly supported stationary or revolving stone. There are a number of grades of commutator stones, from coarse to very fine, that cart be used for handstoning or grinding. Use the finest stone that will do the job in a reasonable time. Do not use coarse stones, as they tend to produce scratches that are hard to remove. In turning or grinding commutators and collector rings, it is essential that the cut be parallel with the axis of the machine; otherwise, a taper will result.

Do not disturb the commutator clamping bolts unless the bars are loose (one or more high bars). Then use a calibrated torque wrench and tighten only to the values specified by the manufacturer's instruction manual for motors and generators. Make all other needed repairs, such as balancing, rebrazing armature connections, and repairing insulation faults, before truing the commutator.

After the commutator is trued (whether by stoning, grinding, or turning), finish with a fine grade of stone or sandpaper, undercut the mica, chamfer the commutator bars (to be explained later in this chapter), clean the commutator and brush holders, and wipe off the brushes with a clean, dry, lint-free cloth.

HANDSTONING.— Handstoning will remove flat spots, grooves, scoring, and deep scratches; but, it will not correct eccentricity, high bars, or an out-of-round condition. The machine should be running at, or slightly below, the rated speed. Generators can normally be turned by their prime movers; however, some generators and motors must be turned by a pneumatic or other prime mover.

The stone should be formed or worn to the curvature of the commutator and should have a surface much larger than the largest flat spot being removed. Hold the stone in the hand and move it very slowly back and forth, parallel to the axis of the surface. Do not press too hard on the stone, just enough to keep it cutting. Being hasty or crowding the stone results in a rough surface and possibly an out-of-round condition. Avoid jamming the stone between the fixed and moving parts of the machine.

MACHINE STONING.— Stoning should be done by machine to correct eccentricity, high bars, or an out-of-round condition. In one method of machine stoning, a commutator dressing stone tool (fig. 7-16) is mounted on the frame of the machine and holds a

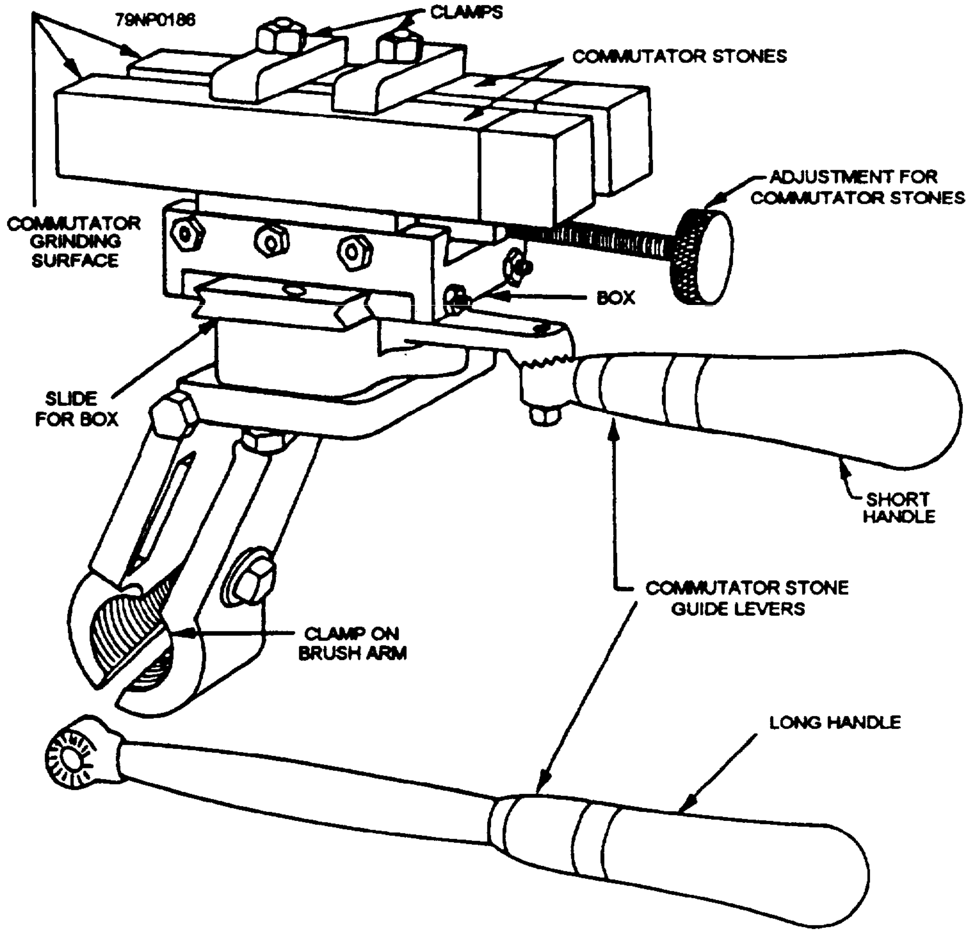


Figure 7-16.—Commutator dressing stone tool.

commutator stone against the commutator as the armature is rotated. This method works for some of the large open and driproof machines. Otherwise, the armature must be removed from the machine and mounted in a lathe and rotated. The commutator stone is mounted in the tool post and fed to the commutator, or a rotating precision grinder is mounted in the tool post and the grinder wheel is fed to the commutator.

GRINDING.— When practical, the armature should be removed from the machine and placed in a lathe for grinding. If not, the commutator can be ground in the machine, provided there is minimum vibration, the windings can be adequately protected from grit, and suitable supports can accommodate the stone.

When grinding the commutator in the machine, rotate the armature by using an external prime mover or, in the case of a motor, by supplying power through just enough brushes to take care of the load. You may use old brushes for this purpose since the y should be discarded after grinding. You should avoid electric shock or fouling of moving parts whenever you are grinding a motor commutator.

A commutator surface stone, when used, should be rigidly clamped in a holder and supported to keep the stone from chattering or digging into the commutator. The support must provide for the axial motion of the stone. To prevent the commutator from having different diameters at both ends, you should never take heavy cuts with a stone. Commutator surfacing stones with tool post handles are available in the Navy supply system in various sizes and grades (such as free, medium, and coarse).

In truing a commutator with a rotating grinder, use a medium soft wheel so that the face will not fill up with copper too rapidly. Even if the commutator is badly distorted, use a light cut, taking as many as needed. If a heavy cut is used, the commutator maybe ground to a noncylindrical shape, although initial eccentricity may be retained because of the elasticity of the support. The speed of the wheel should be that recommended by the manufacturer. The speed of the commutator should be one-half to three-fourths the normal speed until most of the eccentricity has been removed After this, the commutator should be rotated at about normal speed.

LATHE TURNING.— When overhauling an armature in the shop, true the commutator by supporting it in a lathe, turning, and cutting (fig. 7-17). First make sure the armature shaft is straight and in good condition. With a diamond-point tool, cut only enough material to true the commutator. This tool should be rounded sufficiently so that the cuts will overlap and not leave a rough thread on the commutator. The proper cutting speed is about 100 feet per minute, and the feed should be about 0.10 inch per revolution. The depth of cut should not be more than 0.010 inch. The reasons for a light cut are the same as those for grinding. In addition, when you take a heavy cut, the turning tool tends to twist the commutator bars and cut deeper at one end than at the other. Do not remove small pits, bum spots between bars, or other mechanical imperfections in the bars unless they interfere with the free sliding of the brushes.

After turning the commutator, finish it with a handstone and sandpaper. If balancing equipment is available, balance the entire rotating assembly before it is reinstalled in the machine.

SURFACE FILMS

The dark material that develops on the surface of the commutator and collector rings is known as the surface film. Without film, satisfactory operation of the sliding contact is impossible. The existence and condition of this film on the collector ring or commutator is a critical factor in determining proper brush performance and surface wear of the ring or commutator.

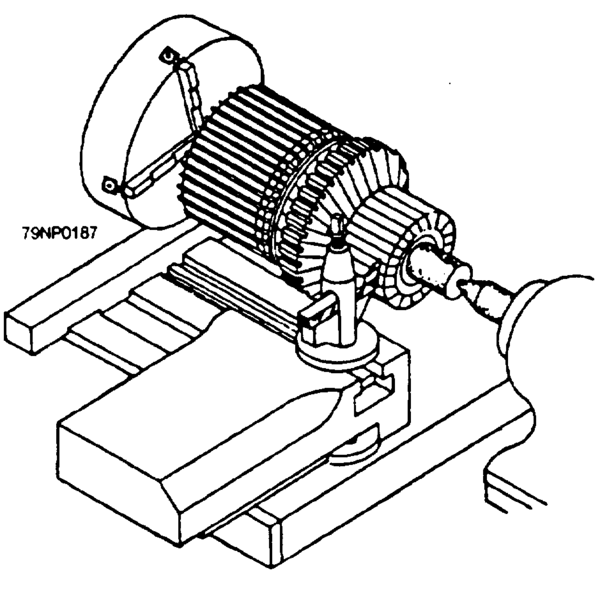


Figure 7-17.—Truing a commutator by turning.

The film itself is a composite of various constituents adhering to both the surface and each other, including copper oxides, graphite particles, and water vapor. This layer of film, although extremely thin (about 1-6 molecules deep), provides sufficient separation between the brush and the ring to allow the brush to slide over the surface with a minimum amount of wear to either.

After the oxide film has been removed from the commutator surface by sandpapering, stoning, grinding, or turning, it is necessary to return the film before the machine is operated at or near full load.

Before passing any current through the commutator or collector ring, make sure the surface is mechanically smooth, and remove, with handbeveling tool, any sharp edges or slivers on the bar. When there are noticeable commutator scratches or roughness, use very fine sandpaper (no coarser than No. 0000) to remove them. Then burnish the ring using a commercial stone (Military Specification MIL-S-17346). After burnishing, carefully brush any debris from between the commutator bars. Before reinstalling a shop-overhauled armature in its motor or generator, make sure the commutator surface is smooth, the bar edges are leveled, and the spaces between the bars are clean.

Any commutator that has been resurfaced should undergo a seasoning process to restore its oxide film before being operated at or near full load. Start with a 25 percent load and operate for 4 hours; then increase the load by 10 percent increments every hour until full load is reached To get the machine on full load in the minimum time, run at 25 percent load for 3 hours, and then increase the load by 15 percent every hour until full load is reached. The shorter seasoning period is not recommended unless the machine is urgently needed A more in-depth study may be obtained in the *Commutator/Slip Ring Maintenance Handbook,* NAVSEA S9310-AC-HBK-010.

UNDERCUTTING MICA OF COMMUTATORS

High mica or feather-edged mica may cause sparking, a rough or uneven commutator surface, streaking or threading, or other difficulties. Rough or uneven commutator surfaces may also be caused if you fail to chamfer the commutator segments after undercutting. Tools are available for undercutting, chamfering, and smoothing slot edges. Figure 7-18 shows a rotary, motor-driven tool for undercutting mica.

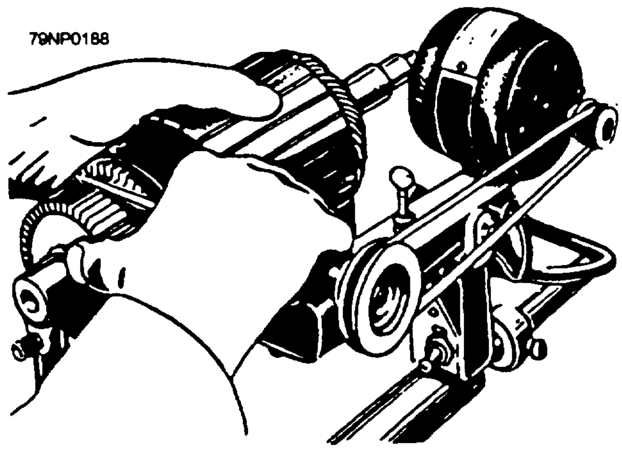


Figure 7-18.—Undercutting commutator mica with undercutter.

The rotary cutters are either U- or V-shaped. The U-slots will give long wear and are best suited to slow-speed machines or machines that operate in a clean atmosphere and require little maintenance. The V-slots, which are more quiet than U-slots, are better if dirt and dust are present. The proper thickness for a U-shaped cutter is equal to the thickness of ± 0.001 inch. In general, it is best not to cut U-shaped slots deeper than one thirty-second of an inch, or, at most, three sixty-fourths of an inch. The V-shaped slots are cut to a depth that will remove some copper at the top.

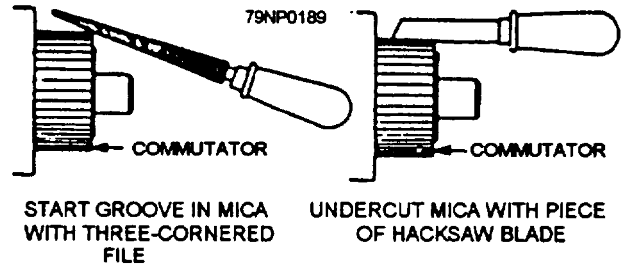


Figure 7-19.—Undercutting mica with a hacksaw blade.

If a mica undercutter is not available, use hand tools to cut the mica, as shown in figure 7-19. Do not use a lubricant. Also, do not widen the commutator slots by removing metal from the bars, nor leave a thin edge of mica next to the bars.

After removing the high mica, smooth off all burrs. Then polish the commutator and test. Figure 7-20 shows examples of good and poor undercutting.

DISASSEMBLY AND REASSEMBLY OF ROTATING ELECTRICAL MACHINERY

When you have to disassemble and reassemble a large motor or generator, follow the procedures outlined in the manufacturer's instruction manual, exercising care to prevent damage to any part of the machine. The

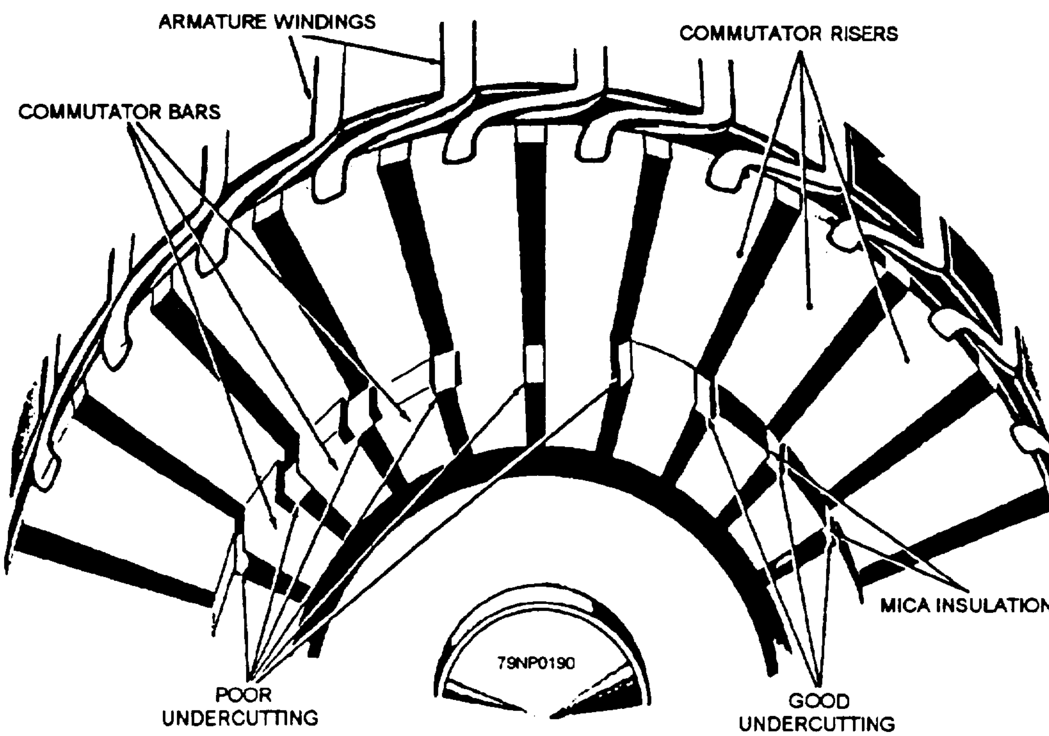


Figure 7-20.—Example of good and poor undercutting.

machine rotors should be supported, while being moved or when stationary, by slings, blocking under the shaft, a padded cradle, or thickly folded canvas under the core laminations. When you are using rope slings to lift ac or dc rotors, place them under the shaft, keeping them clear of the bearing journals. When construction of the rotors does not allow room, except around the bearing journals, you must protect the surfaces with heavy paper or canvas. Ensure rope slings never come in contact with ac or dc rotor coils. When the complete unit (stator and rotor) is to be lifted by lifting the starer, the bottom of the air gap must be tightly shimmed unless both ends of the shaft are supported on the bearings. It is possible, by rough handling or careless use of bars or hooks, to do more damage to a machine during disassembly and assembly than it will receive in years of normal service. Figures 7-21 and 7-22 show typical ac and dc motors.

Never be hasty or careless in disassembling a generator or motor. Handle the delicate components with care to prevent damage or create the need for additional adjustment. Use the proper tools, and label the parts as you dismantle them. Store them in an orderly arrangement in a safe place. Note the necessary information so that you will have no trouble in reassembly.

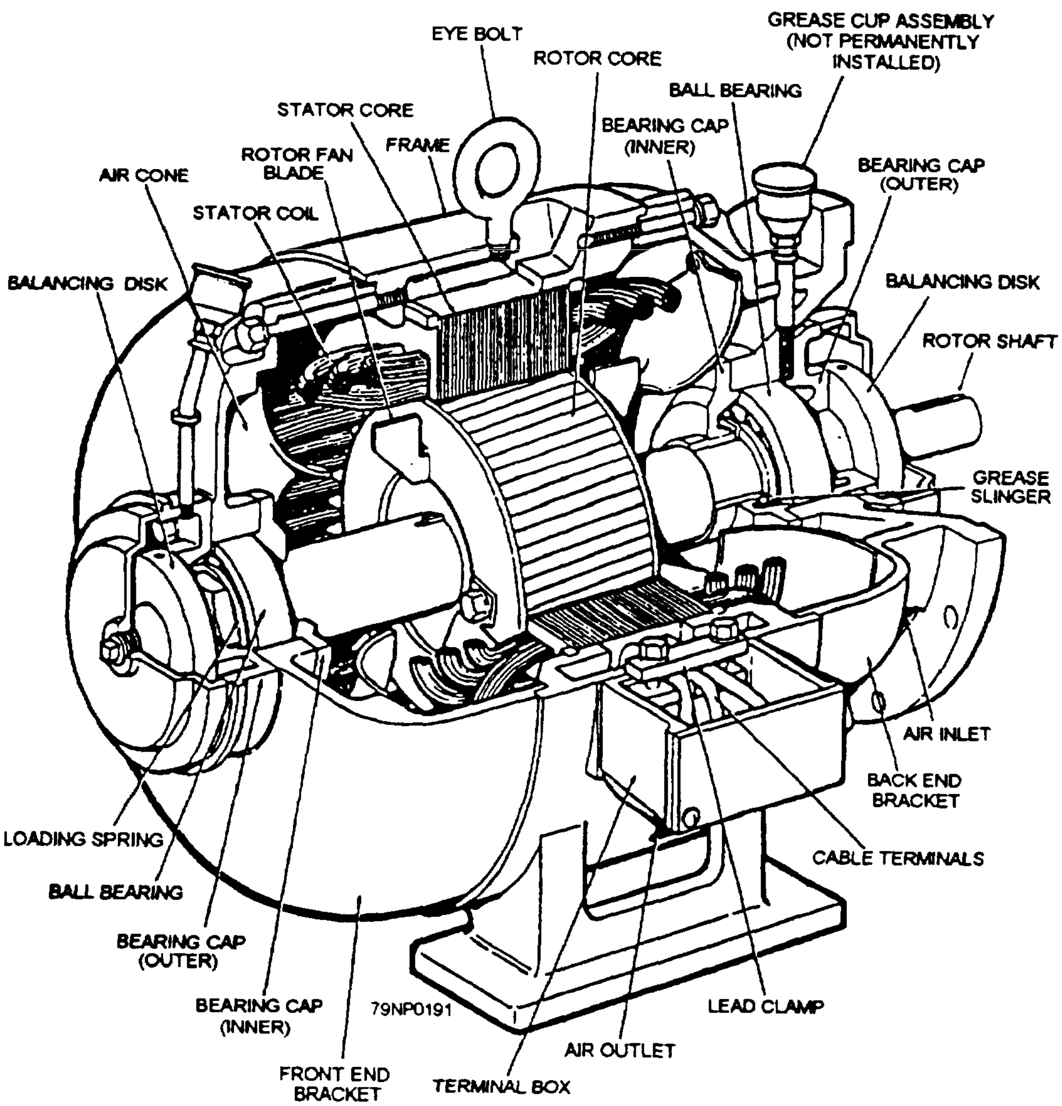


Figure 7-21.—Typical ac motor.

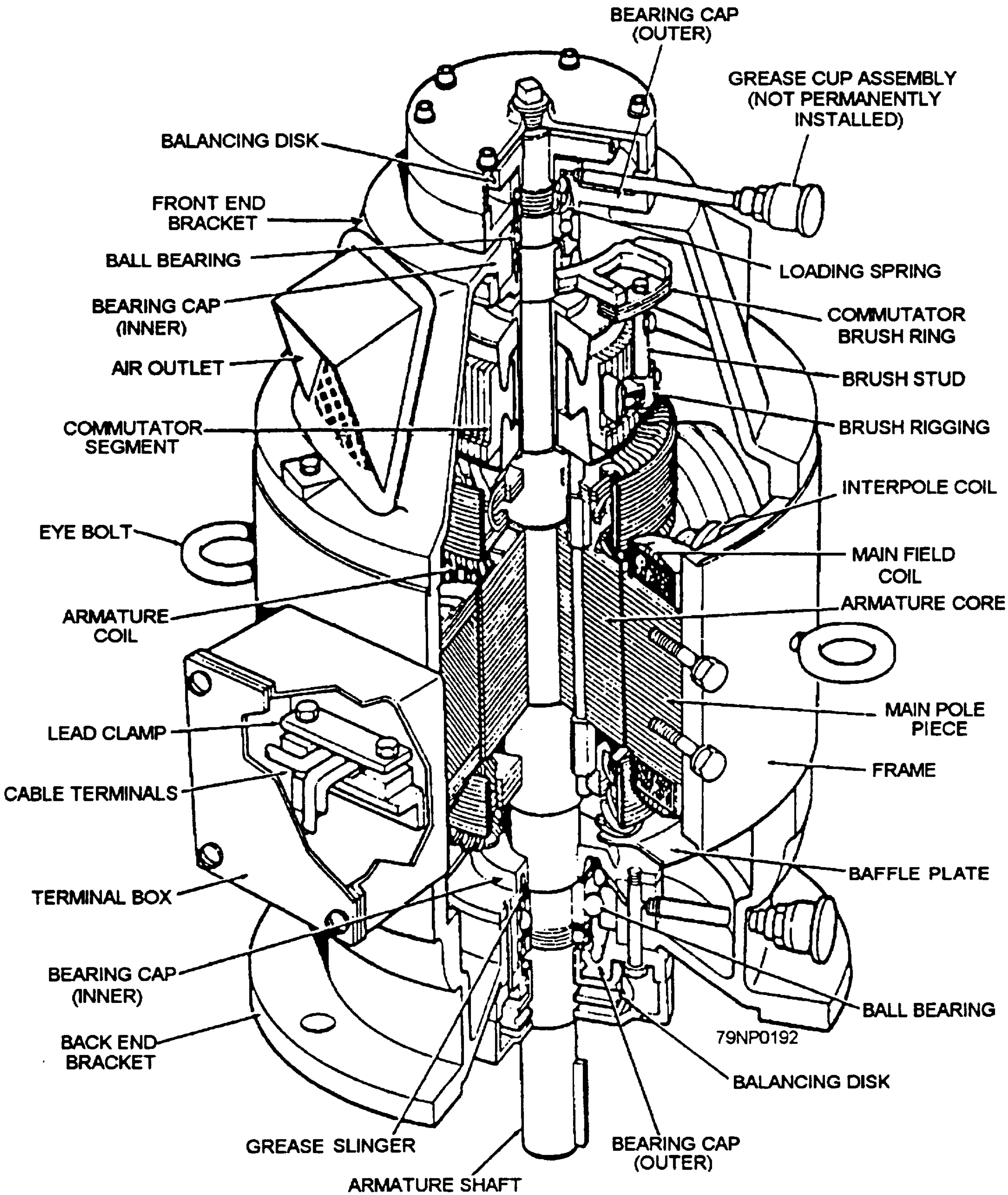


Figure 7-22.—Typical dc Motor.

If you have done a careful job of breaking down a machine into its components, the process of reassembly should be the reverse order of disassembly.

A few simple steps are to be taken when disassembling a motor or generator:

1. Make sure you mark the frame and mating end bells (fig. 7-23), using a different mark for each end
2. When separating the end bells from the frame, use a mallet or block of wood with a hammer (fig. 7-24). Never pry mating surfaces apart with a metal object such as a screwdriver.
3. To prevent damaging the brushes, lift them from the commutator and/or slip rings before removing the rotor.
4. Protect the windings by inserting thin strips of waxed paper between the rotor and stator.
5. When using an arbor press to remove bearings, take the proper precautions. (Place a pair of flat, steel blocks under the inner ring or both rings of the bearing. Never place blocks under the outer ring only. Line up the shaft vertically above the baring, and place a soft pad between the shaft and the press ram. After making sure the shaft is started straight in the bearing, press the shaft into the bearing until the bearing is flush against the shoulder of the shaft). You may use a gear puller to remove a rotor bearing, but take extreme care.

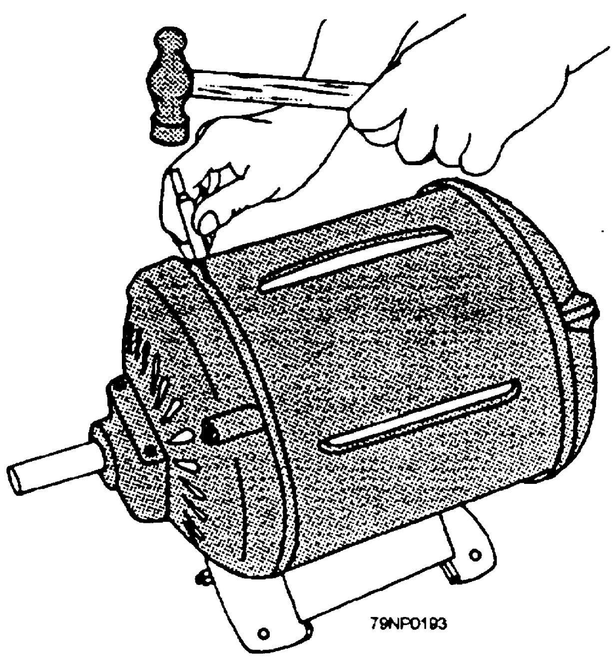


Figure 7-23.—Marking a motor frame and end bell.

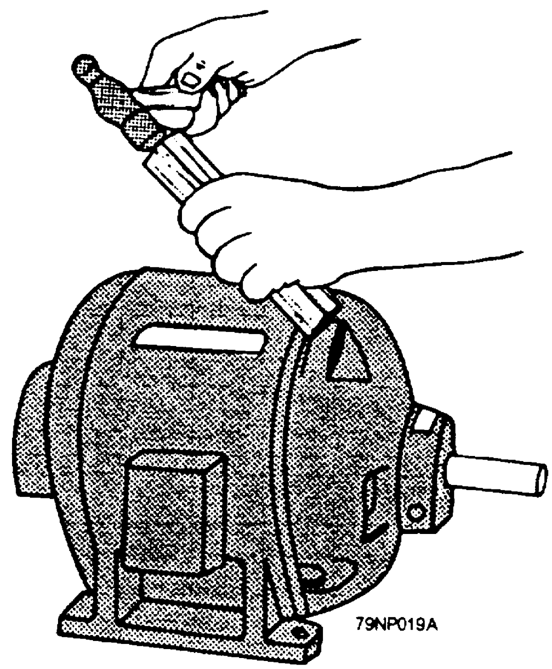


Figure 7-24.—Parting end bells with a hammer and a wood block.

6. Never remove the bearings unless they are to be replaced, or unless they must be removed to allow the removal of the end bells.
7. If you are taking off a ball bearing and plan to use it again, be careful to apply pressure to the inner race only. If pressure has been applied to the outer race, you will have to discard the bearing.
8. Never use a cleaning solvent on a sealed or a semi-sealed ball bearing. Store these bearings in a clean piece of waxed paper until you are ready to use them.
9. Clean the end bells with a brush and an approved solvent. Check them for crocks, burrs, nicks, excessive paint, and dirt.

TESTING COMPONENTS OF ROTATING ELECTRICAL MACHINERY

Preventive maintenance of armatures, rotors, or windings consists mainly of periodic visual inspections and electrical testing to determine the condition of the equipment and proper cleaning practices to preserve the integrity of its insulation. Periodic testing and inspection of the various electrical components of rotating electrical machinery will help to prevent catastrophic failure of the equipment and leads to reduced overall maintenance cost of the equipment.

AC MOTORS

AC motors comprise the majority of rotating equipment to be maintained by the EM aboard ship. Of the three general classes of ac motors in use today (polyphase induction, polyphase synchronous, and single-phase) the polyphase induction motor is, by far, the most common used aboard ship. These motors are well suited to shipboard use and can be counted on to operate for very long periods of time if maintained according to prescribed PMS procedures.

Rotors

Basically, the rotor of an ac motor is a squirrel-cage rotor or a wound rotor. The squirrel-cage rotor usually has heavy copper or aluminum bars fitted into slots in the rotor frame. These bars are connected to short-circuiting end rings by being cast, brazed, or welded together (fig. 7-25). In many cases, the cage rotor is manufactured by die-casting the rotor bars, end rings, and cooling fans into one piece. The cage rotor requires less attention than the wound rotor since it is less susceptible to damage. The cage rotor, however, should be kept clean, and the rotor bars must be checked periodically for evidence of loose or fractured bars and localized overheating.

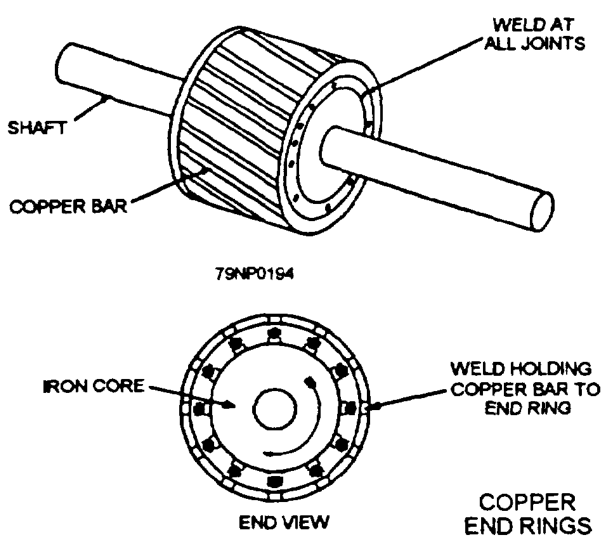


Figure 7-25.—Squirrel-cage rotor.

Wound rotors (fig. 7-26) consist of wound coils insulated from each other and laid in slots in the rotor core. These coils are wye-connected and terminate at three slip rings.

Wound rotors, like other windings, require periodic inspections, tests, and cleaning. The insulation resistance determines if grounds are present. An open circuit in a wound rotor may cause reduced torque accompanied by a growling noise, or failure to start under load. Besides reduced torque, a short circuit in the rotor windings may cause excessive vibration, sparking at the brushes, and uneven collector ring wear. With the brushes removed from the collector rings, a continuity check of the rotor coils will reveal the presence of a faulty coil.

Stator Coils

The ac stator windings require the same careful attention as other electrical windings. For a machine to function properly, the stator windings must be free from grounds, short circuits, and open circuits.

A short circuit in the stator of an ac machine will produce smoke, flame, or an odor of charred insulation. The machine must be secured immediately and tests conducted to find the reason for the abnormal condition.

The first and easiest test that you should conduct is to test the insulation resistance of the winding. This test is made with a megohmmeter or similar resistance-measuring instrument. Connect one instrument lead to ground and the other to each motor lead; crank the meter handle and read the scale on the meter face. If the insulation resistance is within the

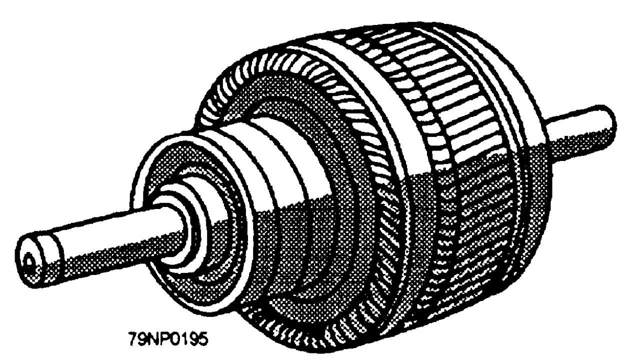


Figure 7-26.—Wound rotor.

range specified in table 7-4, the stator is not grounded and other tests should be made to locate the trouble.

Next, test for continuity with an ohmmeter by connecting the test leads to any two motor leads and then to the next two leads, until all leads have been tested for continuity between each other. Whether the motor is wye- or delta-connected, you should get nearly zero indication on the ohmmeter between any two leads. A high resistance reading between any two leads is a good indication of an open-phase winding.

For your next check, determine whether or not time are any mechanical difficulties, such as frozen bearings or a frozen pump. First, disconnect the motor from the driven unit. Spin the motor shaft to see if it is free to turn. Then check the driven end for freedom of movement. If the driven end is frozen, you need check no further. Inform the maintenance person responsible for the driven end of your findings.

A visual inspection of the stator will usually reveal where the trouble lies. If the stator windings are shorted or have an open, the motor must be disassembled, rewound, and reassembled. If only one phase is open, it is possible to effect an emergency repair by carefully soldering the opened leads together. Care should be taken in soldering these leads because further damage could result if the coil leads are inadvertently shorted. After accomplishing this emergency repair, test the stator winding with a low voltage to ensure the correct phase balance.

Polyphase Stator Troubles

The methods of locating and correcting the common troubles encountered in rewound and reconnected polyphase stator windings are included for the convenience of Electrician's Mates engaged in this work.

SHORTED POLE-PHASE GROUP.— An entire pole-phase group may be shorted in a polyphase stator. Such a defect is usually indicated by excessive heat in the defective part. The trouble can be readily located by a compass test. To conduct a compass test, excite the stator windings with a low-voltage, direct current that will set up the poles in the stator (fig. 7-27). When the windings are excited, a compass is moved around the inside circumference of the stator core. As each pole group is approached, the polarity is indicated by the compass. There should be the same number of alternate north and south poles in a three-phase winding.

Table 7-4.—Satisfactory Insulation Resistances for ac Motors and Generators (Other than Propulsion)

	Insulation Resistance (Megohms at 25° C)[1]			
Circuit	**Minimum for Operation**	**After Cleaning on Ship**	**After Reconditioning**	**After Rewinding**
Stator circuit of generators and motors	0.2	1.0	25	100
Rotor circuit of wound rotor induction motors	0.1	0.5	25	100
Field circuit of generators or of synchronous motors	0.4	2.0	25	400
Stator circuit of motors with sealed insulation system	2.0	25	500	1000[2] 100[3]

Notes:

1. Values are for machines rated 500 volts or less. For machines having a rated voltage (E) > 500 volts, multiply all values in the table by E/500.
2. Minimum acceptable value with winding dry, before and after submergence test.
3. Minimum acceptable value during a 24-hour freshwater submergence test.

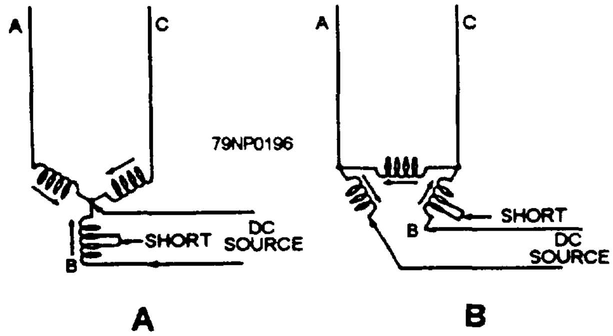


Figure 7-27.—Compass test for shorted pole-phase groups.

In testing a three-phase, wye-connected winding (fig. 7-27, view A), test each phase separately by impressing the dc voltage successively on each of the phase leads and the midpoint of the wye connectiom If there is no trouble in the winding, the compass will indicate alternately north and south for each pole-phase group around the stator. If a complete pole-phase group is shorted, the compass needle will not be deflected at this point.

In testing a three-phase, delta-connected winding (fig. 7-27, view B), open one of the delta connections and apply the direct current to the winding. The current will flow through the three phases in series. If the pole-phase groups are connected properly, the compass will indicate alternate north and south poles around the stator frame. As in the wye-connected winding, a shorted pole-phase group is indicated by no deflection of the compass needle.

SHORTED PHASE.— When an entire phase of a three-phase winding is shorted, the defect is most readily located by a balanced-current test made with a type TA industrial analyzer. This test can also be made with an ammeter and low-voltage ac source (fig. 7-28).

In testing a three-phase, wye-connected winding (fig. 7-28, view A), test each phase separately by impressing the ac voltage successively on each of the phase leads and the midpoint of the wye connection. If there is no trouble in the windings and if the impedance of the winding of each phase is the same, the ammeter

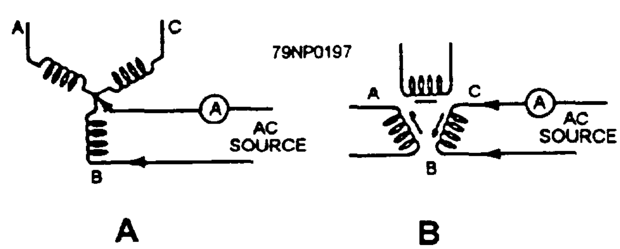


Figure 7-28.—Balanced current test for shorted phase.

will indicate about the same value of current for each of the three phases. If one phase is shorted, the ammeter will indicate a higher current reading for this phase than those of the other two phases because the impedance is less.

In testing a three-phase, delta-connected winding (fig. 7-28, view B), open each delta connection and test each phase separately. As in the wye-connected winding, the shorted phase will be indicated by a much higher current reading on the ammeter.

OPEN CIRCUITS.— In testing a three-phase, wye-connected winding (fig. 7-29, view A), connect the ohmmeter leads across each of the phases to locate the defective phase. When the ohmmeter leads are placed on terminals A and C, no open circuit (a low reading) is indicated. However, when the leads are placed on terminals C and B and then on terminals B and A, an open circuit (a high reading) is indicated in both positions. This denotes an open in phase B. After the defective phase has been located, test each stub connection of the pole-phase groups with the ohmmeter until the open coil is located.

In testing a three-phase, deha-connected winding (fig. 7-29, view B), open one delta connection to avoid shunting the phase being tested. Test each phase separately until the open is located. After the faulty phase is located, test each stub connection of the pole-phase groups, as in the wye connection, until the open coil is located.

If the windings are parallel, open each parallel group and test each group separately.

DC MOTORS

Though not as common as ac motors, dc motors are still used in some applications aboard ship. Because brushes are used in these motors, they are more susceptible to damage caused by dust snd dirt than ac motors. If allowed to accumulate, dust and dirt could

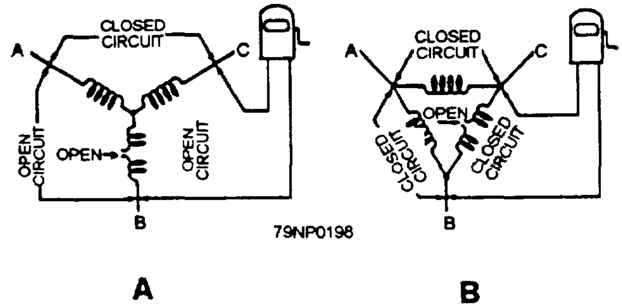


Figure 7-29.—Ohmmeter test for open circuits.

create a path for current between insulated parts of the motor and lead to a fire.

Field Coils

The insulation of the field coils should be tested periodically with a resistance-measuring device. If a ground is detected in the field circuits (shunt, series, and interpole) of a dc machine, you should disconnect all circuits from each other and test separately to locate the grounded circuit. The coils in the circuit must be opened and tested separately to locate the grounded coil. It can then be repaired or replaced as necessary.

When an open circuit develops in the field windings of an ac or dc generator that is carrying a load, it will be indicated by the immediate loss of load and voltage. An open in the shunt field winding of an operating dc motor may be indicated by an increase in motor speed, excessive armature current, heavy sparking, or stalling of the rotor. When an open occurs in the field circuit of a machine, you must secure it immediately and examine the circuit to locate the fault. An open circuit will usually occur at the connections between the coils and can be detected by visual inspection. The opening of an energized field circuit induces a high voltage that can damage the field insulation causing a safety hazard.

Armatures

Frequent checks of the condition of the banding wire that holds down the windings are necessary to determine if the wires are tight, undamagd, and have not shifted. Also check the clips securing the wires to see that the solder has not loosened.

You can detect some armature troubles while making inspections of running machines. Heat and the odor of burning insulation may indicate a short-circuited armature coil. In a coil that has some turns shorted, the resistance of one turn of the coil will be very low, and the voltage generated in that turn will cause a high-current flow. This results in excessive heating that could cause the insulation to burn. If the armature is readily accessible, you can detect the short-circuited coil immediately after stopping the machine because the shorted coil will be much hotter than the others. In idle machines, you can identify a short-circuited coil by the presence of charred insulation.

An open armature coil in a running machine is indicated by a bright spark, which appears to pass completely around the commutator. When the segment to which the coil is connected passes under the brushes, the brushes momentarily y complete the circuit; when the

Table 7-5.—Satisfactory Insulation Resistance for dc Generators and Motors (except propulsion and auxlliary generators for submarines) Including Exciters

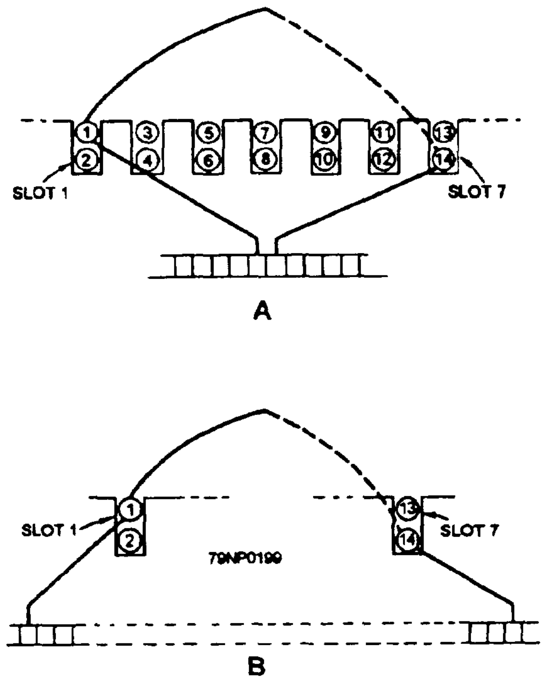
	Insulation Resistance (Megohms at 25° C)[1]			
Circuit	Minimum for Operation	After Cleaning on Ship	After Reconditioning	After Rewinding
Complete armature circuit[2]	0.1	0.5	1.0	100
Armature alone	0.2	1.0	2.0	200
Armature circuit less armature[2]	0.2	1.0	2.0	200
Complete field circuit	0.5	1.5	2.5	200

Notes:

1. Values are for machines rated 250 volts or less. For machines having a rated voltage (E) > 250 volts, multiply all values in the table by E/250.
2. Small machines usually have one of the shunt field leads connected internally to the armature circuit. To avoid disassembly in such cases, the complete armature circuit and the field circuit may be measured without breaking this connection. If necessary, the armature can be isolated by lifting the brushes.

   a. With brushes left in place, the complete circuit will include armature, armature circuit, and the permanently connected field circuit. The values given for the complete armature circuit will apply.

   b. With brushes lifted, the armature circuit, less armature and the complete field circuit will be measured. The values given for armature circuit, less armature will apply.



A. Single-turn lap coil;
B. Single-turn wave coil.

Figure 7-30.—Classfifcation or armature windings.

segment leaves the brushes, the circuit is broken, causing a spark to jump the gap. The open will eventually scar the commutator segments to which the ends of the open coil are connected.

When a ground occurs in an armature coil of a running machine, it will cause the ground test lamps on the main switchboard to flicker on and off as the grounded coil segment passes from brush to brush during rotation of the armature. Two grounded coils will act the same as a short circuit across a group of coils. Overheating will occur in all of the coils in the group and burn out the winding. You can detect grounded coils in idle machines by measuring insulation resistance (see table 7-5). You can connect a Megger, or similar insulation measuring device, to the commutator and to the shaft or frame of the machine to properly measure the resistance of the insulation of the coils.

You can make emergency repairs by cutting out a short-circuited or open-circuited armature coil. This will permit restoration of the machine to service until permanent repairs can be made. However, permanent repairs should be made as soon as possible. Cutout the coil by disconnecting both ends of the coil and installing a jumper between the two risers from which the coil was disconnected. The coil itself is then cut at both the front and rear of the armature to prevent overheating of the damaged coil. A continuity test from one end to the back of the coil will locate the turns of the faulty coil. If a pin or needle is used to puncture the insulation for this test, use insulating varnish to fill the tiny hole if the wrong coil is pierced Insulate all conducting surfaces exposed by the change in connection.s and tie all loose ends securely to prevent vibration

You must be able to identify various types of armature windings to interpret trouble indications and to make the necessary repairs.

LAP AND WAVE WINDINGS.— Armature windings, irrespective of how the elements are placed on the armature core, are generally classified as LAP or WAVE windings. The classification designates the method of connecting the ends of the elements, or coils, to the commutator. If the ends of the coil are connected to adjacent commutator segments or to segments that are close together, the coil is designated as a lap-connected coil, and the winding is a lap winding (figs. 7-30, view A, and 7-31, view A).

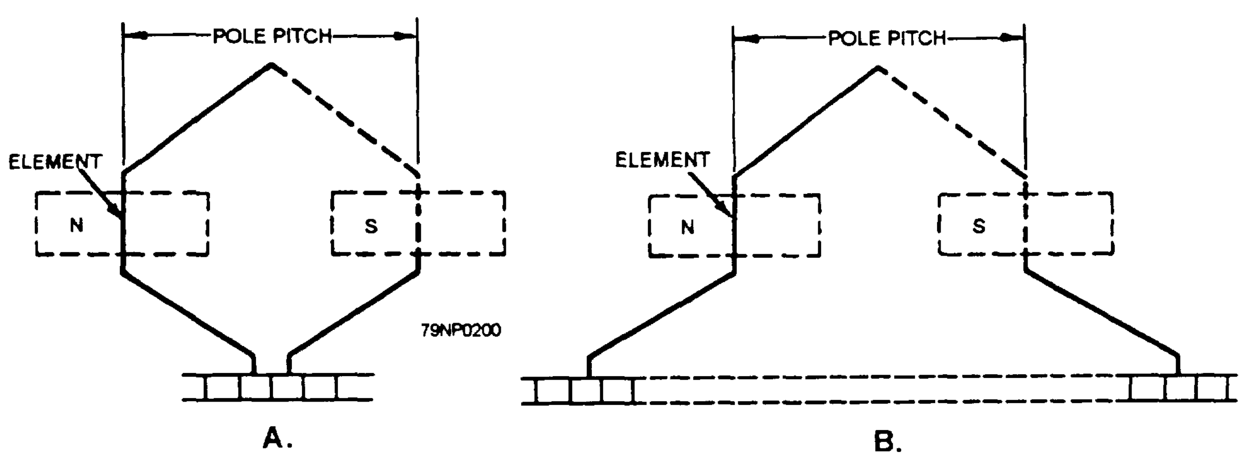


Figure 7-31.—Full-pitch coils.

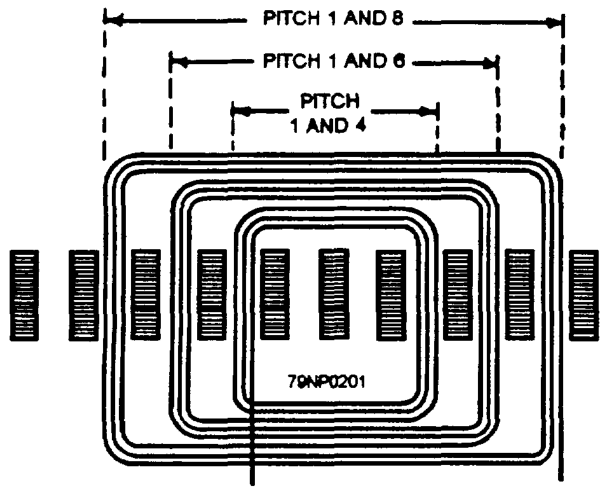


Figure 7-32.—Pole pitch.

PITCH.— Both lap and wave windings are placed on the armature core so that the two sides of an element occupy the slots that are influenced by adjacent poles of opposite polarity, and the emfs generated in the two sides add together. In other words, if the left side of a coil momentarily occupies a position under the center of a north pole, the right side of the same coil will occupy a position under approximately the center of an adjacent south pole. The distance between the centers of two adjacent poles is the pole pitch. The span of one coil should be equal or nearly equal to one pole pitch. If a coil spans exactly one pole pitch, the winding is FULL PITCH (fig. 7-31). If a coil spans less than one pole pitch, the winding is FRACTIONAL PITCH. COIL PITCH is recorded and identified by the number of slots spanned by the coil in the armature (fig. 7-32).

NUMBERING.— The dc armature windings are usually two-layer windings in which each slot contains two coil sides of a single-coil type of winding (fig. 7-30). One side of the winding element is placed in the top of a slot and the other side is placed in the bottom of another slot. Either side of the element maybe placed in the top or bottom of the slot. When you view the armature from the commutator end, the right side of the coil is usually placed in the bottom of one slot, and the left side is placed in the top of another slot. The coils are arbitrarily numbered so that all TOP coil sides have odd numbers and all BOTTOM coil sides have even numbers (fig.

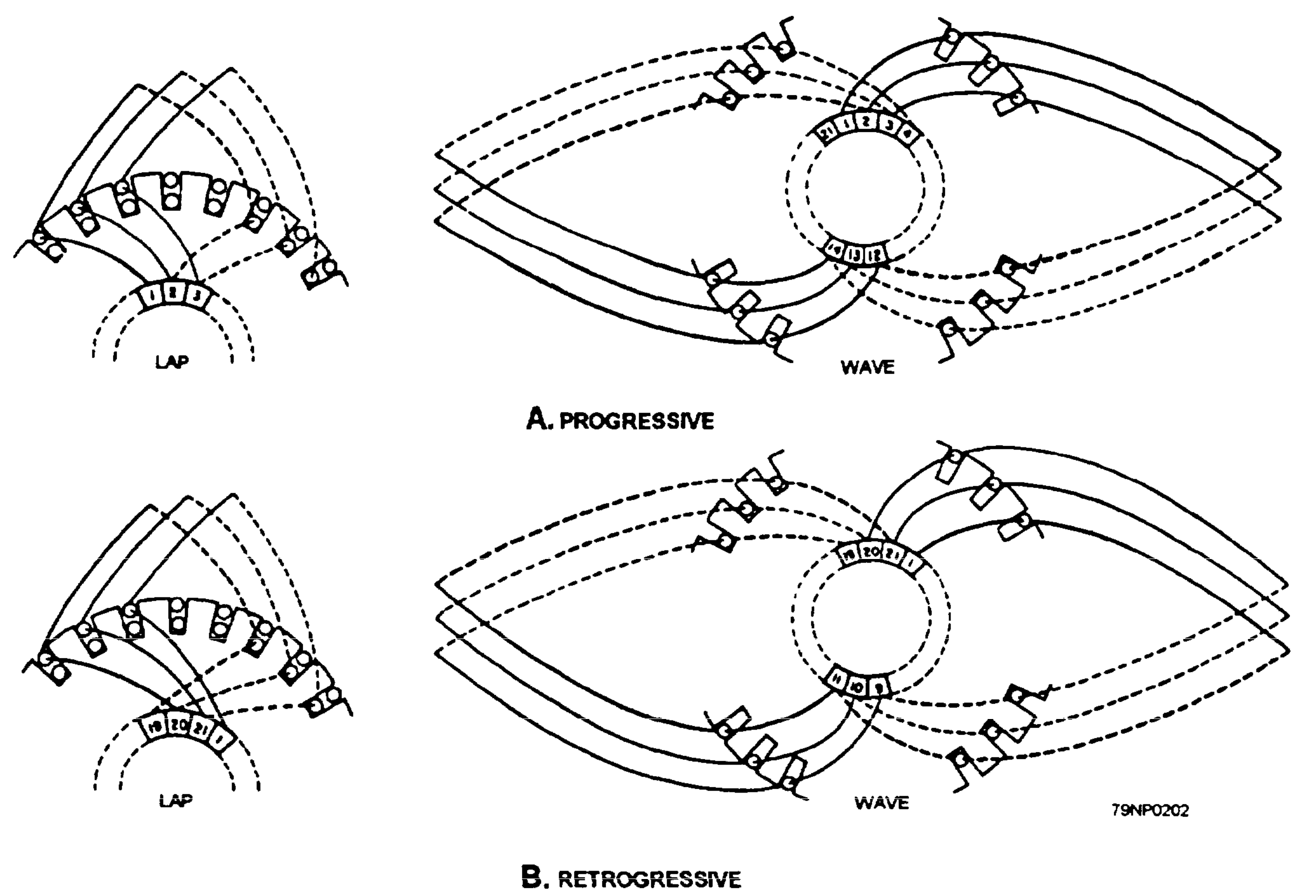


Figure 7-33.—Meaning of coil pitch in armature winding.

7-30). This system helps to place the coils properly on the armature.

PROGRESSIVE AND RETROGRESSIVE WINDINGS.— Lap and wave windings can be progressive or retrogressive, as shown in figure 7-33.

Progressive Windings.— A progressive winding (fig. 7-33, view A) progresses in a clockwise direction around the armature when traced through the winding from the commutator end. In other words, the winding progresses clockwise from segment (bar) through the coil to segment.

Progressive wave windings and retrogressive lap windings are very seldom encountered because of inherent undesirable features, such as the end connections of coil groups crossing over each other, added weight, and longer leads. Therefore, with few exceptions, lap windings are progressive and wave windings are retrogressive.

Retrogressive Windings.— A retrogressive winding (fig. 7-33, view B) progresses in a counterclockwise direction around the commutator when traced through the winding from the commutator end.

MULTIPLEX WINDINGS.— Wmdings may also be classified and connected in SIMPLEX, DUPLEX, or TRIPLEX. A simplex lap winding is one in which the beginning and ending leads of a lap-wound coil are connected to adjacent commutator bars. Duplex and triplex lap windings have their leads connected two or three bars apart, respectively.

Progressive and retrogressive simplex lap windings are shown in figure 7-34. In the progressive lap winding, the current flowing in the coil terminates in the commutator bar clockwise, adjacent to the starting bar, as you view the armature from the commutator end. In a retrogressive simplex lap winding, the current in the coil terminates in the bar counterclockwise, adjacent to the starting bar.

Simplex progressive and retrogressive wave windings are shown in figure 7-35. Compare these with the lap windings shown in figure 7-34.

TEST PROCEDURES. —Use of an organized test procedure will enable you to distinguish the types of armature windings. One method is to use a low-reading ohmmeter (capable of reading minute ohmic values) to indicate variations in the resistance reading as the test probes are shifted around on the commutator. If a low-reading ohmmeter is not available, a milliammeter

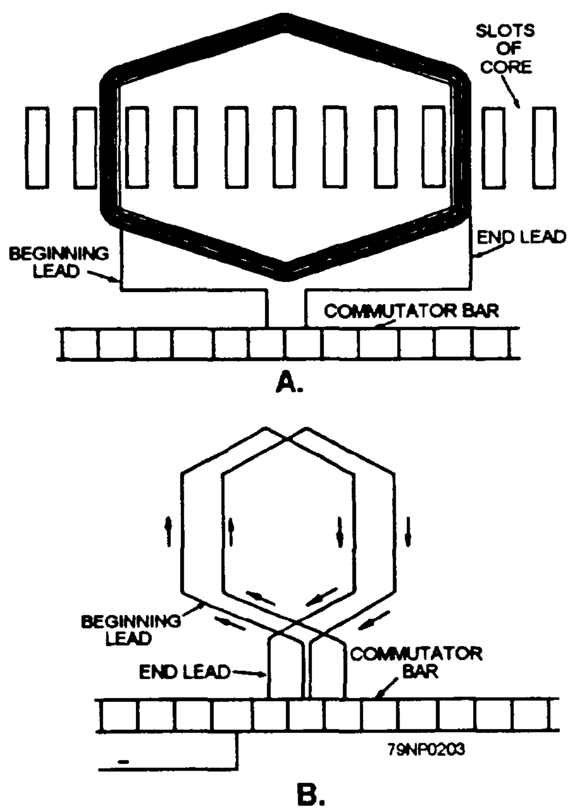


Figure 7-34.—Simplex lap windings.

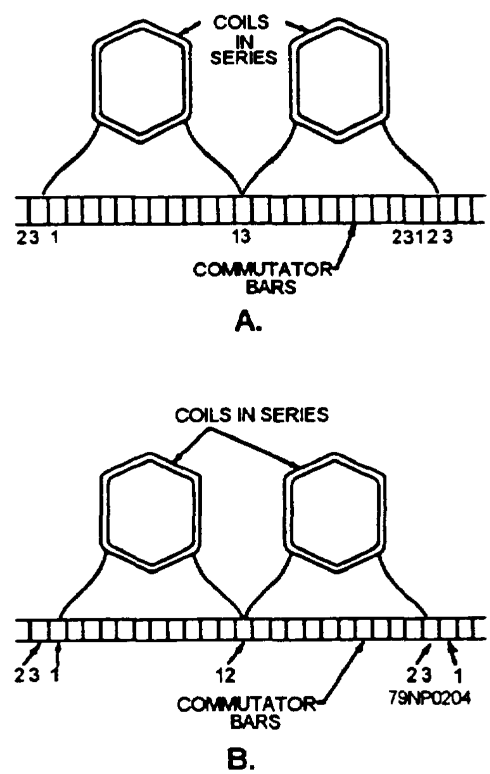


Figure 7-35.—Four-pole simplex wave windings.

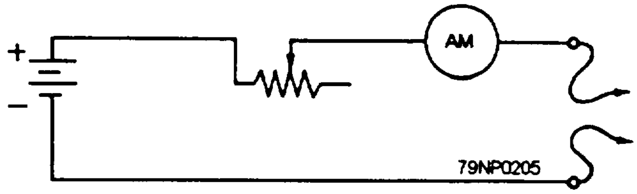


Figure 7-36.—Test circuit for messuring armature resistance.

connected in series with a rheostat and a 6-volt battery can be used (fig. 7-36).

SIMPLEX LAP WINDING.— A schematic diagram of a simplex lap winding is illustrated in figure 7-37. With the test probes placed on adjacent segments, the ammeter should indicate a maximum because the resistance of only one coil shunts the remainder of the widing, and the resistance added to the test circuit is at minimum. When one test probe is moved to the next segment, the ammeter reading should decrease because the resistance between the probes has increased. With one probe stationary and the other probe contacting each segment in succession around the commutator, the ammeter indications should decrease steadily until the test probes are directly opposite each other then the indications start increasing steadily as the other half of the winding is tested. These indications are obtained because of the method of connecting the coils to the commutator, which is determined by the type of winding. A simplex lap winding is the only winding that gives these indications.

SIMPLEX WAVE WINDING.— An important rule to remember for all wave windings is that the ends of each coil are connected to commutator segments that are about two pole pitches apart. Using the test procedure described in the previous paragraph, the maximum ammeter reading is indicated when the test probes are connected across that portion of the winding in which one coil shunts the remaining portion of the winding. Hence, in all wave windings the maximum reading will be indicated when the probes are placed on commutator segments that are about two pole pitches apart. The minimum ammeter reading will occur when the probes are placed on segments about one pole pitch apart.

With one probe stationary on segment 1 (fig. 7-38) and the other probe moved around the commutator from segment to segment (2, 3, 4, and so forth), the ammeter readings should steadily decrease until the probes are about one pole pitch apart. Then the readings should steadily increase until the probes are about two pole pitches apart.

If the probe is circled around the remainder of the commutator, the readings should decrease and then increase once for each pair of poles. In the identification of a six-pole, simplex wave winding, there should be three successive decreases and increases in the meter readings. Thus, you can distinguish a simplex wave winding from a simplex lap winding by measuring the resistances of the armature coils.

ARMATURE TESTING AND REPAIRING.— An armature is bench tested for grounds, opens, and shorts at disassembly to help determine the cause of the dc motor or generator failure and the repairs that are required.

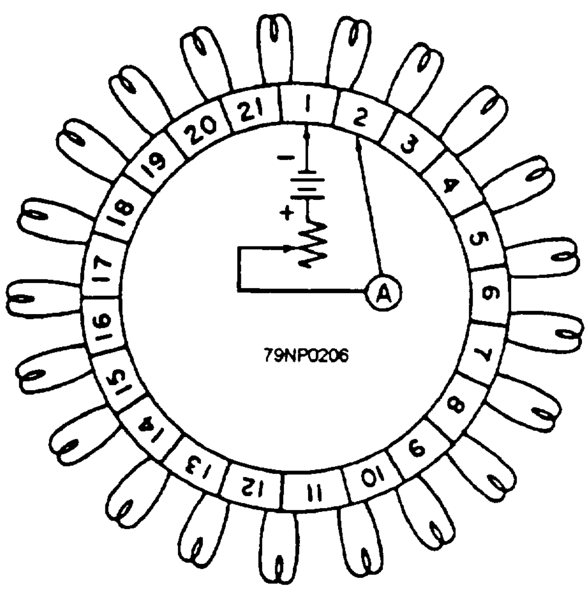


Figure 7-37.—Schematic of a simplex lap winding.

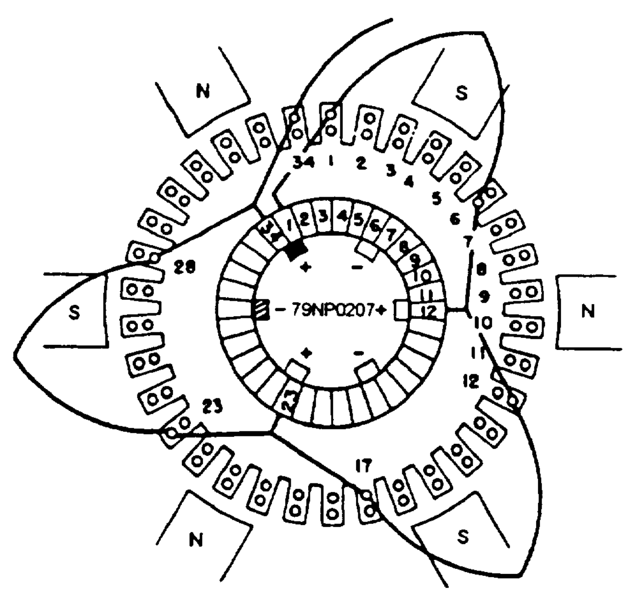


Figure 7-38.—Portion of a six-pole simplex wave winding.

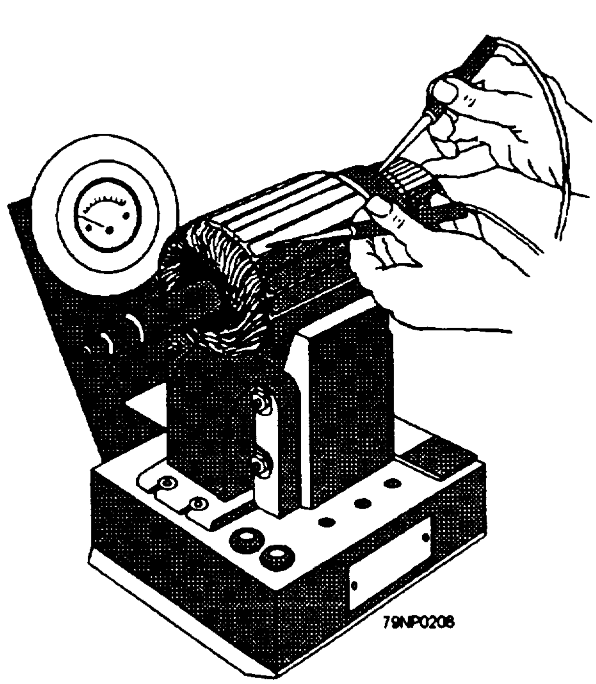


Figure 7-39.—Testing an armature for grounds.

Locating armature grounds (fig. 7-39) may be done with a test lamp, an ohmmeter, or a growler (if it is equipped with test probes and a meter). You then check the dc armature for grounds by placing one probe on the armature shaft and the other probe on successive bars of the commutator until all commutator segments are checked.

Armature opens may be determined with test equipment having test probes to make commutator bar-to-bar contact around the armature (fig. 7-40), Test equipment may be an incandescent lamp with a low-voltage source, a low-reading ohmmeter, a milliammeter with a rheostat and a 6-volt battery, or a growler.

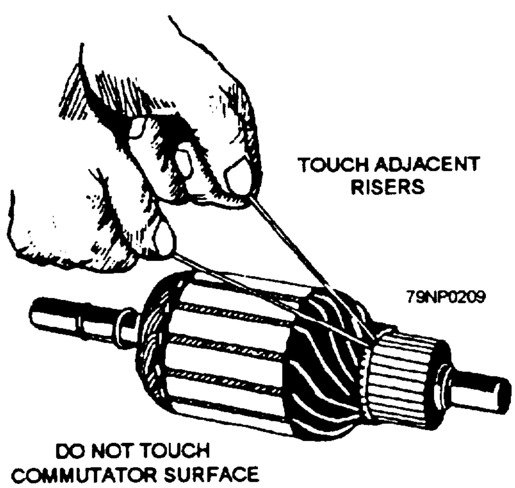


Figure 7-40.—Testing armature coils for an open circuit.

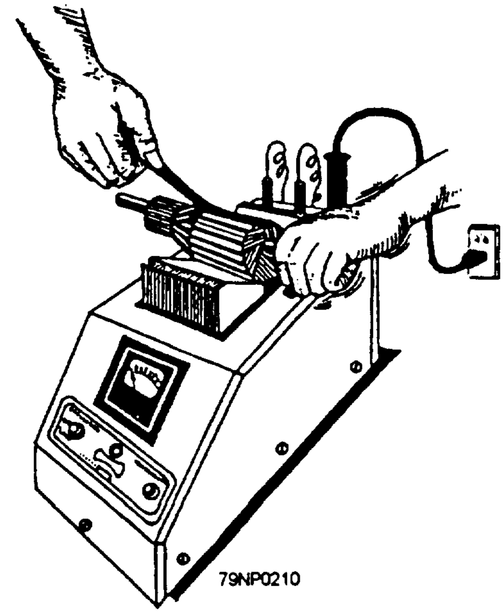


Figure 7-41.—Checking armature shorts with a growler.

An armature coil internally shorted within itself is determined with a growler. The growler (figs. 7-41 and 7-42) is plugged into a 120-volt, 60-hertz power supply and switched to the ON position. A hacksaw blade is held parallel to the windings and run across the top of the armature. The armature is continually rotated in the growler, and the hacksaw blade test made until the complete armature has been checked. If a short exists in the winding below the hacksaw blade, the blade will

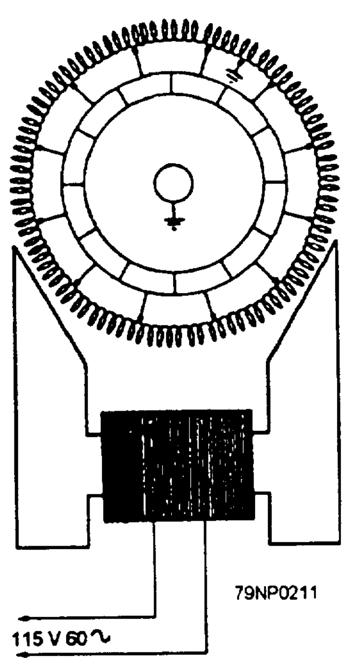


Figure 7-42.—External growler construction.

vibrate noticeably and will cause a chattering noise. Larger armatures, which do not fit in an external growler, may be checked by moving an internal growler over the outside surface of the armature. Internal growlers are used primarily to check stator windings, which will be covered later in this chapter under three-phase stator repair.

You should use a dial indicator for armature commutator radius checks (fig. 7-43). Ensure commutators are not out-of-round more than 1 mil (0.001 inch).

REWINDING PROCEDURES

When tests or observations show that a piece of rotating electrical machinery needs replacing and no replacement is available, rewinding is necessary. The process for rewinding a piece of rotating electrical gear is basically the same for all types of machines. The process can be divided into 9 key steps:

1. Disassembly
2. Burning/stripping
3. Recording data
4. Cleaning
5. Insulating
6. Winding
7. Electrical testing
8. Varnishing
9. Assembly

HAND TOOLS

The hand tools used in rewinding armatures are relatively few and simple. In fact, they are usually handmade by Electrician's Mates engaged in this work. Figure 7-44 shows the following tools:

1. A fiber from, which is used for shaping the coil ends after the coils are placed in the slots
2. A steel slot drift, or tamping tool, which is used for driving the coils to the bottom of partly closed slots
3. A lead lifter, which is used for lifting the coil leads from the commutator risers
4. A hacksaw blade, which is used for removing the fiber wedges that hold the coils in the slots
5. A handsaw, which is used for undercutting the commutator mica between the segments
6. A wedge driver, which is used for driving the fiber wedges out of the slots
7. A lead drift, which is used for cutting off the leads at the risers
8. A rotation indicator, which is used as an aid to determine the proper connections of the windings
9. A wire scraper, which is used for removing the insulation from the ends of the coil leads
10. A wedge inserter, which is used for driving the wedges into partly closed slots

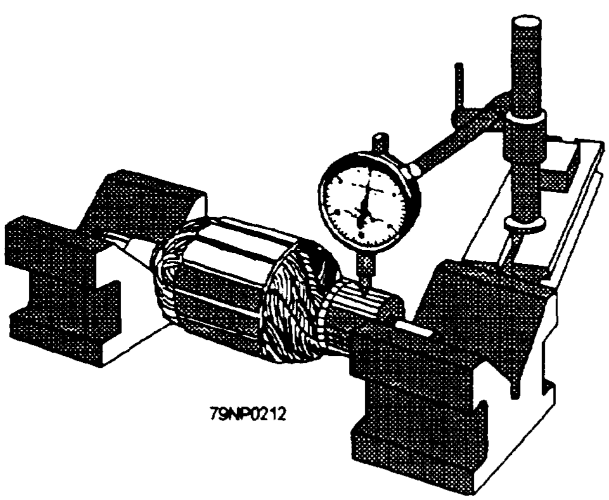


Figure 7-43.—Measuring commutator out-of-round with a dial indicator.

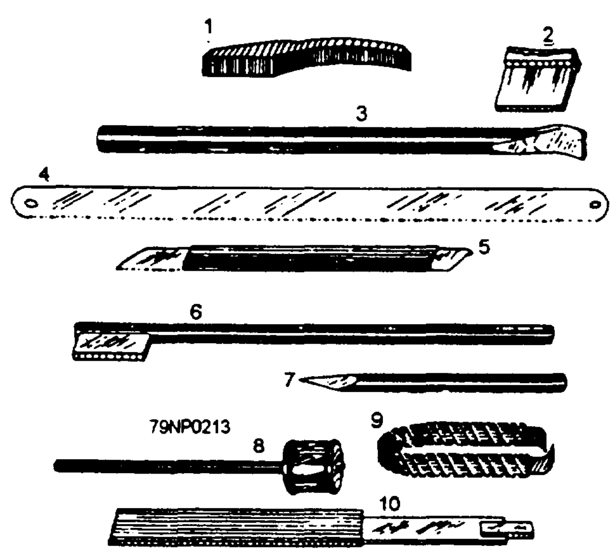


Figure 7-44.—Armature rewinding hand tools.

INSULATING MATERIALS

Electrical insulating materials are classified according to their temperature indices. The temperature index of a material is related to the maximum temperature at which the material will provide a specified life as determined by tests or by experience.

Current-carrying conductors require insulation to isolate them from electrically conductive parts of the unit and to separate points of unequal potential. An understanding of the different types of insulation used will help you in the repair of electrical equipment. The different classes of insulation materials are listed in table 7-6.

There are certain conditions when the rewinding of class A and class B insulated motors with class H insulation becomes necessary. This is done to prevent a recurrence of insulation breakdown and ultimate failure. Examples of such conditions areas follows:

1. Where the location's ambient temperature exceeds the equipment design ambient (usually 50°C or 122°F)
2. Where excessive moisture (usually condensate) is present and the windings are exposed
3. Where the service life of existing equipment is shortened by overload, heat moisture, or a combination of these factors

Silicone insulation is not a "cure all" for motor and generator failures. Before deciding to use silicone insulation, check the installation to determine the cause of failure. Misalignment of bearings, mounting bolts dislocated, a bent shaft, failure or inoperativeness of overload devices, or similar causes may have initiated the failure rather than the insulation itself.

Consideration must be given to the conditions to which the windings will be subjected during winding, varnishing, drying, or baking. Class A, B, and F materials are generally tough and will take a lot of abuse. Class H and N materials are considered somewhat fragile and should be handled with care in order not to damage the resin film.

Varnish

The process of varnishing new or reconditioned windings helps to prolong the life of the machine by preventing the introduction of water vapor and dirt or dust once the machine is placed into operation. In

Table 7-6.—Classes of Insulation

Class Insulation System	Class Material	Materials or Combinations of Materials	Required Thermal Life
A	105	Cotton, silk, and paper when suitably impregnated or coated, or when immersed in a dielectric liquid such as oil.	105°C (221°F)
B	130	Mica, glass fiber, asbestos, etc., with suitable bonding substances.	130°C (266°F)
F	155	Mica, glass fiber, asbestos, etc., with suitable bonding substances.	155°C (311°F)
H	180	Silicone elastomer, mica, glass fiber, asbestos, etc., with suitable bonding substances such as appropriate silicone resins.	180°C (356°F)
N	200	Mica, glass fiber, asbestos, etc., with suitable bonding substances.	200°C (392°F)

addition, varnishing helps windings keep their form and adds mechanical strength. The procedures for varnishing new windings are given in table 7-7.

Polyamide Paper

Before placing windings in a stripped stator or armature the slots must be insulated to prevent current leakage to ground and to insulate the separate windings from one another. Polyamide paper is available in various thicknesses and dielectric strengths for this purpose.

There are four types of paper insulation used in winding.

1. Slot insulation, which is used to separate the coil sides in the slot from the laminations. Prepared from two 7 mil (0.007") pieces of polyamide.
2. Coil side separators, which are placed on top of coil sides as they are laid into slots to prevent two coil sides from touching one another within the same slot. May be made of flat silicon glass insulation or formed (curved) polyamide paper.
3. Slot wedges, which are used to close up slots once all coil sides are inserted. They may be made of flat silicon glass insulation or formed (curved) polyamide paper.
4. Phase insulation, which is used to prevent the ends of adjacent coils from touching one another. It is made of .007 inch polyamide paper.

ELECTRICAL TESTS

Electrical tests are performed on new windings to ensure connections are proper and that workmanship is

Table 7-7.—Varnishing Procedures

PROCEDURE	Processing Rebuilt Armature Coils, Stator Coils, and Field Coils
	Class A, B, F, H, and N
Step 1 Prebaking	Put into oven pre-heated to 150°C (302°F). Hold at temperature for approximately 2-4 hours depending on size of equipment. Cool to approximately 60°C (140,198F) by convection. If necessary, forced air cooling may be used provided the air is filtered with a 50 micron filter.
Step 2 Dipping	Immerse hot coils or wound apparatus (60°C) (140°F) in organic varnish (modified polyester, class 155, MIL-I-24092, grade CB or class 180 grade CB) until bubbling ceases. Viscosity should be between 200 and 1200 centipoises depending upon the varnish used(refer to MIL-I-24092). Dip with commutator up.
Step 3 Draining	Drain and air-dry for 1 hour. Rotate wound apparatus during draining to prevent pocketing the varnish. Drain with commutator down.
Step 4 Cleaning	After draining but before baking, the metal surfaces of the armature, the bore of the stator and the pole faces of the field structure should be cleaned by wiping with a cloth moistened with solvent.
Step 5 Baking	Put into circulating type forced exhaust baking oven (six changes of air per minute) at a temperature of 150°C (302°F) for 6-8 hours.
Step 6 Cooling	Remove from oven and cool to approximately 40°C (104°F).
Step 7 Second treatment	Repeat steps 2 (for 1 minute immersion), 3, 4, 5, and 6. Dip with commutator down, drain with commutator up.
Step 8 Third treatment	Repeat steps 2 (immerse until bubbles cease but no longer than 2 minutes), 3, 4, 5, and 6. Dip with commutator up, drain with commutator down.
NOTE: This procedure applies to solvent-type varnish. For in-place trickle varnishing using solventless varnishes and vacuum-pressure impregnation, see Naval Ships' Technical Manual, chapter 300. For solventless dip varnish procedures, refer to manufacturers instructions.	

satisfactory to prevent improper operation of the equipment. Tests should be performed before and after varnishing in order to ensure reliability of the equipment and prevent the need for rework as much as possible.

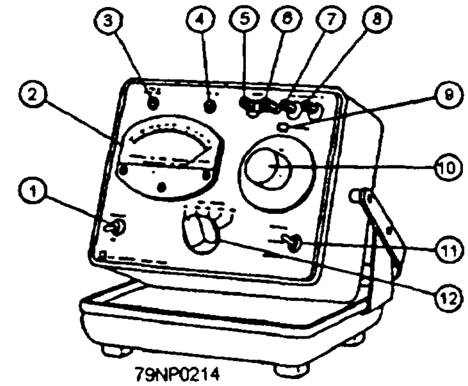
Insulation Test for Grounds

Once coils have been replaced or reconditioned, the equipment insulation must be tested for proper values. Insulation tests are made as described earlier with a megohmmeter (fig. 7-45). Values must be as specified in table 7-5 to ensure safe operation of the equipment.

High-Potential Test

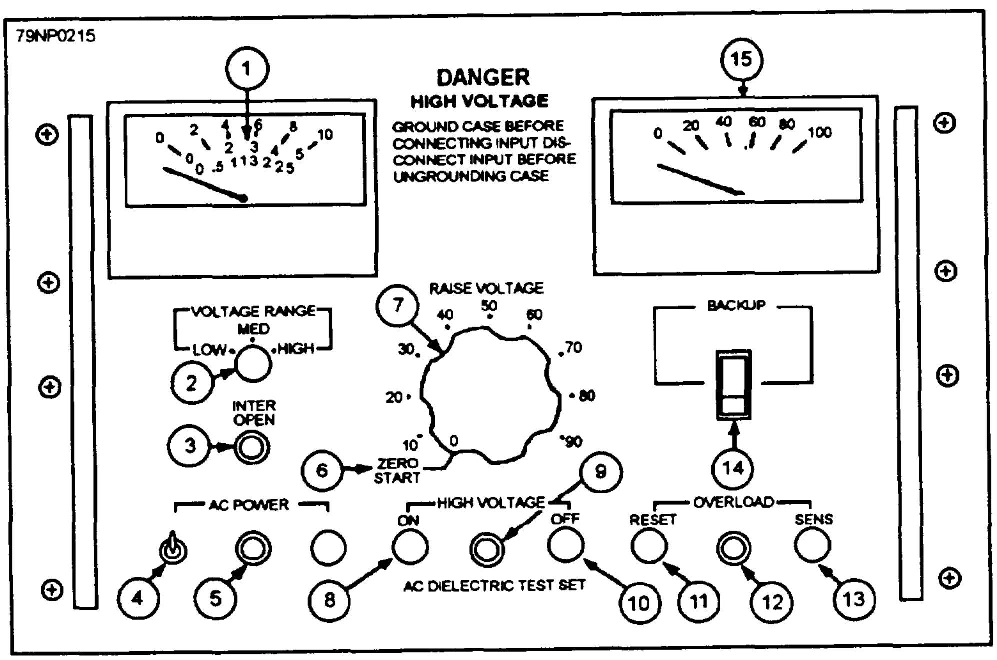
A high-potential testis made by applying (between insulated parts) a test potential that is higher than the rated operating voltage. High potential tests are frequently used in connection with the repair or reconditioning of naval equipment ashore.

The purpose of the test (fig. 7-46) is to break down the insulation if it is weak, thereby indicating defective material and workmanship, and permitting replacement before actual use. Since this is designed to break down



1. **Power switch**
2. **Indicating meter**
3. **Ohmmeter high-range setpoint**
4. **Voltmeter high-range setpoint**
5. **Guard**
6. **Ground**
7. **(+) connection**
8. **(–) connection**
9. **Power indicating light**
10. **Multiplier**
11. **3-position toggle switch**
12. **Test voltage selector switch**

Figure 7-45.—Type 1863 Megohmmeter.



1. **AC voltmeter**
2. **Voltage range selector switch**
3. **Interlock open indicating light**
4. **AC power switch**
5. **AC power indicating light (white)**
6. **Zero start switch**
7. **Raise voltage control**
8. **High-voltage "on" switch**
9. **High-voltage indicator light (red)**
10. **High voltage "off" switch**
11. **Overload reset switch**
12. **Overload indicator light (red)**
13. **Sensitivity control**
14. **Backup circuit breaker switch**
15. **Milliamp meter**

Figure 7-46.—AC Dielectric test set.

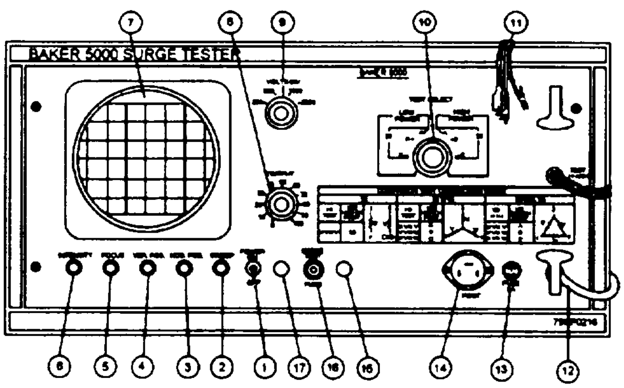
the insulation, it is considered a destructive test and should be performed only when necessary.

The application of each high-potential test tends to weaken insulation even though it does not produce actual failure at the time. Also, the use of high-potential tests requires special equipment and safety precautions.

When making high-potential tests on electrical equipment that has been reconditioned or rewound in a shop, you should **NOT** come in contact with any part of the circuit or apparatus. Never touch the winding after a high-potential test has been made until it has been connectd to ground to remove any static charge it may have retained.

Connect all leads to the circuit being tested to one terminal of the source of test voltage. All the leads to all the other circuits and all metal parts should be connected to ground to shunt the voltage produced by transformer action. No leads are to be left unconnected for a high-potential test as this may cause an extremely severe strain at some point of the winding. For example, to make a high-potential test on a rewound armature, short-circuit the commutator segments by wrapping one or more turns of bare wire around the commutator. Then, apply the high-potential test voltage across the common connection of all the commutator segments and the grounded armature shaft.

A high-potential test should not be made on any equipment until the insulation resistance has been measured and found to be satisfactory as per *NSTM,* chapter 300.



1. **Power switch**
2. **Sweep (trace-length) control**
3. **Horizontal sweep adj.**
4. **Vertical sweep adj.**
5. **Focus**
6. **Intensity control**
7. **Oscilloscope screen**
8. **Output voltage control**
9. **Volts/Div**
10. **Test/select switch**
11. **Test leads**
12. **AC power cord**
13. **Fuse**
14. **Foot switch connection**
15. **Test indicating lamp**
16. **Surge Test switch**
17. **Power indicating lamp**

Figure 7-47.—Baker 5000 Surge Comparison Tester.

Surge Comparison Test

The surge comparison tester (figs. 7-47 and 7-48) uses the principle of impedance balance to simultaneously test turn-to-turn, coil-to-coil, phase-to-phase, and coil-to-ground insulation; in addition, qualitative evaluations are made of a winding's likelihood of satisfactorily passing resistance, impedance, turn balance, and high-potential tests.

Resistance Balance Test

Using a Wheatstone bridge (fig. 7-9) or a digital voltmeter (fig. 7-50), the resistances of the windings are measured very accurate] y to determine whether the phases are electrically balanced.

The lowest resistance readings are subtracted from the highest resistance readings. This number is compared to 5% of the highest resistance reading. If the difference is lower than 5% of the highest resistance reading the windings are said to be electrically balanced.

ARMATURE REWINDING

Once an armature has tested bad and been disassembled, the process of rewinding it can begin.

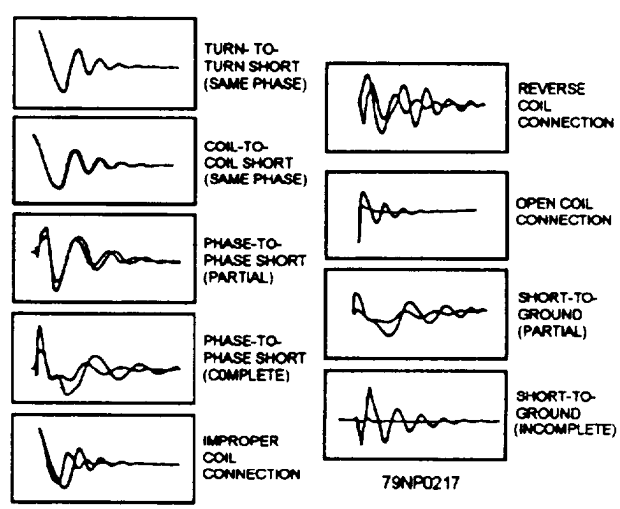
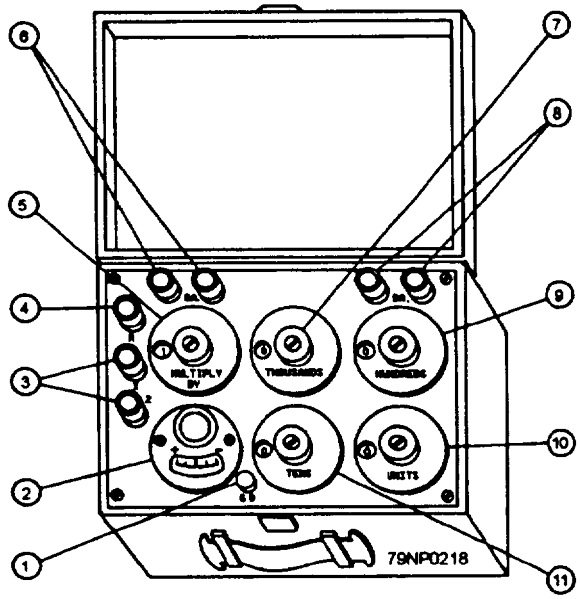
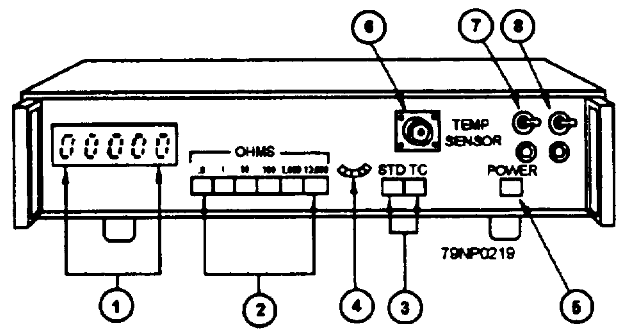


Figure 7-48.—Representative surge test waveforms.



1. Power pushbutton switch
2. Galvanometer
3. Test connection points
4. Connection point to use meter as a rheostat
5. Resistance range setting
6. Terminal for connection of external galvanometer
7. 1000s slide wire resistor rotary control
8. Connection point for external battery
9. 100s slide wire resistor control
10. 1s slide wire resistor control
11. 10s slide wire resistor control

Figure 7-49.—Typical Wheatstone bridge.



1. Digital readout
2. Range selection pushbuttons
3. Temperature coefficient selector switch
4. Zero adjust
5. Power switch
6. Temperature compensation probe connection
7. Voltage lead connection
8. Current lead connection

Figure 7-50.—Digital ohmmeter.

The process of armature rewinding involves stripping the armature, recording the winding data, insulating the core, placing machine-wound coils in the slots or rewinding the coils into the slots by hand, connecting the commutator, testing the windings, varnishing, baking, and balancing.

Stripping

Before stripping an armature, record all available winding data on an armature data card, as shown in figure 7-51, for use in rewinding and for future reference.

DC GENERATOR-MOTOR DATA

NAME PLATE DATA

Make ____________________ Serial # ____________________

Volts________ Amps ____________________ KW/HP ____________________

RPM ________ Temp Rise ____________________ Motor Type ____________________

Model________ Style ____________________ Frame # ____________________

ARMATURE DATA

Lap, or Wave Winding____________ No. of Slots____________________

No. of Segments______________ Lead Swing____________________

Type of Connection ____________ Simplex, or Duplex, or Triplex Winding______________

Coil Pitch ________________ Coils per Slot____________________

Progressive, or Retrogressive Winding __ Wire Size____________________

Turns per Coil ______________ Commutator Pitch ____________________

No. Active Coils______________ No. Dummy Coils ____________________

Name ____________________________________ Date ________

Figure 7-51.—A dc generator or motor data card.

After recording the initial winding data, perform a bar-to-bar test to determine if the winding is lap or wave; then record this information on the armature data card. Now you are ready to disconnect and remove the coils.

During this process, record the winding data that was impossible to obtain before stripping the armature. Remove the banding wires by cutting them in two places. If banding wires are not used, remove the wedges in the slots. A simple means of removing the wedges is to place a hacksaw blade, with the teeth down, on the wedge. Tap the top of the blade to set the teeth in the wedge, and then drive out the wedge by tapping the end of the blade.

Next, unsolder the coil leads from the commutator and raise the top sides of the coils the distance of a coil throw (distance between the two halves of a coil). The bottom side of a coil is now accessible, and the other coils can be removed. Exercise care to preserve at least one of the coils in its original shape to use as a guide in forming the new coils. Next, record the wire size, the number of turns in a coil, and the type of insulation on the coils and in the slots.

The raise the coils without damaging the insulation, use a small block of wood as a fulcrum resting on the armature core and a steel bar or piece of wood as a lever.

After the coil is partly raised, drive a tapered, fiber wedge between the top and bottom coils within the slot to finish raising the top coil from the slot. After stripping the armature, remove all dirt, grease, rust, and scale by sandblasting. File each slot to remove any burrs or slivers, and clean the core thoroughly with dry, compressed air. Dip the cleaned armature core in a varnish and bake according to the steps in table 7-7, using a diluted varnish (20 percent varnish, 80 percent thinner) of the same type to be used after winding.

This treatment prevents the formation of oxides and forms a base for the adherence of the final varnish treatment.

Winding Armature Coils

Formed coils are wound on a coil-winding machine and pulled into the desired shape on the forming machine. The shape of the coil is determined by the old coil. The two wires forming the leads are taped with cotton or reinforced mica tape. The binder insulation, consisting of cotton or glass tape, is applied to the entire coil surface.

The coil is now sprayed with a clear, air-drying varnish (grade CA), which conforms to Military Specification MIL-V-1137. After the varnish has dried, the coil ends are tinned to ensure a good connection to the commutator.

Preformed windings should be used on large armatures, but it is more practical to wind small armatures by hand. End room is very limited, and windings must be drawn up tightly to the armature core. Figure 7-52 shows the methods of winding an armature by hand. One armature in the figure is small enough to be hand held. The other, too heavy for this, rests on a support.

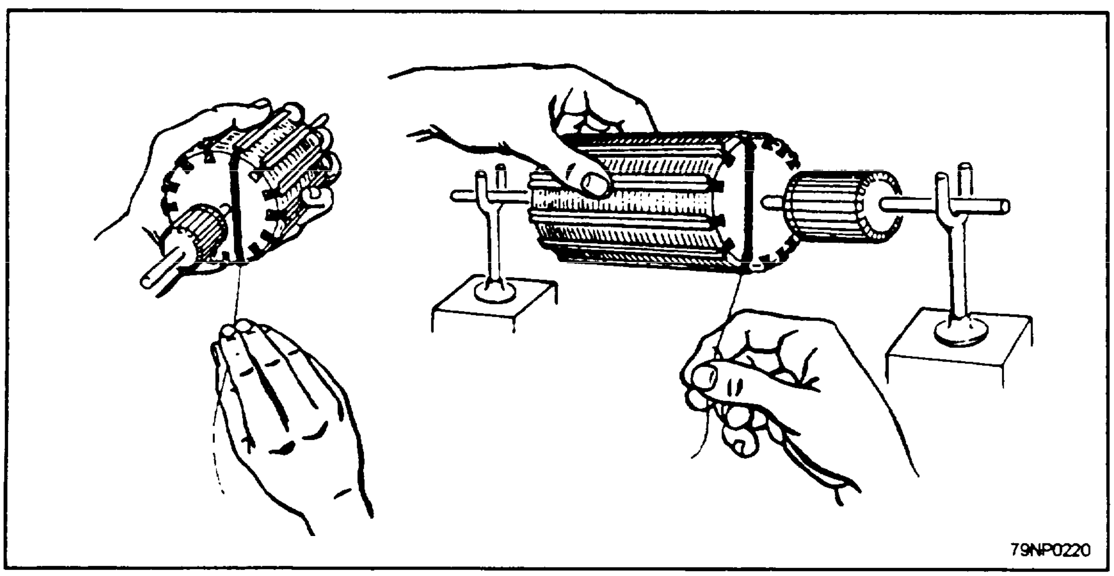


Figure 7-52.—Winding armatures by hand.

Placing Coils in Slots

Before assembling the coils, insulate the armature core. This step is extremely important if the armature contacts the coils, you will have to do your work over. Clean the core slots and ends and true up the laminations. Use polyamide paper, and let it extend one-fourth inch beyond the slots to prevent the edges of the laminations from injuring the coils.

The ground insulation consisting of flexible mica wrappers or layers of reinforced mica tape, is applied to the coil sides that lie in the slots. Next, the formed coils are placed in the slots; the lower side first and then the upper side, until all the coils are inserted and the winding is completed. Be certain that the coil pitch is correct. A strip of rigid laminate, type GME-MIL-P-15037, is placed in each slot between the lower and upper coil sides. A similar strip is placed at the back and front of the armature where top and bottom sides cross each other. If the slots have straight sides, they are filled up with a strip of rigid laminate, type GME-MIL-P-15037, on the tops of the coils so they can be held down by the banding wires. In some armatures the slots are shaped so that fiber wedges can be driven in each slot from one end to hold the coils in place.

Before soldering the coil ends to the commutator segments, test the winding for grounds, opens, and shorts. When soldering, exercise care to prevent the solder from falling or running down the back of the commutator. This could result in a short circuit. Tip the armature so that the solder will not flow to the back of the commutator. Place the tip of the soldering iron on the commutator near the riser and wait until the iron heats the riser sufficiently to melt the solder. Touch the solder to the riser and allow it to flow around the lead and into the wire slot, and then remove the iron.

An ordinary soldering iron cannot supply sufficient heat fast enough to perform a satisfactory soldering job on a large armature. Therefore, apply a soft flame from an acetylene torch to the outside end of the commutator segments to the riser ends where connections are made. Tin the coil ends that will be connected to the commutator risers with a soldering iron. Next, tin the slots in the commutator risers with heat from the torch. Then make the connections while applying the flame to the outside end of the commutator segments. When making the commutator connections, wrap the winding with the proper tape for protection. Too much heat can damage the winding insulation. The completed armature winding is checked electrically for continuity and for shorted turns.

To prevent centrifugal force from throwing the coils outward, wind a band of high-grade, steel piano wire on a strip of Lest.kroid placed around the armature and over the coils about 2 inches from the edge of the core. Do this before the armature has been dipped and after prebaking. Banding wires should be placed on the armature windings while hot because then the wire is more flexible and can be pulled tighter. When the first banding wire is wound on the armature, small tin clips, with insulation under them, are inserted under the wire. When the required number of turns has been applied, the ends of these clips are bent over and hold the wires tightly side by side. The clips are then soldered with tin solder, and a thin coat of solder is run over the entire band to secure the wires together.

The end windings are secured, if necessary, by groups of wire wound on insulating hoods to protect the coils. On the commutator end, strips of thin mica with overlapping ends are usually placed on the commutator neck and held by a few turns of cord. On large armatures, banding wires are sometimes placed over the laminated portion of the armature. The laminations on these armatures have notches in which the banding wire is placed

If you have to rebuild a large commutator, use molded mica to insulate between the spider and the commutator. Commutator mica is used as insulation between the segments. After the commutator is assembled, it is heated and tightened with a clamping ring.

If shrink rings are provided, they are not put on until the commutator has been tightened (while hot) and the banding wires tightly placed around it. If defective, small commutators are usually completely replaced.

REWINDING FIELD COILS

Remove the old field coil from the pole piece and, if spare coils are available, install a new one. If a new coil must be made, record all pertinent coil data as the old coil is stripped.

This data should include the following information:

1. The dimensions of the coil, both with the tape on and with the tape removed
2. The weight of the coil without the tape
3. The size of wire
4. The type of insulation

The two general classes of coils are shunt field coils and series and commutation field coils. Shunt field coils consist of many turns of tine wire and series and commutating field coils consist of fewer turns of heavy wire.

Shunt Coils

The equipment for rewinding shunt coils include a lathe with a suitable faceplate, which can be turned at any desired speed, and an adequate supply of the proper size wire wound on a spool, which can be supported on a shaft so that it is free to turn. Friction should be applied to the spool to provide tension on the wire. Secure a coil form having the exact inside dimensions of the coil to the lathe or faceplate. The form for shaped field coils can be made from a block of wood shaped exactly to the required size and provided with flanged ends to hold the wire in place (fig. 7-53). One of the flanges should be removable so that the finished coil can be taken from the forming block.

The wire is wound from the spool onto the forming block for the required number of turns. The turns must be evenly spaced, one against the other, until the winding procedure is completed. The turns of the completed coil are secured by tape, and the wire leading to the spool is cut, leaving sufficient length to make the external connections. The completed coil must be checked electrically for continuity and for shorted turns.

The coil is now prebaked and varnish treated as specified in table 7-7. When varnish-treated, the finished field coil should withstand a high-potential test of twice the rated excitation voltage plus 1,000 volts.

Series and Commutating Coils

Series and commutating field coils are frequently wound with strap (rectangular) or ribbon copper instead of round wire. These coils have only a few turns that are wound in a single turn per layer.

A series coil wound (with ribbon copper) on edge is illustrated in figure 7-54. It is more difficult to bend the copper ribbon, but it has an advantage in that both terminal leads protrude on opposite sides of the coil. Thus, the connections can be made very easily compared to the strap-wound coils, which have one coil end at the center and the other coil end at the outside of the. coil. The strap-wound construction requires leading the inside coil end over the turns of strap in the coil.

After the winding is completed, the coil is tested electrically for continuity and shorted turns. It is then prebaked, varnished, and tested for polarity, grounds, opens, and shorts, as described previously, at each stage in turn.

Testing Field Coils

Before installing a new or repaired coil, test it for shorts, opens, and grounds, and determine its polarity. The same precautions that were observed during removal of the coil must be observed when installing it. All of the shims originally removed from the pole piece must be in position when it is replaced. With the coil positioned in the machine, it should be temporarily connected to the other coils in the field circuit and a compass and battery again used to check its polarity. For this test, connect the battery to the proper field leads, and check the polarity of all the coils with the compass (fig. 7-55). Adjacent poles must be of oppsite polarity. If necessary, the polarity of the new coil can be reversed by reversing the leads. When the polarity is correct, the coil is connected, and the pole-piece bolts are tightened. Air gaps should be measured to ensure uniformity.

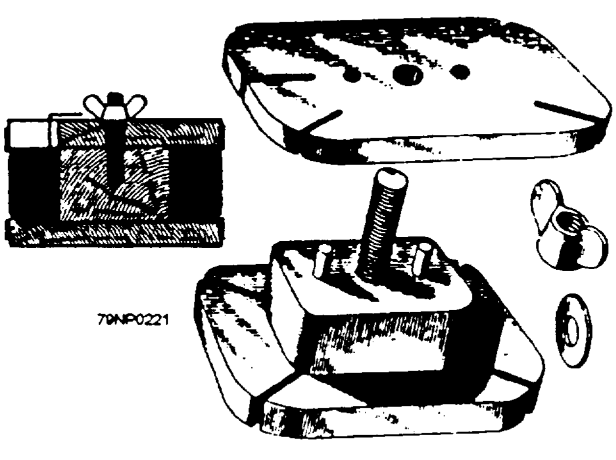


Figure 7-53.—Coil form for field coils.

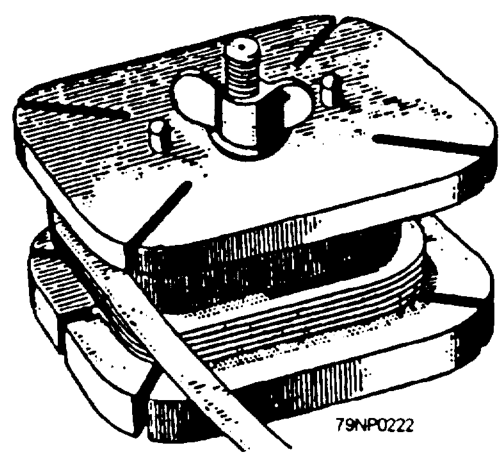


Figure 7-54.—Edge wound series coil.

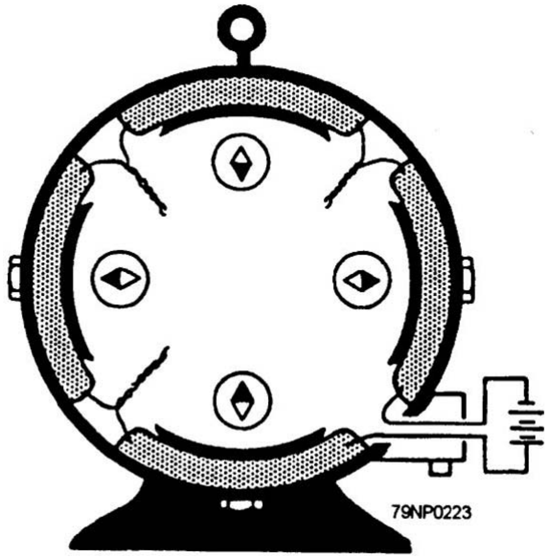


Figure 7-55.—Testing the polarity of field coils.

THREE-PHASE STATOR TESTING AND REPAIR

In testing stator coils as in testing dc armatures, you will find the most common troubles to be grounds, opens, and shorts.

The internal growler (fig. 7-56) is used to check for shorts and opens on the inside of stators and stationary fields, or on large armature surfaces where an external growler cannot be used To make such checks, connect the internal growler to the rated ac source. Run the internal growler over the coils of a motor or generator and listen over for a buzz (fig. 7-57). When a shorted coil exists, transformer action causes the growling noise. Coils may be tested for

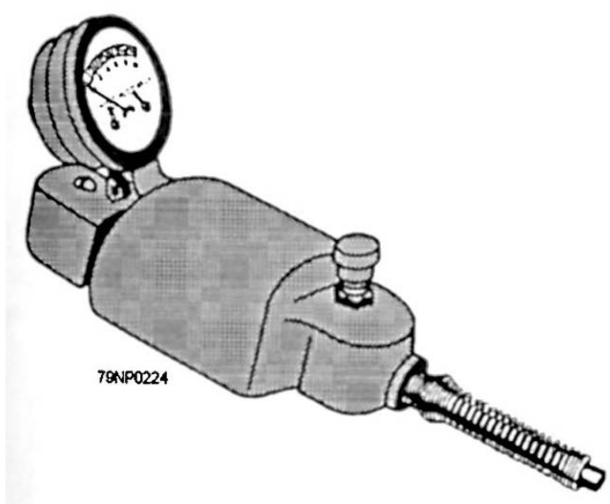


Figure 7-56.—Internal growler.

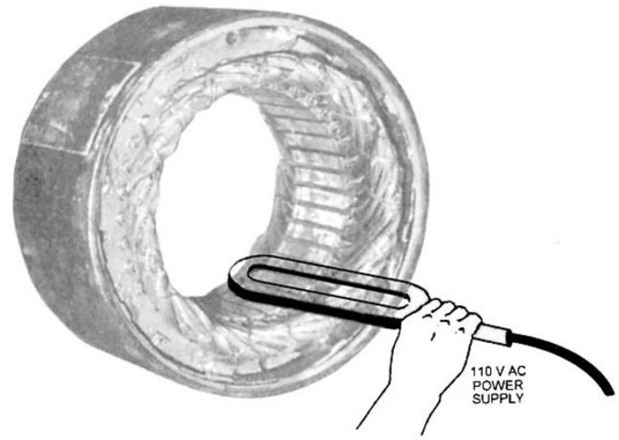


Figure 7-57.—Testing a three-phase stator for shorts.

opens by deliberately shorting each coil. A buzz at any of the coils indicates a closed circuit.

If you use a meter-indicating internal growler (fig. 7-56), a pointer deflection indicates a short; no deflection of the pointer indicates an open circuit.

THREE-PHASE STATOR REWINDING

When tests or observation determine that a three-phase stator needs rewinding, retain data must be recorded.

It is important to keep an accurate record of all the pertinent data concerning the winding on the stator data sheet, as shown in figure 7-58. This information should be obtained before stripping; if not, it can be obtained during the stripping operation in the same manner as for dc armatures.

MAKE

HP	**RPM**	**VOLTS**	**AMP**
HERTZ	**TYPE**	**FRAME**	**STYLE**
TEMP.	**MODEL**	**SERIAL**	**PHASE**

NO. OF COILS	**NO. OF SLOTS**	**CONNECTION**
SIZE WIRE	**NO. OF TURNS**	**NO. OF GROUPS**
COILS-GROUP	**NO.OF POLES**	**PITCH OF COIL**

Figure 7-58.—Stator data sheet.

You rewind new coils for ac stator windings in the same manner as for dc armatures, and you have to form and shape them before you place them in the stator slots (7-59).

You now insert all the coils in the stator slots, insulate the ends, and drive the slot wedges in place (fig. 7-59). Extending from each coil will be the start and finish leads; these leads must be connected to form a series of coils called a pole-phase group.

In arranging these coils into pole-phase groups, start by bending (forming) the inside lead of the first coil toward the center, and then twist the outside lead of that coil and the inside lead of the next coil together. Connect the outside lead of the last coil with the inside lead of the next coil and bend the outside lead of this coil away from the center. Repeat this procedure for each of the pole-phase groups all around the stator. Do not solder the connection at this time.

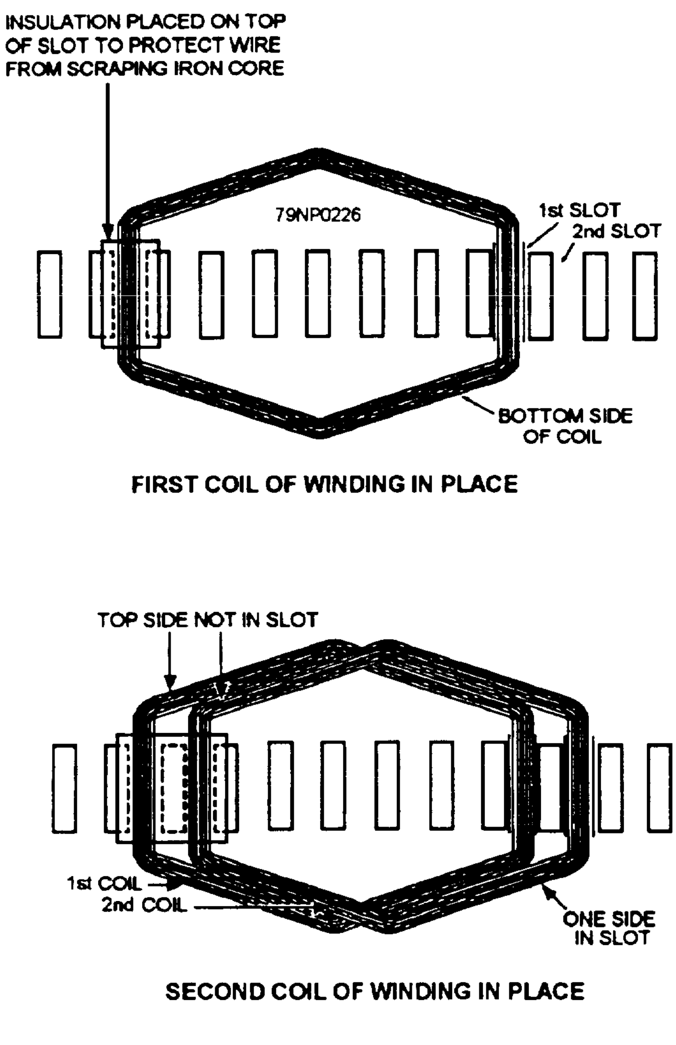


Figure 7-59.—Placing coil sides in slots.

After twisting the ends together, check the individual groups to determine that the proper number of coils have been connected together in each pole-phase group and that they have the proper polarity. Then solder the twisted connections and cut off the ends so that the soldered stubs are about three-quarters of an inch long. Insulate the stubs with acrylic glass.

If the distance to the bearing brackets (frame of the machine) is small, bend the insulated stubs so that they may be laced to the end of the coils before the stator is dipped. Now the stubs will not come in contact with the frame when the stator is assembled.

In practice, the coils that comprise the pole-phase groups are usually gang wound. Gang-wound coils eliminate the need for stubbing because the coils are wound with a continuous length of wire.

Series-Wye Winding

Before connecting the pole-phase groups together, construct a diagram containing the pole-phase groups in each phase and the number of poles for the particular machine, as illustrated in figure 7-60. Pole-phase groups for each phase are connected to produce alternate north and south poles, and the direction of current flow through each pole-phase group is indicated by the arrows.

The As, Bs, and Cs phase leads (s stands for start) are all connected to one polarity of a small battery; the Af, Bf, and Cf phase leads (f stands for finish) are all connected to the other polarity of the battery. If connections are correct, a compass will give opposite polarity as it is moved from one coil group to another. Note the changing polarity in figure 7-60.

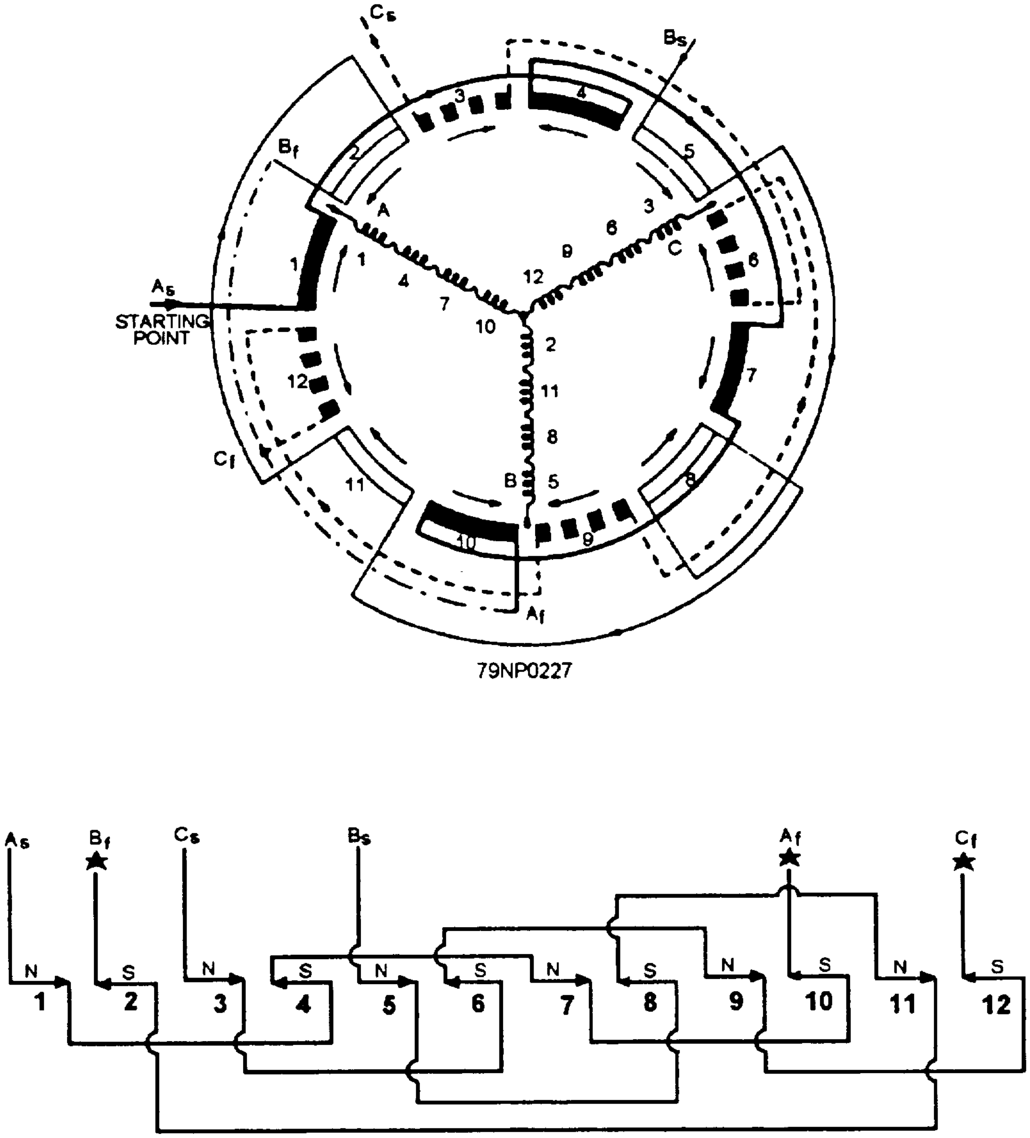


Figure 7-60.—Three-phase, four-pole, series-wye winding.

All the arrows on the line leads (fig. 7-60) indicate current in the same direction toward the center of the wye. Actually, the current at one instant may enter the phase A lead and leave by the other two leads. At the next instant, current may enter through phases A and B and leave by phase C (fig. 7-61). At any instant, current is flowing into and leaving the wye by at least one lead. This illustrates how a four-pole motor or generator actually functions. In rewinding, however, having the current going in at all phases and ending at the internal star connection (figs. 7-60 and 7-61) is best for bench testing the stator.

The series-wye connection (figs. 7-60 and 7-61) is employed in ac machines designed to operate at a comparative y high voltage. Machines that require a relatively high current usually are wound in a multiple or parallel arrangement.

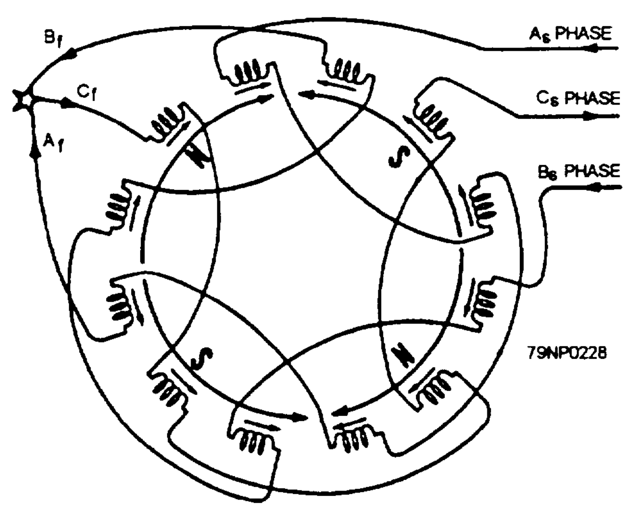


Figure 7-61.—Three-phase, four-pole, series-wye winding showing the four poles.

Parallel-Wye winding

To connect the machine for three-phase, four-pole, parallel-wye operation, use the diagram shown in figure 7-62 with the same number of pole-phase groups and the same assumed directions of current flow through the groups as in the series-wye connection the pole-phase groups of the three phases must be connected so that the current flows through the various groups in the directions indicated to obtain alternate north and south poles. Again, connect the battery, as previously described, by connecting A, B, and C start phase to one side of the battery; and A, B, and C finish phases to the other side. Again the 12 compass polarities should be indicated in one revolution of the stator.

The only difference between the parallel-wye winding (fig. 7-62) and the series-wye winding (fig. 7-60) is the four pole-phase groups, which were originally in series in any one of the phases, but are now split into two parallel paths of two pole-phase groups. In phase A the same coil groups are used, but pole-phase groups 1 and 4 are placed in parallel with pole-phase groups 10 and 7, resulting in an increase in the current-carrying capacity. The voltage drop across that phase remains the same without changing the number of pole-phase groups.

Series-Delta Winding

The same machine connected for three-phase, four-pole, series-delta operation is illustrated in figure 7-63. The same pole-phase group numbers are allotted to the same phase windings, and the directions of current flow through the groups are the same as for the other examples.

Note the difference in the series-wye winding (fig. 7-60) and the series-delta winding (fig. 7-63). In the series-delta winding, the three phases are connected so that they form a delta, and the external connections are made at the three corners of the delta.

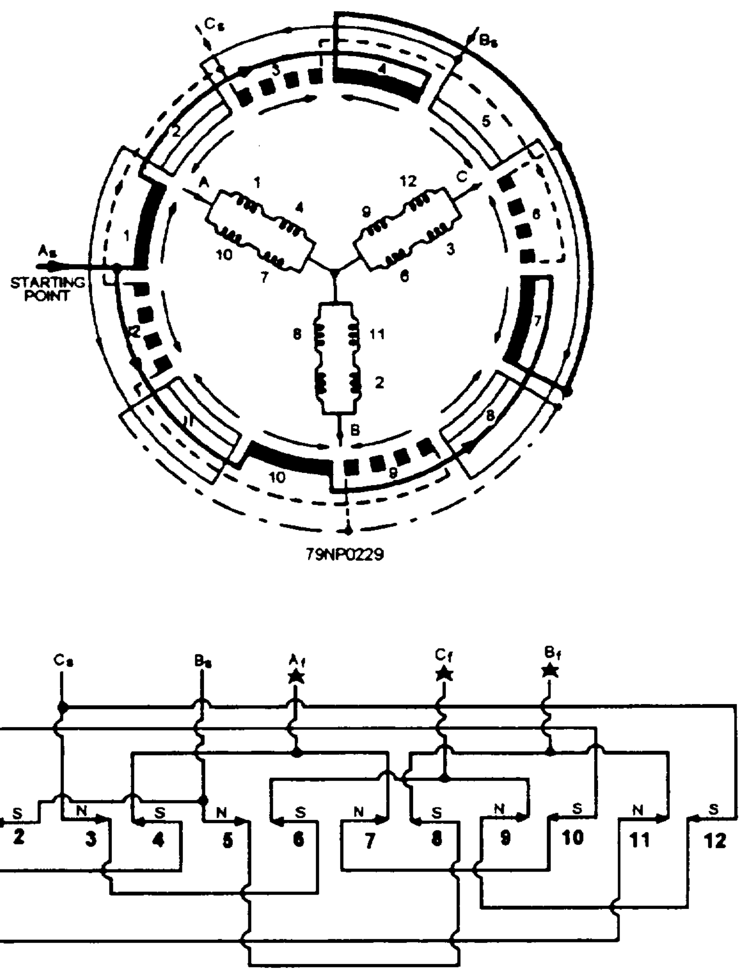


Figure 7-62.—Three-phase, four-pole, parallel-wye winding.

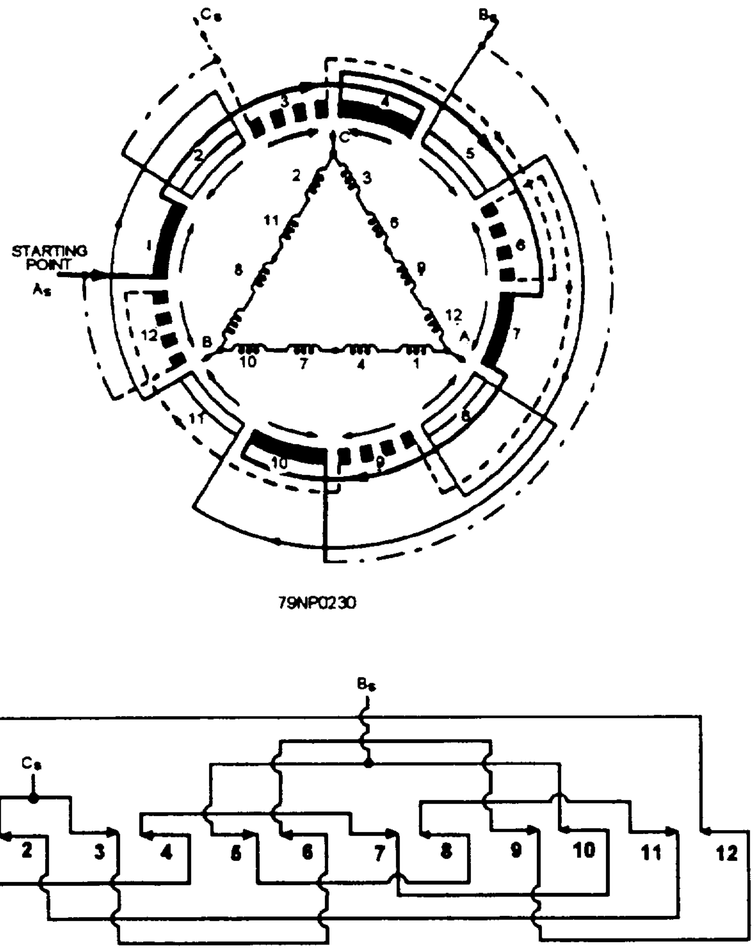


Figure 7-63.—Three-phase, four-pole, series-delta winding.

Parallel-Delta Winding

The machine used in the other examples, connected for three-phase, four-pole, parallel-delta operation is shown in figure 7-64. The phase windings contain the same pole-phase group numbers, and the polarities of the pole-phase groups are the same as in the previous cases.

POST WINDING TESTS

Once repairs have been completed and the unit has been assembled, it is necessary to conduct tests to ensure that all work has been satisfactorily completed. These tests include the following:

1. Roper direction of rotation
2. Proper speed
3. Normal bearing and stator temperature rise
4. Balanced phase currents
5. No unusual noise or vibration

Testing Direction of Rotation

Once the unit has been installed and aligned, it should be tested for proper direction of rotation. This should be done prior to coupling the motor to the driven load if possible. Running some types of equipment in the wrong direction may cause a hazard to personnel or damage the equipment.

Once any danger tags have been properly removed the equipment is ready to be "bumped" or momentarily energized to test for rotation. Ships force should be on hand to verify the rotation of the equipment is proper.

If the direction of rotation is proper, the unit maybe coupled and further tests conducted. If the direction of rotation is incorrect, the direction should be reversed by one of the following methods.

REVERSING DIRECTION OF ROTATION OF DC MOTORS.— The two methods for reversing a dc

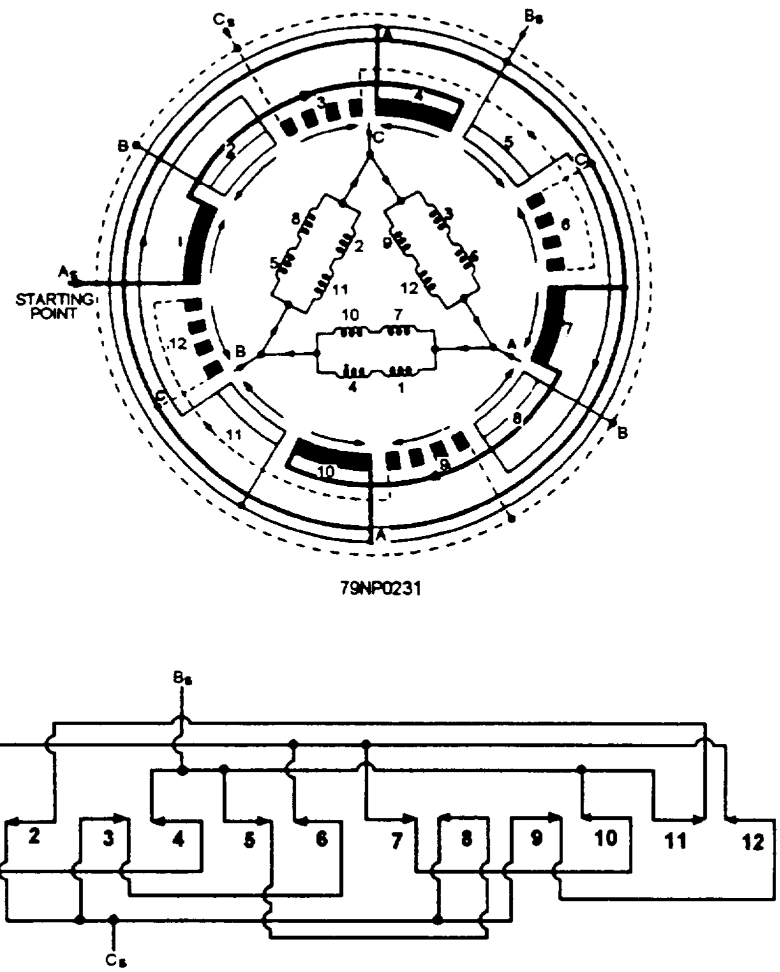


Figure 7-64.—Three-phase, four-pole, parallel-delta winding.

motor are (1) changing the direction of current flow through the armature leads and (2) changing the direction of current flow through the motor fields. In compound motors the reversing of rotation is easier using the first method since a single element is involved. If the second method is used, it becomes necessary to reverse the current through both the series field and shunt field windings.

REVERSING DIRECTION OF ROTATION OF A THREE-PHASE MOTOR.— To reverse the direction of rotation of a three-phase motor, all that needs to be done is to reverse the connections of any two of the three leads of the motor. That is, reverse either the A and B, A and C, or B and C phase leads.

Checking Motor and Generator Speeds

Tachometers indicate, in revolutions per minute (rpm), the turning speed of motors, generators, and other rotating machines. With the unit operating under normal conditions, use a portable tachometer (fig. 7-65),

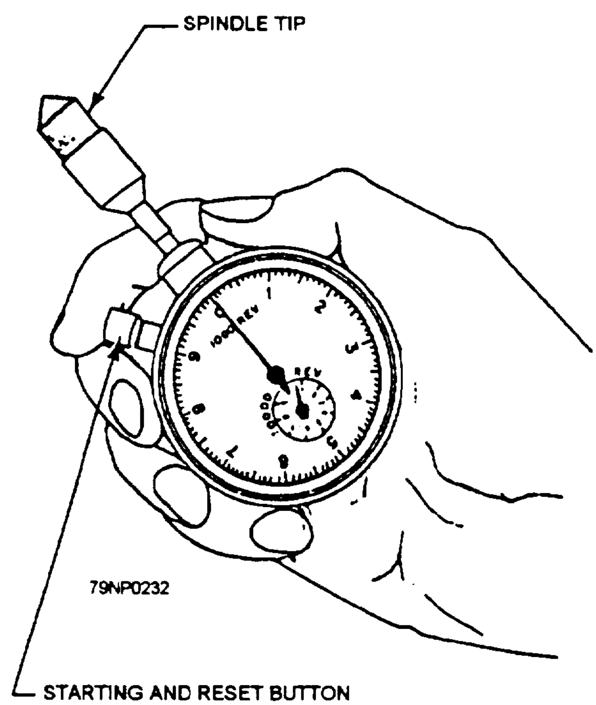


Figure 7-65—A chronometric tachometer.

or stroboscope (fig. 7-66), to measure the speed of a motor or generator after rewinding.

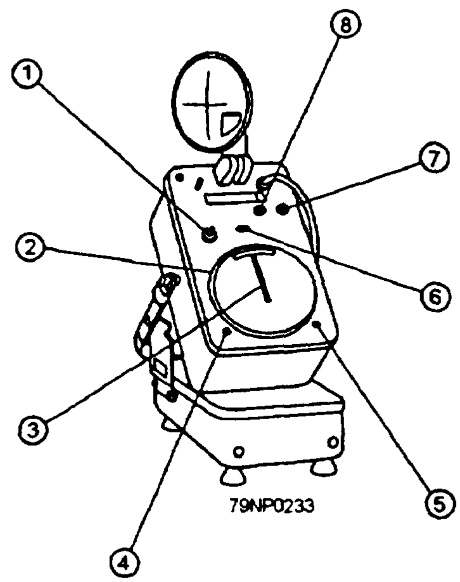
Temperature Testing

Before operational testing the unit, thermometers should be placed at each bearing location and at the mid-point of the stator as a minimum. The ambient temperature should be recorded for each thermometer. Once the unit is placed in operation the temperature of each location should be frequently noted and recorded. Any unusual/rapid temperature rise must be investigated and corrected before the test can be completed.

NOTE: Check bearing temperatures frequently during operation. Temperatures should not exceed 180°F.

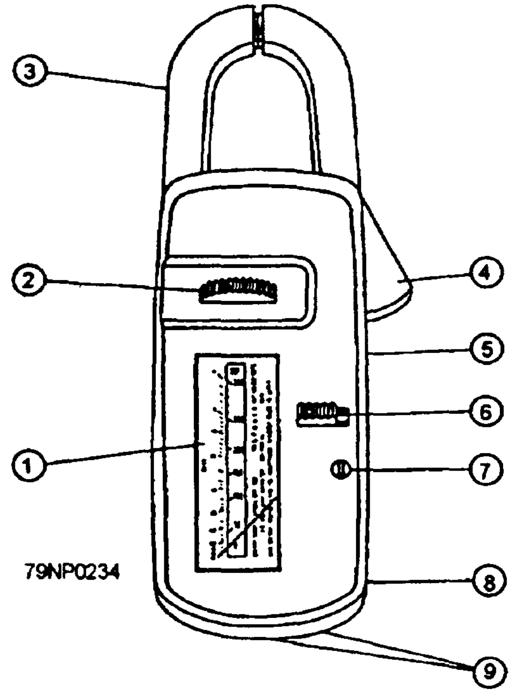
Testing Phase Current Balance

During operation, the phase current of the unit should be checked to ensure they are within normal operating limits. When testing dc machines, you need to have an ammeter installed prior to testing the values of the phase currents. When testing ac machines, a clamp-on ammeter (fig. 7-67) can be used.



1. **Power switch**
2. **Rpm control dial**
3. **Range switch**
4. **High calibration screw**
5. **Low calibration screw**
6. **Calibration indicator**
7. **Input jack**
8. **Output trigger jack**

Figure 7-66.—Type 1531-AB strobotac.



1. **Meter scale**
2. **Range selector**
3. **Transformer jaws**
4. **Trigger**
5. **Ohmmeter lead jack**
6. **Pointer jack**
7. **Zero adjust**
8. **Ohmmeter zero adjust**
9. **Voltmeter jacks**

Figure 7-67.—Clamp-on ammeter.

The current in any phase, at rated load, should not differ from the arithmetic average of the maximum and minimum current values by more than that shown in table 7-8.

Table 7-8.—Maximum Allowable Difference in Phase Currents

Horsepower of Unit	Maximum Allowable Difference
Up to 1 1/2	10%
2 – 3	7 1/2%
> 3	5%
Note: For submarine motors, at no load, the maximum deviation of any phase shall not exceed 3% of the average no load current.	

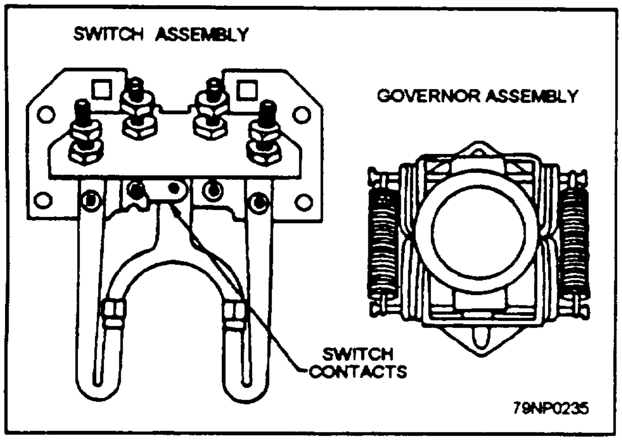


Figure 7-68.—Two major parts of a centrifugal switch.

Noise/Vibration Analysis

Once the equipment has been running long enough to come up to normal operating temperature, it should be tested to ensure there are no unusual noises and vibration is not excessive.

Instructions governing procedures to be followed when conducting noise and vibration analysis can be found in NAVSEA 0900-LP-060-2020.

This test procedure can be used to identify immediate or impending bearing problems and improper balance of rotating elements.

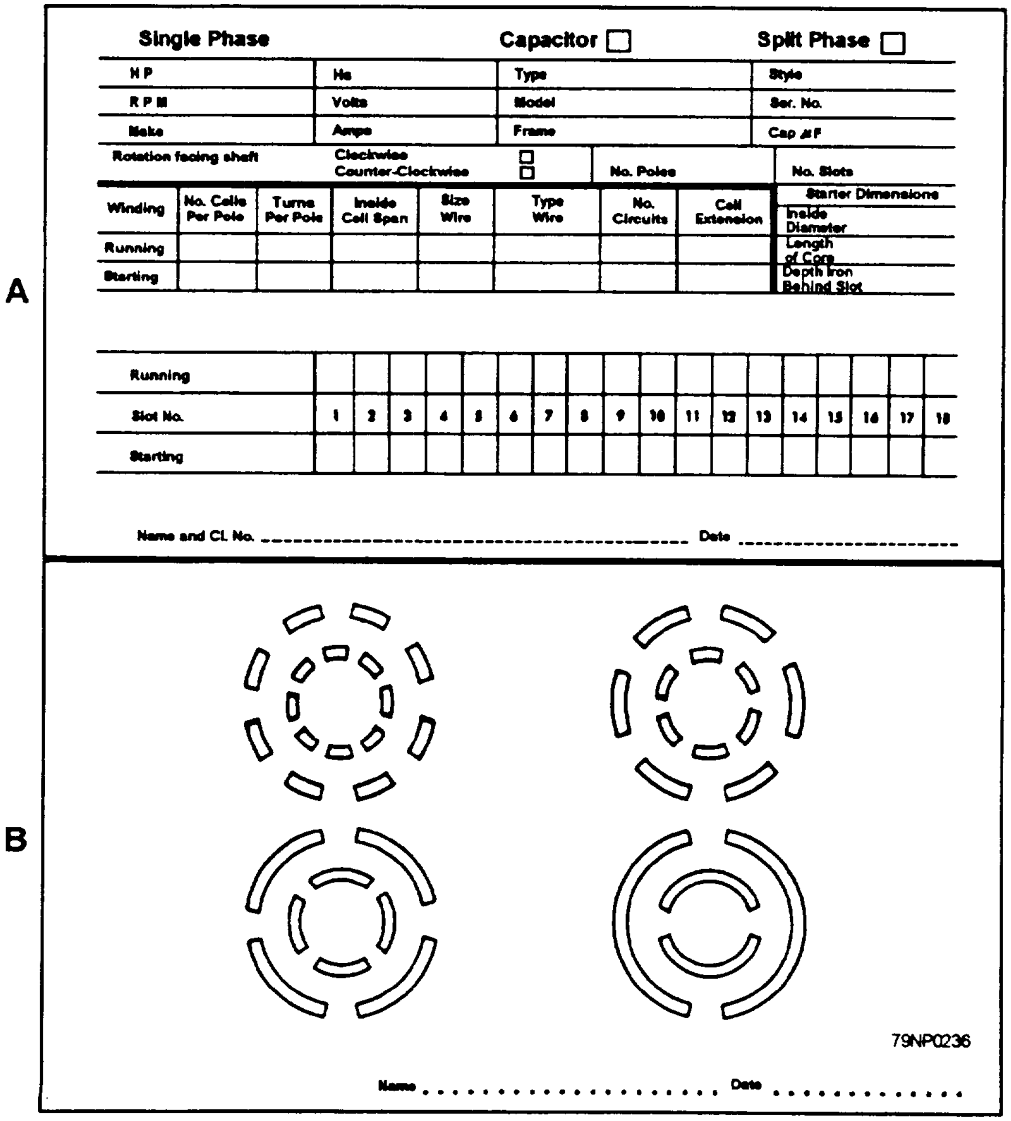


Figure 7-69.—Single-phase motor data card. (A) Front side; (B) back side.

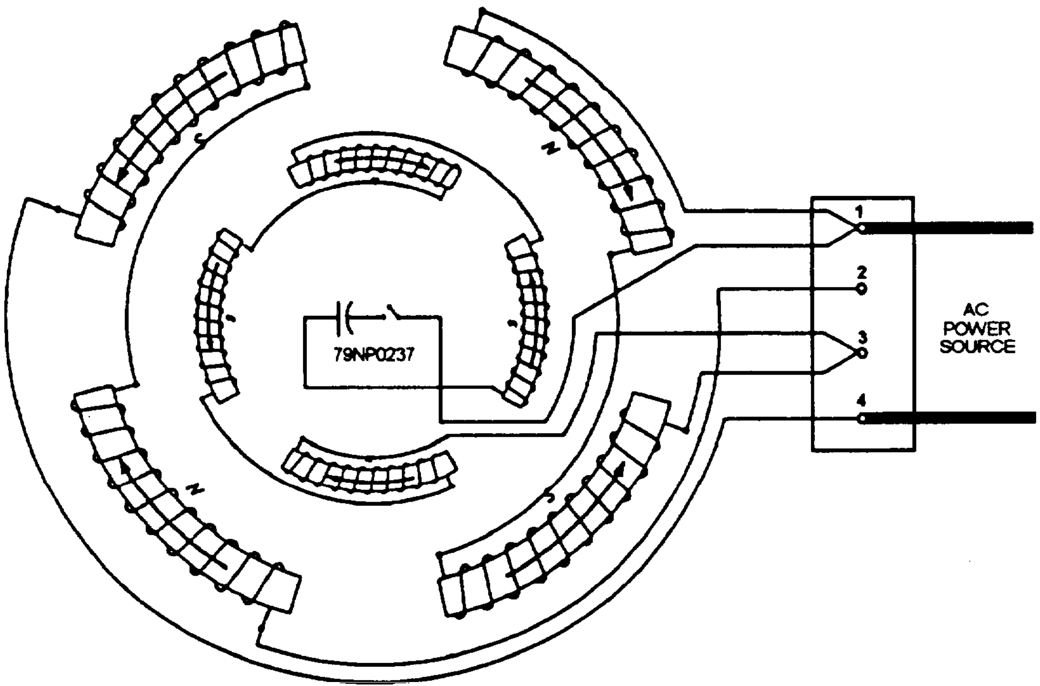


Figure 7-70.—Single-phase, capacitor-start, inductor-run motor diagram.

SINGLE-PHASE (SPLIT-PHASE) AC MOTOR REPAIR

There are many applications for single-phase motors in the Navy. They are used in interior communications equipment, refrigerators, fans, drinking fountains, portable blowers, portable tools, and many other applications. Single-phase motors are considerably cheaper in fractional horsepower sizes; but above 1 horsepower, the three-phase motors are less expensive. The use of single-phase motors also eliminates the need of running three-wire service to supply small loads.

Single-phase motor failure is usually caused by the starting winding burning out. The centrifugal switch (fig. 7-68) cuts the starting winding out of the system when the motor reaches about 75 percent of rated speed. When the motor is overloaded, the speed decreases and allows the centrifugal switch to energize the starting windings. Then, the motor speeds up enough so that the centrifugal switch opens the starting winding again. This constant opening and closing of the starting winding circuit can cause failure of the winding due to excessive temperature.

Steps in analyzing motor troubles should proceed, as previously mentioned, following a logical sequence to determine what repairs are required for reconditioning the motor:

1. Inspect the motor for defects such as cracked end plates, a bent shaft, a broken or burned winding.
2. Check the motor forbearing troubles.
3. Test the motor for grounds, opens, and shorts (see armature and three-phase stator sections).

If rewinding is required, record the necessary data on a single-phase motor data card (fig. 7-69).

A single-phase motor connection is shown in figure 7-70. When you connect the motor to a power source of 110 volts ac the motor run windings are connected in parallel by placing the two connecting bars as shown in figure 7-71, view A.

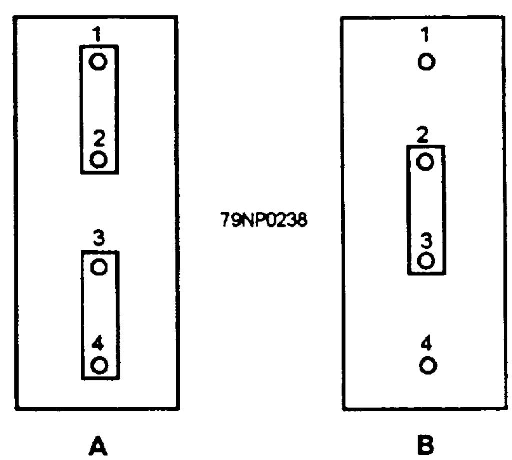


Figure 7-71.—Connecting bars. (A) Low voltage input; (B) High voltage input.

When you reconnect the motor to a power source of 220 volts ac, the run windings must be connected in series by placing the two connecting bars as shown in figure 7-71, view B.

By tracing through the two series and parallel bar-connected circuits, you will note that the starting winding operates on 110 volts regardless of a parallel or series connection.

Figure 7-72 is a diagram of a four-pole, split-phase motor. The type of winding used on both the running and starting windings is the spiral winding. The difference between the two windings is their impedance and position in the stator slots. The running winding has a low resistance and a high reactance (because of many turns of large wire), and the starting winding has a high resistance and a small reactance (being wound of small or high-resistance wire).

The running winding is placed in the bottom of the slots, and the starting winding is placed on top of the running winding. Both windings are energized in parallel at starting. The currents are out of phase with each other, and the combined effects produce a rotating field that starts the motor (some motors use capacitors for starting). When the motor has almost reached normal speed, the centrifugal switch opens the starting winding circuit, and the motor operates as a single-phase induction motor.

A pole for the running or the starting winding in a single-phase motor is made up of more than one coil. These coils differ from each other in size and, depending on the winding specifications, in the number of turns per coil. When coils are placed in stator slots, they can be wound in place by hand or wound in a coil winder on forms, and then placed in the slots of the stator.

Capacitors used with single-phase motors for starting should be checked by means of a capacity tester. This also applies to the capacitor-start, capacitor-run type of motors.

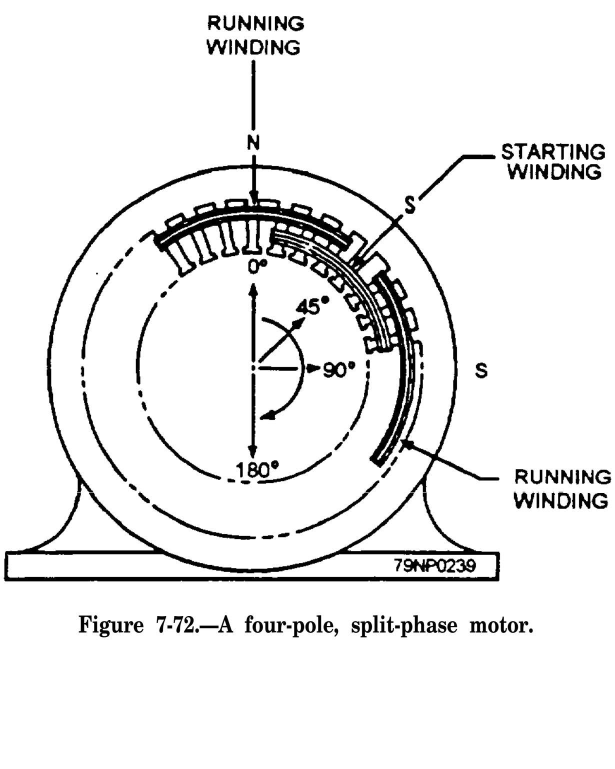


Figure 7-72.—A four-pole, split-phase motor.

MOTOR AND GENERATOR AIR COOLERS

Some large electric motors and generators, such as propulsion generators and motors, are equipped with surface-type air coolers. In this system the air is circulated by fans on the rotor in a continuous path through the machine windings and over the water-cooled tubes of the cooler. The ceder is of double-tube construction (one tube inside another). This minimizes the possibility of damage due to water leakage. I&location of the air cooler on a generator is shown in figure 7-73.

The air and water sides of air cooler tubes must be kept as clean as possible because foreign deposits will decrease heat transfer. When you are required to clean the air side of the tubes, the individual tube bundles may be removed and washed with hot water or cleaned with a steam jet. The water side of cooler tubes must be cleaned following instructions contained in the *NSTM,* chapter 254.

When a leak between an inner tube and the tube sheet occurs, water will seep from the cooler head through the leaky joint into a leak-off compartment and out the leakage drain. If a leak in an inner tube, water will seep into slots in the outer tube where it is carried to a leak-off compartment and out the leakage drain. The leakage drain line is equipped to give a visual indication of the presence of water in the line.

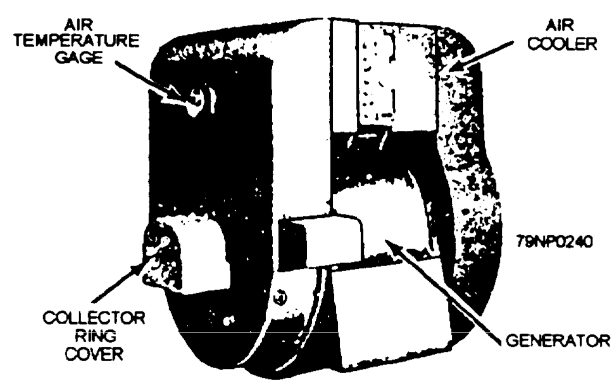


Figure 7-73.—Generator equipped with an ailr cooler.

When a leaky tube is found, both ends of the tube should be plugged with plugs provided as spare parts or with condenser plugs. When the number of plugged tubes in a cooler section becomes large enough to adversely affect the heat-dissipating capacity of the cooler, the cooler section must be removed and replaced.

Since you will encounter the terms *mandatory turn-ins* arid *repairables* in the process of obtaining replacement parts from supply, you should understand the purpose of the repairable program and your responsibilities to it.

When a component fails, your primary concern is to locate the trouble, correct it, and get the equipment back on the line. In most cases this involves troubleshooting the equipment and tracing the trouble to the defective component, drawing a replacement from supply, installing it, and discarding the old one.

The repairable program enters the picture when defective parts are expensive and can be economically repaired at a factory. In these cases, the time and money saved makes it quicker and cheaper to repair an item than to contract with manufacturer to build a new one. The old part should be turned in to supply so that it may be repaired and returned to service in the fleet through the supply system.

For the repairable program to work as intended, you and others have certain responsibilities. At the time you turn in your request for a replacement part, supply must inform you whether or not it is a mandatory turn-in item. At this point proceed as follows:

- Remove the defective part without damaging it.
- Provide adequate protection for the part to prevent additional damage. Use the same container in which the new one was packaged, if at all possible.
- Return the defective part to supply as soon as possible.

DO NOT CANNIBALIZE THE PART FOR COMPONENTS YOU THINK YOU MAY NEED FOR FUTURE USE.

When the required part is not in the storeroom, supply must take appropriate action to obtain it. The failed part should be turned into supply before receiving the new one, unless its removal will cause limited or reduced operating capabilities.

SUMMARY

Now that you have finished this chapter, you should have a better understanding of motor and generator repair and troubleshooting. Some of the areas covered were the proper care and cleaning of bearings, the correct seating of brushes on commutator and slip rings, and the tests and repairs required for motor and generator windings.

The information covered in this chapter does not include the necessary specifications or the specific procedures for repair and maintenance of each piece of equipment you will encounter. This information can only be obtained from the *Naval Ships' Technical Manual* and the manufacturer's instruction manuals.

CHAPTER 8

VOLTAGE AND FREQUENCY REGULATION

Sophisticated electronics and weapons systems aboard modem Navy ships require closely regulated electrical power for proper operation. The increased demand for closely regulated power is being met by establishing new standards for ac shipboard power system. Also, new voltage and frequency-regulating equipment has been developed. Following a brief discussion of the new standards and equipment, this chapter contains a discussion on the various types of voltage regulators for ac generators in use aboard Navy ships and the SPR 400 in-line regulator.

LEARNING OBJECTIVES

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

1. *Recognize the need for voltage and frequency regulation.*
2. *Recognize the types of power used aboard ship, and identify their use.*
3. *Identify the characteristics of the components used in various voltage and frequency regulators.*
4. *Recognize the operation of various voltage and frequency regulators in use today.*
5. *Troubleshoot various voltage and frequency regulators by observing their operation.*
6. *Recognize the approved servicing techniques for transistorized circuits.*

TYPES I, II, AND III POWER

MIL-STD-761B (Ships) of 15 July 1965 established standard electrical characteristics for ac power systems. The three basic power supplies (types I, II, and III) are described in table 8-1. The power system characteristics shown are those existing at the load. They do not represent generator output characteristics. All figures are the maximum allowable percentages or times for that type power.

Present ship's service generators and distribution systems are adequate for 60- and 400-Hz type I power. Type II power differs principally from type I. Type II has more stringent voltage requirements. Better voltage regulation at the ship's service generator will not satisfy these voltage requirements. This is because the specified voltage is at the equipment or load, not at the generator output. Static type line voltage regulators which provide type II voltage control at the load are discussed in the chapter.

Voltage and frequency requirements for type III power cannot be met without isolating the equipment requiring the power from the rest of the power system. Motor generator sets are normally used for this purpose.

PRINCIPLES OF AC VOLTAGE CONTROL

The voltage regulation of an ac generator is the change of voltage from full load to no load, expressed in percentage of full-load volts, when the speed and dc field current are held constant.

$$\%Regulation = \frac{E_{NL} - E_{fL}}{E_{fL}} \times 100$$

For example, the no-load voltage of a certain generator is 250 volts, and the full-load voltage is 220 volts. The percent of regulation is

$$\frac{250 - 220}{220} \times 100 = 13.6\ \%$$

In an ac generator, an alternating voltage is induced into the armature windings when magnetic fields of alternating polarity are passed across these windings. The amount of voltage induced into the ac generator windings depends mainly on the number of conductors in series per winding, the speed at which the magnetic field passes across the winding (generator rpm), and the strength of the magnetic field Any of these three factors could be used to control the amount of voltage induced into the ac generator windings.

This can be represented by the following formula:

$$E_g = K\Phi N$$

Table 8-1.—Standard Elctrical Characteristics for Shipboard Ac Power Systems

	Type I	Type II	Type III
Voltage	440 or 115	440 or 115	440,115 or 115/200 (see note 1)
(a) Nominal user voltage, volts rms			
(b) User voltage tolerances			
(1) Steady state voltage (see figures 2 through 7)			
a. Average of the three line-to-line voltages	±5%	±5%	+1/2%
b. Any one line-to-line voltage including a. above and line voltage unbalance tolerance	±7%	±7%	±1 1/16%
(2) Line voltage unbalance	3%	3%	1%
(3) Voltage modulation	2%	2%	1%
(4) Voltage transient			
a. Voltage transient limits	±16%	±16%	±5%
b. Voltage transient recovery time, seconds	2	2	0.25
(5) Voltage spike (peak value) volts	2500	2500	2500
(6) The maximum worst case departure from nominal user voltage resulting from (b) (1) and (b) (3) combined, except under transient or fault conditions.	±6%	±6%	±1%
(7) The worst case voltage excursion from nominal user voltage resulting from (b) (4) a, (b) (1) a, and (b) (3) combined except under fault conditions—see note 2	±20%	±20%	5 1/2%
Waveform			
(c) Total harmonic distortion	5%	5%	3%
(d) Maximum single harmonic	3%	3%	2%
(e) Deviation factor	5%	5%	5%
Frequency			
(f) Nominal frequency (Hz)	60	400	400
(g) Frequency tolerances			
(1) Steady state frequency	±3%	±5%	±1/2%
(2) Frequency cyclic variation	+1/2%	1/2%	1/2%
(3) Frequency transient	±4%	±3%	±1%
(4) Frequency transient recovery time, seconds	2	2	0.25
(5) The worst case frequency excursion from nominal frequency resulting from (g) (1), (g) (2), and (g) (3) combined, except under fault conditions	5-1/2%	6-1/2%	1-1/2%
Power Continuity			
(h) Typical power interruption time, seconds	0.5 to 20	0.5 to 20	0.5 to 3

Notes:

1. When a 115-/200-volt, three-phase, four-wire, wye system is supplied from line voltage regulators, the type III characteristics apply to line-to-neutral power. Line-to-line power characteristics may be expected to exceed these limits under certain conditions. 115/200 volt power is only supplied for aircraft servicing and avionics ships.

2. Excursions of this magnitude will only occur infrequently.

where

E_g is the generated voltage output of the generator,

K is a constant determined by the physical characteristics of the generator (the number of windings, their location in respect to the rotating field, the materials used in construction, and so forth.)

ϕ represents the strength or intensity of the rotating magnetic field, and

N represents the speed or frequency of the rotating field and thus the frequency of the output.

The number of windings and their physical characteristics are fixed when the generator is manufactured so K cannot be altered to produce changes in voltage.

The various loads throughout the ship require a constant value of generated output frequency; therefore, the speed of the rotating field must be held constant. This prevents the use of the generator speed as a way to control voltage output. Therefore, the only practical remaining method for obtaining voltage control is to control the strength of the rotating magnetic field (ϕ).

In almost all applications, ac generators use an electromagnetic field rather than a permanent magnetic type of field. The strength of the electromagnetic field may be varied by a change in the amount of current flowing through the coil. This is accomplished by a variation in the amount of voltage applied across the coil. When the excitation voltage to the rotor windings is varied, the ac generator field strength is also varied. Thus, the magnitude of the generated ac voltage depends directly on the value of the exciter output voltage. This relationship allows a relatively large ac voltage to be controlled by a much smaller dc voltage.

The next principle of voltage regulation that must be understood is how the dc excitation to the rotor field winding is controlled. Voltage control in a dc generator is obtained when the strength of the dc generator shunt field is varied. This is accomplished by the use of a number of different types of voltage regulators.

A device that will vary the excitation current to the rotor field winding as changes occur in the ac generator voltage is called an ac generator voltage regulator. This regulator must also maintain the correct value of exciter shunt field current when no ac voltage corrective action is required (steady state output).

In figure 8-1, note that a pair of connections labeled ac sensing input feeds a voltage proportional to the ac

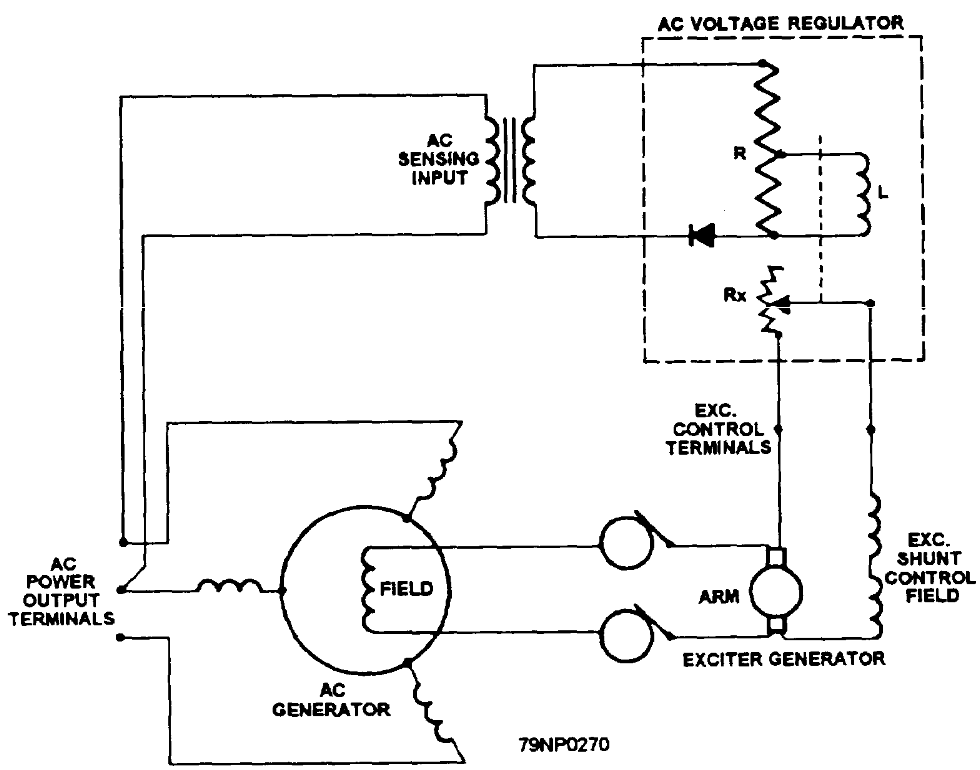


Figure 8-1.—Simplified voltage regulator circuit.

generator output voltage to the ac voltage regulator. You should also note that a portion of the exciter's armature output is connected through the exciter's field rheostat (Rx) then through the exciter shunt field windings and finally back to the exciter armature. Obviously, the exciter supplies direct current to its own control field, in addition to the ac generator field, as determined by the setting of Rx. The setting of Rx is controlled by the magnetic strength of the control coil (L). The magnetic strength of L is controlled by the voltage across the resistor (R). The voltage across R is rectified dc and is proportional to the ac line voltage. (Rectifiers are devices that change ac to dc.)

Thus, the essential function of the voltage regulator is to use the ac output voltage, which it is designed to control, as a sensing influence to control the amount of current felt by the rotor field windings. A drop in the output ac voltage will change the setting of Rx in one direction and cause a rise in the excitation to the field windings.

Conversely, an increase in the output ac voltage will change the setting of Rx in the opposite direction and cause a drop in the excitation to the field windings. These latter two characteristics are caused by actions within the voltage regulator. These characteristics are common to both the resistive and magnetic (magnetic amplifier) types of ac voltage regulators. Both types of regulators perform the same functions, but accomplish them through different operating principles.

TYPES OF VOLTAGE REGULATORS

A voltage regulator consists of a control element and associated mechanical or electrical means to produce the changes in the generator field current that are necessary to maintain a predetermined constant generator terminal voltage. These changes are necessary to maintain a predetermined constant generator terminal voltage and to provide for proper division of the reactive current between generators operating in parallel.

When used on dc generators, voltage regulators and their auxiliary equipment maintain the generator terminal voltage within specified limits. They also provide proper division of the load between generators operating in parallel.

When used on ac generators, voltage regulators and their auxiliary equipment function to maintain the generator terminal voltage within specified limits. They also provide proper division of the reactive current between generators operating in parallel.

The types of voltage regulators used in naval vessels are

1. the indirect acting rheostatic,
2. the direct acting rheostatic,
3. the rotary amplifier, and
4. the combined static excitation and voltage regulation system.

One voltage regulator is provided for each generator to be regulated. In some ship's service. installations a spare voltage-sensitive (control) element is installed on the switchboard. The switchboard is provided with a transfer switch. This allows the spare element to be placed in service if either of the other control elements become disarranged. Spare control elements are not installed for voltage regulators used on emergency generators.

INDIRECT-ACTING RHEOSTATIC VOLTAGE REGULATOR

The indirect-acting rheostatic type of voltage regulators were used on all ac ship's service generators and many emergency generators until 1943. Very few of these voltage regulators are still in service; therefore, they aren't discussed in this TRAMAN.

DIRECT-ACTING RHEOSTAT VOLTAGE REGULATOR

Direct-acting rheostatic voltage regulators consist of a control element in the form of a regulator coil that exerts a mechanical force directly on a special type of regulating resistance.

The installation of direct-fig (silverstat type) voltage regulators used on emergency ac generators is shown on the schematic diagram in figure 8-2. As you have already learned, in each installation one regulator controls one ac generator. When a standby regulator is installed, a standby regulator transfer switch is also installed. This allows for substituting of the standby regulator for the normal regulator.

The voltage regulator controls the voltage of the dc exciter by the variable regulating resistance. This is built into the regulator. It is connected in series with the shunt field of the exciter. The complete regulator includes

1. a control element,

2. a damping transformer, and

3. across-current compensator

The dc exciter in turn controls the voltage output of the ac generator.

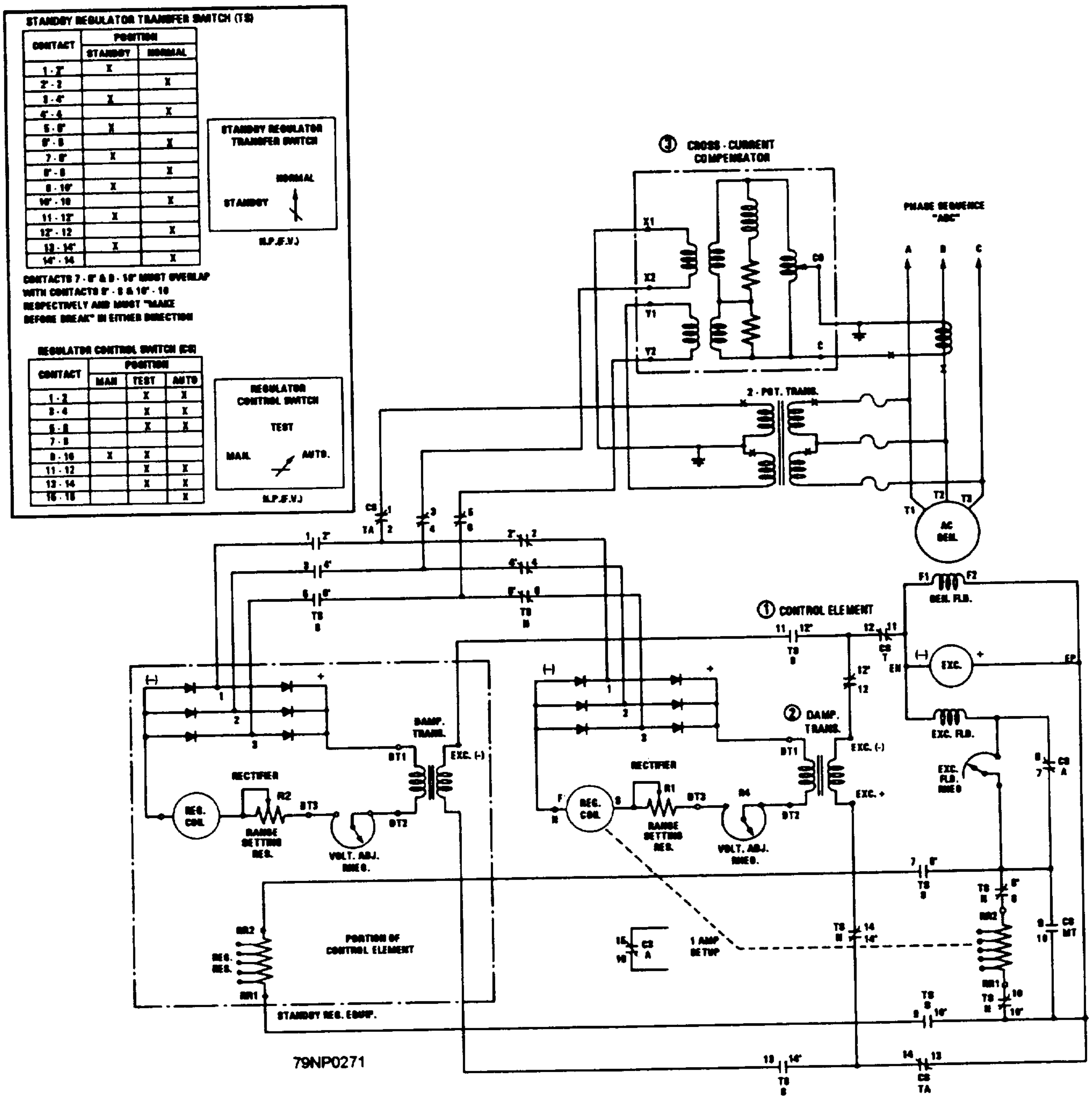


Figure 8-2.—Schematic diagram of direct acting voltage regulator installation.

Control Element

The control element (fig. 8-3) consists of a regulator coil and a regulating resistance. The regulator coil is a stationary coil wound on a C-shaped iron core with a spring-mounted moving arm. The nonmagnetic spring-mounted moving arm is pivoted so that an iron armature attached to one end is centrally located in the fixed air gap of the magnetic circuit. A pusher arm and a coiled spring are attached to the other end of the moving arm. The pusher arm carries two insulated pusher points arranged to bear against silver buttons. These are spring mounted and connected to the regulating resistance.

The silver buttons are individually mounted on leaf springs. They are insulated from each other. They are connected to consecutive taps on the stationary regulating resistance plates (fig. 8-4). The resistance plates consist of tapped resistance wire embedded in vitreous enamel. The control element includes two resistance plates. There is one for each silver button assembly. They are mounted in the rear of the unit. The silver buttons connect to taps from the associated resistance plate.

The control element also includes two adjustable range-setting resistors (fig. 8-3). They are connected in series with the regulator coil. These resistors are used to set the range (covered by the voltage-adjusting rheostat) so that rated generator voltage is obtained with the voltage-adjusting rheostat in the midposition.

The primaries of two potential transformers, connected in open delta, are connected across the terminals of the ac generator as shown in figure 8-2. The secondaries of these transformers are connected to a

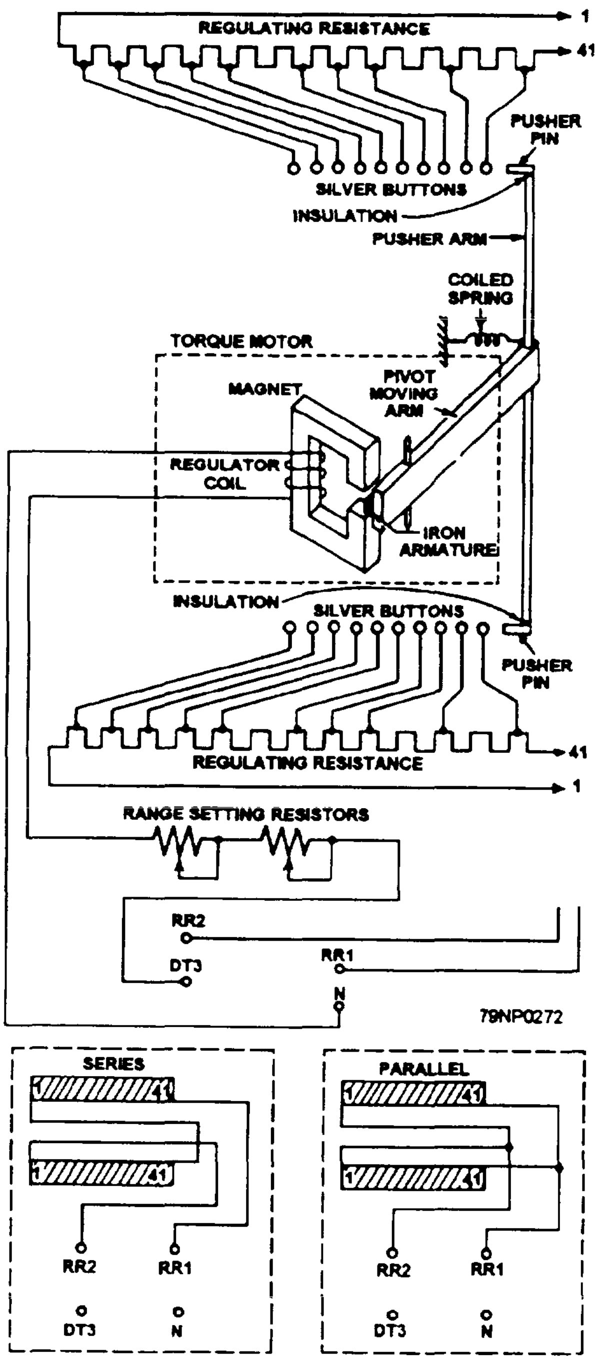


Figure 8-3.—Control element of a direct-acting voltage regulator.

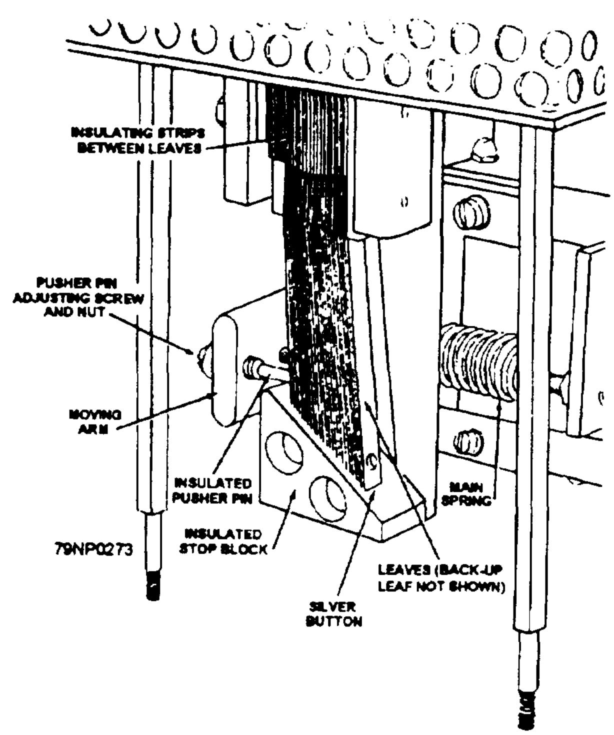


Figure 8-4.—Silver button assembly.

three-phase, full-wave rectifier through the compensator. The dc output of the rectifier is applied to the series circuit. This consists of the regulator coil, range-setting resistance, voltage-adjusting rheostat, and secondary of the damping transformer. In the following description of operation, note that the standby regulator on the left side of the schematic (fig. 8-2) is not energized or used

When the regulator coil is energized, the magnetic pull on the iron armature is balanced against the mechanical pull of the coiled spring.

IF	THEN
The magnetic pull of the armature overcomes the pull of the spring	Silver buttons are separated from each other, adding more resistance in the field circuit
The tension of the coiled spring overcomes the pull of the armature	Silver buttons are pressed together, causing less resistance in the field circuit

Thus, the moving arm operates through its travel, depending on the direction of motion, to successively open or close the silver buttons. This increases or decreases the resistance in the exciter field. The moving arm has a short travel so that all resistance can be inserted or cut out quickly. It can also be varied gradually. This depends on the required change in excitation.

For example, when the alternating voltage rises, the following events occur:

1. The regulator operates because of the increasing magnetic pull on the armature.
2. This action inserts resistance in the exciter field circuit to reduce the exciter field current and armature voltage,
3. The primary of the damping transformer across the exciter circuit is subjected to this change in current. Through transformer action, a momentary voltage is induced in the secondary that opposes the increase in regulator coil current.
4. This action is a form of negative feedback. It lowers the magnitude of the increase in regulator coil current.
5. This restricts the magnitude of the decrease in exciter field current and armature voltage.

Conversely, when the alternating voltage decreases, the following events occur:

1. The regulator operates in the opposite direction. This is because of the pull exerted by the coiled spring.
2. This action shorts out resistance in the exciter field circuit.
3. The impulse from the damping transformer momentarily opposes the decrease in regulator coil current.
4. This action reduces the extent of the decrease in regulator coil current.
5. This then restricts the magnitude of the increase in exciter field current and armature voltage.

Damping Transformer

The damping transformer is an antihunt device. It consists of two windings placed on the center leg of a C-shaped laminated iron core. The primary of this transformer is connected across the output of the exciter (fig. 8-2). When a change occurs in the exciter voltage, the primary of the damping transformer induces a voltage in its secondary. The secondary voltage acts on the regulator coil to dampen the movement of the armature. This prevents hunting and excessive changes in the generator terminal voltage.

The voltage-adjusting rheostat (fig. 8-2) is used to raise or lower the regulated value of the ac generator voltage.

The regulator control switch has three positions—MANUAL, TEST, and AUTOMATIC.

When the control switch is in the MANUAL position, you can control the ac generator voltage manually by the exciter field rheostat (fig. 8-2).

When the control switch is in the TEST position (as shown), the control element is energized. However, the regulating resistance is shorted out. The current in the exciter field circuit can be varied by the exciter field rheostat. The operation of the moving arm in the control element can be observed.

When the control switch is in the AUTOMATIC position, the generator is under full control of the regulator. The regulator will adjust the voltage to the value predetermined by the position of the voltage-adjusting rheostat.

When operating the control switch from the MANUAL to the AUTOMATIC position, you should pause in the TEST position. This allows the transient current in the regulator coil circuit to disappear without effecting the ac generator output voltage. The transient current is caused by the sudden connection of the damping transformer primary across the exciter armature.

Cross-Current Compensator

When two or more regulator-controlled ac generators operate in parallel on the same bus, you must equalize the amount of reactive current carried by each generator. This equalization of reactive current is accomplished by giving the regulator a drooping characteristic. This is done by a cross-current compensator provided with each ac generator and associated regulator.

The compensator (fig. 8-2) consists of a tapped autotransformer connected across a resistor-reactor combination The autotransformer is energized from a current transformer. It is connected in the B phase of the ac generator between the generator terminals and the bus. Two isolation transformers, with a 1-to-1 ratio, pick up the voltage drops from the resistor-reactor combination. The output potential terminals of these transformers (X1, X2 and Y1, Y2) are connected in series with the ac potential leads. These leads are between the secondaries of the two 440/110-volt open delta potential transformers and the three-phase, full-wave rectifier. This rectifier supplies direct current for the regulator coil. The compensator is designed to supply compensating voltages in two legs of the three-phase regulator potential circuit. This ensures that a balanced three-phase voltage is applied to the regulator element.

The taps on the autotransformer are connected to two DIAL SWITCHES (not shown) on the compensator faceplate. One of these switches provides a coarse adjustment. The other provides a fine adjustment of the compensator. A total of 24 steps is available on the two switches. In the case of the standard 12-percent compensation, this gives a one-half percent change in compensation per step. The 12 percent compensation is based on four amperes supplied from the current transformer. If the current transformer ratio should give some other value of secondary current, the compensation settings will be affected

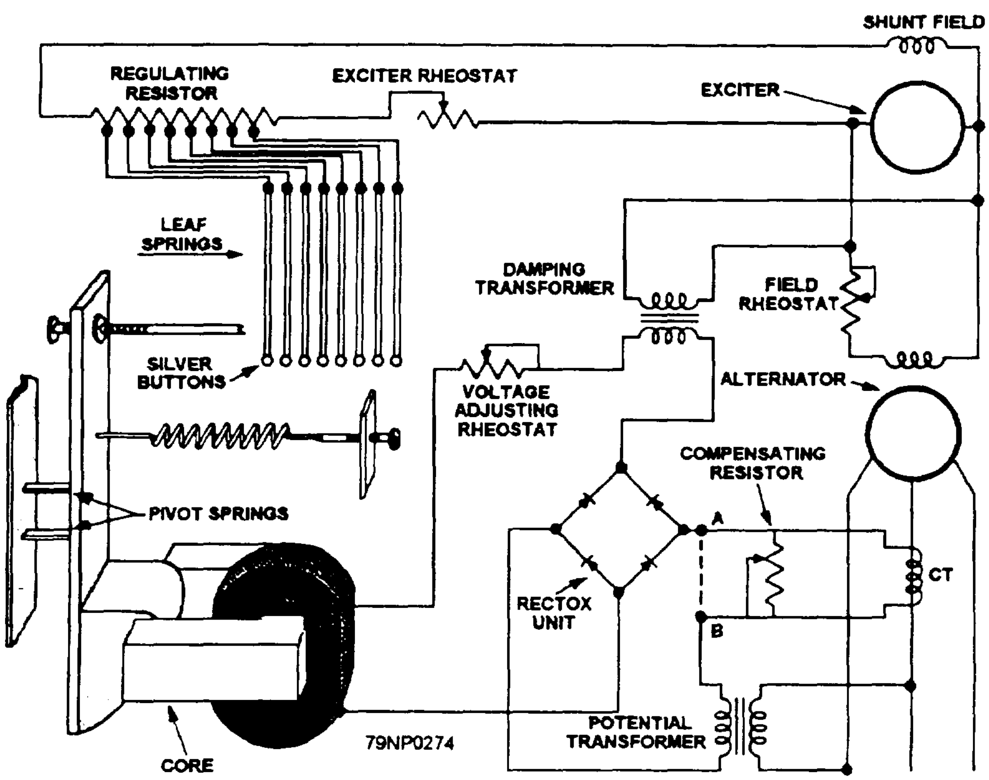


Figure 8-5.—A Silverstat voltage regulator on an ac generator.

proportionally. You should set the compensating droop introduced by the compensator to approximately 6 percent from no load to full load at 0.8 lagging power factor. However, when you have made the proper connections and settings, no further adjustments should be necessary.

Operation

When the generator circuit breaker is closed and the control switch is in the AUTOMATIC position, the generator is under control of the voltage regulator (fig. 8-5). If the ac generator voltage is normal, the regulator moving arm is at rest in a balanced state.

If an additional load is placed on the generator,

STEP	ACTION	EFFECT
1.	The terminal voltage will drop.	An increase in the exciter field current is required to increase generated voltage and restrict the fall in terminal voltage.
2.	The decrease in terminal voltage is transmitted thru the 440/110-volt potential transformers and the rectifier.	This decreases the magnetizing effect of the regulator coil.
3.	The pull of the coiled spring overcomes the magnetic pull on the armature.	The arm moves in a direction that begins closing more of the silver buttons. This action shorts out (in small steps) additional positions of the regulating resistance.
4.	This causes lower resistance in the exciter field circuit.	This causes the exciter field current to be increased and the ac generated voltage to be raised.

This action prevents a further decrease in the terminal voltage. When the voltage decrease is checked, the moving arm of the regulator is again in a balanced state. The position of the regulator moving arm, however, has changed to correspond to the increase in load on the generator.

If some load is removed from the generator,

STEP	ACTION	EFFECT
1.	This causes the terminal voltage to rise.	A decrease in the exciter field current is then required to restore the voltage to normal.
2.	The increase in terminal voltage is transmitted thru the 440/110-volt potential transformers and the rectifier.	The increase in terminal voltage increases the magnetizing effect of the regulator coil.
3.	The magnetic pull on the armature then overcomes the pull of the coiled spring.	This moves the arm in a direction to begin separating, in sequence, more of the silver buttons. This action inserts (in small steps) additional portions of the regulating resistance.
4.	This causes higher resistance in the exciter field circuit.	This causes the exciter field current to be decreased and the ac generated voltage to be lowered.

The Silverstat voltage regulator can increase the excitation to the ceiling voltage of the exciter. It can also reduce the excitation to the lowest value required. Because total travel of the moving arm is only a fraction of an inch, the regulating resistance can be easily varied. This depends upon the requirements of the operating conditions.

To place the voltage regulator in control for the first time, you should perform the following steps:

STEP	ACTION
1.	Be certain that the generator line circuit breaker is open.
2.	Turn the regulator control switch to the MANUAL position.
3.	Turn the exciter field rheostat in the direction to lower the voltage.
4.	Turn the voltage-adjusting rheostat to a position midway between the lower and raised ends of its travel.
5.	After bringing the generator and exciter up to speed, turn the exciter field rheostat gradually in the direction that raises the voltage.
6.	At the same time, observe the ac generator voltmeter.
7.	When the voltmeter indicates the rated ac generator voltage, stop turning the rheostat.

To place the regulator in control of the ac generator voltage, you should perform the following steps:

STEP	ACTION
1.	Turn the regulator control switch from the MANUAL to the TEST position.
2.	Pause for 2 r 3 seconds, then turn the switch to the AUTOMATIC position.
3.	Turn the voltage adjusting rheostat until the ac generator reaches the rated value.
4.	The regulator moving arm should settle promptly after a load or voltage change. (If the arm should swing back and forth continuously, check the polarity of the damping transformer terminals. The wrong polarity or an open circuit will cause this violent swinging.)
5.	When the generator voltage is approximately at rated value, close the generator circuit breaker if the generator is operating alone.

If operated in parallel with a generator already connected to the bus, close the circuit breaker of the incoming generator only when the two outputs are synchronized. The incoming generator can be connected to the line with the regulator control switch in the NORMAL or AUTOMATIC position. As soon as the two generators are operating in parallel, readjust the governor motor (speed-changer) until each unit takes its share of the kilowatt load.

To shut down the unit, remove the kilowatt load on the generator by turning the governor motor control rheostat while observing the wattmeter. If necessary turn the voltage adjusting rheostat in a direction to reduce the reactive load. As the load approaches zero, open the generator line circuit breaker.

Maintenance

In addition to the actions shown on the maintenance requirement cards and the instructions given in the voltage regulator technical manuals, routine maintenance should include ensuring that connections are tight and strictly in accordance with installation diagrams. This maintains the effective resistance in the shunt field circuit of the exciter. You should also ensure that the operation of the silver buttons is smooth throughout the entire travel of the movable core.

It would be advisable to review the information about silver contacts in chapter 6, Motor Controllers. Contacts made of silver or its alloys conduct current when discolored (blackened during arcing) with silver oxide. This discolored condition therefore requires no filing, polishing, or removing.

ROTARY AMPLIFIER VOLTAGE REGULATOR

The rotary amplifier (amplidyne) type of voltage regulator uses a special type of exciter. It finishes a large change in output voltage for a small change in the control field current of the exciter. The control element detects variation of the ac generator voltage from a reference voltage. This can be set to a predetermined value. The variation between the actual alternating voltage and the reference voltage sends a current through the control field of the exciter. This changes its output voltage current and hence, changes the ac generator field current. This holds the alternating voltage at the desired value.

The complete amplidyne voltage regulator equipment consists of the following components:

1. An amplidyne exciter (1)
2. A pilot alternator (2)
3. A stabilizer (3)
4. A voltage-adjusting unit (4)
5. An automatic control unit (5)
6. A manual control unit (6)
7. A potential unit (7)

This is illustrated by the block diagram in figure 8-6. Some installations include two normal voltage regulators and one standby regulator for two ac generators.

A cutout switch with two positions (manual and automatic) is provided for each generator. The cutout switch is used to connect the amplidyne exciter and the regulator for either manual or automatic control of the ac generator voltage.

A transfer switch with three positions (NORMAL, GEN A, and GEN B) is also provided. The transfer switch permits substituting the standby voltage regulator for either of the two normal regulators.

In the NORMAL position, generators A and B are connected in the normal automatic voltage control circuits of their respective regulators. The standby regulator is disconnected.

In the GEN A position, the standby regulator has taken control from the normal regulator of generator A. Generator B is connected to its normal regulator.

In the GEN B position, the standby regulator has taken control from the normal regulator of generator B. Generator A is connected to its normal regulator.

Amplidyne Exciter

The amplidyne exciter (fig. 8-6) is a rotary amplifier that responds quickly to small changes in control field current to cause large changes in output. It is mounted on the shaft of the prime mover. It provides the excitation for the ac generator.

Pilot Alternator

A voltage regulator requires a "reference" or standard to which the voltage being regulated may be compared. This determines whether or not the regulator should act to change the excitation of the ac generator, In a direct-acting voltage regulator, discussed above, the reference is provided by a coiled spring. In the amplidyne voltage regulator, the reference is provided by a "boost" current. Ths current is approximately 0.5 ampere from the pilot alternator. The pilot alternator (fig. 8-6) is a small permanent-magnet, single-phase ac generator, mounted on an extension of the amplidyne

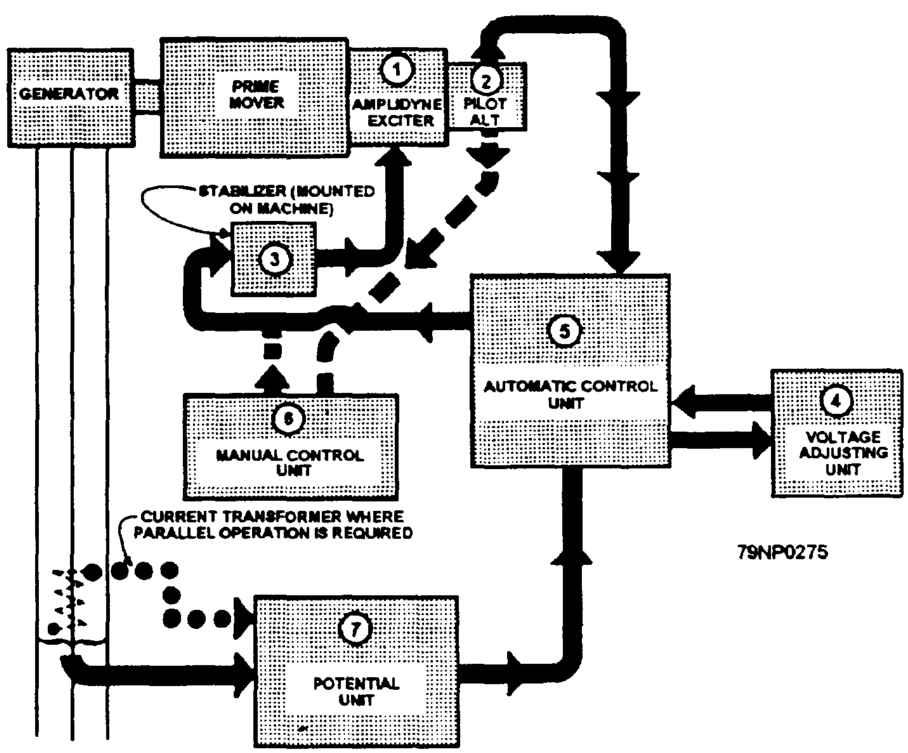


Figure 8-6.—Block diagram of an amplidyne voltage regulator system.

shaft. The effective voltage output of the pilot alternator is essentially constant.

Stabilizer

The stabilizer (fig. 8-6) is mounted on or near the amplidyne exciter. It prevents sustained oscillations in generator output. It is essentially a transformer. However, because it is in a de circuit, the stabilizer functions only when there is a change in the exciter voltage. The secondary winding is connected in series with the control field of the amplidyne exciter.

When the regulator operates to change the exciter voltage, a voltage is induced in the control field circuit through the stabilizer. This momentarily affects the control field current to restrain the regulator from making excessive correction of the exciter voltage. This prevents hunting.

Voltage-Adjusting Unit

The voltage-adjusting unit provides ac generator voltage that the regulator will maintain. This unit (fig. 8-7) consists of a tap switch and a tapped saturated reactor. It mounts directly behind the generator control panel. The handle of the tap switch is on the front of the panel. The saturated reactor is the main component of the voltage-adjusting unit. It is the heart of the regulator system.

The saturated reactor determines the ac generator voltage that the regulator will maintain. It consists of a tapped coil of approximately 400 turns wound on a soft iron core. The core is operated in the saturated region so that a very small change in the applied voltage and flux density will produce a large change in coil current.

Changing the taps on the coil changes the reactance of the coil circuit. It also changes the voltage level held by the regulator. Increasing the turns (to a higher tap number) increases the reactance and voltage required to maintain a given coil current. Conversely, decreasing the turns decreases the reactance and voltage required to maintain the current. Tap changing is done only during original installation or an overhaul.

Automatic Control Unit

The automatic ccontrol unit (fig. 8-8) has the static elements that are required for automatic voltage control. It is mounted inside the generator control switchboard. Portions of the control-unit circuit make the voltage regulator responsive to the average of the three-phase

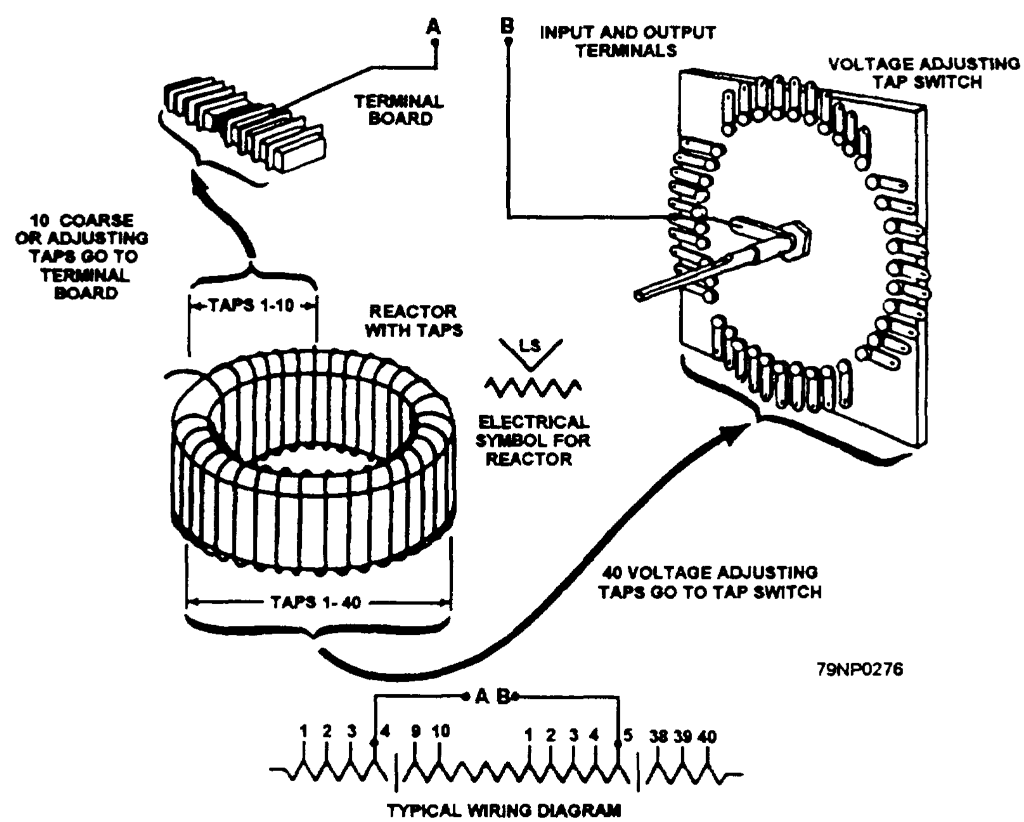


Figure 8-7.—Voltage-adjusting unit.

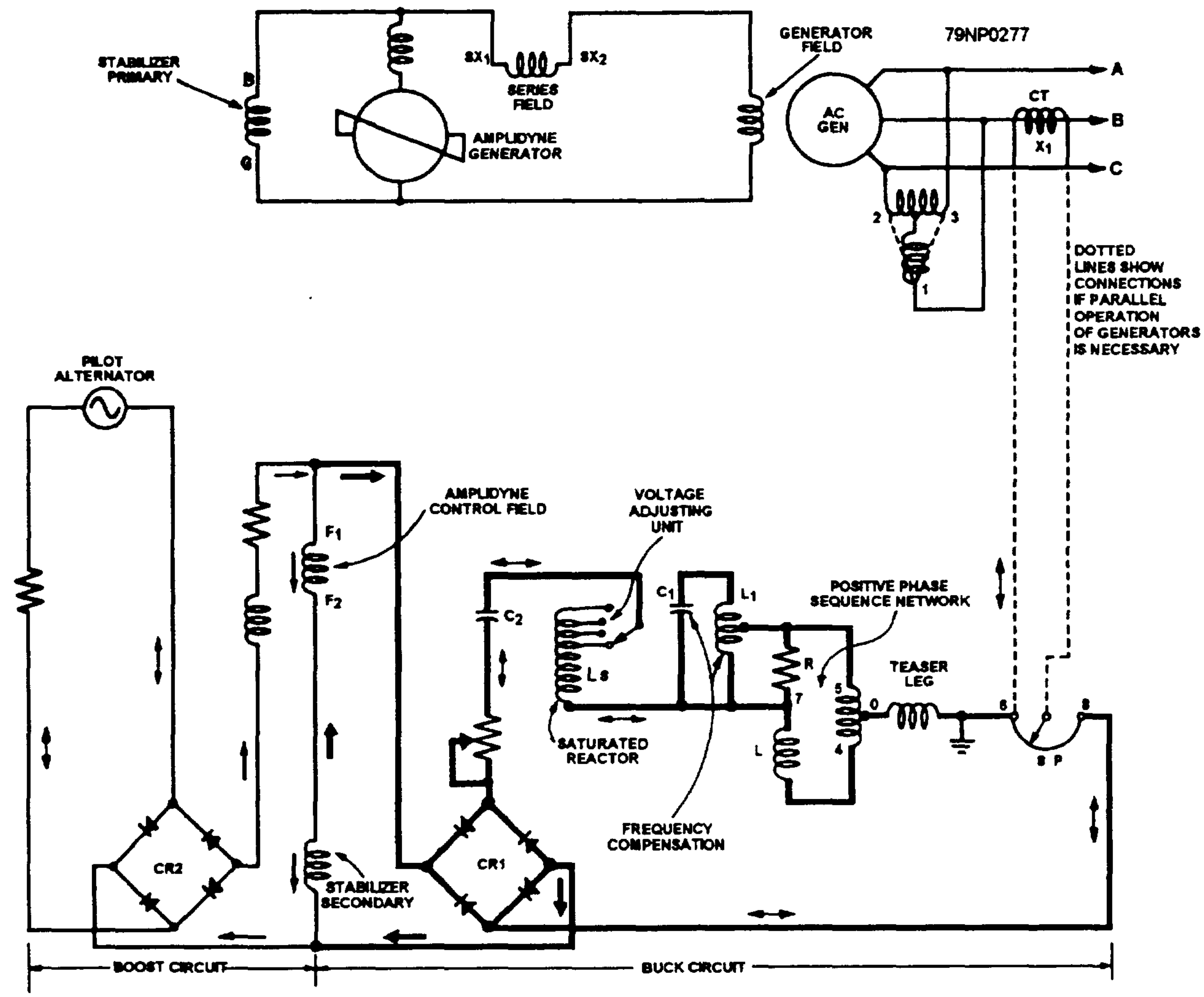


Figure 8-8.—Automatic control circuit.

voltages of the generator. Also, a frequency-compensating network permits the regulator to hold the ac generator voltage practically constant between 57 and 63 Hz.

A schematic diagram of the automatic control circuit is shown in figure 8-8. The circuit consists of a buck circuit, shown in heavy lines, and a boost circuit, shown in light lines. The ac portions of the circuit are indicated by double-headed arrows. The dc portions are represented by single-headed arrows. The saturated reactor, Ls, is energized by the ac generator voltage that is to be regulated. It is connected to rectifier CR1. The pilot alternator feeds rectifier CR2. The amplidyne control field, F1 and F2, is connected across the output of CR1 and CR2. The amplidyne exciter supplies the ac generator field directly.

The voltage from the pilot alternator tries to force current through the amplidyne control field. It does this in such a direction (from F1 to F2) that the amplidyne will boost the ac generator voltage. The saturated reactor circuit tries to force current through the control field in the opposite direction (from F2 to F1). This tends to decrease the generator voltage. When the ac generator voltage is near normal, the regulator is at its normal operating point. The boost current supplied by the pilot alternator is in the opposite direction. It is nearly equal to the buck current supplied by the saturated reactor circuit. Thus, the current through the control field is negligible. The amplidyne excitation is provided by the series field of the amplidyne to maintain normal terminal voltage of the ac generator.

If the generator voltage should drop slightly below normal, the buck current supplied by the saturated reactor would drop, considerably. This action causes a boost current to flow in the control field, which tends to raise the ac generated voltage and prevents a further decrease in the terminal voltage.

This action occurs because the pilot alternator is not affected by the generator voltage and is still trying to force a boost current through the control field

If the generator voltage increases slightly above normal, the saturated reactor circuit would pass a large additional current through the amplidyne control field. This tends to buck or decrease the ac generated voltage and prevents further increase in terminal voltage.

Manual Control Unit

The manual control unit (fig. 8-6) controls the voltage of the generator when the automatic control equipment is not in use. It consists of two resistor plates and a single-phase, full-wave rectifier. The two resistor plates are connected as a rheostat and a potentiometer, which operate concentrically. The manual control unit is mounted inside the switchboard. The operating handwheels protrude through the front of the panel. The large handwheel provides coarse voltage adjustment. The small handwheel is used for fine or vernier adjustment.

Potential Unit

The potential unit (fig. 8-6) provides signal voltage to the regulator. This voltage is proportional to the voltage of the ac generator. The unit has a potential transformer and a potentiometer rheostat. The unit is mounted inside the generator switchboard near the current transformer and the generator circuit breaker.

The potential transformer is a special T-connected, 450-volt transformer. The potentiometer rheostat is connected in the circuit of a current transformer. It is used to provide the reactive load division between generators operating in parallel.

Three-Phase Response Circuit

The three-phase response circuit (fig. 8-9) consists of the following components:

1. AT-connected potential transformer (T)
2. A resistor (R)
3. An inductor (L)

The resistance and inductance are in series across one secondary winding of the potential transformer (fig. 8-9, view A). When a balanced three-phase voltage is impressed on the primary, 1-2-3, a voltage, 4-5-6, appears across the secondary. The voltages across the inductor, L, and the resistor, R, are 4-7 and 7-5,

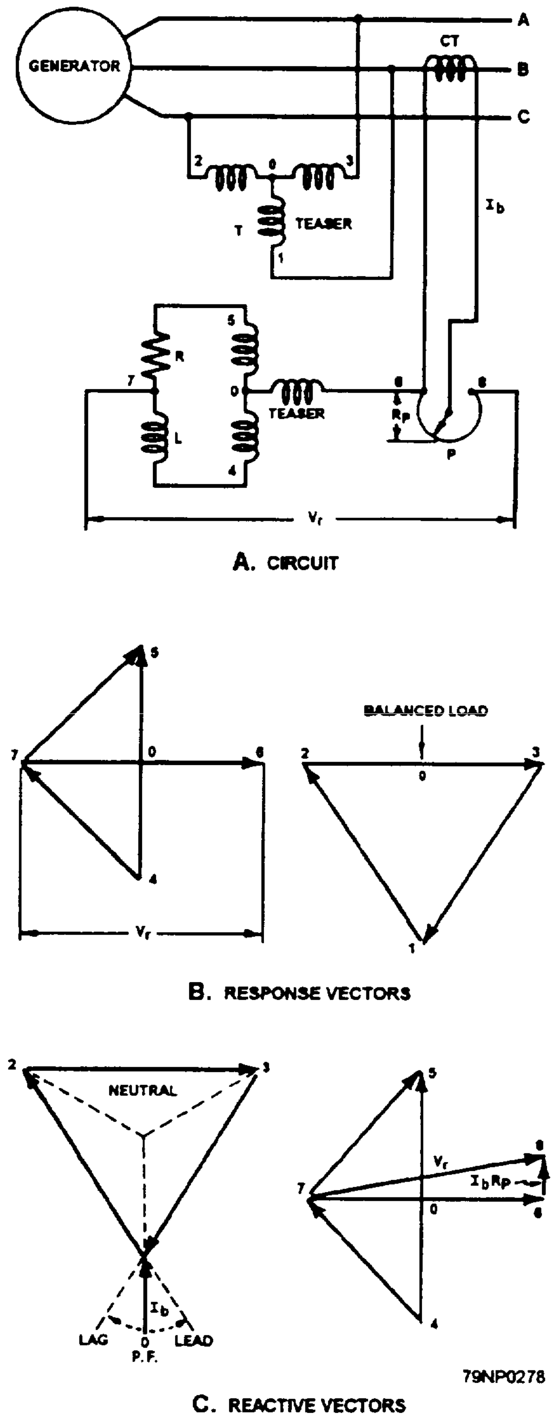


Figure 8-9.—Three-phase response circuit.

respectively (fig. 8-9, view B). The relationship of these voltages is 4-7-5, giving a resultant voltage, 7-0, in phase with and added to the voltage 0-6.

The resulting voltage, 7-0-6 (V_r), is the voltage of the network used to energize the regulator circuits. The regulator at constant frequency will always act to maintain voltage V_r constant. If there is any deviation in generator voltage from its normal value, the system will make corrections until the three-phase voltages, 1-2-3, are the values that will produce normal voltage V_r.

Correct phase sequence of the connections of the potential unit to the generator leads is required for correct functioning of this network. If the connections are reversed, for example, by interchanging the two leads from the secondary teaser winding, the voltage, 7-0, would be subtracted from the voltage, 0-6, instead of added to it. The voltage, V_r, impressed on the regulator would then be approximately one-fifth the required value. Thus, the regulator in attempting to go to the ceiling voltage would overexcite the generator to abnormal levels.

Frequency Compensation

The reactance of the saturated reactor (fig. 8-8) increases as the frequency increases. Thus, an increase in frequency from 60 to 63 Hz at normal 100 percent voltage would decrease the buck current. The boost current would predominate so the regulator would tend to hold a higher voltage. A frequency lower than 60 Hz would have the opposite effect. This would tend to increase the buck current so it would predominate. The regulator would then tend to hold a lower voltage.

Therefore, a voltage regulator system using a saturated reactor must have a means to compensate for frequency changes. Frequency compensation is provided by an inductor, L1, and a capacitor, C 1, in parallel with each other. They are across the resistance portion of the positive phase sequence network used for three-phase response (fig. 8-8). The values of the inductor and capacitor are such that at 60 Hz they provide a resonant parallel circuit. This acts like a high resistance. The other components of the system are adjusted so this resistance has no effect on the action of the regulator at normal frequency.

When the frequency increases above 60 Hz, the parallel circuit has a capacitive effect. This raises the apparent voltage "seen" by the saturated reactor. his causes it to pass as much buck current on normal voltage at the higher frequency as at normal frequency.

When the frequency decreases below 60 Hz, the parallel circuit has an inductive effect. This lowers the apparent voltage as "seen" by the saturated reactor. This causes it to pass as much buck current at normal voltages at the lower frequency than it would at normal frequent y. Thus, the parallel circuit compensates for the frequency effect on the saturated reactor. It passes the same buck current at a particular line voltage at any frequency between 57 and 63 Hz.

Reactive Compensation

When ac generators are operated in parallel, division of the load between machines is a function of the governors of the prime movers. The division of the reactive load (kVA) is a function of the regulators, which increase or decrease the excitation of the generators.

The division of the reactive load (kVA) between generators (when operated in parallel) is accomplished by a compensating potentiometer, P, and a current transformer, CT, provided for each machine (fig. 8-9, view A). The rheostat is connected in series with the teaser leg of the T-connected potential transformer secondary. The current transformer is connected in the B phase of the generator. Its secondary is connected across one side of the potentiometer.

The generator voltage, 1-2-3, feeds the primary of the T-connected potential transformer (fig. 8-9, view A). The line current, I_b, of phase B in which the current transformer is connected, is in phase with the line-to-neutral voltage at unity power factor. I_b is at 90° to the voltage, 2-3 (fig. 8-9, view C). At any other power factor, current I_b swings out of phase with the line-to-neutral voltage depending on lag or lead conditions.

The secondary voltage, 7-6 (fig. 8-9, view B), which is the resultant output voltage of the three-phase response network, is in phase with the line voltage, 2-3, and is the voltage impressed on the saturated reactor. At unity power factor, current I_b produces a voltage, 6-8, across the compensating rheostat, P, which is 90° out-of-phase with voltage 7-6 (fig. 8-9, view C). The voltage 6-8 (I_bR_p) is the compensating voltage. The voltage 7-8 (V_r) is now impressed on the saturated reactor. The regulator tends to hold the voltage proportional to 7-8.

When two duplicate generators, A and B, are operating in parallel at rated power factor, the line-currents, I, will be equal. The voltage 7-8 (V_r,) "seen" by the saturated reactors of both regulators will also be equal if the following conditions exist:

1. The field currents are balanced (made equal)
2. The compensating rheostats are set at the same value of resistance
3. The governors are set for equal division of the kilowatt load

Assume an instantaneous unbalance occurs with generator A having a weaker field than generator B. This unbalance can be caused by slight differences in the reactance or saturation characteristics of the generators or in the characteristics of the regulators. Because the excitation is unbalanced, there is a circulating current between the two generators. Their power factors are therefore unbalanced.

The effect of this unbalance distorts the voltage triangle, 7-6-8 (fig. 8-9, view C). The network voltage 7-6, decreases slightly because of the drop in line voltage. The compensating voltage, 6-8 (I_bR_p), from the current transformer and the compensating rheostat have changed. This is because of the unbalanced line currents and power factors. Therefore, the compensating voltage, 6-8, for generator B is greater and at a different phase angle than the corresponding voltage for generator A. Thus, the resultant voltage, 7-8 (V_r), of the two machines is unequal and different from the original voltage that the regulators were set to hold constant .

The regulators will act to change the excitation of the two generators. This is done to restore the voltage, 7-8, to equal values of V_r for both regulators. They are set by changing the values of the field currents so they are balanced. The line currents and power factors will then be approximately balanced to give equal compensating voltages, 7-8. These voltages "seen" by the regulators for generators A and B, respectively, will then be equal to each other.

The regulator attempts to hold voltage V_r constant. Voltage, 7-8, depends on the value and phase angle of the compensating voltage, 6-8. The network voltage, 7-6, which is the difference between V_r and 6-8 and is proportional to the line voltage, has decreased slightly because of this change. Thus, the line voltage will be slightly less than that maintained before any change occurred to the system. This drop in line voltage resulted from the increase in reactive load current.

Manual Control Circuit

An elementary diagram of the manual control circuit is illustrated in figure 8-10. The buck and boost circuits are indicated by heavy and light arrows, respectively. The voltage that the amplidyne exciter will maintain across its terminals can be adjusted by the manual control rheostats. Thus, the ac generator terminal voltage can be varied. The manual control circuit is so designed that for any one setting of the manual control rheostat, the amplidyne terminal voltage applied to the generator field will remain constant.

Operation

The schematic diagram of an amplidyne voltage regulator installation is shown in figure 8-11.

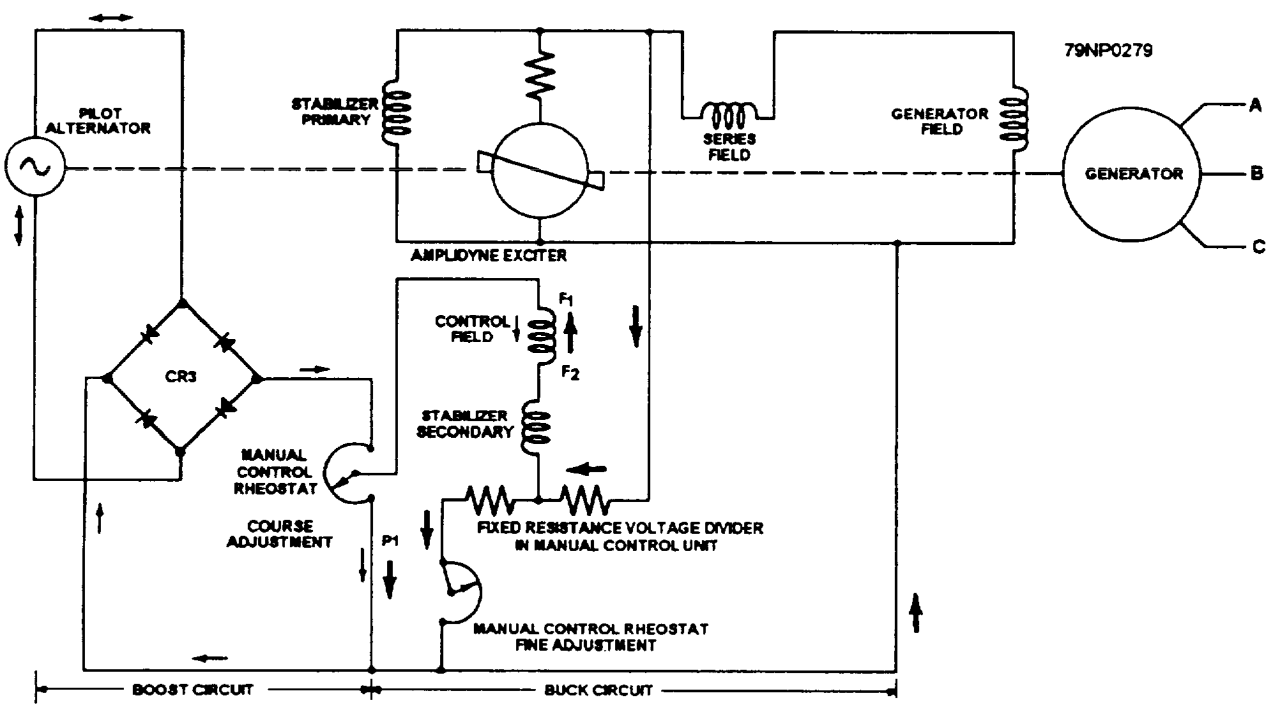


Figure 8-10.—Manual control circuit.

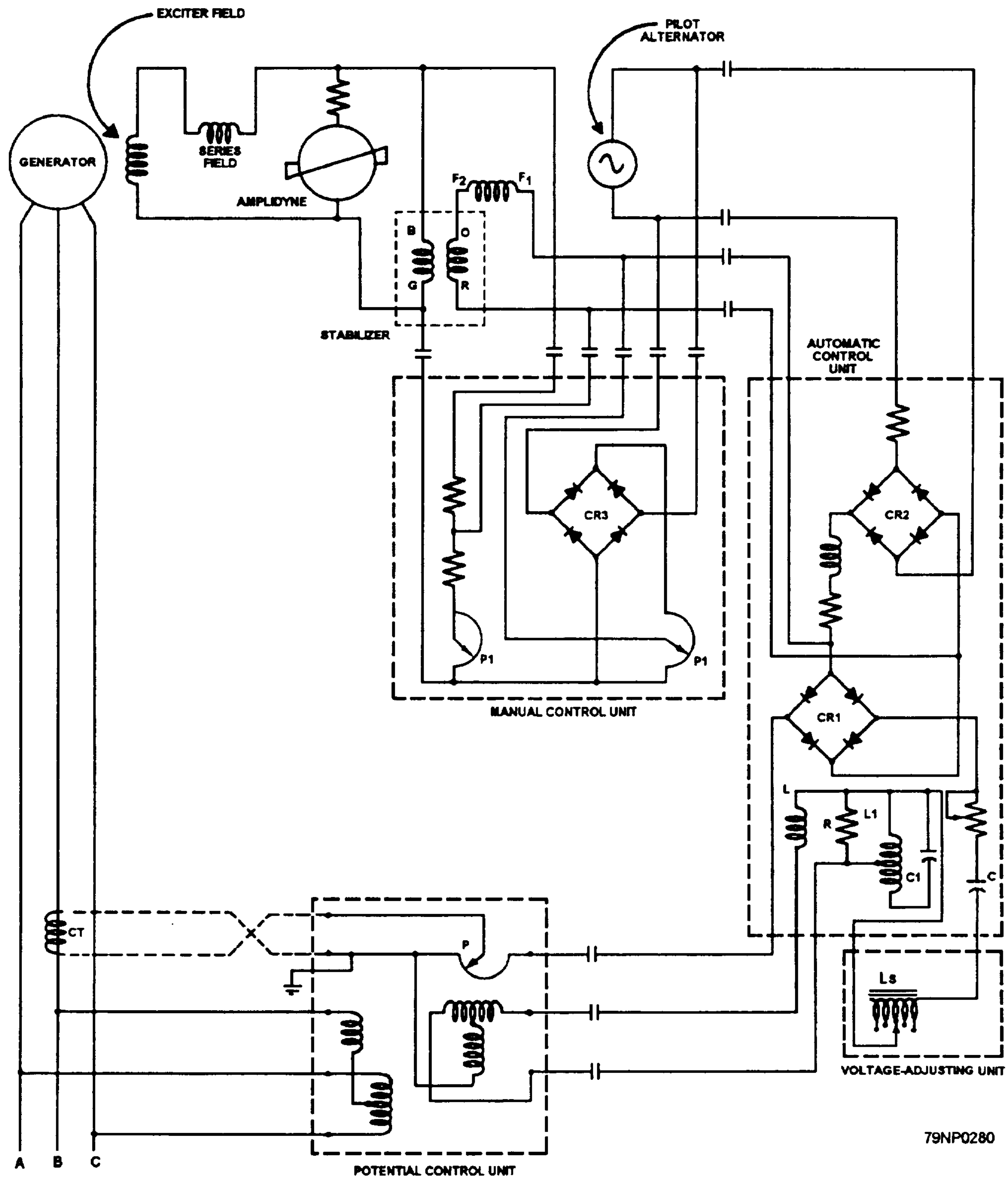


Figure 8-11.—Schematic diagram of amplidyne voltage regulator installation.

The normal operational sequence for placing a single generator on the line is as shown in table 8-2.

Table 8-2.—Normal Operating Sequence for Starting One Generator

STEP	ACTION
1.	Set both handwheels of the manual control unit in the extreme LOWER position.
2.	Turn the regulator cutout switch to MANUAL.
3.	Turn the transfer switch to NORMAL after making certain that the generator circuit breaker is open.
4.	Start the prime mover and bring the generator up to speed.
5.	When the generator is up to speed, raise the generator. voltage to approximately 450 volts by turning the handwheels of the manual control unit in the RAISE direction.
6.	Set the handle of the voltage-adjusting unit for 450 volts corresponding to no load.
7.	Place the automatic control unit in control of the ac generator voltage by turning the cutout switch from MANUAL to AUTOMATIC.
8.	Finally, adjust the generator voltage to 450 volts by turning the handle of the voltage-adjusting unit.
9.	The generator circuit breaker may then be closed.

If the generator is to be operated in parallel with a generator already connected to the bus, close the circuit breaker of the incoming generator only when the two voltages are synchronized. As soon as the two generators are operating in parallel, readjust the governors of the prime movers until each unit takes its share of the kW load. Then equalize the power factors of the machines by means of the voltage-adjusting units. When the kW loads and power factors on the generators are equal, the current of each generator should then be equal.

If the system voltage is high after the power factors are balanced, slowly turn the voltage-adjusting units of both generators in the lower direction. Turn it until the system voltage is approximate y 450 volts. If the system voltage is low, slowly turn the voltage-adjusting unit of both generators in the raise direction until the system voltage is approximately 450 volts.

Table 8-3 gives the procedure to remove an alternator from the line.

Table 8-3.—Removing an Alternator From the Line

STEP	ACTION
1.	Remove the kW load by adjusting the governor while observing the wattmeter.
2.	When the kW load approaches zero, reduce reactive current load with the voltage-adjusting unit.
3.	Trip the alternator's circuit breaker.
4.	After the generator is off the line, check to see that the manual control unit is set to the mark for 450 volts corresponding to no load.
5.	Shift the voltage regulator from AUTOMATIC to MANUAL.
6.	Turn the manual control in the lower direction.

Maintenance

Maintenance instructions for a specific rotary amplifier regulator given in the MRC and 3-M instructions take precedence over other procedures. However, the articles concerning care of rotating electrical machinery in chapter 310 of the NSTM should be observed in all cases where they do not conflict with the MRC, 3-M, or manufacturer's instructions.

The amplidyne's short-circuiting brushes should be checked periodically. Improper brush contact may result in an excessively high amplidyne voltage output.

STATIC EXCITATION AND VOLTAGE REGULATION SYSTEM

The static excitation voltage regulator system furnishes ac generator field current by rectifying a part of the ac generator output. After the ac generator has built up some output with the aid of a field-flashing power source, an automatic voltage regulator controls the output of a static exciter to supply the necessary field current.

The schematic of a static excitation and magnetic amplifier-type voltage regulator system is illustrated in figure 8-12. The system provides field excitation in either manual or automatic control for the 400-kW, 450-volt, three-phase, 60-Hz generator.

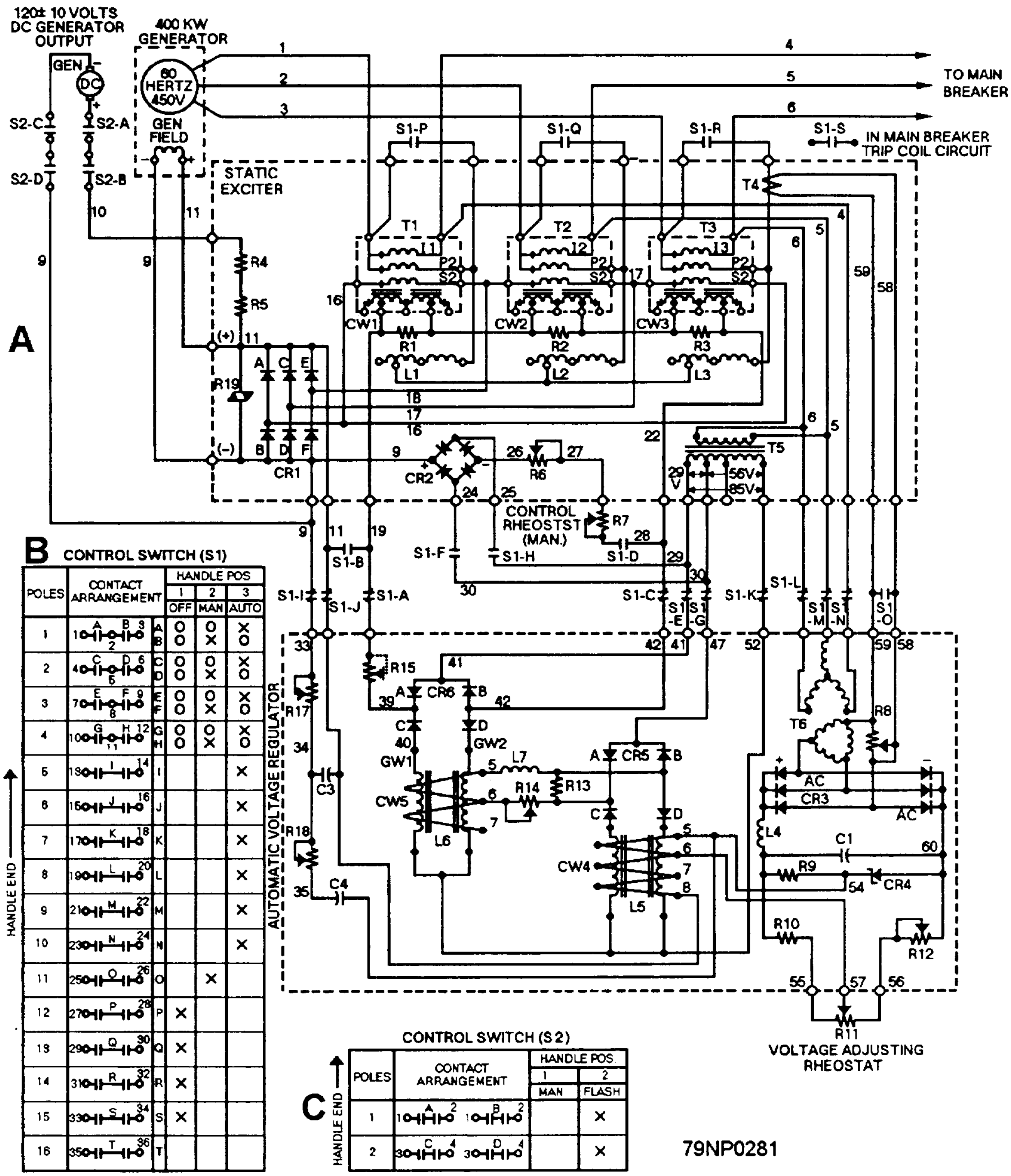


Figure 8-12.—Elementary diagram of static excitation voltage regulator system.

The control switch (S1) in figure 8-12, view B, has three positions-OFF, MANUAL, and AUTOMATIC. The setting of this switch determines the type of operation to be used. The OFF position can be used to quickly de-energize the generator in case of an emergency. With the switch in the OFF position, four sets of contacts (sets P, Q, R, and S) are closed. Contacts P, Q, and R "short circuit" the potential winding of the three potential transformers. They are identified as T1, T2, and T3 in figure 8-12, view A. They remove rectified current from the exciter. Concurrently, contact S (upper right, fig. 8-12, view A) functions to trip the main breaker.

An analysis of the contact arrangement (fig. 8-12, view B) in switch S 1 shows 32 contacts are placed (four per pole) on 16 poles. The first four poles produce 8 single-pole-single-throw contact switches (each SPST identified by 8 letters, A through H). These 8 have 12 terminals (identified further by 12 numbers, 1 through 12).

The fifth pole (No. 5 in fig. 8-12, view B) has only two numbered terminals (13 and 14) to identify switch section I. Its two SPST contacts are arranged in series. The function of this series arrangement is twofold:

1. It provides two contacts that can open fast and wide, preventing excessive arcs produced (in an inductive-reactance circuit) during the OFF "break" of the switching action.
2. It provides optimum cooling of heated contacts that become hot from arcing.

The remaining 11 poles of switch S1 are arranged with series assemblies like switch section I. They are identified by letters *J* through *T,* with their terminals numbered 15 through 36. Switch section T is a spare. The letter *X* denotes those contacts that are closed and letter *0* denotes those contacts that are open when the switch is put into a selected position of OFF, MANUAL, or AUTOMATIC. S 1 is shown in the AUTOMATIC position in figure 8-12, view A.

Switch S2 is an assembly of 18 contacts (fig. 8-12, view C). They are connected in series, operate simultaneously, and function as a single ON-OFF device. Again, the function (using many contacts) serves to break a long arc into several smaller arcs and produce longer life for the heat-dissipating contacts.

Static Exciter

As you read this section about the static exciter, refer to figure 8-13. The static exciter consists of a three-phase rectifier; CR1, three linear inductors, L1, L2, and L3; and three transformers, T1, T2, and T3.

The transformers are alike and interchangeable. Each transformer has four windings (figure 8-13 shows only the three windings that perform in the basic exciter circuits). The first winding is the potential or primary (P2) winding, the second winding is the secondary (S-2) winding, and the third winding is the current winding. The fourth winding is the control winding, which is discussed later. Each transformer is identified as a saturable current potential transformer (SCPT).

The primary windings of T1, T2, and T3 are Y-connected through the linear inductors L1, L2, and L3 by conductors 13, 14, 15, and 23.

The secondary winding is delta connected to diodes (A, B, C, D, E, and F) of rectifier CR1 by means of conductors 16, 17, and 18. Rectifier CR1 delivers de to conductors 11 and 9, which supply the generator field.

The current in the control windings CW1, CW2, and CW3 (fig. 8-12, view A) controls the output of the SCPT secondaries and thus the output of the static exciter. The control windings are supplied by the voltage regulator output as discussed later. Load current flowing in the current windings (I1, I2, and I3 in fig. 8-12, view A) compensates for changes in the generator load.

FIELD-FLASHING CIRCUIT.— The static exciter cannot supply field current until some ac voltage has built up on the 400-kW generator. DC power is temporarily provided by a 50-kW dc generator delivering 120 volts.

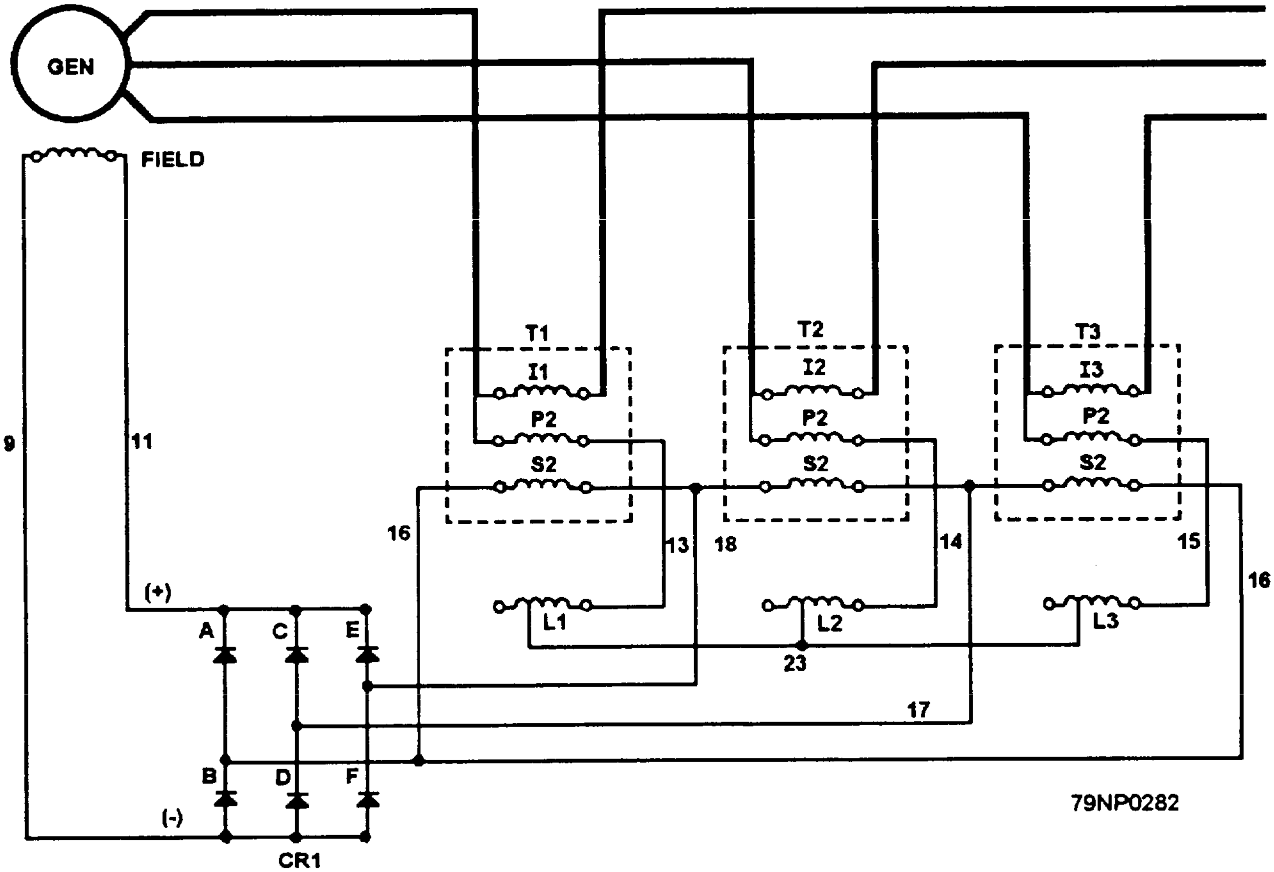


Figure 8-13.—Static exciter.

Perform the following procedure to start the system:

1. Place the control switch (S1) in either the MANUAL or AUTOMATIC position.
2. Move the spring-return field-flashing switch S-2 (fig. 8-12, view C) to the FLASH position. This allows flashing current to flow temporarily to the field of the ac generator, as shown in figure 8-14, when the prime mover is started and the generator is brought up toward its rated speed.
3. Remove switch S2 as soon as the generator voltage begins to build up. This is because thereafter the static exciter is capable of continuing the dc voltage required by the generator field.

The field does not have to be flashed every time the system is placed in operation. It is usually necessary to flash the field only after a generator malfunction or when the generator is idle for long periods of time, such as overhaul periods.

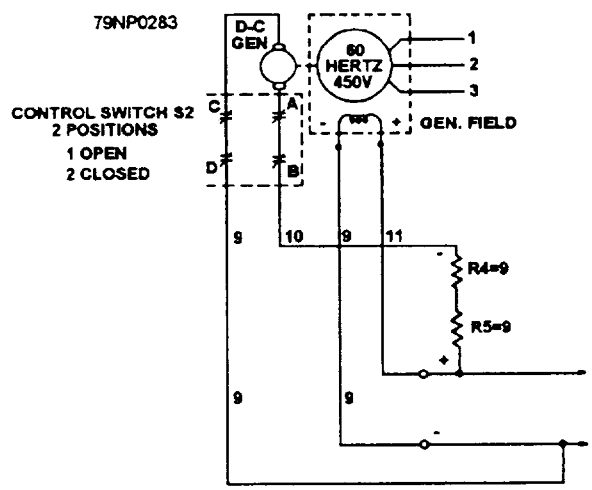


Figure 8-14.—Field-flashing circuit.

MANUAL VOLTAGE CONTROL CIRCUIT.— With switch S1 (fig. 8-15) in the manual position, contacts F and H are closed, connecting the 29-volt secondary of transformer T5 to the bridge rectifier CR2. The resulting dc signal flows in the following manner:

1. From the negative terminal of CR2 through resistor R6
2. Through the manual control rheostat R7,
3. Through closed switch S1-D to conductor No. 22, and
4. Through the series arrangement of each SCPT control winding.
5. There, it combines temporarily with the flow of the generator's dc field passing from the+ side to the – side of rectifier CR1, and finally
6. It terminates at the positive terminal of rectifier CR2.

Five switch sections of S1 are closed to establish manual control for the exciter's output, namely, B, D, F, H, and O. Switch S1-0 short circuits the output of transformer T4 to eliminate a drooping characteristic, which is not now required. Manual control of generator voltage is achieved by the manual control rheostat R7.

Varying the resistance of potentiometer R7 functions to vary the saturation of the cores of T1, T2, and T3. Varying the amount of dc alters the core saturation. Those variations will change the voltage value that is induced from each primary into its associated secondary winding (8- 13).

Automatic Voltage Regulator

The static exciter alone (fig. 8-13) will not maintain the different amounts of field current required to maintain a constant value of ac voltage at the generator terminals during various load changes. Therefore, a voltage regulator is needed to hold the generator voltage constant.

The automatic regulator controls the exciter output by precisely regulating the flow of dc in the control winding of each SCPT (T1, T2, and T3 shown in figure 8-16). Here, the initial ac is provided by the 85-volt secondary of transformer T5. This feeds rectifier CR6 (through terminals 41 and 52) to provide the dc source

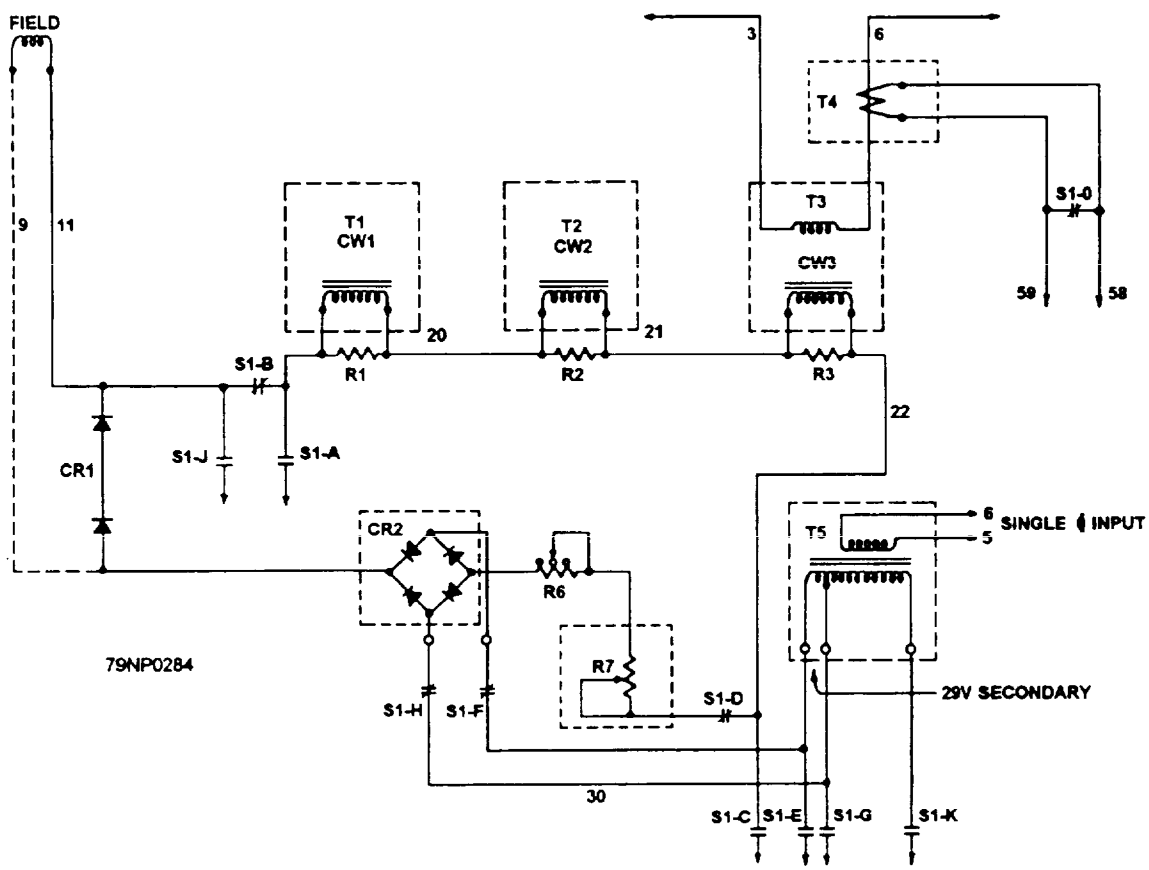


Figure 8-15.—Manual voltage control circuits.

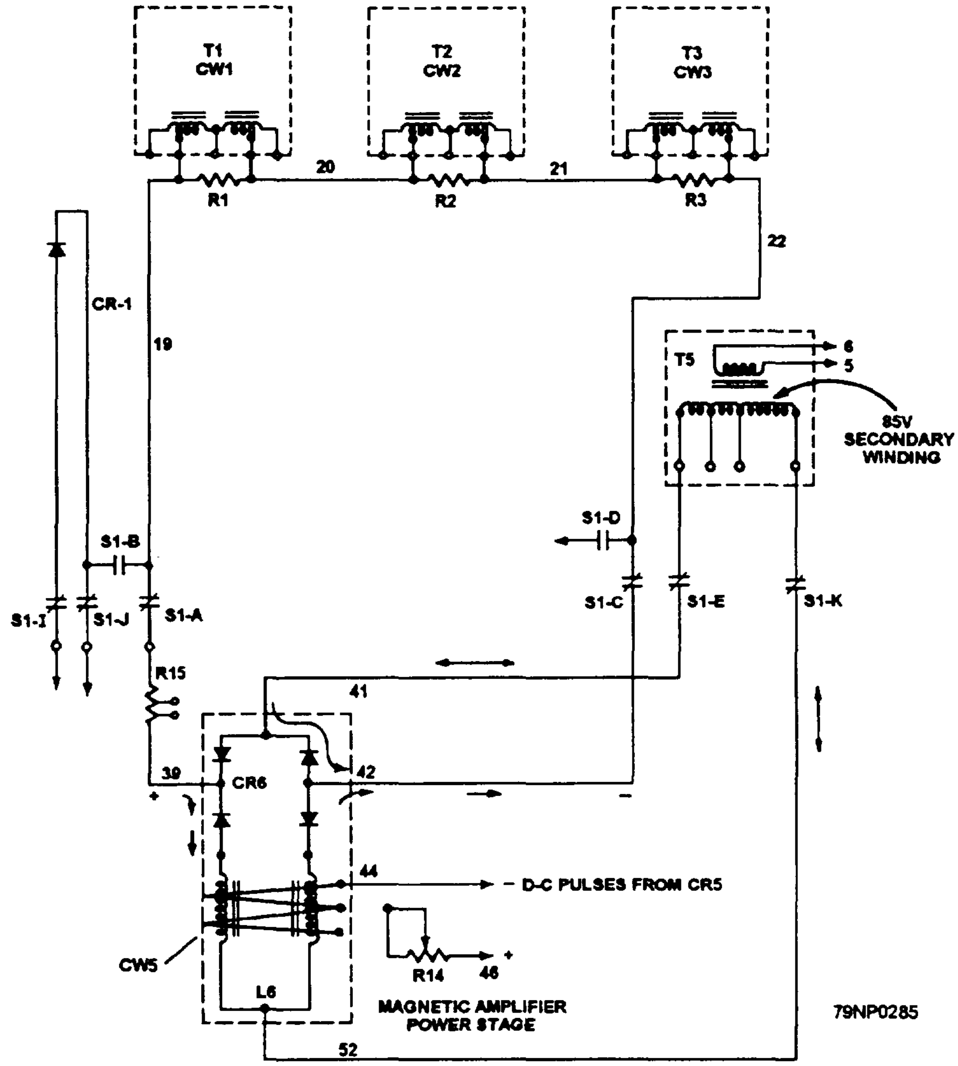


Figure 8-16.—Final-stage magnetic amplifier.

at terminals 39 and 42. The flow of dc is precisely controlled by the ohmic reactance values of each coil of L6.

The reactance of each coil of L6 is controlled by the state of magnetic saturation produced by the regulated dc flow from rectifier CR5 of the first stage magnetic amplifier (fig. 8-17, view A). This regulated dc signal is transmitted to the control windings of the coils in L6 through terminals 5 and 6 of fig. 8-12, view A.

The control of this regulated output of rectifier CR5 originates with sampling the average of the three line voltages by the sensing circuit in figure 8-18, view A. This voltage is processed further in the reference and comparison circuits (fig. 8-18, views B and C) for amplification in the preamplifier of figure 8-17.

SENSING CIRCUIT.— To obtain the best regulation during unbalanced load conditions in the three phases, the regulator uses the sensing circuit (fig. 8-18, view A), which responds to the average of the three values of ac line voltages (terminals 4,5, and 6).

Transformer T6 reduces the line voltage of each phase to a convenient value. Rectifier CR3 converts the three-phase ac to dc voltage. If an unbalanced condition causes the three line voltages to become unequal, the dc across the rectifier will have considerable (third harmonic) ripple. However, the combined filter actions of inductor L4 and capacitor C1 will remove the ripple and produce dc across C1 (near 50 volts). This is always in proportion to the average of the three line voltages.

Resistor R8 is used for reactive droop compensation and will be discussed later.

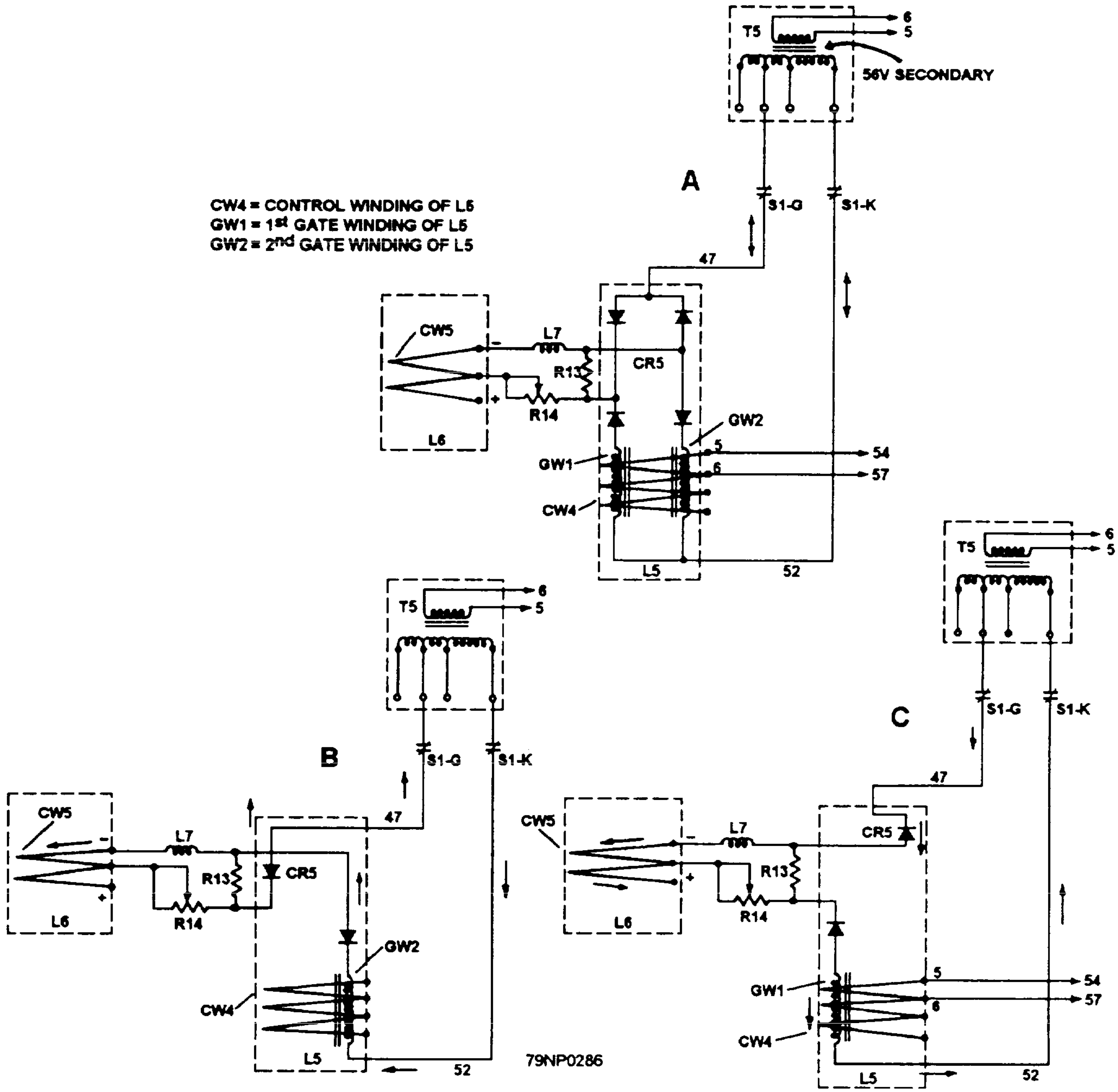


Figure 8-17.—First-stage magnetic amplifier.

REFERENCE CIRCUIT.— The reference circuit (fig. 8-18, view B) consists of resistor R9 and Zener diode CR4. The function of CR4 is to supply a nearly constant (25 volt) reference voltage to the comparison circuit (fig. 8-18, view C). Dropping resistor R9 limits the current through CR4 to a safe value. If the voltage (near 50 volts) across R9 and CR4 increases, the current increases in both items. The voltage increases only across R9, leaving the voltage across CR4 at its original voltage value (25 volts). CR4 consists of four Zener diodes with each diode operating in the breakdown region and having nearly a constant 6.2 voltage drop across each unit.

COMPARISON CIRCUIT.— The comparison circuit consists of the reference circuit (fig. 8-18, view B), combined with resistors R10, R11, and R12 (fig. 8-18, view C). Its function is to compare the "average line voltage" to the reference voltage. It also acts on the first-stage magnetic amplifier to correct any transients.

ERROR VOLTAGE.— Three sets of tests are made with a dc voltmeter at the three terminals

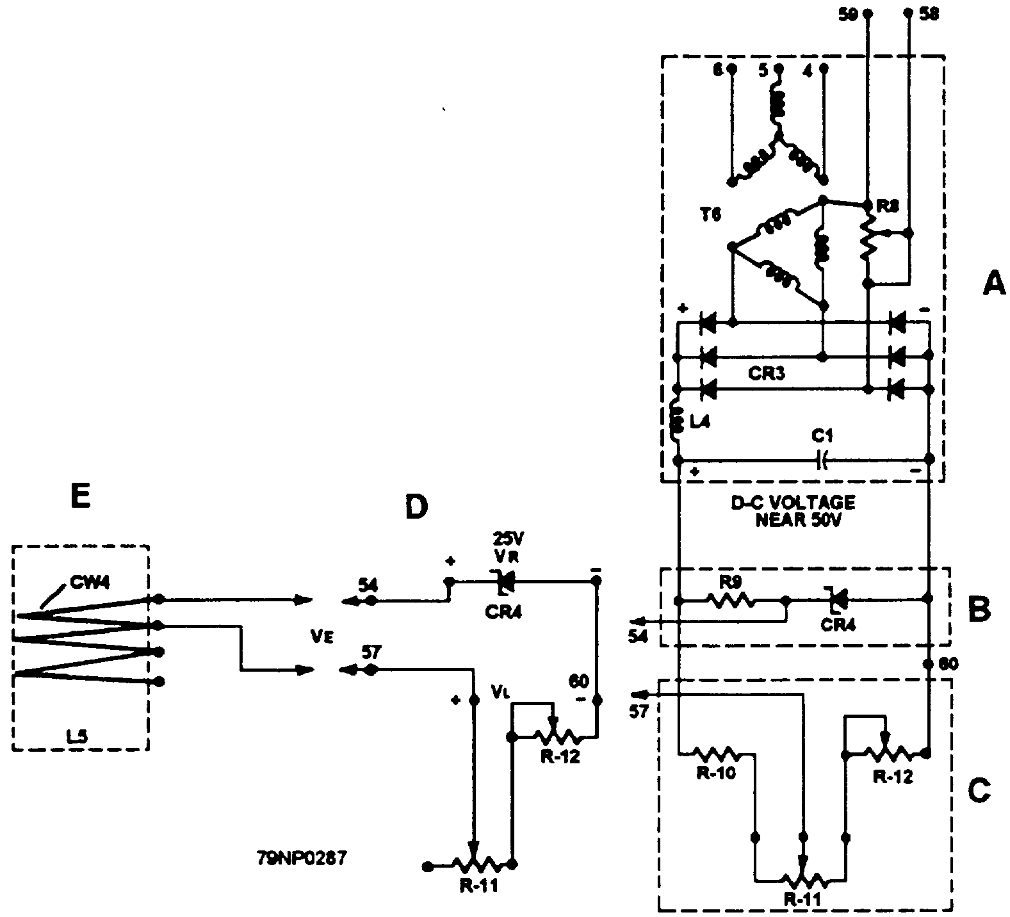


Figure 8-18.—Automatic voltage regulator.

(numbered 54, 57, and 60) in figure 8-18, view C. These tests reveal several facts that explain the **ERROR VOLTAGE** (V_E) produced across terminals No. 54 and No. 57 (fig. 8-18, view D). To use the dc voltmeter, use the following procedure:

1. Connect a dc voltmeter to the VE terminal. Disregard meter-polarity connections since some of the performance tests will cause the meter to read downscale when the polarity (of the error voltage) reverses.
2. Initial changes in the amount of V_E are made by adjusting the slider on VOLTAGE ADJUSTING RHEOSTAT R11. A slider position of R11 will be found where V_E registers zero.
3. Then, reposition the meter leads to verify that the reference voltage V_R (terminal No. 60 is negative; No. 54 is positive) will always remain at 25 volts regardless of generator output.
4. Relocate the meter leads to measure line voltage V_L and verify that it has the same value (25 volts) as V_R, when V_E is zero.

his will be for this measurement only. If resistor R11 is readjusted to produce, for example, either a 27- or a 23-volt reading for V_L, then V_E has a numerical value of 2 volts. However, polarities are reversed.

The two conditions that may cause a change to the excitation voltage by the automatic voltage regulator are given in table 8-4.

Table 8-4.—Effects of Changes to V_L and V_R

CONDITION	RESULT
VR > VL	The voltage regulator will increase the exciter voltage, which raises the line voltage.
VL > VR	The voltage regulator will reduce the exciter voltage, thereby lowering the line voltage.

MAGNETIC AMPLIFIER CIRCUITS.— The essential parts of the two stages of magnetic amplifiers (figs. 5-16 and 5-17) consist of L5, L6, CR5, CR6, R13, R14, and R15.

Changes in generator voltage produce changes in current in the comparison circuit. These are in the order of milliamperes while flowing in the control winding, CW4 (fig. 8-17). It is necessary to amplify these initial small currents so their effect is in the order of several amperes in the final control windings of CW1, CW2, and CW3 of the SCPTs.

Two magnetic-amplifier gates (GW1 and GW2 as shown in figure 8-17) function automatically and alternately to regulate the flow of ac delivered by the 56-volt secondary of transformer T5. The automatic regulation is achieved by saturating and&saturating the flux in the cores of GW1 and GW2. The degree of flux at any moment in each core is determined by the previously described conditions of dc flow in the control winding, CW4.

The flow of gated ac and its conversion into dc pulses in another control winding (CW5 of the power amplifier L6), is readily traced by inspection of the arrows in figure 8-17, views B and C. These arrows alongside the conductors and rectifier elements are in the direction of electron flow during one half cycle in figure 8-17, view C. The control winding current can be changed until the full supply voltage is applied to the load In this way, a control winding in each stage of the several saturated cores controls the output from the magnetic amplifier.

The series resistors R14 (fig. 8-17) and R15 (fig. 8-16) are adjusted so each amplifier operates in the center of its saturation curve.

Inductor L7 (fig. 8-17) is used to assure smooth continuous control of the second-stage amplifier.

Transformer T5 is used to supply power to the two magnetic amplifiers. It is also used to supply control current when it is operating in manual control.

A control winding would function to change its flux by means of either dc pulses or filtered dc. Control winding CW4 employs filtered dc by using capacitor Cl (fig. 8-18) in the sensing circuit.

If, in figure 8-17, view B, the supply voltage (from transformer T5) is applied to the gate winding in series with its CW5 load, most of the voltage drop is across the gate winding (and very little voltage drop is across the CW5 control-winding load), provided the flux in the L5 core never reaches saturation. If the control-winding CW4 current changes so the core flux reaches saturation for part of the cycle, the gate-winding inductance drops to a very low value for that part of the cycle. A portion of the supply voltage wave is then applied to the load.

STABILIZING CIRCUIT.— In any closed-loop regulating system that contains several time constants and has high gain, sustained oscillations would be produced. Undesired oscillation is sometimes called hunting. To prevent hunting, a stabilizing falter circuit (resistor R17 and capacitor C3 in figure 8-12, view A) is used to remove the normal ripple from the exciter output voltage. Another network (resistor R18 and capacitor C4) stabilizes the exciter output voltage. Nonlinear resistor R19 is used to suppress abnormally high transient voltage that may appear across the field rectifier CR1.

REACTIVE DROOP COMPENSATION CIRCUIT.— Current transformer T4 and resistor R8 are used to obtain the generator-drooping characteristic. The vector diagrams for this circuit are shown in figure 8-19, views A and B. Figure 8-19, view A shows the line voltages and currents for real and reactive loads. Figure 8-19, view B shows the voltages on the secondary of the transformer T6, along with the IR (voltage) drop (produced across resistor R8 because of its current from the secondary T4, called I_4).

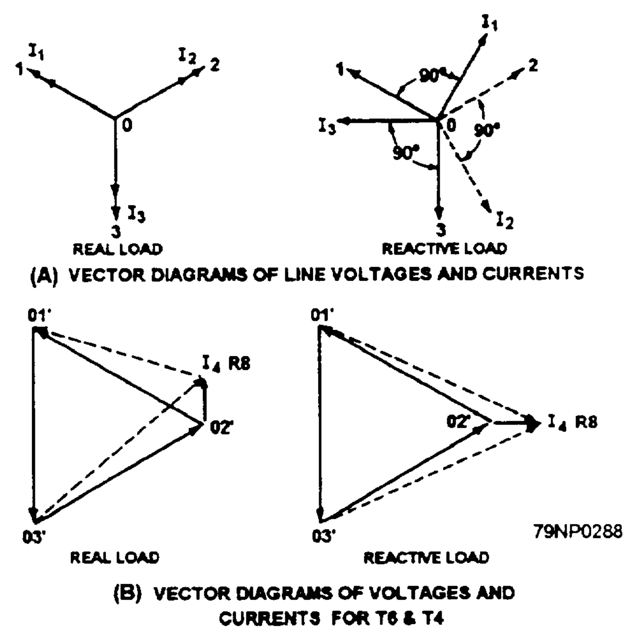


Figure 8-19.— Vector diagrams of reactive droop circuit-

For an in-phase, real load, this I_4R8 voltage drop shortens vector 01' but lengthens vector 02' (dashed lines). The average of the three vectors remains essentially constant. However, for a reactive load the I_4 R8 voltage drop lengthens vectors 01' and 02' (dashed lines) and increases the average of the three vectors. The regulator senses this higher voltage and reduces the generator voltage. It does this by giving the generator a drooping characteristic for reactive loads. Since the average of the three vectors 01', 02', and 03' did not change for a real load, the generator output should remain essentially constant.

The amount of reactive droop can be increased by increasing the resistance of resistor R8. You should make sure that the resistance is 2 ohms or more.

Manual Operation

To start the static excitation and voltage regulation system equipment to run in manually, you should use the following procedure:

1. Set the manual control rheostat R7 for minimum volts (fully counterclockwise).
2. Set the control switch S1 on MANUAL.
3. Hold the FLASHING SWITCH S2 in the FLASH position until the generator starts to build Up.
4. Adjust the manual control rheostat R7 to obtain the proper generator voltage.

Automatic Operation

To operate the system in AUTOMATIC, bring the system up in MANUAL control as just described, then proceed as follows:

1. Turn the control switch S1 to the AUTO position
2. Adjust the voltage-regulating rheostat R11 to obtain the proper voltage.

NOTE: Never leave control switch S1 in an intermediate position between MANUAL and AUTOMATIC.

The control switch S1 has an emergency shutdown feature when placed in its OFF position. This can be used to quickly de-energize the generator in case of an emergency.

Maintenance

The static regulator has no moving parts. Its components are extremely rugged; therefore, little maintenance besides preventive maintenance is required. Some of the actions you should take are as follows:

- Ensure that the regulator is kept clean and internal connections remain tight.

- Protect all parts from moisture-this is an essential action, especially when selenium rectifiers are involved. Exposure to moisture or mercury compounds will destroy selenium cells.

- When you replace new rectifier units in CR4, CR5, or CR6, don't overheat their leads when soldering. To prevent overheating, use a low-temperature solder (rosin core). Attach a small heat sink, such as an alligator clip or long-nosed pliers, between the rectifier and the attached lead where the soldering occurs. This will prevent damaging heat from reaching the rectifier cell.

- If it is necessary to apply a high-potential test to the exciter or generator using a megger, you should short out all rectifiers with clip leads. High-potential tests are discussed in the *NSTM,* chapter 300.

SPR-400 LINE VOLTAGE REGULATOR

The SPR-400 line voltage regulator (fig. 8-20) is a general-purpose, automatically controlled ac line regulator. It ensures precision voltage regulation for line, load, frequency, and power factor variations in single or three-phase (delta or wye connection) circuits. There are several designs of line voltage regulators available. The operation described in the next section will cover a typical design. The line voltage regulator is designed around the use of the silicon controlled rectifier (SCR). The SCR acts as a switch when a control voltage is applied to it.

OPERATION

The voltage regulator is installed in series with the load, which requires a precise] y regulated power supply.

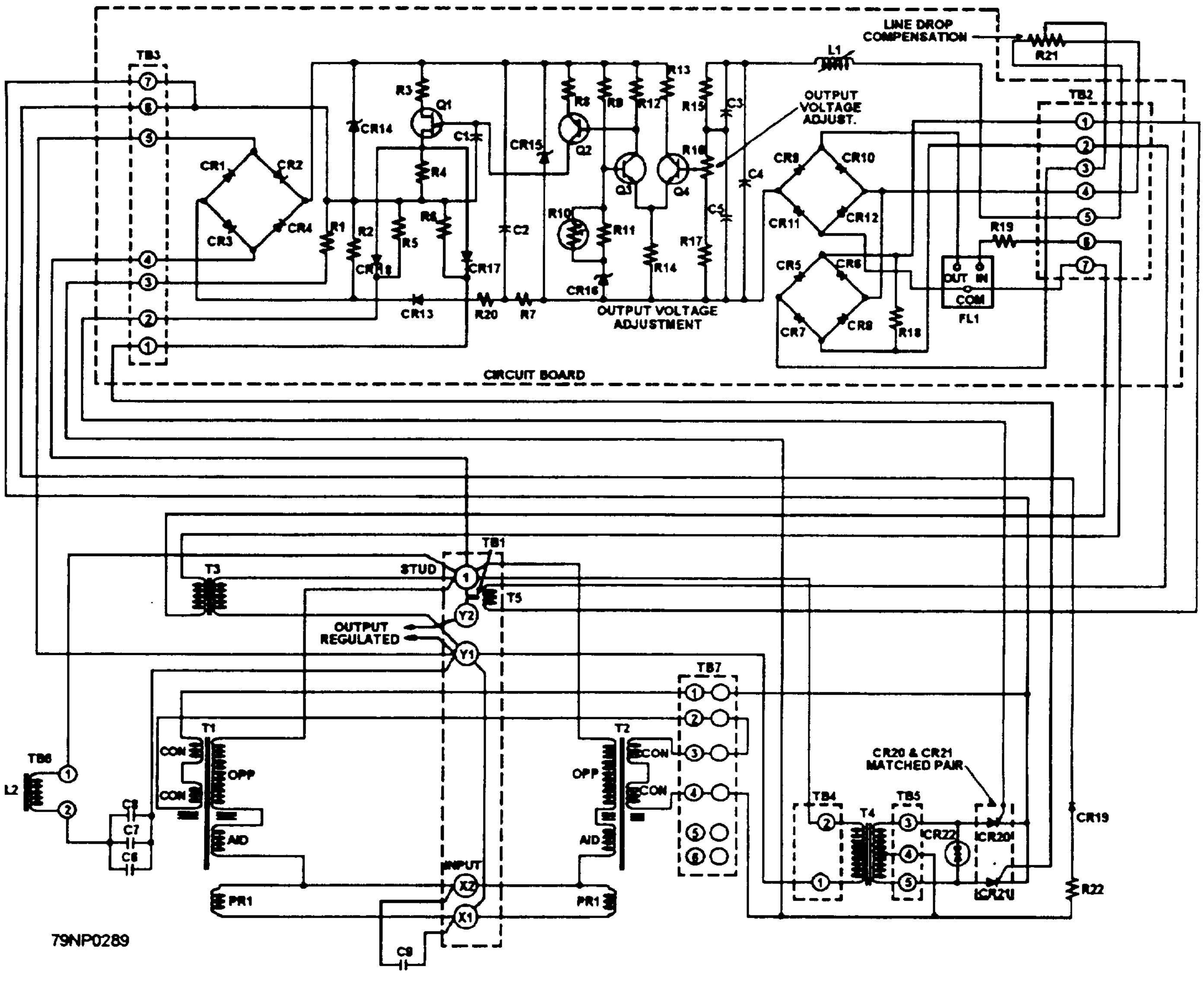


Figure 8-20.—SPR-400 line voltage regulator.

The unit shown in figure 8-20 controls a single-phase circuit. The input is at terminals X1 and X2 on terminal board 1 (TB1). Regulated output is from terminals Y1 and Y2 on TB1. Regulation is achieved by controlling the two autotransformers, T1 and T2.

An acceptable waveform is ensured where one side of the transformer output goes to a harmonic filter via terminal 1 on TB1. The filter consists of the inductor L2 on TB6 and the parallel capacitors C6, C7, and C8.

Voltage from terminals Y1 and 1 on TB1 drives the rectifier bridge consisting of CR1, CR2, CR3, and CR4, on the circuit board. This bridge provides dc power for the solid state components on the board

The operational sequence of the SPR-400 line voltage regulator is shown in table 8-5.

Table 8-5.—Operation of the SPR-400 Line Voltage Regulator

STEP	ACTION
1.	The input is applied to Y1 and 1 through autotransformers T1 and T2.
2.	Transformer T3 senses the line voltage changes and varies the conduction of transistors Q4 and Q3, through the rectifier bridge, by varying the voltage drop across R16.
3.	Q2 is controlled by differential amplifiers Q4 and Q3.
4.	Q2, in turn controls the charging rate of capacitor C1.
5.	C1 raises the emitter-base 1 potential of Q1.
6.	The firing of Q1 sends gate pulses to SCRs CR20 and CR21 through terminals 1 and 2 of TB3.
7.	When the SCRs are gated, autotransformer T1 and T2 control windings receive dc current, which controls the output of the autotransformers.

For example, when line voltage increases, the following events occur:

1. Q4 conducts more and Q3 conducts less.
2. Q2 in turn conducts less.
3. C1 will charge more slowly and Q1 will fire later in each half cycle.
4. The SCRs will also be gated later in each half cycle.
5. Autotransformer control windings receive dc current later in each half cycle and the potential at Y1 and 1 will decrease.

If line potential at Y1 and 1 decreases too far, then the following events will occur:

1. Q4 will conduct less and Q3 more.
2. Q2 will now conduct more and charge Cl faster.
3. Q1 will now fire earlier in each half cycle and gate the SCRs earlier.
4. Control windings in the autotransformer receive dc current earlier, decreasing autotransformer impedance and allowing line potential to increase.

Remember, the application of input power (across terminals X1 and X2 of TB1, fig. 8-20) energizes the two parallel operated autotransformers. The input voltage is stepped up by an aiding winding (AID). This is wound directly over the primary winding (PRI). The voltage is then reduced to nominal output by an opposing winding (OPP). The magnitude of induced voltage in the opposing winding is varied by the level of dc in the control windings (CON) from the SCRs. The opposing and the control windings are separated from the primary and the aiding windings by a magnetic shunt. Increasing the dc in the control windings forces the magnetic flux through the shunt. This decreases the opposing voltage, and thus increases the output.

Items used to control the operation of the SCRs (CR20 & CR21) in figure 8-20 are shown in table 8-6 below:

Table 84.—Description of Items Used in Controlling the Operation of CR20 and CR21

ITEM	USE/FUNCTION
Stepdown transformer T4	Supplies power to the SCRs
Diode CR19	Provides a discharge path via terminals 6 and 7 of TB3 for control windings of T1 and T2 when the SCRs are shut off.
Silicone diode CR22	Protects SCR's from excessive peak inverse voltage. It acts as an insulator during normal operation and shorts when excessive voltage is applied.

An additional output voltage compensation is provided for cable loss when the stud of terminal Y2 passes through current transformer T5. It induces a signal in T5 proportional to the load current. Adjustment of potentiometer R21 provides compensation in this circuit. The potentiometer setting compensates for the resistance in cables from the regulator to the load. Once set, it doesn't have to be changed unless the cables (not the load) are changed.

MAINTENANCE

Normally, voltage regulators require little preventive maintenance, other than that described on the MRCs. This is because the components are stable and nonwearing with no moving parts (other than two potentiometers). However, you do need to make frequent inspections for dust, dirt, and moisture accumulation. Also, you need to clean the equipment as necessary.

CLOSELY REGULATED POWER SUPPLIES

Certain weapons, interior communications, and other electronics systems aboard modem Navy ships require closely regulated electrical power (type 111) for proper operation. Special closely regulated motor-generator (MG) sets supply the greater part of this power. Static-type converters are also used in some installations.

30-KW MOTOR-GENERATOR SET

The closely regulated MG set (fig. 8-21) consists of a 450-volt, three-phase, 60-Hz, 50-hp, wound rotor induction motor driving a 450-volt, three-phase, 400 Hz, 30-kW generator. The set is regulated and controlled by a voltage and frequency regulating system (housed in the rotor resistor and regulator unit control cabinets) and a magnetic controller with associated push buttons and switches (located in the control cabinet).

The magnetic controller is a conventional size 3 across-the-line semiautomatic motor controller (starter). The voltage-regulating system functions to supply the proper field current to the generator so as to maintain the generator output voltage within plus or minus one-half of 1 percent of rated output voltage for all load conditions. The frequency-regulating system functions to control the speed of the drive motor to maintain the output frequency of the generator within plus or minus one-half of 1 percent of its rated value for all load conditions. In addition, power-sensing networks that function to eliminate speed droop with increased generator loads and to maintain equal sharing of the load between paralleled generators are included.

Voltage Regulating System

The voltage regulating system consists of a voltage regulator and a static exciter, as shown in figure 8-22. The output from the power section of the regulator, in conjunction with windings within the static exciter,

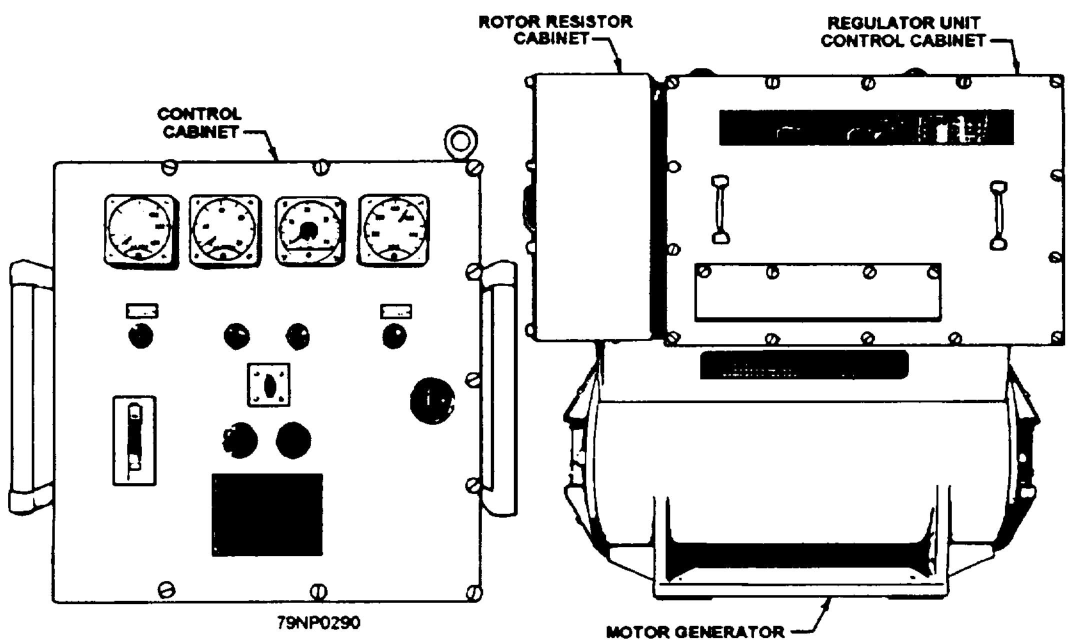


Figure 8-21.—Motor-generator set with control equipment.

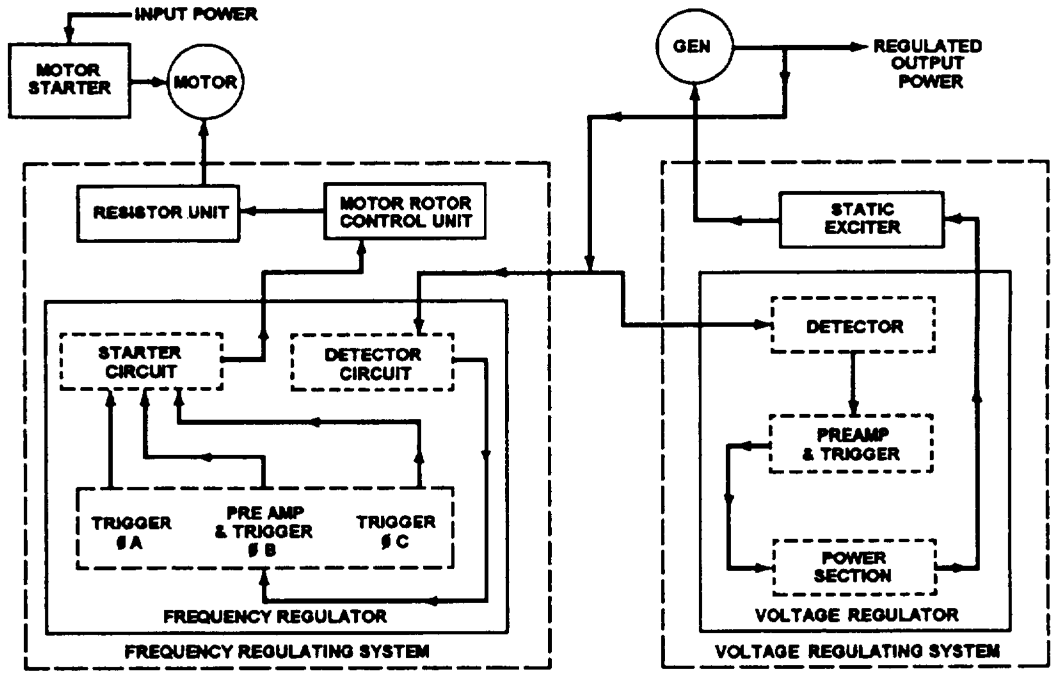


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Figure 8-22.—Motor-generator set simplified block diagram.

controls the static exciter output. The static exciter output, in turn, supplies dc (excitation current) to the generator field of the proper magnitude so as to maintain the generator output voltage within specified limits under all load conditions.

The static exciter consists of the following components:

1. A saturable current-potential transformer (SCPT)
2. Three linear reactors (chokes)
3. A three-phase bridge rectifier unit

The SCPT contains (1) a primary winding consisting of both voltage and current windings, (2) a dc control winding, and (3) a secondary winding. The voltage primary windings are connected in series with the chokes across the generator output. The current primary windings are connected in series with the load, and thus carry load current. The secondary winding output is connected to the bridge rectifier unit, which supplies the dc for the generator field. The SCPT control winding is connected to the output of the voltage regulator.

The voltage regulator consists of the following components:

1. A detector circuit
2. A preamplifier (preamp) and trigger circuit
3. A power section

The detector circuit includes a sensing circuit and a three-phase bridge rectifier. The sensing circuit consists of three voltage sensing transformers with their primary windings connected to the generator output and their secondary windings connected to the bridge rectifier. The bridge rectifier provides a dc output voltage that is proportional to the average of the three-phase voltage outputs from the generator. This dc voltage is filtered and fed to a Zener reference bridge in the preamp and trigger circuit.

The dc output from the detector is compared with a constant Zener voltage in the reference bridge. The difference (error) voltage output from the bridge is amplified by transistor amplifiers and fed to a unijunction transistor circuit, which provides the pulses to trigger the SCRs in the power section. The SCR output from the power section is fed to the control winding of the SCPT in the static exciter.

During starting, generator field current is supplied by a field flashing circuit, which is cut out after the generator builds up an output voltage. At no-load voltage, the primary windings of the SCPT are energized through the choke coils and induce a voltage in the SCPT secondary windings. The rectified output of the secondary windings supplies the generator field. This is the no-load field excitation.

When a load is applied to the generator, load current flows through the SCPT primary current windings causing a flux, which combines vectorially with the primary voltage windings flux to induce a voltage in the secondary windings. Thus, any change in generator load or load power factor is automatically compensated for. This arrangement, without the use of the voltage regulator, would hold the generator output voltage fairly constant under all load conditions.

The voltage regulator is necessary, however, for the high degree of regulation required. The voltage regulator acts as a fine control by effectively varying the coupling between the SCPT primary and secondary windings.

Frequency-Regulating System

The frequency-regulating system consists of a motor rotor control and resistor unit and a frequent y regulator. The detector circuit of the frequency regulator receives its input from a special type of frequency-sensing transformer whose voltage output varies linearly on changes in generator output frequency. This input is rectified, filtered, and compared in a Zener reference bridge, and the bridge output is amplified by transistor amplifiers. The amplified detector output (which represents the output frequency of the generator) is fed to the preamp and trigger section.

The detector output is further amplified in the preamp and trigger section, and this amplified output is used to control three pulse forming networks, which provide trigger pulses for SCRs located in the starter circuit.

The SCRs in the starter circuit (controlled by the weak trigger pulses from the preamp and trigger section) provide output pulses of sufficient magnitude to fire other SCRs located in the motor rotor control unit. The output of the SCRs in the motor rotor control unit is fed through three large resistors (about 3,000 watts). These

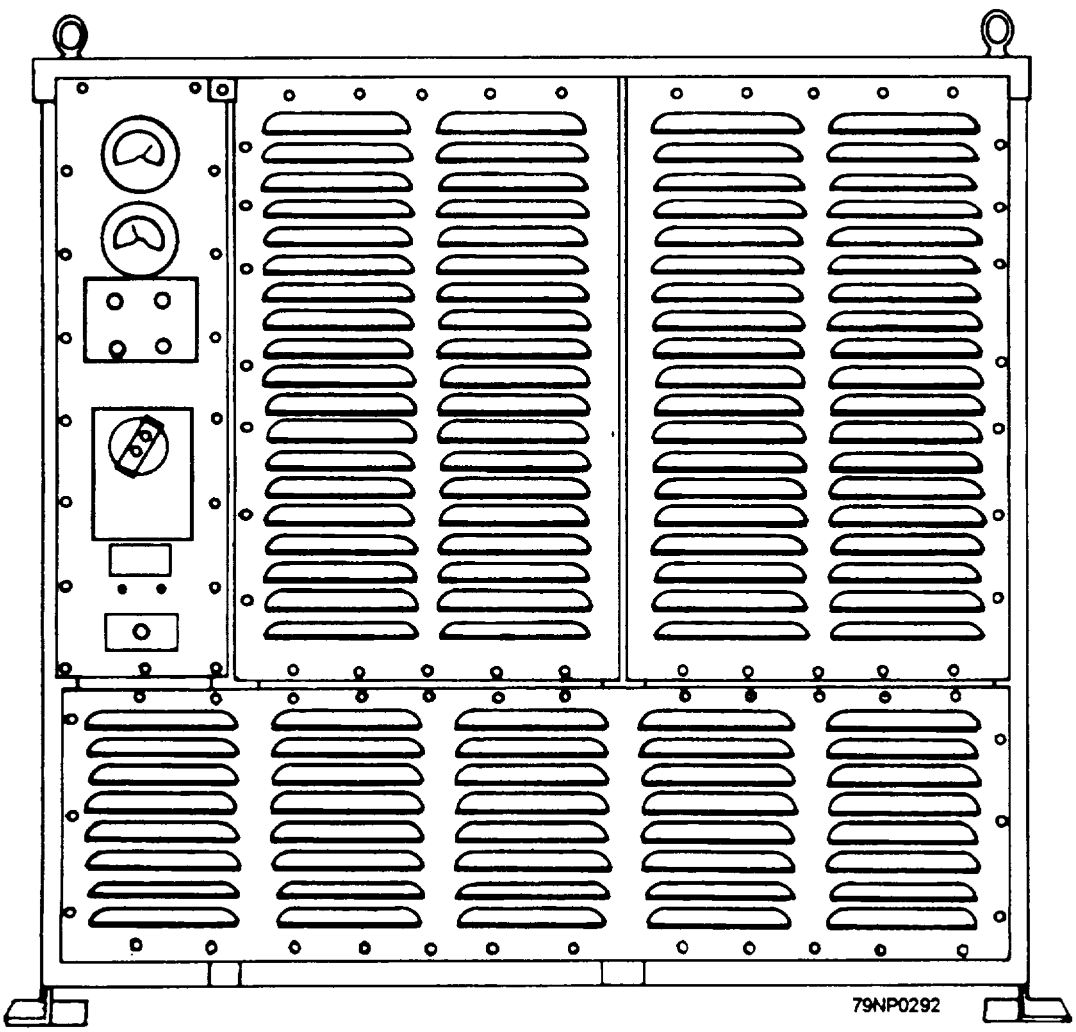

Figure 8-23.—Static converter, front view.

are connected in the wound-rotor circuit of the drive motor.

Any change from the normal generator output frequency will cause the frequency-regulating system to increase or decrease the rotor current, allowing the speed of the drive motor to compensate for the change. Thus, the output generator frequency is maintained constant by maintaining the speed of the directly connected drive motor.

STATIC CONVERTER

The static converter (fig. 8-23) converts 450-volt, three-phase, (50-Hz power to 120-volt, three-phase, 400-Hz power for use as a shipboard closely regulated power supply. The converter automatically maintains the output voltage and frequency within plus or minus one-half of 1 percent of rated value for all load conditions. This high degree of regulation is maintained even though the input voltage and frequency may vary as much as plus or minus 5 percent of rated value. The 450-volt, 60-Hz input is stepped dowm rectified, and fed to two static inverters. Each static inverter contains two main SCR groups consisting of two SCRs in series. The inverter outputs are fed to Scott-connected transformers to produce the three-phase output. A simplified block diagram of the converter is shown in figure 8-24.

Transformer Rectifier

The transformer rectifier unit (fig. 8-24) is an autotransformer and a three-phase, full-wave, bridge rectifier. The rectifier output is faltered and fed through choke coils to the static inverters. The choke coils limit the voltage appearing across the inverter SCRs.

Oscillator Circuit

The oscillator circuit (fig. 8-24) provides the pulses for firing the SCRs in the main inverter. This circuit consists of a unijunction transistor oscillator that provides pulses at a rate of 800 per second. These pulses switch a bistable (flip flop) transistor multivibrator circuit whose output supplies the primary of a transformer. The transformer output (which is a square wave) is amplified by a transistor push-pull circuit and fed to the primary of the oscillator output transformer. This transformer has a separate secondary winding for each main SCR in the main inverter. The output of these secondary windings, fed through a differentiating circuit (which converts the square waves to pukes), is used to fire the SCRs. Each SCR being fired from a separate secondary winding ensures simultaneous firing of the SCRs in series. The phasing of the secondaries allows firing of opposite SCRs at 180-degree intervals for proper inverter action.

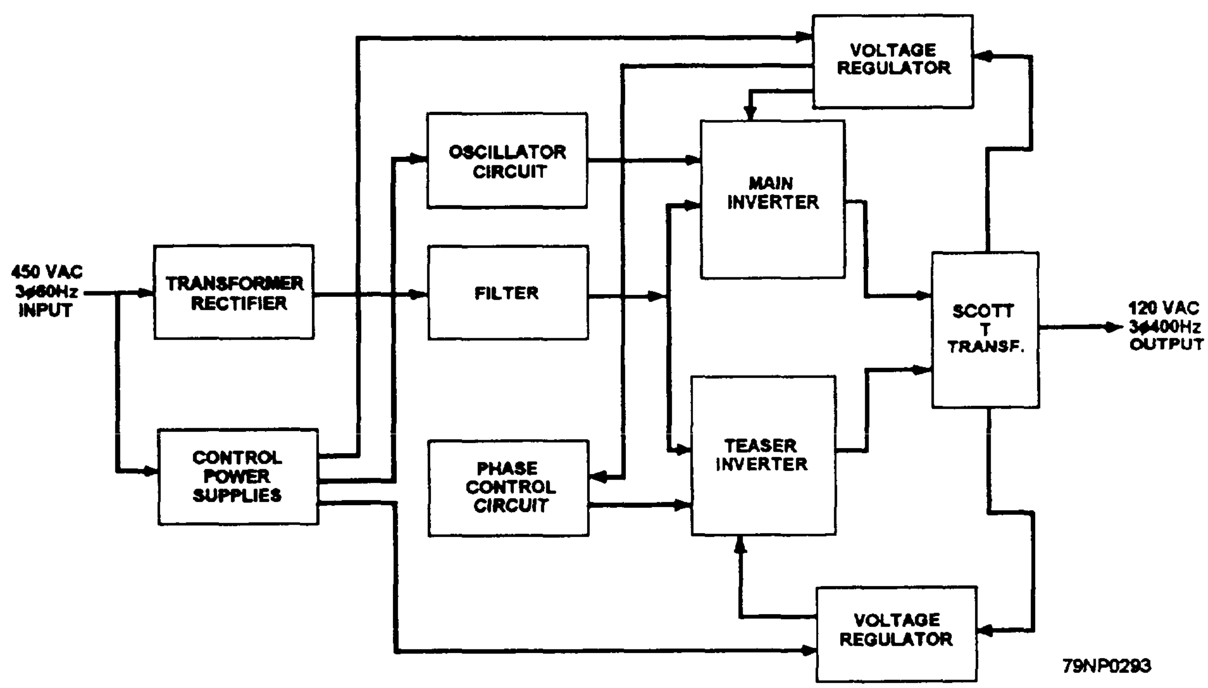

Figure 8-24.—Static converter, simplified block diagram.

Phase Control Circuit

The phase control circuit (fig. 8-24) contains components and circuits (similar to those in the oscillator circuit) that function to control the firing of the SCRs in the teaser (secondary) inverter and maintain the proper phase relationship between the outputs of the two inverters.

Voltage Regulators

The voltage regulator circuits (fig. 8-24) regulate the converter output voltage by controlling the firing time of the main SCRs in each inverter. The output of a transformer connected across the converter output is rectified to produce a dc signal that is proportional to the converter output voltage. This signal is filtered and compared in a Zener reference bridge to produce an error signal output when the converter output voltage varies from normal. This error signal is used to fire the inverter control SCRs, which in turn, control the firing time of the main SCRs.

Control Power Supplies

The converter (fig. 8-24) contains two control power supplies (one for each inverter), which supply regulated +30 volts dc to the various converter circuits. The input to the power supply transformer is taken from the 450-volt ac line. The power transformer output is rectified by a full wave bridge rectifier and regulated by a Zener diode regulator to produce the +30 volt dc output.

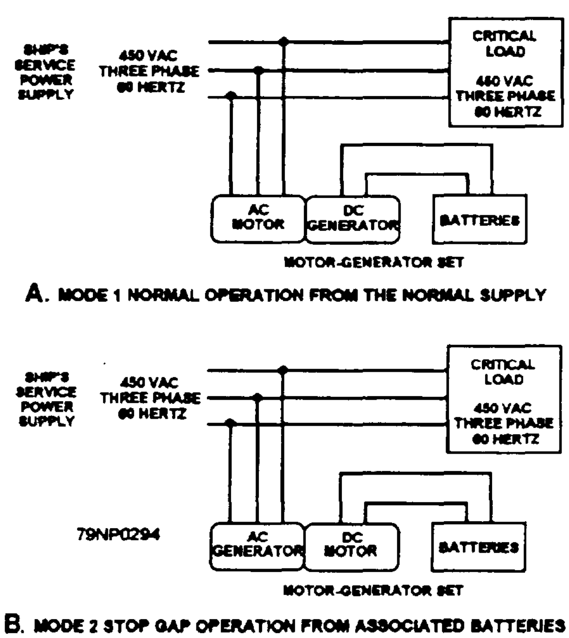

Figure 8-25.—No-break power supply, block diagram.

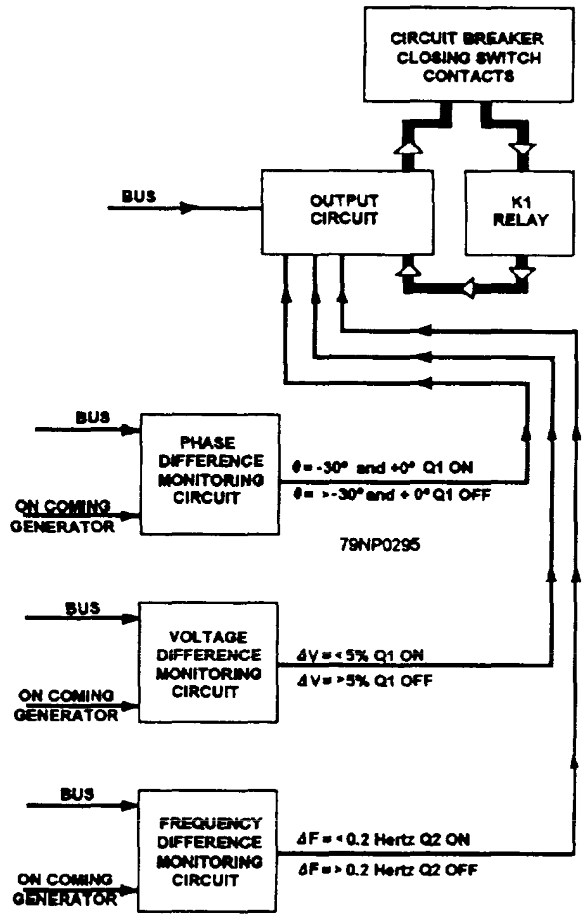

Figure 8-26.—Block diagram of synchronizing monitor.

NO-BREAK POWER SUPPLY SYSTEM

A no-break power supply system (fig. 8-25) is designed to provide an uninterruptible electrical power supply that is relatively constant in voltage and frequency under all load conditions. The no-break supply automatically takes over the power supply to a load when the normal supply is interrupted by a change infrequency or voltage. This type of system is required by ships with equipment, control, or computer systems that need an uninterrupted electrical power supply for effective operations. It is presently being used with ships using central operations systems.

The system uses an MG set, batteries, and associated controls to provide its regulated output. Either unit of the MG set can perform as a motor with the other as a generator, thus permitting two modes of operation.

MG MODE 1

In mode 1 operation of the MG set (fig. 8-25, view A), the ac end of the set is being driven from the ship's service power supply; and the dc end is a generator providing power to charge the system batteries. This motor-generator condition exists when the ship's service power supply is meeting the voltage and frequency requirements of the critical load.

MG MODE 2

Mode 2 operation of the motor-generator set (fig. 8-25, view B) represents the condition by which the set receives power from the batteries, and the ac end of the set provides the power requirements for the critical load. Mode 2 is referred to as the stop gap operation.

SYNCHRONIZING MONITOR

The synchronizing monitor (fig. 8-26) monitors the phase angle, voltage, and frequency relationship between the 450-volt, 60-Hz generator and an energized bus. Circuits within this panel energize a relay when the phase angle (0) is between -30° and 0°, the voltage difference **(ΔV)** is less than 5 percent, or the frequency drift **(ΔF)** between an oncoming generator and an energized bus is less than 0.2 Hz.

The synchronizing monitor does not automatically parallel two generators when it is connected to the system. The generators must be paralleled manually. This is independent of whether or not the synchronizing monitor is connected to the circuit. The function of the synchronizing monitor is to prevent the manual paralleling of two generators when the phase angle, voltage difference, and frequency difference of the two generators are not within safe limits.

The synchronizing monitor consists of the following four main circuits:

1. The output circuit
2. The phase difference monitor circuit
3. The frequency difference monitoring circuit
4. The voltage difference monitoring circuit

OUTPUT CIRCUIT

The output circuit (fig, 8-27) contains the K1 relay, its power supply, and a set of contacts (circuit breaker

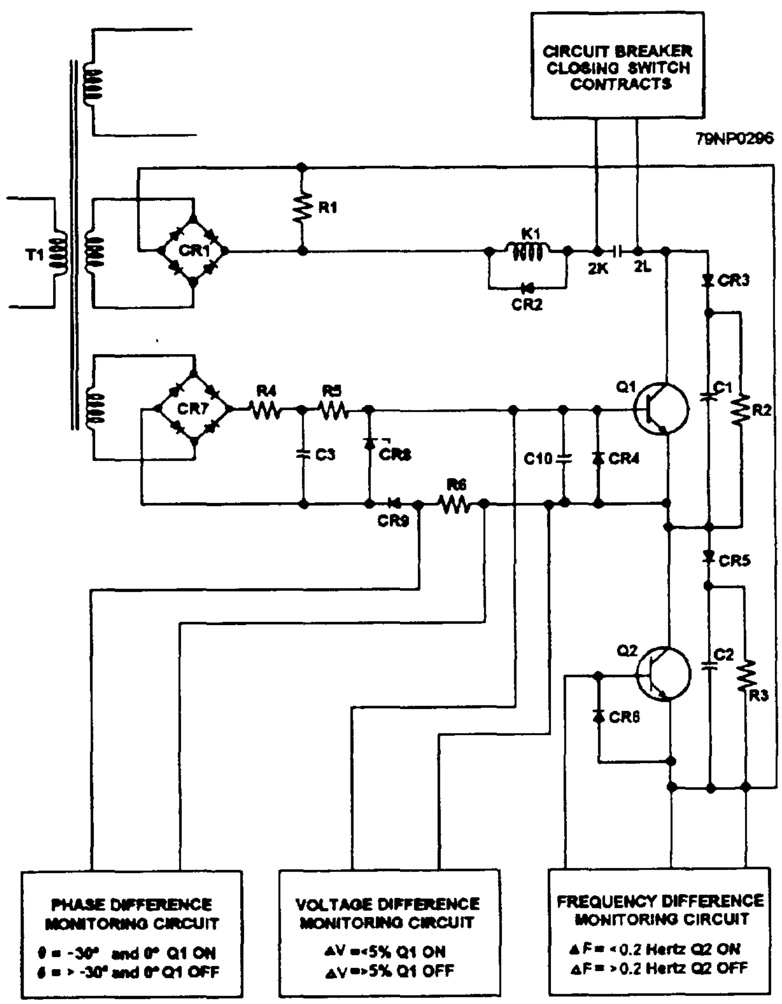

Figure 8-27.—0utput circuit.

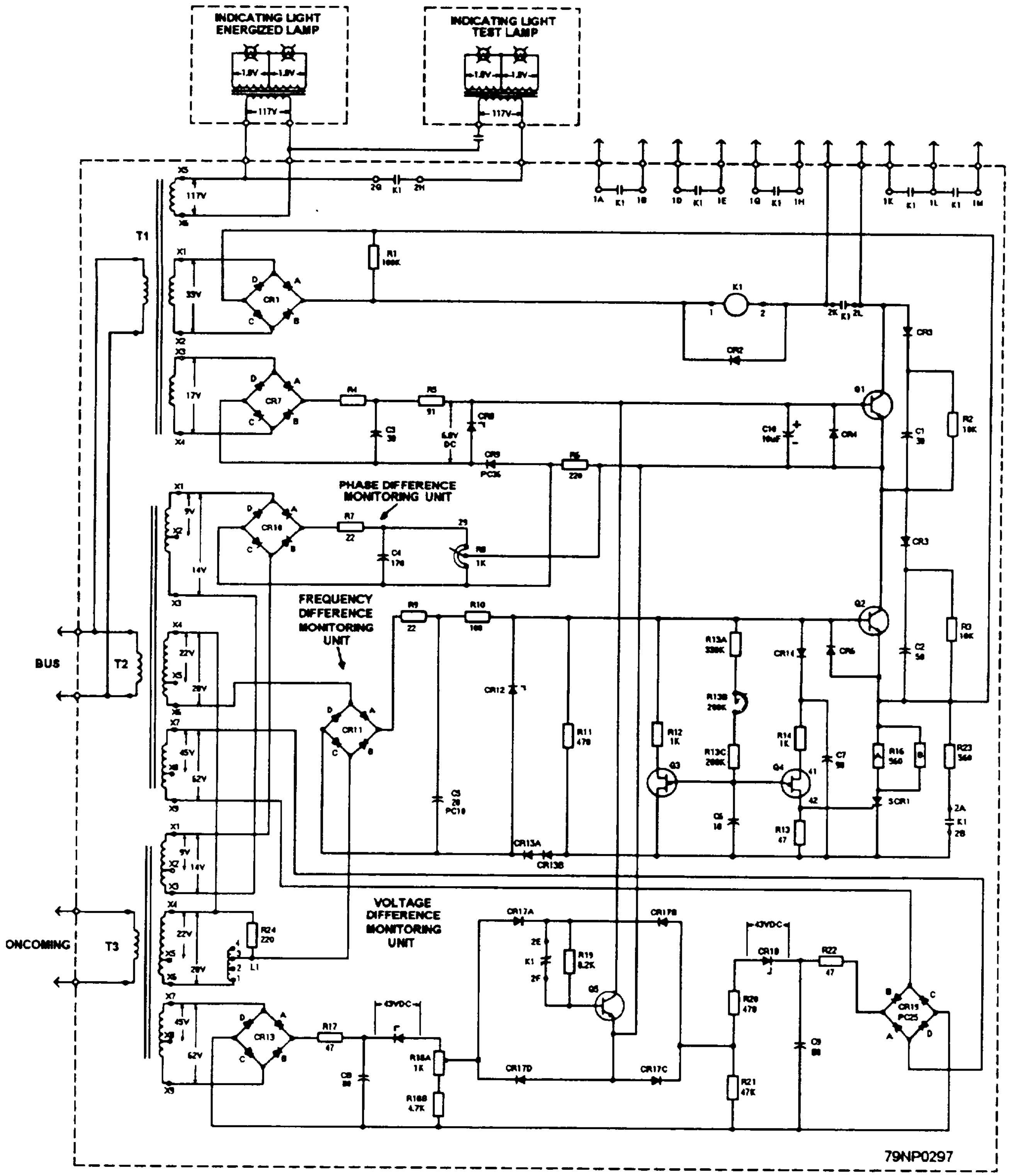

Figure 8-28.—Synchronizing monitor.

closing switch contacts) in series with transistors Q1 and Q2. The K1 relay provides an electrical interlock through the closing circuit of the generator circuit breaker. The electrical interlock will prevent an operator from electricaly closing the circuit breaker unless the necessary conditions have been met. The circuit breaker closing contacts must be open to energize the K1 relay. Also, Q1 and Q2 must be ON. With proper circuit breaker line up, the first condition is met. The monitoring circuits must provide the current signals to Q1 and Q2 to turn them on. The functions of the devices in the output circuit are shown in table 8-7.

Table 8-7.—Devices in the Output Circuit

ITEM	USE/FUNCTION
Transformer T1	Steps down energized bus voltage.
Rectifier CR1	Rectifies input from T1 to form the power supply for relay K1 and transistors Q1 and Q2.
Rectifier CR7	Rectifies the output of transformer T1 to form the reference bias supply to transistor Q1.
Resistor R4 and capacitor C3	Filter the output of rectifier CR7.
Zener diode CR8	Maintains a constant voltage reference to Q1.
Resistor R5	Limits the voltage across Zener diode CR8 to a safe value.
Transistor Q1	Acts as a switch to turn on or turn off K1 relay.
Transistor Q2	Completes the circuit to energize relay K1. It is biased on from the frequency difference monitor. ($\Delta F<0.2 \Rightarrow$ Q2 on) ($\Delta F>0.2 \Rightarrow$ Q2 off)
Rectifiers CR2, CR3, and CR5, capacitors C1 and C2, and resistors R2 and R3	Damp-out voltage spikes on Q1 and Q2.
Rectifiers CR4 and CR6	Limit emitter to base (reverse bias) voltages on Q1 and Q2 to low values.

The operation of the output circuit is centered around the operation of Q1. In order to operate the circuit breaker being monitored by the synchronizing monitor (fig. 8-28) on.

Two circuits affect the bias voltage of Q1:

1. The phase difference monitoring circuit, which includes resistor R6. When a voltage of sufficient magnitude is developed across R6, the base to emitter bias of transistor Q1 is reversed. This turns off Q1.
2. The voltage difference monitoring circuit. This circuit is connected across the base to the emitter of transistor Q1. When transistor Q5 conducts, this circuit disables Q1 by shorting the base to emitter of Q1. This removes the bias reference supply.

Q1 can conductor be biased on only when these two circuits are off. The action by the Q1 transistor is similar to that of a switch.

A transistor can be used to act like contacts that are either closed or opened. This is done by using a large enough base current signal that can drive the transistor into saturation. At this point, the transistor acts like a short circuit (equivalent to closed contacts). If the base current signal is weakened, reversed, or eliminated, the transistor then acts as an open circuit (equivalent to open contacts).

The operation of the transistor circuit is as follows: Relay K1 is energized when transistors Q1 and Q2 are biased on, and circuit breaker switch contacts connected between 2K and 2L are closed.

PHASE DIFFERENCE MONITORING CIRCUIT

The phase difference monitoring circuit (fig. 8-29) prevents energizing of the K1 relay if the phase difference between the bus and the oncoming generator is more than -30° and 0°. It does this by reducing and comparing both input voltages, using its output to control transistor Q1.

Look at the schematic in figure 8-30. The secondary winding X1 and X3 of T2 and X1 and X3 of T3 are connected so the output voltages of T2 and T3 subtract from each other. For instance, assume that the voltages are in phase, as shown in

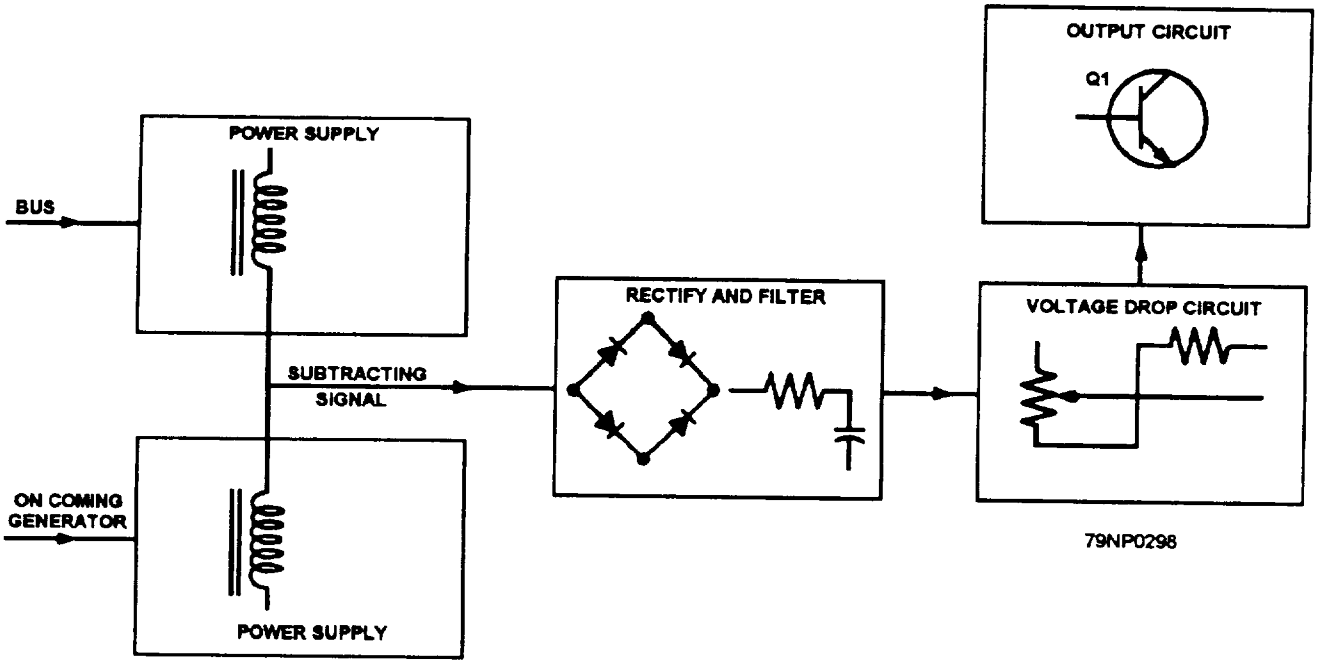

Figure 8-29.—Block diagram of phase difference monitoring circuit.

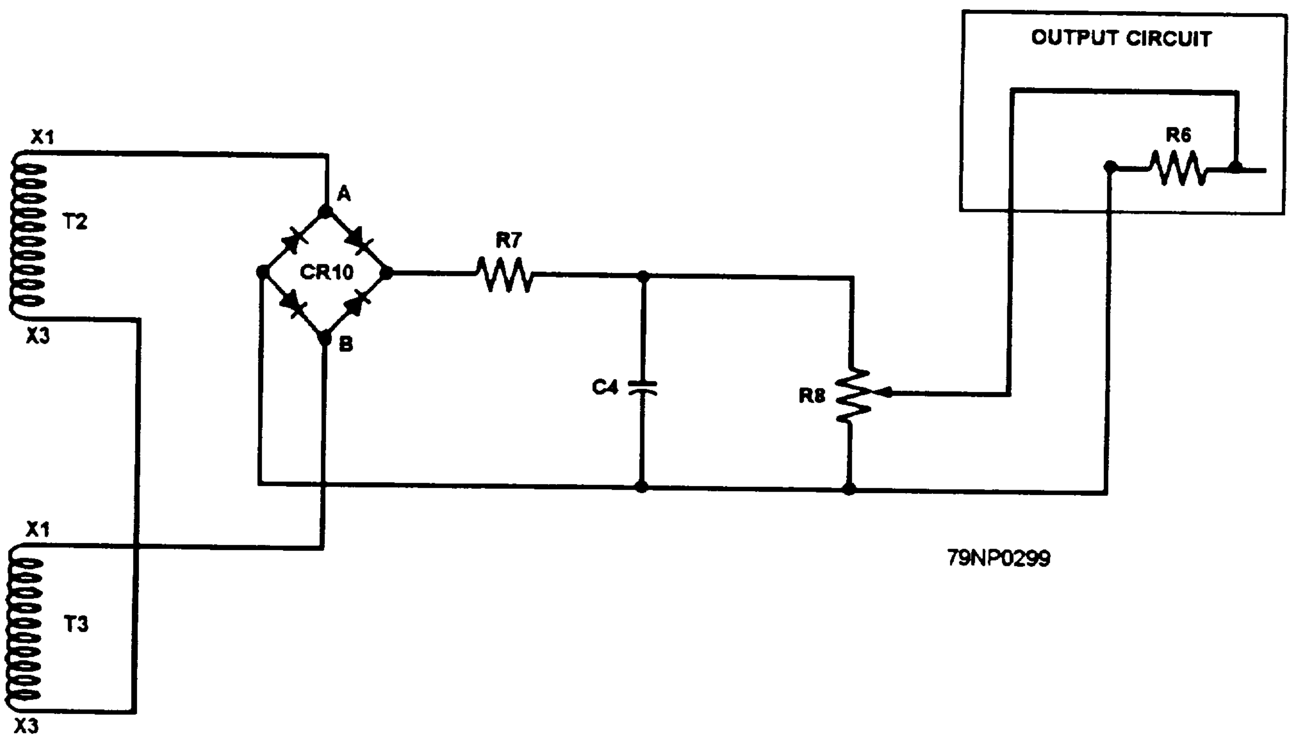

Figure 8-30.—Schematic diagram of a phase differnce monitoring circuit.

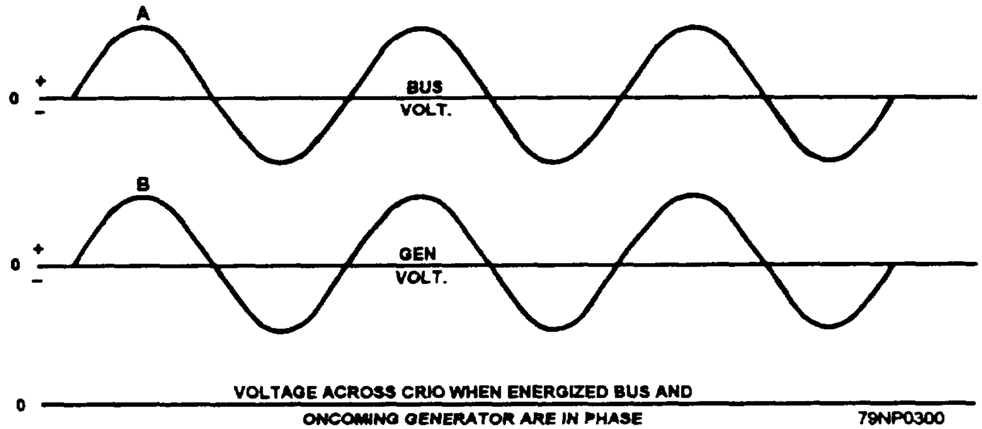

Figure 8-31.—Input voltage to CR10 (in phase).

figure 8-31. When these voltages are in phase, the potential at points A and B (across rectifier CR10) in figure 8-30 will be the same, so no current can flow. Now assume that the energized bus and the energized bus are 180° out of phase (fig. 8-32). Under these conditions the voltage at point A is at a maximum in a negative direction. This causes maximum current to flow in rectifier CR10. Filtering of the rectified current is accomplished by resistor R7 and capacitor C4 (fig. 8-30). Remember that when no phase difference exists between the energized bus and the oncoming generator, the CR10 rectifier output is zero. A maximum output is developed when the difference is 180° between the two signals. The CR10 output is applied across resistors R8 and R6.

At a given magnitude, the voltage drop across resistor R6 (fig. 8-28) overcomes the positive bias from base to emitter of transistor Q1 (because of Zener diode CR8). The net result is a negative bias which shuts off transistor Q1. This will prevent energizing of the K1 relay which prevents closing the circuit breaker for the oncoming generator.

FREQUENCY DIFFERENCE MONITORING CIRCUIT

The frequency difference monitoring circuit prevents energizing of relay K1 if the frequency difference between the bus and the oncoming generator is more than 0.2 Hz. It does this by changing both frequency signals into a beat frequency voltage

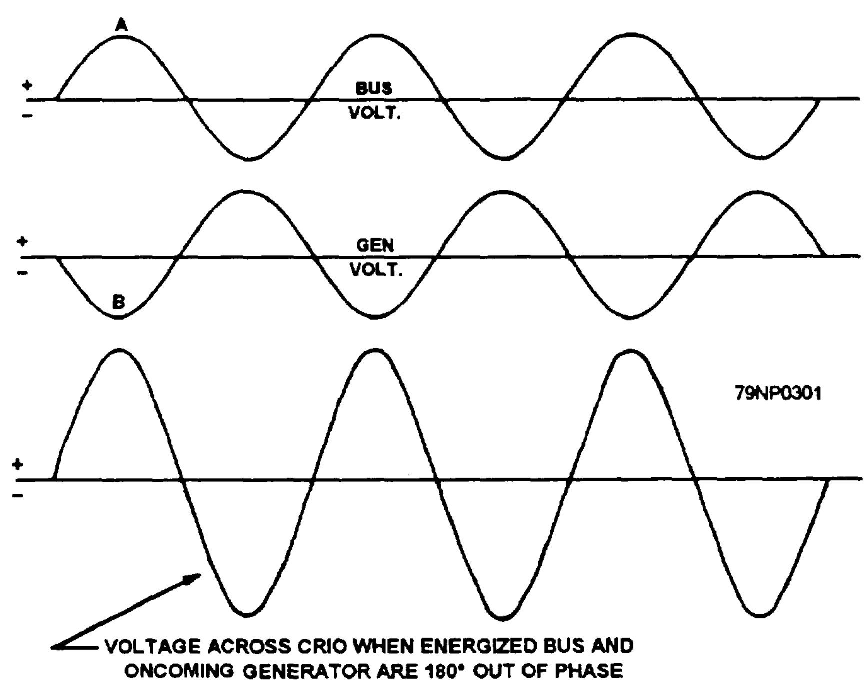

Figure 8-32.—Input voltage to CR10 (180° out of phase).

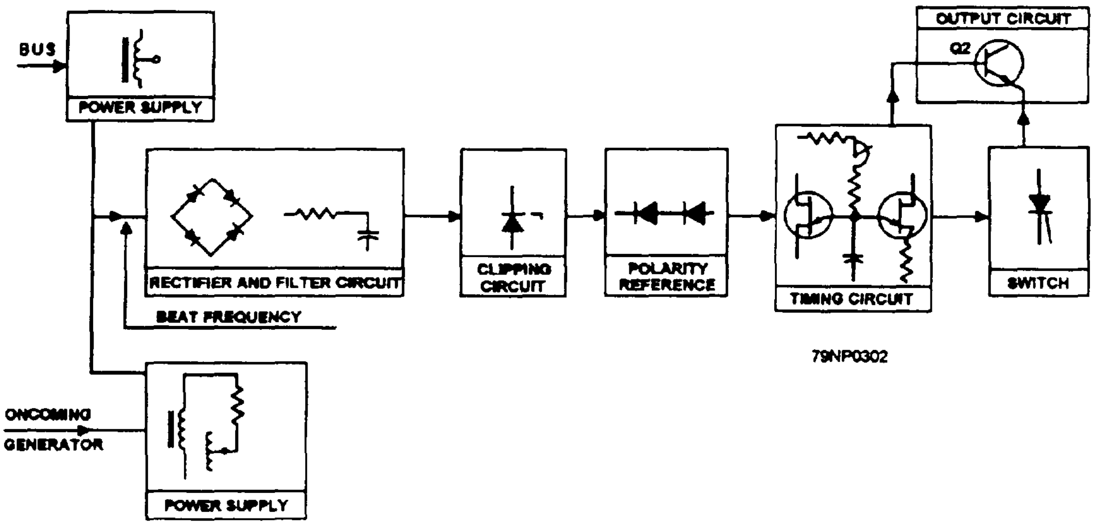

Figure 8-33.—Block diagram of frequency difference monitoring circuit.

(fig. 8-33). It rectifies, filters, and reduces the beat frequency voltage. It then uses the beat frequency voltage in a timing circuit to fire an SCR.

Look at the schematic in figure 8-34. The secondary windings X4 and X6 of T2 and X4 and X6 of T3 are connected in such a manner that a beat frequency voltage (heterodyne wave) is generated. This beat frequency voltage is the difference between bus and oncoming generator frequencies (fig. 8-35, view A). Refer to figures 8-34 and 8-35 as you see how the circuit functions:

1. The beat frequency voltage is rectified by CR11
2. The resulting dc signal (fig. 8-35, view B) is filtered by resistor R9 and capacitor C5 (fig. 8-35, view C)
3. The beat frequency voltage is clipped by resistor R10 and Zener diode CR12 to a constant dc level (fig. 8-35, view D)
4. The signal is now sent to resistor R11 and diode CR13 (views A and B). Here, about 1 volt is subtracted from the clipped beat frequency signal (fig. 8-35, view E) to ensure the clipped beat frequency voltage signal goes to zero when the original beat frequency goes to zero
5. The clipped beat frequency voltage signal is applied across base 1 and base 2 of unijunction transistors Q3 and Q4 (fig. 8-34). This signal is also applied to the RC circuit, consisting of resistors R13A, R13B, R13C, and capacitor C6.

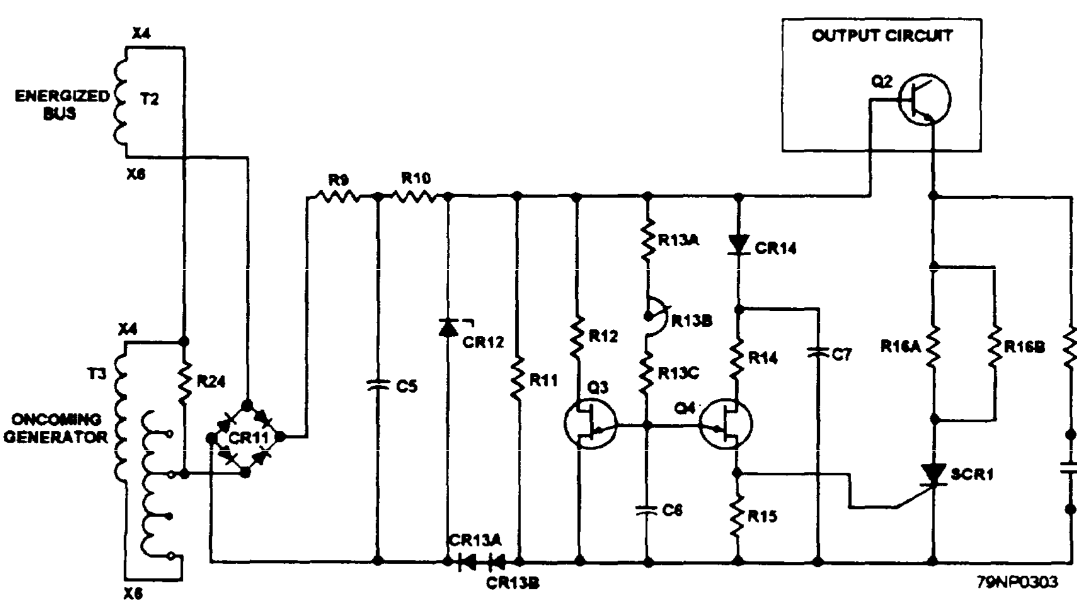

Figure 8-34.—Schematic diagram of frequency difference monitoring circuit.

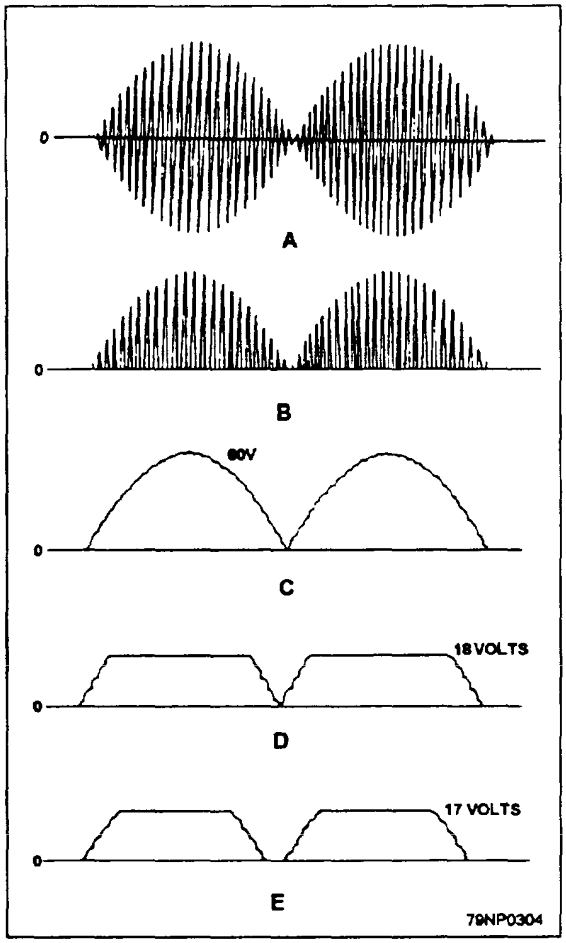

Figure 8-35.—Beat frequency voltages.

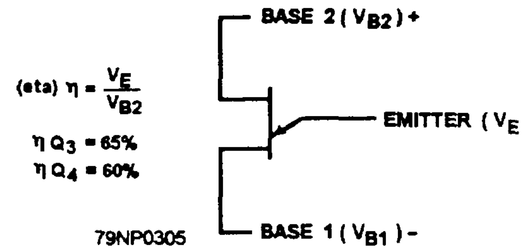

Figure 8-36.—Unijunction transistor.

Before continuing with the circuit description, you need a brief explanation of the operation of a unijunction transistor (fig. 8-36). A unijunction transistor has two bases, B1 and B2, and one emitter. When the voltage between B1 and the emitter rise to a certain percentage of the voltage between B1 and B2, the unijunction transistor will fire, The percentage is equal to emitter voltage divided by the B2 voltage. In the case of the unijunction transistors, it is equal to a nominal 62 percent. This means that when the emitter voltage is approximately 60 percent of B2 voltage, both in reference to B1, the unijunction transistor will fire. By knowing that (1) Q3 and Q4 have different values for the same voltage, (2) C6 has a definite charging rate (determined by R9, R10, R13, and rectifier CR14), and (3) that different beat frequencies have different time intervals, you should have a basic understanding of how the timing circuit operates.

In the following examples of how unijunction transistors are find, the values used are arbitrary.

In the first example, (fig. 8-37), there is a difference of 0.2 Hz in the beat frequency voltage. This causes a time period of 5 time constants for 1 cycle. Within the 5 time constant period, the following events will occur:

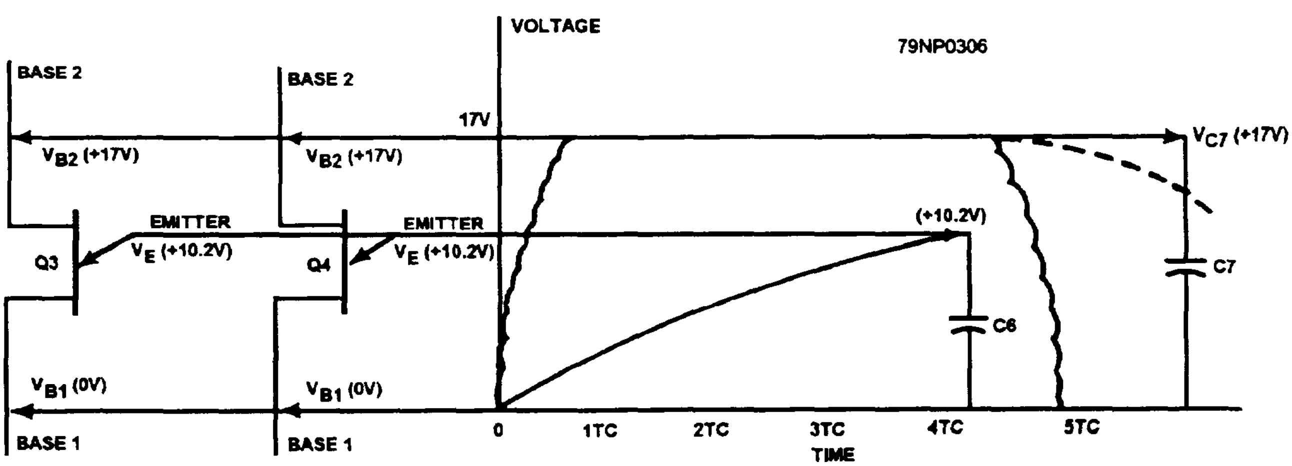

Figure 8-37.—Firing sequence for Q4.

- The voltage across Q3 and Q4 increases sharply and remains at 17 volts until the end of the cycle.

- The 17 volts are applied across B1 and B2 of unijunction transistors Q3 and Q4, across capacitor C7, and across the RC circuit containing C6.

- Capacitor C7 blocks rectifier CR14 and therefore will maintain approximately 17 volts. The only place C7 can discharge is through Q4, which has a very low leakage rate.

The RC circuit containing C6 is charging at a specific rate. If we assume that within 4 time constants C6 reaches 10.2 volts, then the following events will occur:

- The V_E for Q4 will fire before Q3.

- When Q4 fires, a voltage pulse is generated across R15 (fig. 8-34) and is applied to the gate of SCR1.

- SCR1 is then turned on.

- When SCR1 turns on, transistor Q2 in the output circuit is supplied with a base current through limiting resistor R16.

- This turns on Q2. When the beat frequency voltage goes to zero, SCR1 turns off.

- The timing process then repeats itself.

In the second example (fig. 8-38), there is a difference of 4.0 Hz in the beat frequency voltage. This causes a time period of half the previous example. Within this period of 2.5 time constants, the following events occur:

- The voltage across Q3 and Q4 increases sharply and remains at 17 volts until the end of the cycle,

- The 17 volts are applied across B1 and B2 of unijunction transistors Q3 and Q4. It is also applied across capacitor C7 and across the RC circuit containing C6.

- Capacitor C6 charges at the same rate as before (assuming 10.3 volts in 4 time constants). The period of time for this cycle is only 2.5 time constants. Therefore, the voltage across C6 can only reach approximately 6.5 volts within this time.

At the end of 2.5 time constants, approximately 17 volts are held across Q4 by capacitor C7, with a sharp decrease of voltage across B1 and B2 of Q3. When the voltage reaches approximately 10 volts, Q3 can fire because of its relative value of this voltage. Q4 still has approximately 17 volts across it.

After Q3 fires and the beat frequency goes to zero, the time process again repeats itself.

You can see that different beat frequencies are compared just as the differences were in phase and voltage. The function of the frequency difference circuit is to energize relay K1 through the control of transistor Q2, if the difference of the frequency of the bus and the oncoming generator is less than 0.2 Hz.

VOLTAGE DIFFERENCE MONITORING CIRCUIT

The voltage difference monitoring circuit (fig. 8-39) prevents energizing of the K1 relay if the voltage difference between the bus and the oncoming generator is more than 5 percent. The circuit does this by doing the following:

- Reducing and rectifying both input voltages (bus and incoming generator)

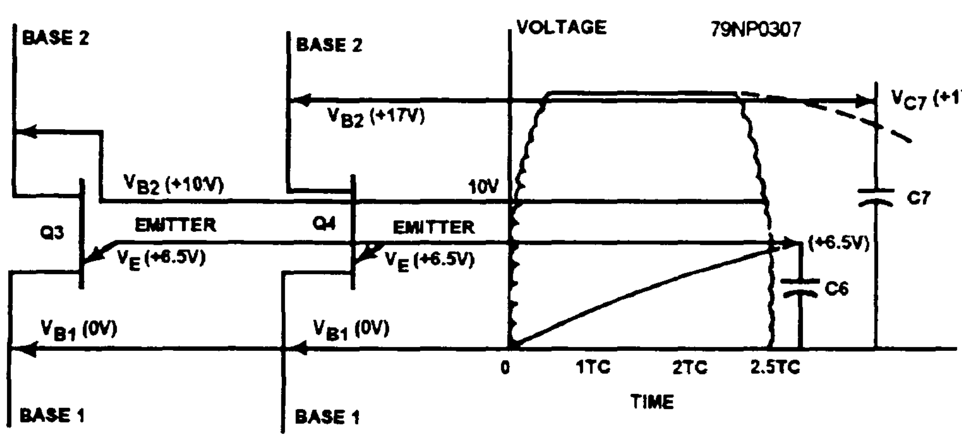

Figure 8-38.—Firing sequence for Q3.

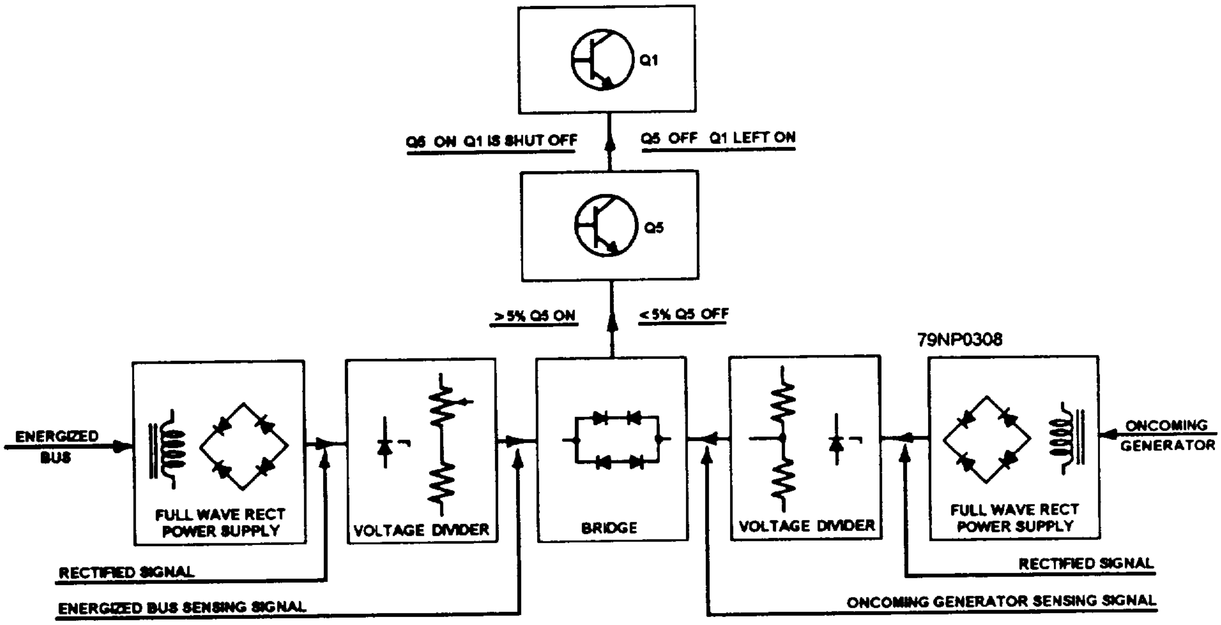

Figure 8-39.—Block diagram of voltage difference monitoring circuit.

- Producing and delivering a sensing signal from each input
- Comparing the difference in magnitude of the two sensing signals in a bridge circuit
- Using transistor Q5 for an ON-OFF switch

Look at the schematic in figure 8-40. You can see that the bus voltage is stepped down by windings X7 and X9 on T2. The reduced voltage is then rectified by a full-wave rectifier CR19 and filtered by R22 and C9. The same thing occurs for the oncoming generator voltage at T3. Transformer T3 steps the voltage down. CR15 rectifies it, and R17 and C8 filter it.

Zener diode CR18 is used to increase the sensitivity of voltage dividers R20 and R21 in the bus signal circuit. The Zener diode causes all the increase or decrease of the bus signal voltage to appear across the voltage divider. This also happens to voltage dividers R18A and R18B, using Zener diode CR16. The resultant signal out of each voltage divider is the sensing signal. These sensing signals are then fed to a rectifier bridge consisting of CRs 17A, B, C, and D. When the bus and the oncoming generator sensing signals are equal, there

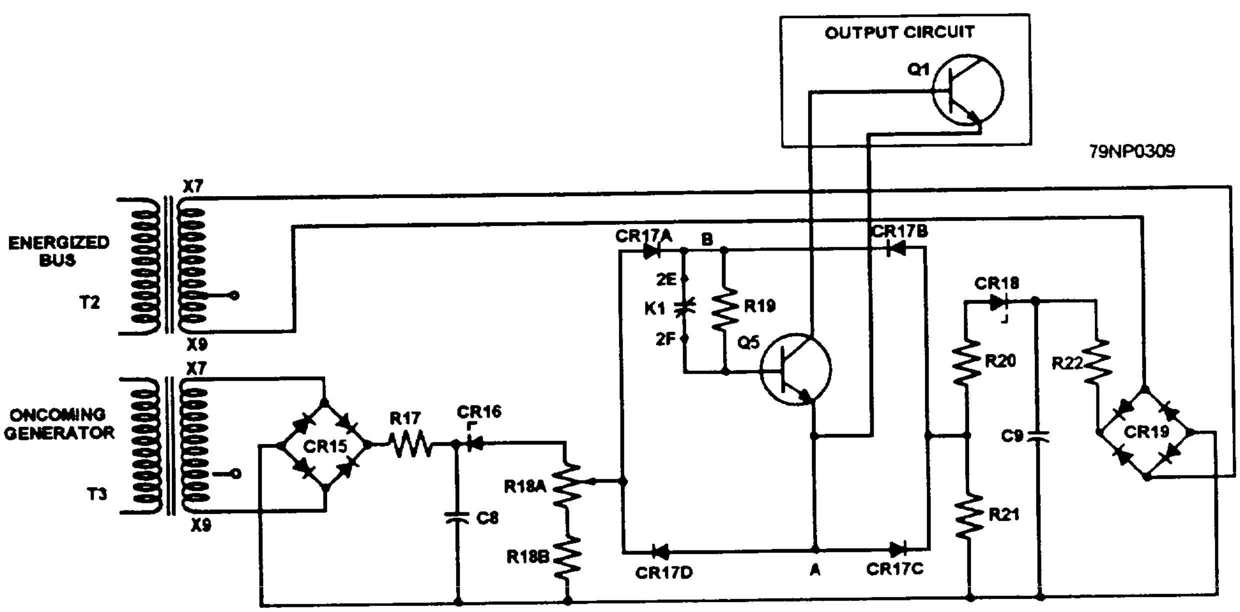

Figure 8-40.—Schematic diagram of voltage difference monitoring circuit.

is zero voltage between the bridge (points A and B). A difference between the bus voltage and the oncoming voltage causes a voltage to exist across the bridge.

Connected between points A and B of the bridge is the emitter and base of transistor Q5. The collector of Q5 is connected to the base of Q1. The circuit is completed from the emitter of Q1 to the emitter Q5. If the voltage between A and B (across the bridge) is zero, Q5 cannot be biased on. Therefore, the base to emitter of Q1 is not shorted out. If a voltage does appear across points A and B of the bridge, which can be caused by as little as a 5 percent voltage difference between the bus and the oncoming generator, Q5 will be biased on and short out the base to emitter of Q1. This will turn off Q1 (fig. 4-21) and prevent energizing of relay K1. Resistor R19 prevents small momentary changes in voltage differences from turning on Q5 once relay K1 has picked up.

SERVICING TECHNIQUES FOR TRANSISTORIZED CIRCUITS

There are many differences between transistorized and electron tube circuits from the standpoint of servicing. For instance, you rely on your senses of sight, touch, and smell in the visual inspection of electron tube circuits. This is not as feasible in transistor circuits. Many transistors develop so little heat that you can learn nothing by feeling them. High-frequency transistors hardly get warm. Usually, if a transistor (except a high-powered transistor) is hot enough to be noticeable, it has been damaged beyond use.

In electron tube circuits, you often make a quick test by the tube substitution method. You replace the tube suspected of being bad with one you know to be good. In solid state circuits, the transistors are frequently soldered in. This makes the substitution method impractical. Furthermore, you should avoid indiscriminate substitution of transistors and other semiconductors. You should test transistors with an approved transistor test set.

Most good quality test equipment used for electron tube testing can also be used for transistor circuit testing. You can use signal generators, both RF and AF, if the power supply in the equipment is isolated from the power line by a transformer.

CAUTION

Before you make any tests with a signal generator, connect a common ground wire from the chassis of the equipment to be tested to the chassis of the signal generator before you make any other connection.

You can use signal tracers (such as dual trace oscilloscopes) on transistor circuits if you observe the precautions concerning the power supplies. Many signal tracers use transformerless power supplies. To prevent damage to the transistor, use an isolation transformer.

Multimeters used for voltage measurements in transistor circuits should have a high ohms/volt sensitivity to ensure an accurate reading. This should beat least 20,000 ohms/volt.

Ohmmeter circuits that pass a current of more than 1 milliampere through the circuit under test cannot be used safely in testing transistor circuits. Before using an ohmmeter on a transistor circuit, check how much current it passes on all range settings. Do not use any range that passes more than 1 milliampere.

When used in the closely confined areas of transistor circuits,

test prods are often the cause of accidental shorts between adjacent terminals. In electron tube circuits the momentary short caused by test prods rarely results in damage. However, in transistor circuits this short can destroy a transistor. Also, since transistors are very sensitive to improper bias voltages, you must avoid the practice of troubleshooting by shorting various points to ground and listening for a click. When you test transistor circuits, remember the vulnerability of a transistor to surge currents.

SUMMARY

In this chapter, you have learned about voltage and frequency regulation. Within this area, you have learned about types I, II, and III power, the principles of ac voltage control, the various types of voltage regulators, closely regulated power supplies, and synchronizing monitors. You have also learned about the various techniques used to service transistorized circuits.

CHAPTER 9

ELECTROHYDRAULIC LOAD-SENSING SPEED GOVERNORS

This chapter contains a discussion about the operation and maintenance of electrohydraulic load-sensing speed governors. If you do not have a thorough understanding of solid state circuitry, components, or terms, review the *Navy Electricity and Electronics Training Series* (NEETS). The modules that deal with solid state circuitry include the following:

- Module 6, NAVEDTRA 172-06-00-92
- Module 7, NAVEDTRA 172-07-00-92
- Module 8, NAVEDTRA 172-08-087
- Module 9, NAVEDTRA 172-09-00-85

LEARNING OBJECTIVES

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

1. *Identify some of the characteristics of electrohydraulic load-sensing speed governors.*
2. *Identify the function of various components in an electrohydraulic load-sensing speed governor.*
3. *Identify the sequence of operation of EG-M load-sensing speed governor through speed changes.*
4. *Identify the sequence of operation of the EG-R hydraulic actuator through speed changes.*
5. *Identify the sequence of operation EGB-2P electohydraulic load-sensing speed governor during speed changes.*
6. *Identify the minimum maintenance requirements for maintaining electrohydraulic load-sensing speed governors.*

Electrohydraulic load-sensing speed governors have been developed for the ship's service generators in electrical systems that require closer frequency regulation than that provided by mechanical-type governors. Electrohydraulic governors have been used successfully on steam turbine, gas turbine, and diesel-driven generators.

An electrohydraulic governor may be operated as an isochronous governor; that is, at constant speed regardless of load, provided the load does not exceed the limits of the prime mover. An isochromous governor may also be used with speed droop; that is, as the load increases, the speed of the prime mover decreases. Speed droop permits paralleling with other generators that have dissimilar governors or paralleling with an inifinite bus (such as shore power).

The operation of a typical electrohydraulic load-sensing governoring system may be generally described as follows:

1. The throttle that controls the prime mover fuel medium is operated by an electrohydraulic actuator.
2. This electrohydraulic actuator responds to the output of an electronic amplifier.
3. Generator speed and load signals are fed into the electronic amplifier.
4. The electronic amplifier produces a power output that operates the electrohydraulic actuator.
5. The electrohydraulic actuator correctly positions the steam valve or throttle.

The speed signal is usually provided by a small permanent magnet generator (PMG) or a permanent magnet alternator (PMA). The PMG or PMA are driven from the shaft of the prime mover controlled by the governor. When used to control a ship's service generator, the speed signal is sometimes obtained by sensing the output frequency of the generator. However, a loss of signal, which could be caused by a short circuit on the generator, is a disadvantage of this method. The speed signal is applied to a frequency-sensitive and reference circuit in the governor control unit. The output of this circuit is a net error signal if there is any deviation from the set speed.

Stability of the prime mover is obtained by the use of electrical feedback circuits.

Load-measuring circuits are used in the electrohydraulic governor to obtain proper load sharing on each paralleled generator. Most governing systems are designed so that any change in load produces a signal that is fed into the electronic amplifier. This acts to offset any anticipated speed change caused by load change. The load-measuring circuits of governors on all generators that operate in parallel are connected by a bus tie cable. The governor maybe designed or preset so that each paralleled generator will equally share the total load. If not, a load-sharing adjustment must be provided.

The steady state and transient frequency requirements for type II electrohydraulic governors power can be met with of the type just described.

However, a motor generator or static converter will still be required for type III voltage control.

NOTE: Refer to chapter 8 of this TRAMAN to identify the characteristics of type II and type III power.

The electrohydraulic load-sensing governor used in this chapter is made up of three separate assemblies (fig. 9-1)—an EG-M control box, a speed-adjusting potentiometer, and a hydraulic actuator. Depending on the control box and the type of service in which it is used, a load signal box and a resistor box may be required

EGM SYSTEM

The EG-M electrohydraulic governor system (fig. 9-2) offers diversified work capabilities. Large or small prime mover governor requirements can be met by the

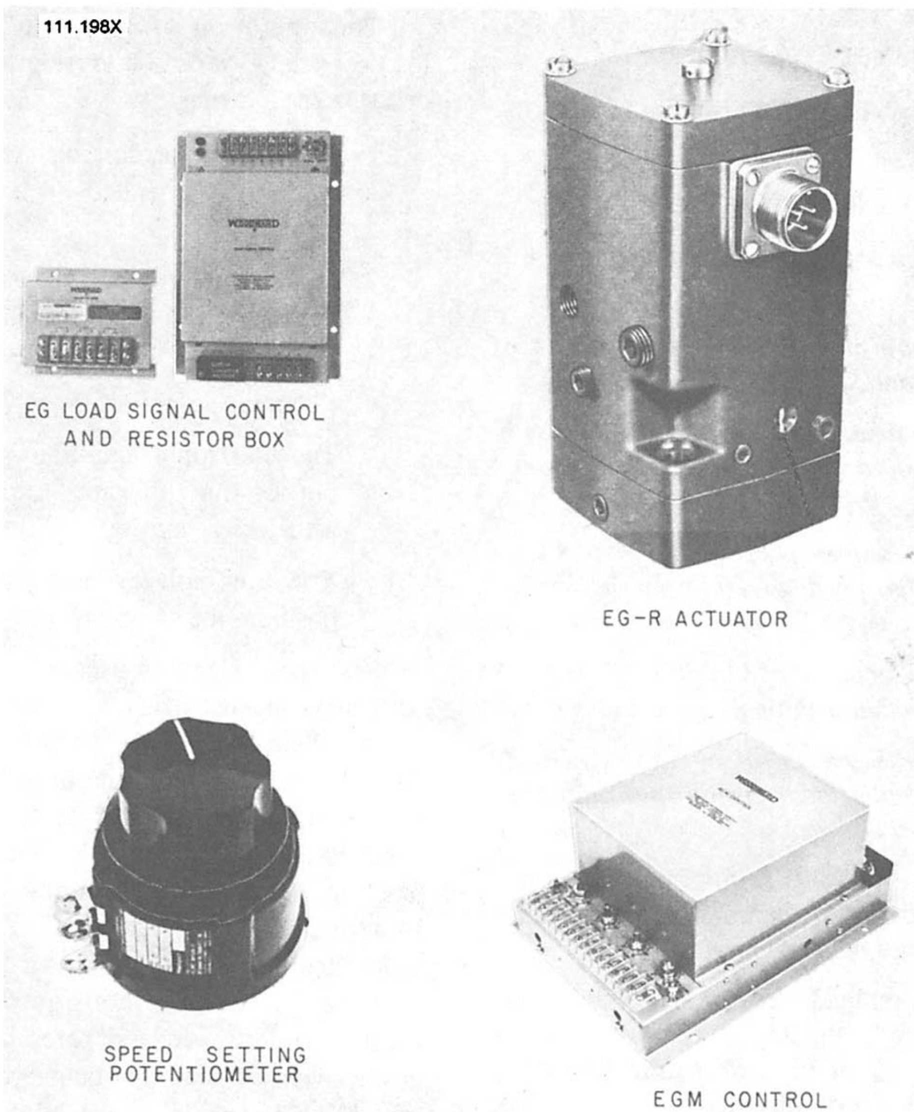

Figure 9-1.—Electrohydraulic load-sensing governor system components.

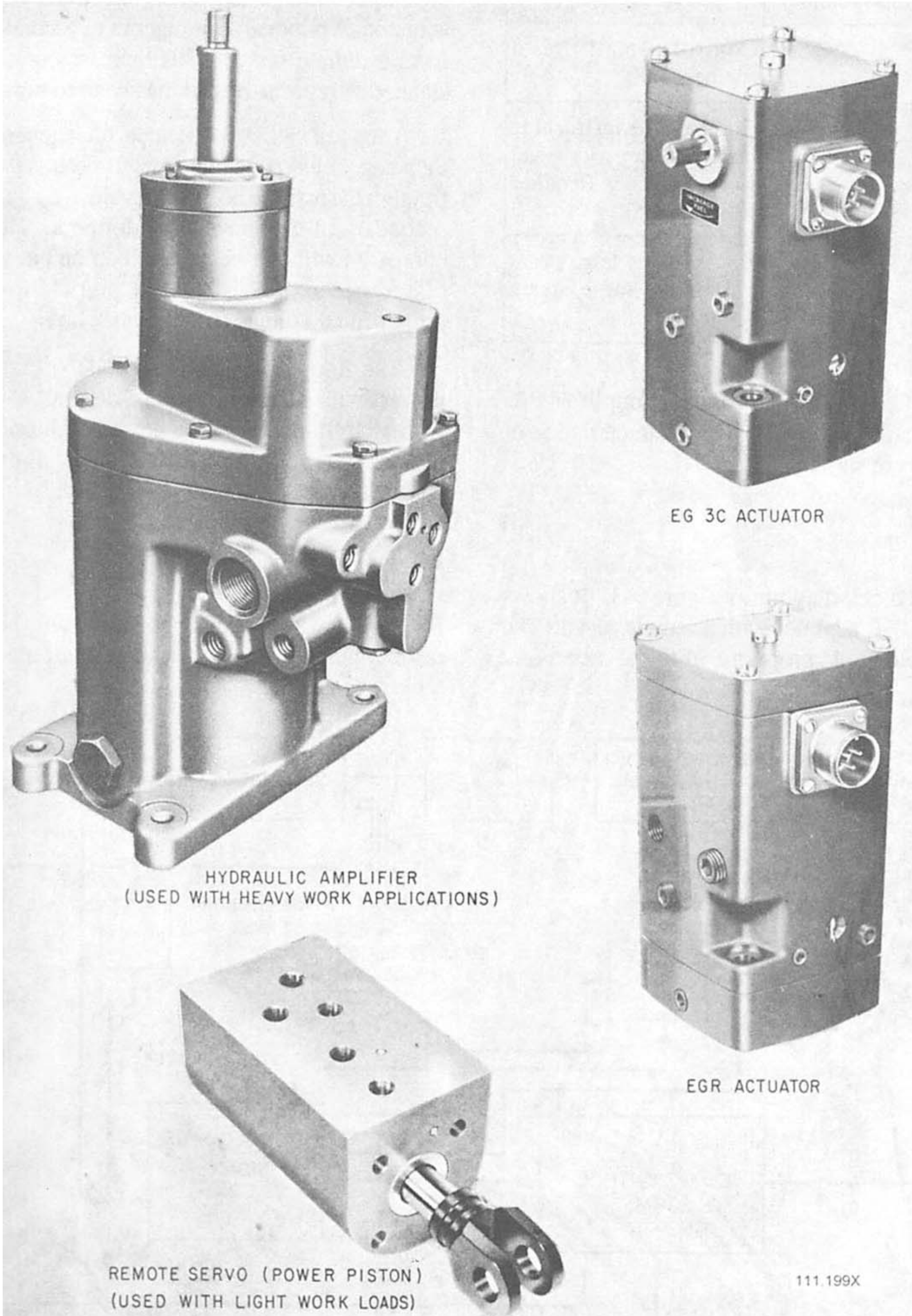

Figure 9-2.—EG-M electrohydraulic systems.

Table 9-1.—EG-M Electrohydraulic Governor Characteristics

Governor Type	Work Capacity (foot-pounds)	Typical Uses
EG-3C	3	Controls small diesel engines.
EG-R	20	Controls steam turbine prime movers with small work capacities (requires remote servo).
EG-R with hydraulic actuator	1800-6500	Controls very large steam valves for large steam turbines.

use of the EG-3C, the EG-R, a hydraulic amplifier, and the EG-R hydraulic actuator. The characteristics of these governors are shown in table 9-1.

OPERATION

Look at the block diagram of figure 9-3. It shows the use of the EG-R actuator with a remote servo. The input signal (voltage) is proportional to the speed of a permanent magnet generator and is applied to the EG-M control box. The control box compares this voltage with a reference voltage. If there is a difference, it supplies art output voltage that energizes the EG-R hydraulic actuator. A pilot valve plunger in the actuator directs oil from a remote servo. This increases or decreases the steam that returns the turbine speed to normal.

The load signal box detects changes in load before they appear as speed changes. It detects these changes through the resistor box that develops a voltage from the secondary of the current transformers. This voltage is compared with the generator load output voltage. If a difference exists, the load signal box applies a proportional voltage to the control box.

The droop switch allows parallel operation of prime movers with similar governors, dissimilar governors, or with an infinite bus (shore power). The circuit breaker provides a path for control load signals to other paralleled units.

EG-R Hydraulic Actuator

The EG-R hydraulic governor will be considered next. Figure 9-4 shows a schematic arrangement of this

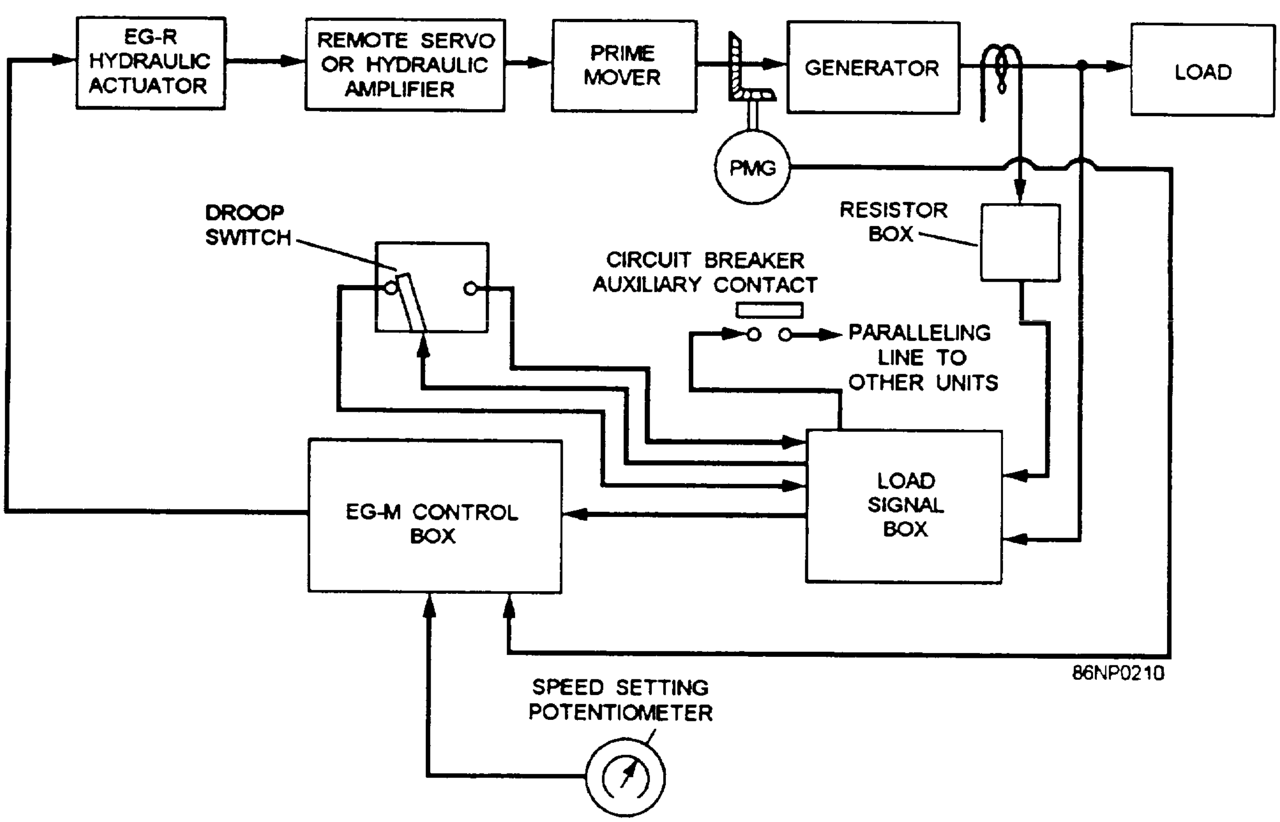

Figure 9-3.—Electrohydraulic load-sensing governor system, block diagram.

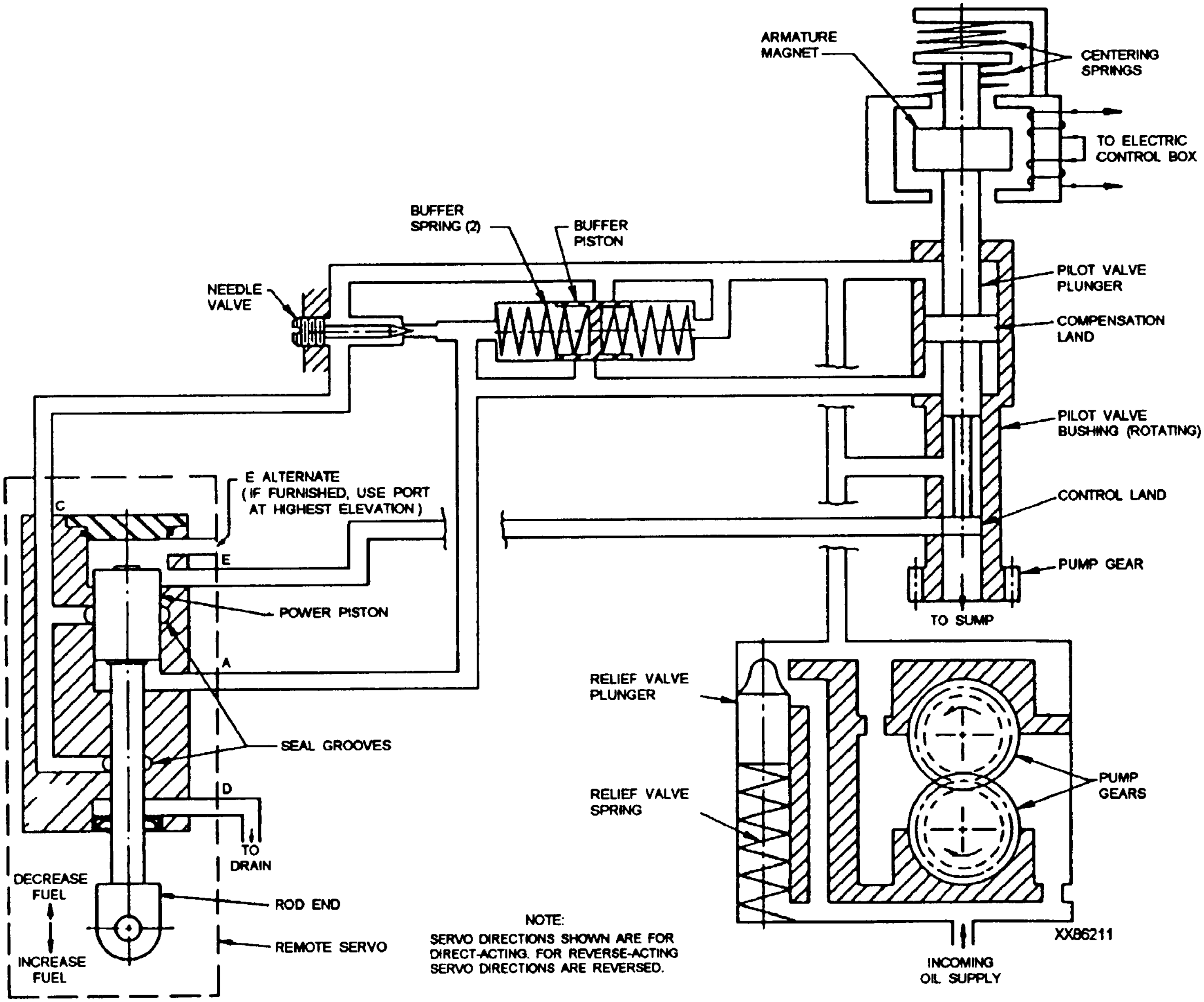

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Figure 9-4.—Schematic arrangement of the EG-R actuator.

governor. You can see that in this application the EG-R hydraulic actuator is coupled with a remote servo piston. High-pressure lines provide the means of connecting the actuator to the remote servo. Oil from an external source enters the suction side of the oil pump. The pump gears carry the oil to the pressure side of the pump. This fills the oil passages and then increases the hydraulic pressure. When the pressure becomes great enough, the relief valve spring force is overcome, and the relief valve plunger is pushed down. This uncovers the bypass hole and allows oil to recirculate through the pump.

The linear movement of the power piston in the remote servo, used in conjunction with the EG-R actuator, moves the engine or turbine linkage to increase or decrease the prime mover speed. The EG-R actuator controls the flow of pressure oil to or from the servo piston. Pressure oil from the pump is supplied directly to one end of the buffer piston. The other end on the buffer piston connects to the underside of the servo piston. Pressure in this hydraulic circuit always tends to move the power piston up in the *decrease fuel* direction. The power piston cannot move up unless the oil trapped on top of the power piston is allowed to drain. It is drained to the sump by raising the pilot valve plunger.

When starting the prime mover, manual control of the speed of the prime mover is necessary until an input signal and power becomes available to the control box.

A drive force is necessary to rotate the actuator pump gears and provide a relative rotation between the nonrotating pilot valve plunger and its rotating bushing. Upon loss of the electrical signal, the EG-R and EG-3C hydraulic actuator can go to shutdown. This depends upon design application.

The major parts of the EG-R actuator (fig. 9-4) and their functions are shown in the following table:

PART	FUNCTION
Pilot valve plunger	Connects the motion of the armature magnet to the compensation land and the control land.
Armature magnet	Reacts with the two-coil solenoid input from the electronic control box. Movesthe pilot valve plunger up or down to control the position of the compensation land and the control land.
Control land	Allows oil to flow to or from the top of the remote servo power piston, which allows movement of the rod end adjusting the prime mover speed.
Compensation land	Prevents overtravel of the throttle by reacting to a temporary negative feedback signal in the form of a pressure differential across it during changes in position of the power piston.
Buffer system	Consists of the buffer piston, buffer springs, and the needle valve. Acts to produce the temporary negative feedback (in the form of a pressure differential) applied to the compensation land of the pilot valve plunger during speed changes, to anticipate the return of the prime mover to the on speed condition and prevent overtravel of the power piston.
Needle valve	Used to control the rate at which the pilot valve plunger returns to the centered position after a change in load condition on the prime mover.
Power piston	Reacts to position of the control land to increase or decrease the speed of the prime mover through a linkage to the fuel or steam valve.
Centering springs	Keeps the pilot valve plunger in the centered position to hold the power piston in position during normal steady-state operation.
Oil pump	Provides pressure oil to operate the power piston to increase or decrease fuel or steam to the prime mover.
Relief valve	Opens, once oil pressure is high enough, to allow oil to recirculate through the oil pump.

The hydraulic actuator (fig. 9-4) controls the position of the prime mover fuel or steam supply valve through the flow of oil to and from the upper side of the power piston in the remote servo. The output signal from the electronic control box is applied to a two-coil solenoid surrounding the armature magnet of the pilot valve plunger. This produces a force, proportional to the current in the coil, that moves the armature magnet and, in turn, moves the pilot valve plunger up or down. An electronic amplifier is housed in the electronic control box (fig. 9-1). When a positive dc voltage is sent to the actuator from the control box, the pilot valve travels in a downward direction. If a negative dc voltage is sent to the actuator from the electronic control box, the pilot valve plunger will travel in an upward direction.

With the pilot valve plunger centered, no oil flows to or from the upper side of the power piston. The following will occur if there is a decrease in the load

STEP	ACTION
1.	The increase in speed causes the control box to send a signal to raise the pilot valve plunger.
2.	The trapped oil on the upper side of the power piston is then free to escape, past the control land on the pilot valve plunger, to the sump.
3.	Pressure oil on the right-hand side of the buffer piston forces the buffer piston to the left.
4.	The oil displaced by the buffer piston forces the power piston up in the decrease fuel direction.
5.	The higher pressure oil applied to the right-hand side of the buffer piston is also felt on top of the compensation land.
6.	As the power piston is raised to decrease fuel, pressure on top of the compensation land causes the pilot valve plunger to lower.
7.	The control land covers the drain port to the sump and the power piston movement is stopped as the prime mover again reaches normal speed.

The rate at which the pilot valve plunger is moved by the pressure on top of the compensation land is controlled by the needle valve setting. It is adjusted to match the rate at which the prime mover returns to normal speed.

The following will occur if there is an increase in load:

STEP	ACTION
1.	The decrease in speed causes the control box to send a signal to lower the pilot valve plunger.
2.	Pressurized oil is allowed to flow past the control land of the pilot valve plunger to the top of the power piston.
3.	The power piston is forced down in the increase fuel direction.
4.	Oil displaced on the left side of the buffer piston increases compression to the right-hand buffer spring, causing a slightly higher pressure on the left side of the buffer piston and the bottom of the compensation land.
5.	The pilot valve plunger is forced to the center position by the higher pressure on the bottom of the compensation land, raising the control land to stop the flow of oil to the top of the power piston as the prime mover returns to normal speed.

Stability of the system is controlled by the electric governor section. It is enhanced by the temporary feedback signal in the form of a pressure differential applied across the compensating land of the pilot valve plunger. The pressure differential is derived from the buffer system and is allowed to fade away, as the engine returns to normal speed, by the needle valve.

The power piston and its piston rod are surrounded by seal grooves. These seal grooves are used to ensure that any leakage of pressure oil from the power piston comes from a part of the hydraulic circuit where it will do no harm.

Hydraulic Amplifier

The hydraulic amplifier is a linear pilot-operated servo actuator. It is used where relatively large forces are required to operate power control mechanisms, such as turbine steam valves or the fuel control linkage of large engines.

When using a hydraulic amplifier in conjunction with the EG-R actuator, a remote servo piston is not used. The various ports of the actuator (ports A, C, and E) are directly connected to the amplifier with high-pressure lines. The control servo piston, which is an integral part of the amplifier, is used in place of the remote servo piston to control the movement of the hydraulic amplifier pilot valve plunger.

The use of a three-way valve, a starting valve, and a yield spring are necessary starting aids. These will be discussed later.

The hydraulic amplifier does not have its own oil pump. Consequently, operating oil pressure and supply must come from an external source (usually the prime mover lubricating system). The use of a starting oil pump is necessary when the prime mover is being started. Once the prime mover develops its own pressure, this pump is secured.

Refer to figure 9-5 for a schematic diagram of the hydraulic amplifier. The control ports are connected to correspondingly identified ports in the EG-R actuator (fig. 9-4). Oil at these ports perform the following:

1. Port A- *Actuator buffer compensation system pressure* always tends to move the amplifier control servo piston downward (decrease fuel or steam).
2. Port C- *Actuator pump output pressure* is connected to annular seal grooves in the control piston and piston rod bores, ensuring that any oil leakage comes from a part of the hydraulic circuit where it does not adversely affect control pressure or oil flow.
3. Port E- *Actuator control pressure* tends to move the control servo piston upward (increase fuel or steam).

Pressure in the compensation or buffer port (port A) and the control port (port E) are constant at steady state for all control servo positions. Control oil pressure at port E is approximately one-half the compensation oil pressure at port A. The control oil pressure varies much more than the compensation oil pressure during a transient. The variations in control oil pressure causes the control piston to move.

The control servo piston is connected to one end of a floating lever in the amplifier. Any change in position of the control piston is transmitted to the floating lever. The movement of the floating lever is transmitted to the

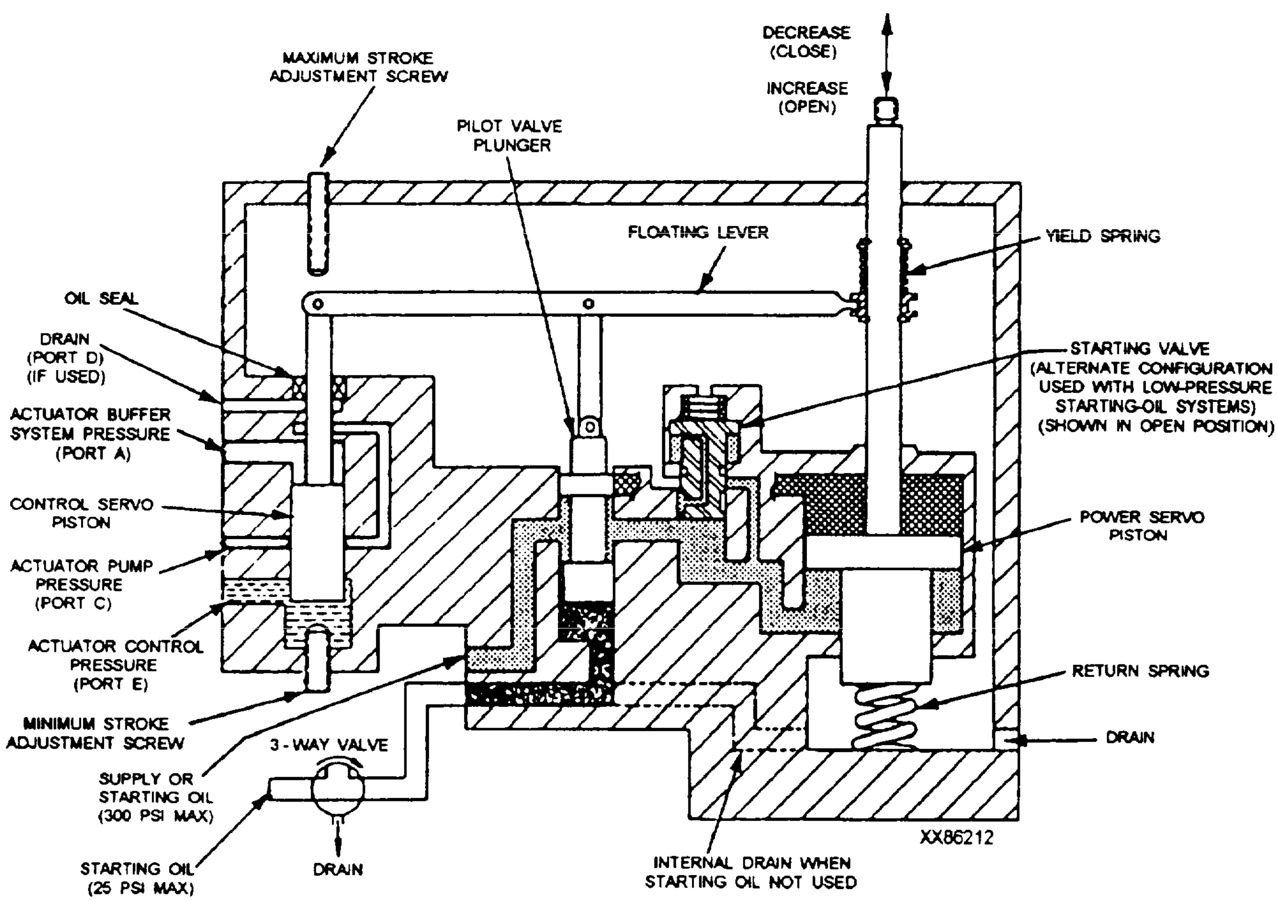

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Figure 9-5.—Hydraulic amplifier schematic diagram.

pilot valve plunger. This controls the flow of oil to or from the power servo cylinder and piston.

The following will occur when the electrical control unit senses an underspeed condition:

STEP	ACTION
1.	The electrical control unit senses an underspeed condition and it signals for an increase in speed (caused by an increase in load or speed setting).
2.	The pilot valve plunger in the EG-R actuator then directs oil to port E in the amplifier at increased pressure.
3.	The increase in control pressure input displaces the amplifier control servo piston upward, causing an increase in pressure in the buffer system (port A).
4.	This, in turn, displaces the buffer piston in the EG-R actuator, causing higher pressure on the left of the buffer piston. The upward movement of the amplifier control piston raises one end of the floating lever.
5.	This lifts the amplifier pilot valve plunger, admitting oil at supply pressure (less the pressure drop occurring across the pilot valve) to the opening (increase) side of the power servo cylinder.
6.	Although the oil pressure on the opening side of the power servo piston is lower than that on the closing side, it acts over a much larger surface area, causing the piston to move in the open direction, and increases power (fuel) to the prime mover.
7.	As the power piston moves, the end of the floating lever connected to the piston rod also moves in the same direction to gradually recenter the land on the pilot valve over the oil control port. This stops movement of the power servo piston just as the fuel control or steam valve reaches its new position as called for by the electrical control unit.

During an on-speed condition, the control signal to port E is maintained at a given pressure and the amplifier pilot valve plunger is held in its centered position. This covers the oil control port. With flow of oil to the opening side of the power servo piston blocked, except to compensate for leakage, the power piston will maintain its position in relation to the speed setting of the electric control (hydraulic actuator) or load on the prime mover.

The following will occur when the electrical control unit senses an overspeed condition:

STEP	ACTION
1.	It signals for a decrease in speed (caused by a decrease in load or speed setting).
2.	The pilot valve plunger in the EG-R actuator then allows oil to drain from port E in the amplifier.
3.	The decrease in the control pressure inlet allows the buffer system pressure (port A) to displace the amplifier control servo piston downward.
4.	The downward movement of the control piston lowers one end of the floating lever, pushing the pilot valve plunger down.
5.	This then allows oil to drain from the top side of the power servo piston.
6.	The oil pressure acting on the opposite side of the power piston along with the return spring force causes the power piston to move in the closing direction (decrease fuel).
7.	Movement of the power servo piston continues until the amplifier pilot valve plunger is again recentered by the floating lever.

In some applications the steam valve or fuel control must be opened before starting the prime mover. If this is necessary, you must use a three-way valve, a starting valve, and a yield spring. The yield spring and starting valve are an integral part of the hydraulic amplifier. The three-way valve is an external component. An additional tube connection must also be made on the hydraulic amplifier. This provides a passage for starting oil (which is developed from a hand pump or an electric-driven oil pump) to move the hydraulic amplifier pilot valve plunger on startup. This connection allows oil (25 psi minimum) to be used to raise the hydraulic amplifier's pilot valve plunger and direct starting oil to the power servo piston. This is necessary since the EG-R hydraulic actuator is inoperative on initial startup. The yield spring permits one end of the floating lever to move upward when stinting oil is applied to the bottom side of the pilot valve plunger. You must turn the three-way valve to drain after starting. Otherwise, oil will be trapped under the pilot valve plunger and render the amplifier inoperative.

In this low-pressure starting-oil system, the starting valve minimizes the force acting on the closing side (bottom) of the power servo piston. Starting oil pressure within the range of 25 to 30 psi (typical) cannot generate sufficient force on the opining side (top) of the power piston to overcome the combined forces of low oil pressure and return spring force on the closing side of the power servo piston.

In the shutdown position, the starting valve blocks the flow of starting oil to the closing side of the power piston. It also simultaneously opens the area to drain.

When the prime mover starts and the normal supply pressure (prime mover oil pressure) becomes greater than the starting oil pressure, the following actions will occur:

STEP	ACTION
1.	The increasing pressure is sensed through the axial passage in the starting valve plunger.
2.	Oil flow into the area under the large diameter of the starting valve plunger begins to lift the valve against the opposing spring force.
3.	When the pressure of the supply oil reaches a predetermined pressure (somewhat less than operating pressure), the valve opens.
4.	This closes the drain passage and opens the control port.
5.	Supply oil is then admitted to the closing side of the power servo piston.
6.	The starting valve remains in the open position during normal operation.

At shutdown, spring force returns the plunger to the closed position.

EG-M Control Box

The EG-M control box is designed to provide the control signal to the electrohydraulic transducer in the hydraulic actuator.

As shown in the block diagram of figure 9-6, the control box has three inputs. One is from the load signal box and will be discussed later. The other two are from the PMG and the speed setting (reference) potentiometer.

The input from the PMG is applied to the speed section where it is converted into a negative dc voltage. This voltage is proportional to the speed of the turbine. The positive reference voltage (speed control) is established by the speed-setting potentiometer but is developed internally.

The outputs of the speed section and the speed reference section are compared. If equal and of opposite polarity, no signal is applied to the amplifier section. If the speed of the turbine changes, there is a corresponding change in the signal from the PMG. This causes a change in the output of the speed section. An error voltage is then applied to the amplifier section. This is amplified and sent to the hydraulic actuator. Some output is fed back through the stabilizer section to keep the system from overreacting.

The schematic representation of the control box (fig. 9-7) is a simplification of the actual amplifier and is useful in describing its operation.

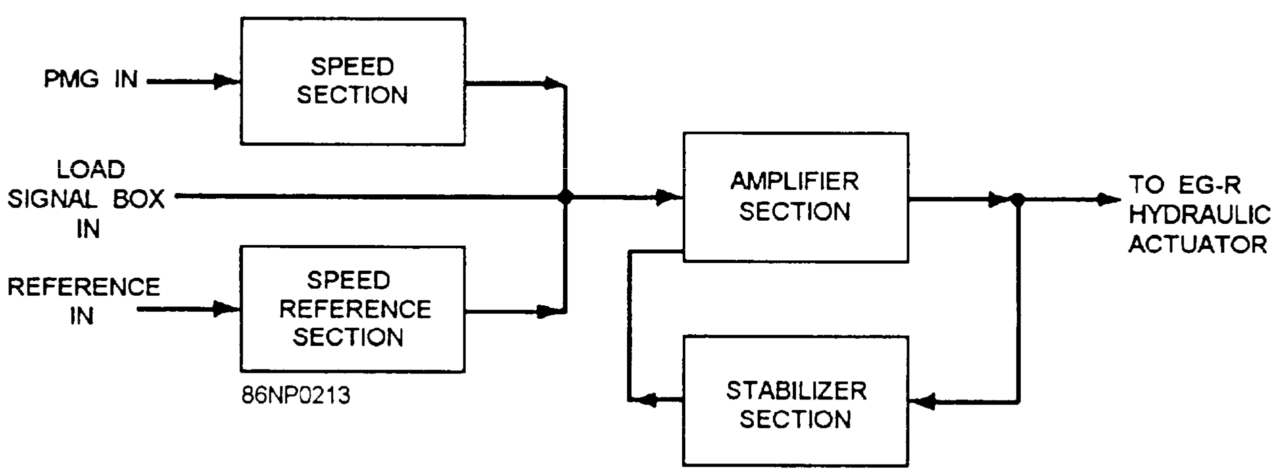

Figure 9-6.—EG-M control box, block diagram.

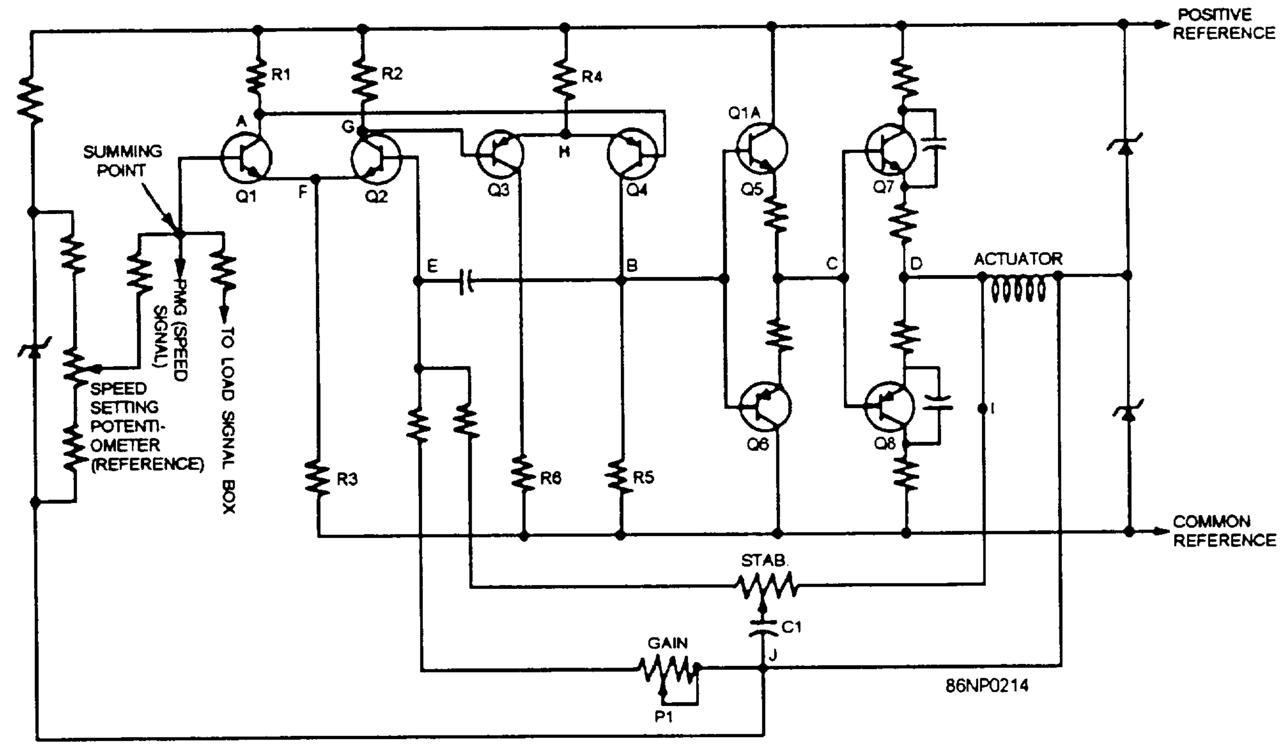

Figure 9-7.—EC-M control box, simplified schematic.

If the speed-setting potentiometer is adjusted to increase speed, the following actions will occur:

STEP	ACTION
1.	It causes a voltage signal change at the base of transistor Q1 in the positive direction.
2.	This increases the conduction of transistor Q1 causing increased current through resistor R1 and a drop in potential at point A (base of transistor Q4).
3.	The effect on transistor Q4 is to cause an increase in current through resistor R5. The increased voltage drop across resistor R5 raises the potential at point B.
4.	An increase in potential at point B (base of transistors Q5 and Q6) causes Q5 to conduct more and Q6 to conduct less increasing the potential at point C (base of transistors Q7 and Q8).
5.	This increase causes Q7 to conduct more and Q8 to conduct less which increases the potential at point D.
6.	An increase in potential at point D causes current to flow through the actuator coil in the direction to move the actuator pilot valve plunger in the increase steam direction.

This steam increase causes the turbine to increase speed. The negative speed signal increase counteracts the previous positive speed signal increase. A new steady-state condition of essentially zero voltage is then reached both at the summing point and the actuator.

To further explain the function of the amplifier and its stabilizing feedback network, refer to the voltage waveforms of figure 9-8 as well as the schematic of figure 9-7.

Assume that a step input voltage signal is applied to the summing point of the amplifier, as shown on curve 1 (fig. 9-8). If the feedback circuit is disconnected at point I (fig. 9-7), the output voltage for this condition (without feedback and stabilization) will be very high. This is shown in curve 2 (fig. 9-8). This will cause the turbine to hunt excessively. The gain (output voltage divided by input voltage) is very high in this condition. Assume that the feedback network is reconnected at point I, and the stabilizing network is disconnected at point J. In this case the output signal from point D is fed through the stability potentiometer to the base of transistor Q2 (point E). This reduces the amplifier gain. In response to the step input of curve 1, an output voltage for this condition (feedback connected but without stabilization) is obtained (curve 3, fig. 9-8).

Earlier, we stated that the output voltage at point D and at the actuator increases in response to an increased positive potential at the summing point of the amplifiers,

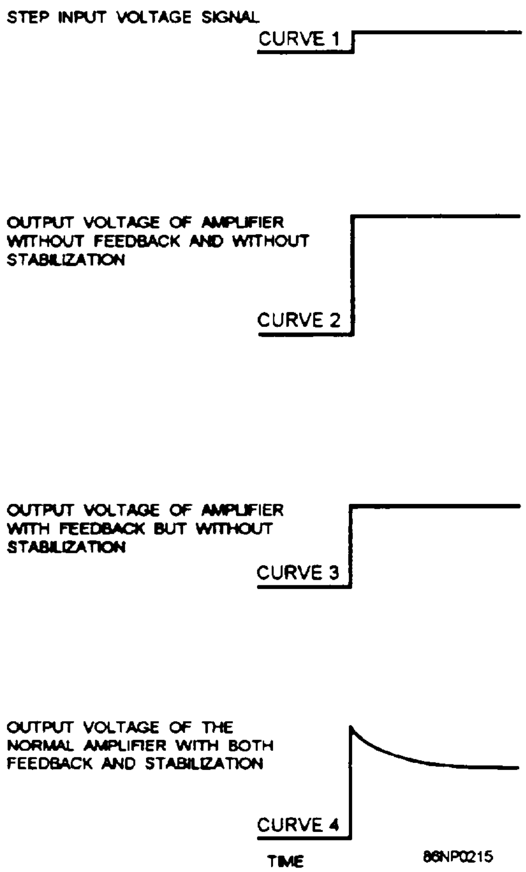

Figure 9-8.—Voltage relationships.

which causes the turbine speed to increase. Resetting of the amplifier is now achieved by the following actions:

STEP	ACTION
1.	The increase in potential across the actuator, which is applied to the base of transistor Q2, causes Q2 to conduct a greater amount.
2.	This increases the voltage drop across resistor R3, raising the potential at point F (the emitter of input transistor Q1), causing Q1 to conduct less.
3.	This reduces the amount of voltage drop otherwise experienced at point A, and in turn, the amount of conductance of transistor Q4 is reduced. Consequently, there is less voltage change at point B.
4.	Adjustment of P1 is used to increase the potential at point E and reduces the amplifier gain.
5.	Transistor Q2 conducts a greater amount, thereby reducing the potential at point G (because of the greater voltage drop across resistor R2).
6.	The potential at G (applied to the base of transistor Q3) causes Q3 to conduct more with a greater voltage drop across resistor R4.
7.	The lower potential at point H (the emitter of transistor Q4) causes it to conduct less resulting in a smaller increase in potential at point B or a gain reduction.

The stabilization signal is obtained through the use of a capacitor. With capacitor C1 disconnected at point J (fig. 9-7), the negative feedback effect reduces the gain (curve 3, fig, 9-8). When the circuit is reconnected at point J, the capacitor temporarily diverts some of the feedback signal away from point E during the charging period of the capacitor.

In response to the input voltage (curve 1, fig. 9-8), the initial output voltage of the amplifier goes to a high level (curve 4, fig. 9-8) at the first instant the signal is applied and the feedback signal is varied. As the capacitor charges, the voltage comes down on the curved portion of the line. It levels off at approximate] y the same level as curve 3 when a steady-state condition is reached. The shape of curve 4 is determined by an RC time constant. R is adjustable by the stability potentiometer. The normal response of the amplifier to an open loop test (fig. 9-8) produces an output voltage waveform characteristic of curve 4. This is in response to the input voltage of curve 1.

Load Signal Box

The load signal box (fig. 9-9) enables the governor system to respond to generator load changes, as well as to speed changes. Load changes are detected and responded to before they appear as turbine speed changes. This minimizes speed change transients.

The load signal box converts a three-phase input signal (from the generator leads through the resistor box) to a positive dc voltage. This voltage is proportional to the kW load on the generator. The voltage is applied to the load pulse section and the paralleling network. When operated with dissimilar governors, the droop and load pulse sections are used. The droop switch determines the operating mode for which the system is set up.

SINGLE GENERATOR OPERATION.— Look at the simplified schematic of the load signal box in figure 9-10. Input signals for the load signal box are taken from the secondary of the generator current transformers and developed in the resistor box. The resistor box contains three resistors (one for each phase). The voltage input is applied to transformer T2 and compared to the generator voltage phase. This is taken from the generator line, stepped down, and applied to transformer T1. If both voltages are in phase, they will cancel. Therefore, no output will appear. If they are out of phase (the load is changing), a voltage in proportion

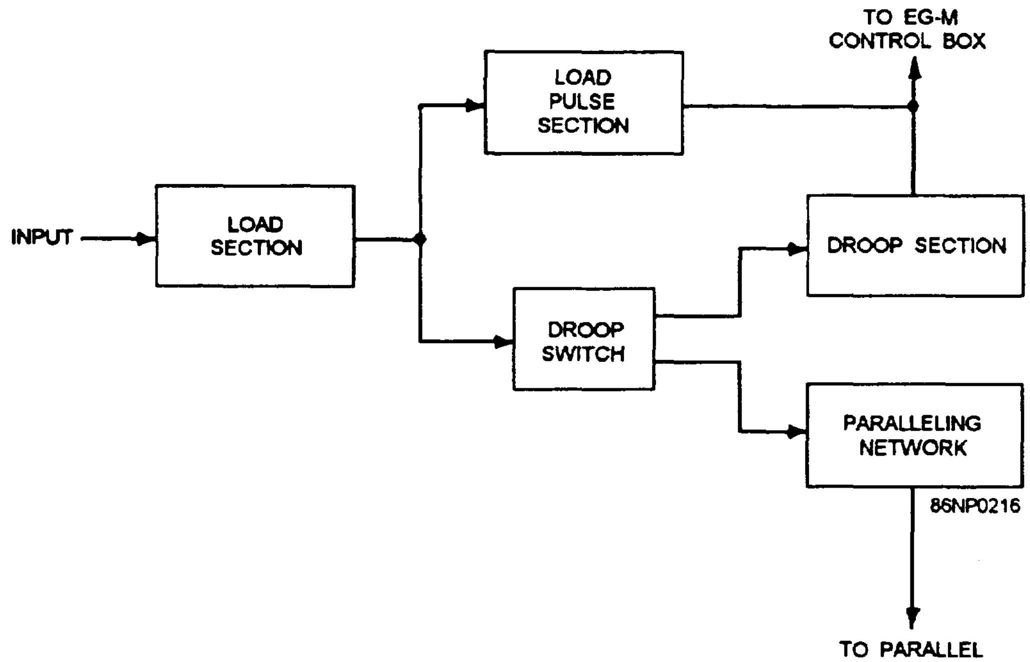

Figure 9-9.—Load signal box, block diagram.

to the generator load will be rectified by CR1 and CR2. Although only one phase is shown in figure 9-10, each phase is compared. The comparison circuitry is identical to that shown.

The amplitude of the signal can be varied by the GAIN ADJ. potentiometer. A variable pulse output is developed by the charge/discharge time of C1 through the LOAD PULSE ADJ. potentiometer.

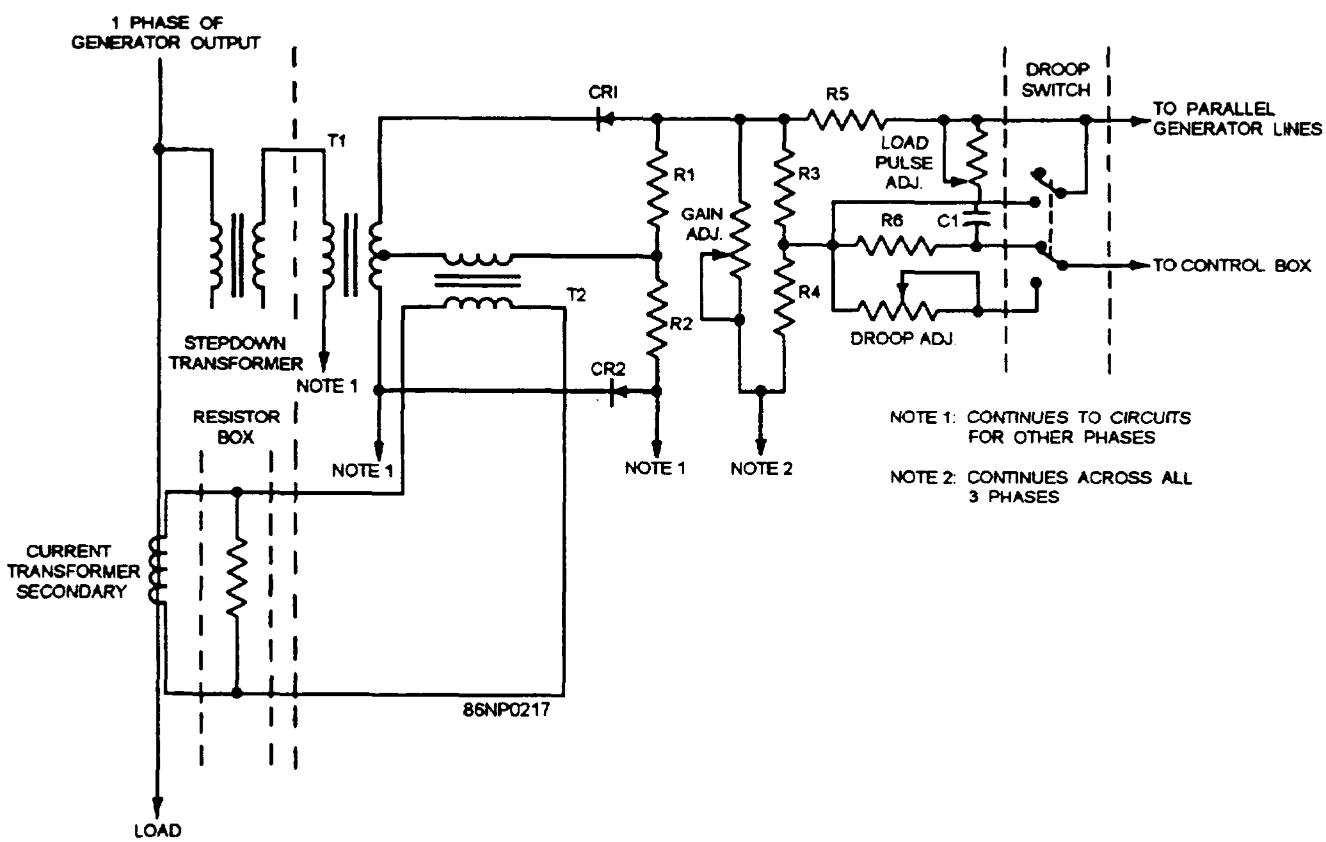

Figure 9-10.—Load signal box, simplified Schemstic.

The load pulse signal is initially maximum and gradually decreases to zero. Figure 9-11 represents load pulse signals in response to load changes. The signal is of the proper polarity to set the steam valve in the right direction to compensate for the change. The output signal is applied to the summing point in the EG-M control box (fig. 9-7).

PARALLEL OPERATION WITH OTHER EG GOVERNOR SYSTEMS.— When the load signal box is used with other EG governor systems, the operation is the same as for single operation (fig. 9-10) except for a closed circuit breaker (not shown). The closed circuit breaker connects the paralleling lines. This enables the load signal box to provide the same signal information to the control box of all the parallel units.

PARALLEL OPERATION WITH DISSIMILAR TYPE GOVERNOR SYSTEMS.— For operation with dissimilar type governor systems, the droop switch must be turned on (down position in fig. 9-10). This shorts out the paralleling lines so that the parallel units are effectively not connected to the load signal box. The signal to the control box is fed by the DROOP ADJ. potentiometer. This adjustment compensates for differences in generator ratings and the reactive load carried by them.

MAINTENANCE

Governor faults are usually revealed in turbine speed variations. However, a check of the system is necessary since not all speed variations are caused by a faulty governor.

Check first to determine that the changes are not a transient result of load changes. If the load is constant, hold an inspection to see that the operating linkage between the hydraulic actuator and the turbine is free from binding or lost motions. If the linkage is proper, check the voltage regulator for proper operation. If these checks do not reveal the cause of the speed variation, the governor is probably faulty.

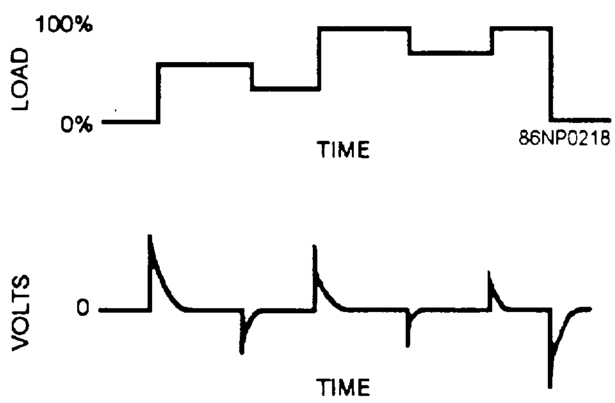

Figure 9-11.—Comparison of load pulse signals to load changes.

In troubleshooting the governor system, first check the voltage across the input to the hydraulic actuator. This should be done with the system running on speed and set for single operation. If the voltage is not correct (+0.5 volt dc to -0.5 volt dc) and cannot be set within range by the centering screw in the actuator, or if the voltage fluctuates more than +0.25 volt dc and cannot be stilled by the GAIN ADJ. or the STAB. ADJ., the control box may be defective.

To bench test the control box, disconnect it from the load signal box. Use a three-phase power supply instead of the normal supply. Instead of the speed signal, apply a frequency oscillator output signal set to the rated speed frequency of the PMG (fig. 9-7). Use a resistive load instead of the actuator. If an oscillator is not available, you can manually control the turbine-generator set to provide the PMG signal.

The converter section is working properly if, after removing the amplifier section, the voltage at the collector of Q2 (fig. 9-7) is correct (6 volts dc at rated speed). If this is correct, place the amplifier back in the circuit. The voltage across the resistive load should be about zero volts. If not, the amplifier section is faulty.

If the trouble is a change in unit steady-state speed as the load is changed, check the voltage across the actuator input under different load conditions. If the volt age is the same at both loads, the control box may be defective. If the voltages differ by more than 0.2 volt dc, the actuator is probably faulty,

The source of most troubles in the hydraulic actuator or valve operator is dirty oil. Grit and other impurities may be introduced into the system with the oil or may form when the oil begins to break down (oxidize) or become sludge. The moving parts within the actuator and valve operator are continually lubricated by the oil within the units. Thus, grit and other impurities can cause excessive wear of valves, pistons, and plunger. This can cause these parts to stick or freeze in their bores.

For the remainder of this chapter, we will discuss the EGB-2P governor/actuator and the 2301 load and speed-sensing control, which are used to form another system.

EGB-2P GOVERNOR/ACTUATOR

The EGB-2P (fig. 9-12) is a proportional actuator with a ballhead backup governor. The proportional actuator's terminal (output) shaft position is directly proportional to the magnitude of the output signal from the electronic control unit. The uses and functions of a proportional actuator are different and distinct from integrating types of EG actuators. To have a correct governoring system, you must use the EGB-2P actuator with the 2301 or similar integrating electronic control. By comparison, the EGB-2C is an integrating actuator with the companion EG-A control box being basically a proportional amplifier.

Proportional actuators can be used in the same type of service as other actuator models. They are particularly well suited to engines operating in tandem to drive a common load. In such installations, one electric control can be used for two or more proportional actuators wired in series with the control's output. This furnishes the same input signal to each actuator. Since each actuator receives the same signal, their output shafts take the same position. This gives each engine the same fuel.

Externally the EGB-2P is similar in size and appearance to the EGB-2C actuator. Internally, each has two sections. These are the ballhead governor and electric actuator section. The ballhead governor section acts as a backup governor in event of failure of the electric control. The electric actuator section is different in function and construction. The actuator section of the EGB-2P includes feedback linkage from its power piston to its pilot valve. This gives the proportional feature to the actuator.

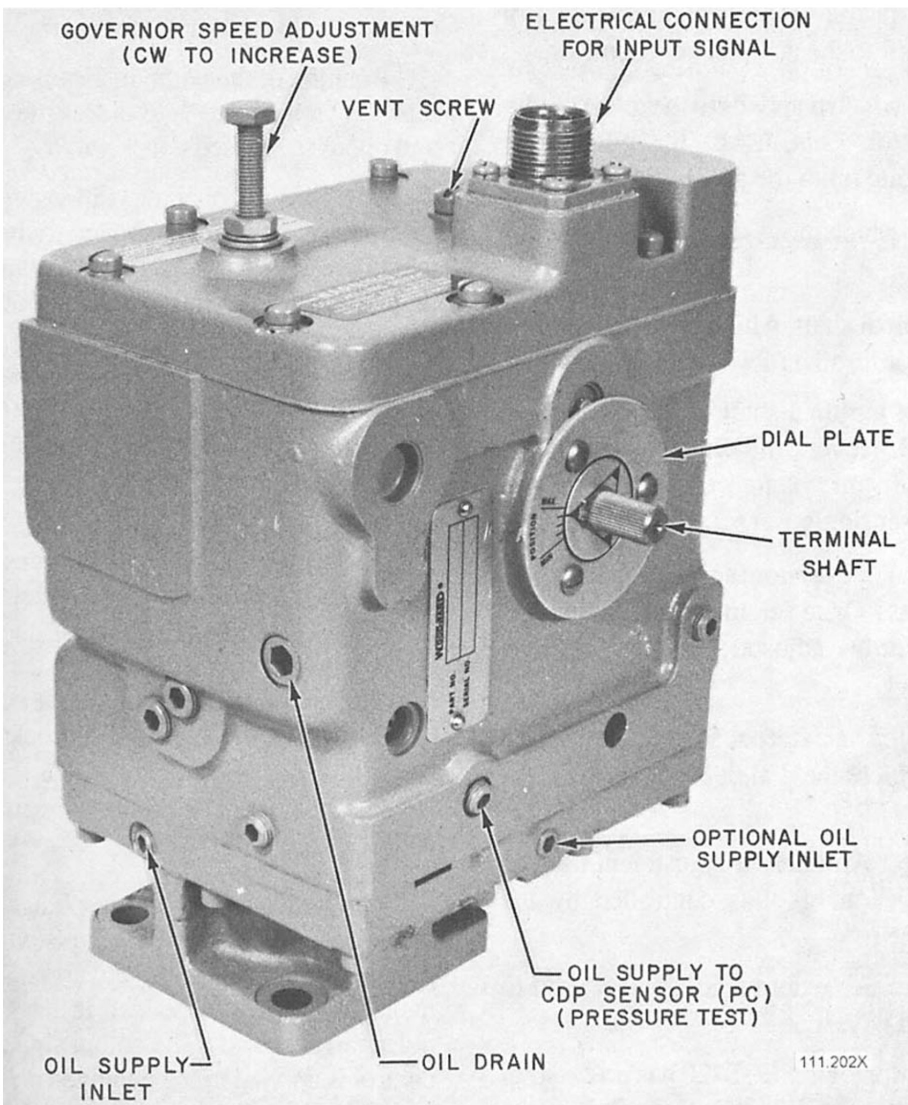

Figure 9-12.—EGB-2P governor actuator.

The proportional actuator requires a continuous electric input signal. This is in contrast to the nominally zero input signal under steady-state conditions for integrating-type actuators. Woodward 2301 electric controls are used to furnish the control input signal for the proportional actuator. The exact 2301 control used depends upon the operating scheme of the installation. Control assemblies are available to sense speed, frequency, load, and other combinations.

The following are the essential elements of the actuator section of the EG-B2P;

• Electrohydraulic transducer, which directs pressure oil to and from the power piston to actuate the fuel or steam control mechanism. It consists of a solenoid attached to the pilot valve plunger.

• Pilot valve plunger, which controls oil flow to and from the power piston by positioning the control land to add or drain oil to the actuator power piston.

• Solenoid coil, which responds to the given output of the electric control. This moves the pilot valve plunger down, directing oil to the power piston.

• Power piston, which moves the terminal shaft of the actuator.

• Actuator terminal shaft, which is the attachment point for the engine or turbine fuel linkage.

Strict linearity of terminal shaft travel versus load is not required. However, the linkage should be arranged to give the same degree of linearity given conventional speed-sensing governors.

The centrifugal governor section has three operating adjustments. Once set, these adjustments do not usually require further adjustment. These settings are listed below.

1. **Speed setting.** An external adjustment used to set the speed at which the ballhead governor will control.

2. **Speed droop.** An internal adjustment used to permit parallel operation of units controlled by the ballhead governor.

3. **Needle valve.** An external adjustment used to stabilize the ballhead governor.

The actuator section of the EGB-2P has no external operating adjustments. The actuator uses oil from the engine lubricating system or from a separate sump. It does not have a self-contained sump.

EGB-2P governor/actuators are available with the terminal shaft extending from either or both sides of the case. They can be furnished with the speed-adjusting shaft (for the ballhead governor section) extending on either side. However, most units use a speed-adjusting screw in the top cover. They omit the speed-adjusting shaft entirely.

OPERATION

The schematic arrangement of the EGB-2P is shown in figure 9-13. The parts are in their relative positions during normal operation. Oil enters the unit through either of the two inlet holes in the side of the base. The oil passes from the suction to the pressure side of the pump. After filling the oil passages, the pump builds up the oil pressure. When the pressure is high enough to overcome the relief valve spring force, it pushes the relief valve plunger back to uncover the bypass hole. Oil then recirculates through the pump.

Rotation of the pump in the opposite direction from that shown in figure 9-13 closes the open check valves and opens the closed check valves.

The loading piston positions the terminal shaft. Constant oil pressure is applied to the upper side of the loading piston. This tends to move it in the decrease fuel direction. Either the governor power piston or the actuator power piston can move the loading piston in the increase fuel direction. This is because the effective area on which the control oil pressure acts is greater on the power piston than on the loading piston.

In the event of an electrical failure, the unit goes to minimum fuel. If the actuator goes to minimum fuel, apply a 9-volt dc supply to the transducer. This takes the actuator toward maximum fuel. This allows the governor to take control. Adjust the speed-adjustment screw to give the desired steady-state speed. If the unit has a manual override knob on the cover, push it down and turn it to the right. This locks out the actuator control.

Actuator Control

The actuator's pilot valve plunger controls the flow of oil to and from its power piston. The pilot valve plunger is connected to an armature magnet. This magnet is spring-suspended in the field of a two-coil polarized solenoid. The output signal from the electric control is applied to the polarized coil. This produces a force, proportional to the current in the coil. This tends to force the armature magnet and pilot valve plunger down. The restoring spring force tends always to raise

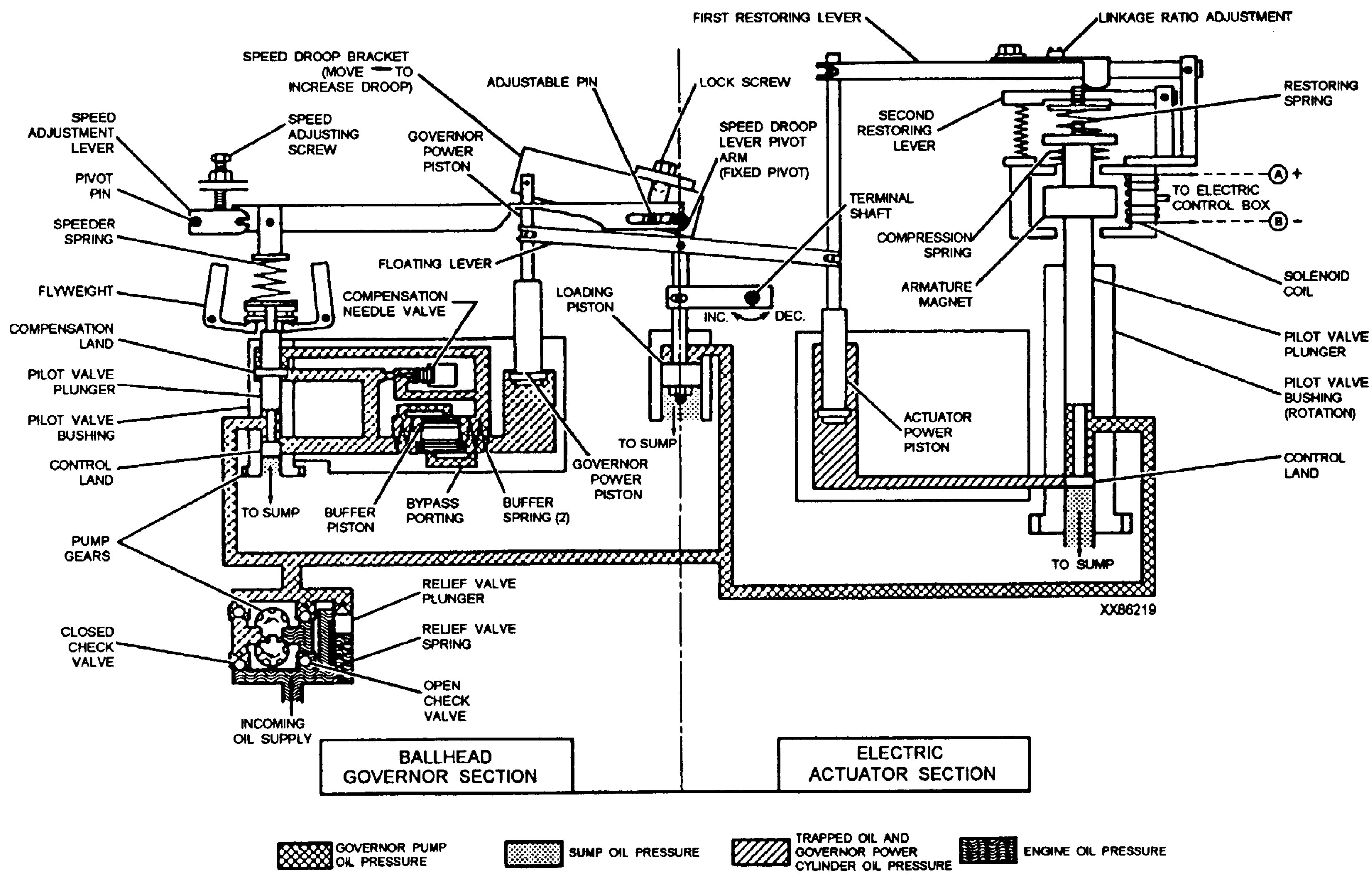

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Figure 9-13.—Schematic diagram EGB-2P governor/actuator.

the magnet and pilot valve plunger. When the unit is running under steady-state conditions, these opposing forces are equal. The pilot valve plunger is then centered This means the control land of the plunger exactly covers the control port in the pilot valve bushing. With the pilot valve plunger centered, no oil flows to or from the power piston.

An increase in engine or turbine speed or a decrease in unit speed setting will cause the following actions to occur:

STEP	ACTION
1.	The signal from the electric control decreases.
2.	This makes the restoring spring force relatively greater.
3.	This then raises the pilot valve plunger.
4.	Oil under the actuator power piston drains to sump.
5.	The oil pressure is constantly applied to the upper side of the loading piston and power piston.
6.	This forces the pistons down as the floating lever pivots about its connection to the ballhead governor power piston.
7.	The loading piston rotates the terminal shaft in the decrease fuel (or steam) direction as it moves down.

As the actuator power piston moves down, the following actions occur:

STEP	ACTION
1.	It lowers the left end of the first restoring lever.
2.	The clamping plate, attached to the first restoring lever, pushes down on the second restoring lever.
3.	The loading on the restoring spring is increased.
4.	The loading piston and actuator power piston move down until the increase in restoring spring force is sufficient to offset the increased force, resulting from the increased electric signal.

When the pilot valve plunger is pushed back to its centered position, movement of the power piston, loading piston, and terminal shaft stop.

Position of the actuator shaft is proportional to the electric input signal to the actuator. An increase in the electric input signal caused by a decrease in engine or turbine speed or an increase in unit speed setting creates similar movements in the opposite directions.

STEP	ACTION
1.	The pilot valve plunger lowers, allowing pressure oil to flow to the underside of the power piston.
2.	This pushes the piston up.
3.	The loading piston then raises.
4.	This rotates the terminal shaft in the increase fuel (or steam) direction.
5.	At the same time, the upward movement of the power piston, acting through the restoring levers, decreases the restoring spring force.

This recenters the pilot valve plunger and stops movement of the terminal shaft.

Governor Control

The governor pilot valve plunger controls the flow of oil to its power piston. If the plunger is centered, no oil flows through the pilot valve. The power piston is then stationary. The greater of two opposing forces, the upward force of the flyweights and the downward force of the speeder spring, moves the pilot valve plunger. With the pilot valve centered, there is one speed at which the centrifuged force of the flyweights is equal and opposite to the speeder spring force.

With the speed setting of the governor set slightly higher than the actuator, the centrifugal force of the rotating flyweights is not sufficient to lift the pilot valve plunger to its centered position. With the actuator controlling, pressure oil is continually directed to the underside of the governor power piston. This holds it up against its stop. This is why the power piston of the governor is against its stop when the actuator is controlling.

With the unit running on speed with the governor controlling, the pilot valve plunger is centered. If a load is added to the engine, the following actions occur:

STEP	ACTION
1.	The engine and governor speeds decrease.
2.	The pilot valve plunger is lowered by the speeder spring force.
3.	This force is now greater than the centrifugal force of the flyweights.
4.	Pressure oil flows to the buffer piston.
5.	This moves it towards the power piston.
6.	The oil displaced by the buffer piston forces the power piston upward.
7.	The loading piston is raised.

The terminal shaft is then rotated in the direction to provide the additional fuel needed for the new load.

The movement of the buffer piston towards the power piston partially relieves the compression of the left-hand buffer spring.

STEP	ACTION
1.	This increases the compression of the right-hand buffer spring.
2.	The force of the right-hand buffer spring tending to resist this movement results in a slightly higher oil pressure on the left side of the buffer piston than on the right.
3.	The pressure on the left of the buffer piston is transmitted to the underside of the compensation land of the pilot valve plunger.
4.	The pressure on the right of the buffer piston is fed to the upper side of the compensation land.
5.	The difference in pressures on the two sides of the compensation land produces a force that acts to push the pilot valve plunger back to its centered position.

When the terminal shaft has rotated far enough to satisfy the new fuel requirement, the pilot valve recenters. This is caused by the differential force on the compensation land plus the centrifugal force of the rotating flyweights. This happens even though the engine speed has not returned complete] y to normal. Power piston and terminal shaft movement stops. The continued increase of speed to normal increases the centrifugal force developed by the rotating flyweights. However, this increase of speed to normal does not cause the flyweights to lift the pilot valve plunger above center. Oil leakage through the needle valve orifice equalizes the pressure above and below the compensation land. This is at a rate proportional to the return of the engine speed to normal. Then, as the centrifugal force increases, the compensating force decreases.

With the pressures above and below the compensation land equalized, the buffer springs return the buffer piston to its normal centered position.

When engine load decreases, the following actions occur:

STEP	ACTION
1.	The resultant increase in governor speed causes the flyweights to move outward.
2.	This raises the pilot valve plunger.
3.	With the pilot valve plunger raised, the area to the left of the buffer piston is connected to sump.
4.	The loading piston is continually urged downward by oil pressure from the governor pump.
5.	The piston moves down and forces the governor power piston down.
6.	The movement reduces the fuel to meet the new requirement.

Again, differential pressure across the compensation land helps to recenter the pilot valve plunger.

The speed at which the governor controls the engine is determined by the loading or compression of the speeder spring. This spring opposes the centrifugal force of the flyweights. The standard EGB-2P has a speed-adjusting screw in the top cover, as shown in figure 9-13.

Speed Droop

Speed droop is used in governors to divide and balance load between engines or turbines driving the same common load or driving generators paralleled in an electrical system. Speed droop is defined as the

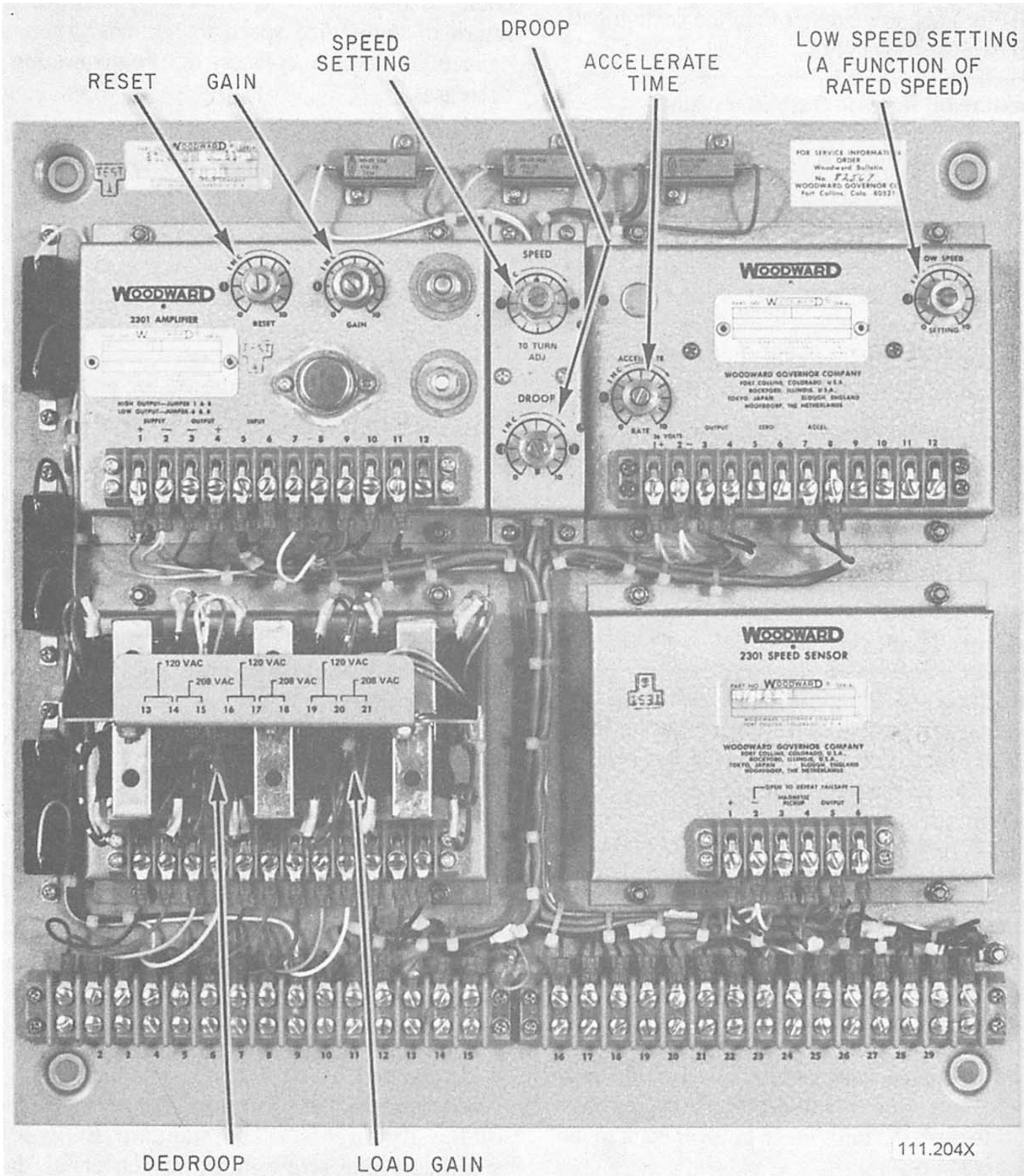

Figure 9-14.—2301 load - and speed-sensing control.

decrease in speed taking place when the governor output shaft moves from the minimum to the maximum position in response to a load increase. It is expressed as a percentage of rated speed. Speed droop is provided in the EGB-2P through linkage, which varies the loading on the speeder spring as a function of the power piston position. The change in speeder spring force for a given movement of the power piston is determined by the position of the adjustable pin in the linkage between the power piston and speeder spring. If the pin is on the same centerline as the speed droop lever pivot arm, there is no change in speeder spring force as the power piston moves. The governor then operates as an isochronous (constant speed) control. The further the adjustable pin is moved away from the pivot arm centerline, the greater the change in compression of the speeder spring for a given power piston movement.

With the unit operating under the electric control, the speed droop feature is, in effect, inoperative. During such operation, the governor power piston remains in the maximum position for all engine or turbine loads (except possibly momentarily during transients). Therefore, the speed droop linkage does not alter the speeder spring compression when the actuator is controlling.

MAINTENANCE

As stated earlier, the source of most troubles in any hydraulic actuator or governor stems from dirty oil. Valves, pistons, and plungers will stick and even freeze in their bores, due to excessive wear caused by grit and impurities in the oil. If this is the case, erratic operation and poor response can be corrected by flushing the unit with fuel oil or kerosene. The use of commercial solvents is not recommended as they may damage seals or gaskets.

If the speed variation of the unit is erratic but small, excessive backlash or a tight meshing of the gears driving the unit may be the cause. If the speed variation is erratic and large and cannot be corrected by adjustments, repair or replace the unit.

2301 ELECTRIC GOVERNOR

The 2301 electric control (fig. 9-14) is a combination of four modules mounted on a single control panel. The control panel is the controlling portion of the 2301 system. The system is comprised of the 2301 electric control (described here), a magnetic pickup, current and potential transformers, and a hydraulic actuator. The system can provide isochronous (constant speed) or droop (speed regulation) operation for prime movers such as diesel or gas engines and steam or gas turbines.

Isochronous operation provides constant engine speed for single unit operation or when several units are paralleled on an isolated bus. Droop operation allows paralleling of two or more units and provides speed regulation as a function of generator load.

Two engines driving a common load can be operated from one 2301 electric control by connecting the actuators in series. Since each actuator receives the same input signal, each engine receives the same amount of fuel.

The output of the 2301 electric control provides a unidirectional continuous voltage level to the actuator, which provides the desired speed and load relationship called for by the input signals to the control panel. This type of output signal requires a proportional actuator. The proportional actuator contains a servo piston, which operates in proportion to the input voltage applied

The electric control also contains a ramp generator module which controls the rate of acceleration during initial start-up. After the unit reaches set speed further control action from the ramp generator is blocked.

The load sensor provides either parallel isochronous load sharing or droop operation for the unit.

As with any governor, the engine should be equipped with a separate overspeed device. This prevents runaway (loss of control with maximum rpm) if a failure should render the governor inoperative.

OPERATION

The 2301 system is programmed to maintain preset speed- and load-sensing levels. These are in proportion to the capacity of the unit being controlled. For purposes of explanation, the system is divided into two sections: input and control (see fig. 9-15).

Input Section

The input section consists of the following components:

1. Load sensor,
2. External magnetic pickup, and
3. Speed sensor.

These circuits detect and process the speed and load input signals.

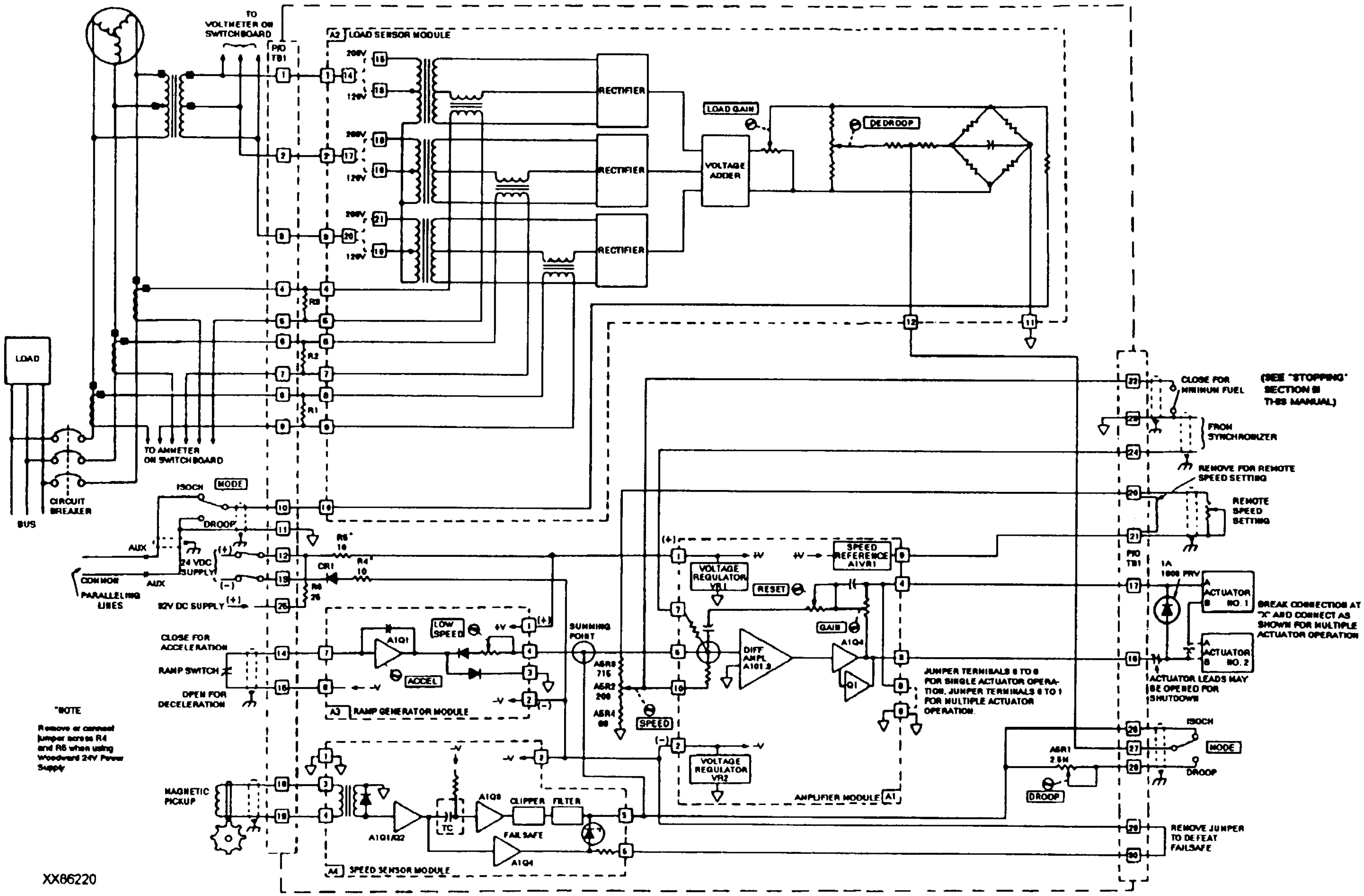

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Figure 9-15.—2301 block schematic diagram.

LOAD SENSOR.— External three-phase current and potential transformers are used to monitor the generator load. Load sensor input transformers process the current signals (expressed as a voltage level developed across burden resistors R1-R3) and the potential signals to compute the kW load on the generator. Rectifiers convert the ac voltage from the transformers to dc. A voltage adder circuit adds the dc voltage of each phase and provides a signal representative of the kW load.

The internal LOAD GAIN potentiometer applies a portion of the load voltage to the bridge circuit. When connected to other units through paralleling lines, the bridge circuit compares this signal with that of the other units. This allows each unit to share equally in proportion to its capability.

The correcting signal of the load sensor is applied to the summing point to provide the load control function to the amplifier.

MAGNETIC PICKUP/SPEED SENSOR.— Ac input pulses from a magnetic pickup provide the speed input signal to speed sensor A4. The magnetic pickup consists of a coil of wire wound around a permanent magnet. This magnet pickup is mounted close to a toothed gear, which is driven by the prime mover. As the gear teeth pass through the magnetic field produced by the permanent magnet, a step voltage (pulse) is generated in the coil of wire.

Control Section

The control section consists of

1. the SPEED setting control,
2. the ramp generator,
3. an external mode switch,
4. the DROOP control, and
5. the amplifier module.

These circuits combine to provide the control signal to the actuator, thus controlling the speed of the prime mover.

SPEED SETTING CONTROL.— The SPEED setting control applies a variable dc voltage to the amplifier summing point. When a jumper wire is connected to TB1 terminals 20 and 21, the SPEED potentiometer on the panel sets the speed. Disconnecting the jumper wire and connecting a 10-turn 100-ohm potentiometer allows external speed control of approximately ±4 percent from the internal SPEED setting.

RAMP GENERATOR.— Ramp generator A3 biases the speed signal to control the rate of acceleration of the prime mover from idle to rated speed. Closing the external switch or contacts connected to TB1 terminals 14 and 15 starts the acceleration ramp. Opening the switch or contacts returns the unit to idle speed. Front-panel screwdriver adjustments set the LOW SPEED SETTING and ACCELERATE RATE of the ramp generator.

MODE SWITCH.— This switch selects either the isochronous or the droop mode of operation. This is a two-section ganged switch. The first section (a speed switch) either connects the paralleling lines to the load sensor (TB1-10) for isochronous operation, or it unbalances the load sensor bridge by shunting one leg to common (TB1-11). The second section (also a speed switch) connects the load sensor output (A2TB1-5) for isochronous or droop operation. In the isochronous mode, the load sensor output is connected directly to the summing point. In the DROOP mode, the output is connected to the DROOP control potentiometer.

DROOP CONTROL.— DROOP control A5R1 biases the engine speed to decrease speed as the load increases. This is accomplished by setting the external mode switch to DROOP. This connects the DROOP potentiometer in series with the load sensor output.

AMPLIFIER— The output signals from the load sensor, the speed sensor, the SPEED setting potentiometer, and the ramp generator are applied to the summing point input of amplifier Al. Amplifier Al amplifies the resultant input voltage to increase or decrease fuel proportionally. Internal GAIN and RESET controls determine the magnitude and the response time of the amplifier. The complete control system is a closed loop (sensors, amplifier, actuator, fuel flow, prime mover speed, sensors), and the purpose is to match the electronic response time to the system response time for stable operation.

DETAILED CIRCUIT DESCRIPTION

The following sections provide a more detailed description of the 2301 electric control circuitry. These detailed descriptions are keyed to the individual module schematics. The block schematic diagram, figure 9-15, shows all the modules in relationship to one another including inputs and outputs.

Input Voltage Distribution

The 2301 electric control operates with either a 24-volt dc supply or a 32-volt dc supply. The source of this supply can be either a battery or a regulated dc power supply.

Resistors R4 and R5 (see block schematic diagram fig. 9-15) are current-limiting resistors for zener voltage regulators A1VR1 and A1VR2 (see amplifier schematic fig. 9-16). When you are using a 24-volt dc supply, this operating voltage is applied to TB1 terminals 12 (+) and 13 (-) (fig. 9-15). When you are using a 32-volt dc supply, operating voltage is applied to TB1 terminals 25 (+) and 13 (-). Resistor R6 drops the +32-volt to +24-volt dc before being applied to current-limiting resistor R5.

Protection diode CR1, mounted on the panel, is in series with the negative voltage supply lead (common to both the 24-volt and 32-volt dc supplies). The diode protects the circuitry by reverse biasing if the input voltage polarity should ever be reversed.

Voltage regulators A1VR1 and A1VR2 regulate the 24-volt dc to +9 and -9 volt dc with respect to center tap common (A1TB1 terminal 6). This +9 and -9 volt dc is the regulated supply voltage for the 2301 electric control system.

Speed Setting Reference Voltage

Since the speed setting input voltage determines the speed of the prime mover, a stable reference voltage is necessary for stable speed control. Zener diode A1A1VR1 provides a stable 6.6-volt dc at TB1 terminal 21 (fig. 9-15) for the speed-setting control.

Amplifier

Input signals from the various input and control circuits (fig. 9-16) are algebraically added together at the summing point input to the amplifiler (A1TB1 terminal 5). The steady-state condition of the closed loop (sensors, amplifier, actuator, fuel flow, prime mover speed, sensors) is a value approaching null voltage at the summing point input to the amplifier.

The speed-setting input voltage (positive) at A1TB1 terminal 10 is algebraically added to the speed sensor voltage (negative) at the summing point (A1TB1 terminal 5). A resultant positive voltage causes input transistor A1A1Q1 to turn on and conduct. This causes the differential amplifier to become unbalanced. The Q1A emitter potential decreases conduction through Q1B. The Q1B collector potential decreases conduction through Q2. Collector potential from Q1A forward biases A1A1Q3, causing increased conduction through Q3.

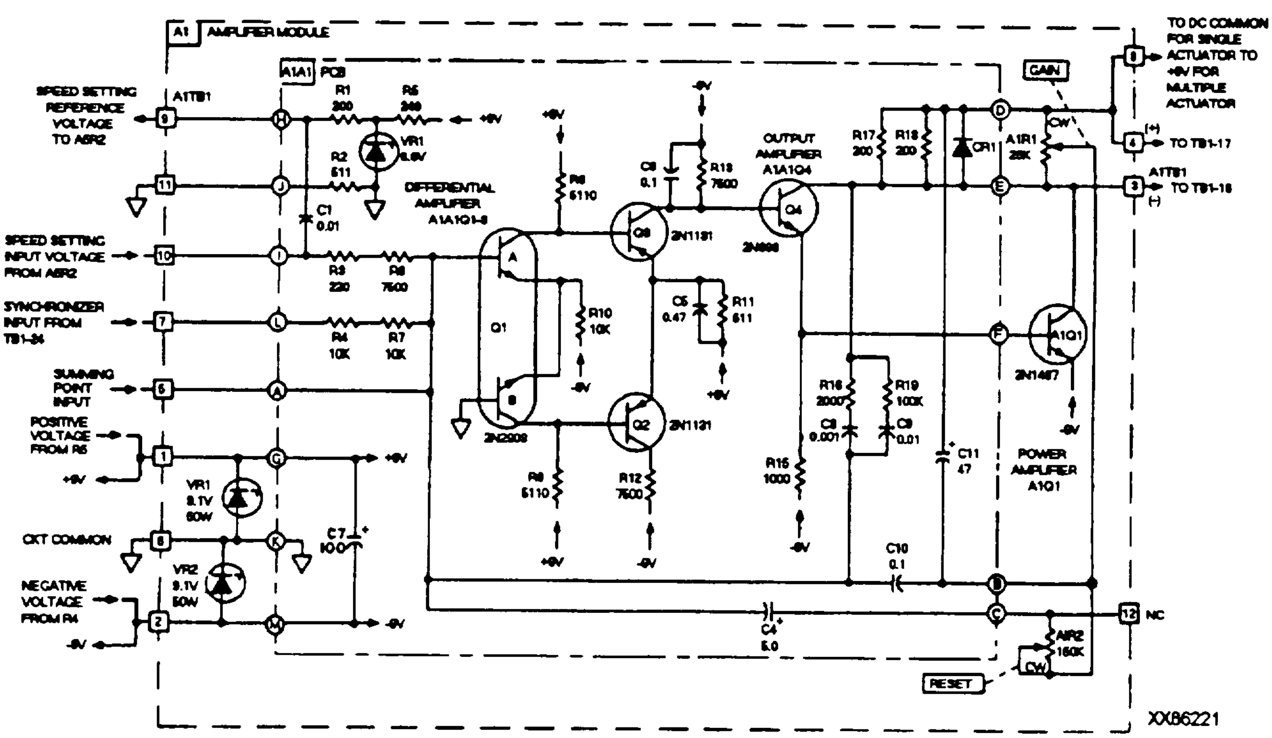

Figure 9-16.—Amplifier schematic.

The differential amplifier is now set to call for an increase in fuel. Q1A and Q3 are turned on, and Q1B and Q2 are at the threshold level. The differential amplifier remains in this configuration until the speed sensor input nulls out the speed- setting voltage level. At that time the differential amplifier becomes balanced.

As conduction increases through A1A1Q3, the Q3 collector potential biases output amplifier A1A1Q4 for increased conduction. The Q4 emitter potential forward biases power amplifier A1Q1, turning A1Q1 on. Power amplifier A1Q1 saturates to clamp -9 volt to A1TB1 terminal 3 and supply the current required by the actuator coil.

System stability is derived by feeding a portion of the output signal back to the amplifier input. GAIN potentiometer A1R1 sets the gain of the amplifier by varying the amount of inverse feedback. As the amplitude of feedback increases, amplifier gain decreases.

RESET potentiometer A1R2 sets the stability of the control loop by changing the reset time constant of the feedback signal. The time constant is the product of the value of RESET potentiometer A1R2 and integrating capacitor A1A1C4. As the time constant increases, reset time increases. This increases stability by slowing the response time.

A high-frequency feedback circuit consisting of A1A1R16/C8 and A1A1R19/C9 compensates for any high-frequency interference that might be introduced.

Derivative capacitor A1A1C11 provides derivative control action for the amplifier by effectively acting as a short circuit to common for the feedback signal when there is a step change in the output voltage. This allows the amplifier to reach maximum gain momentarily. Then the effect is dissipated exponentially to zero.

For single actuator operation, A1TB1 terminal 8 is connected to dc common terminal 6. For multiple actuator operation, terminal 8 is connected to the +9-volt power supply at terminal 1.

Ramp Generator

Ramp generator (fig. 9-17) A3 biases the speed setting input signal to the amplifier module in either of two modes: a deceleration mode to a low speed or an acceleration mode.

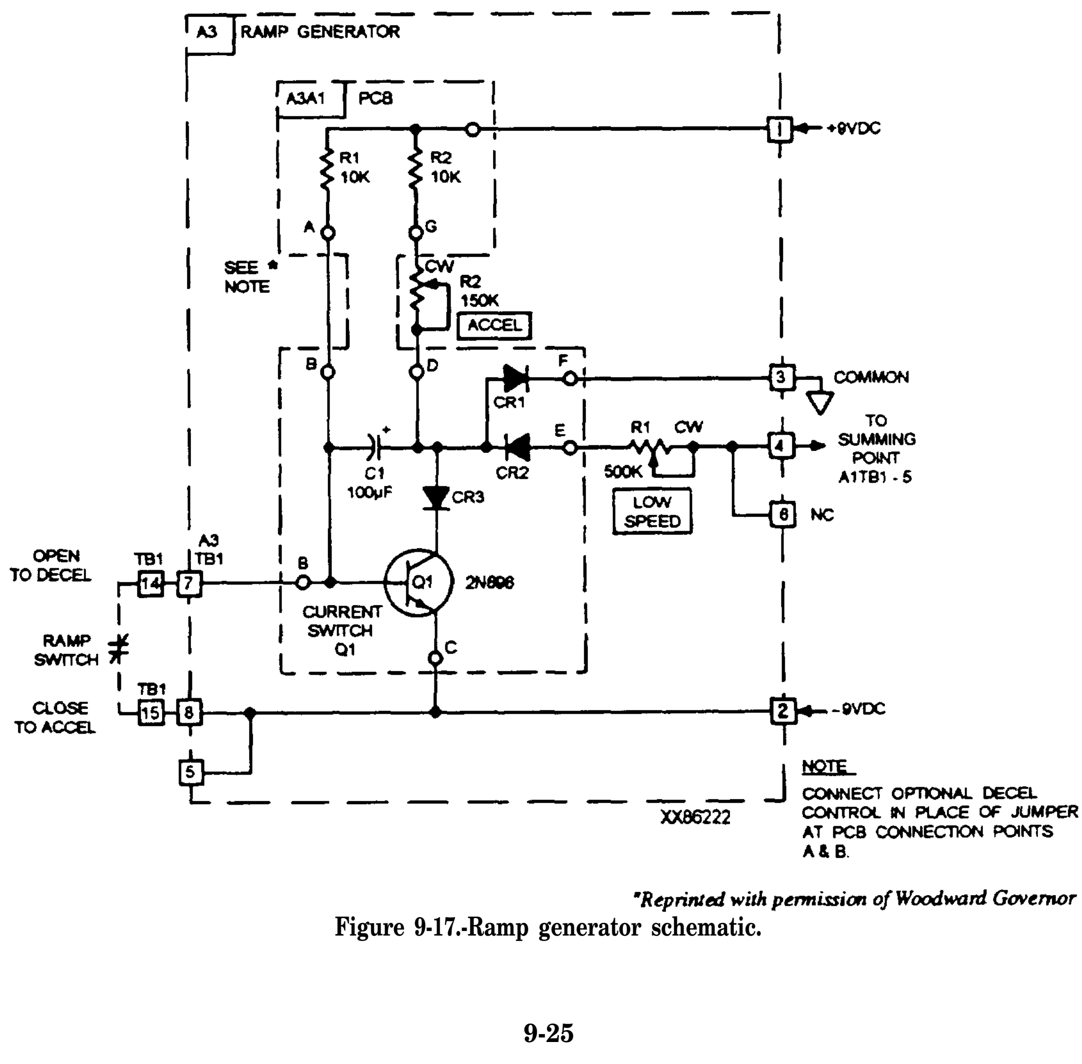

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Figure 9-17.-Ramp generator schematic.

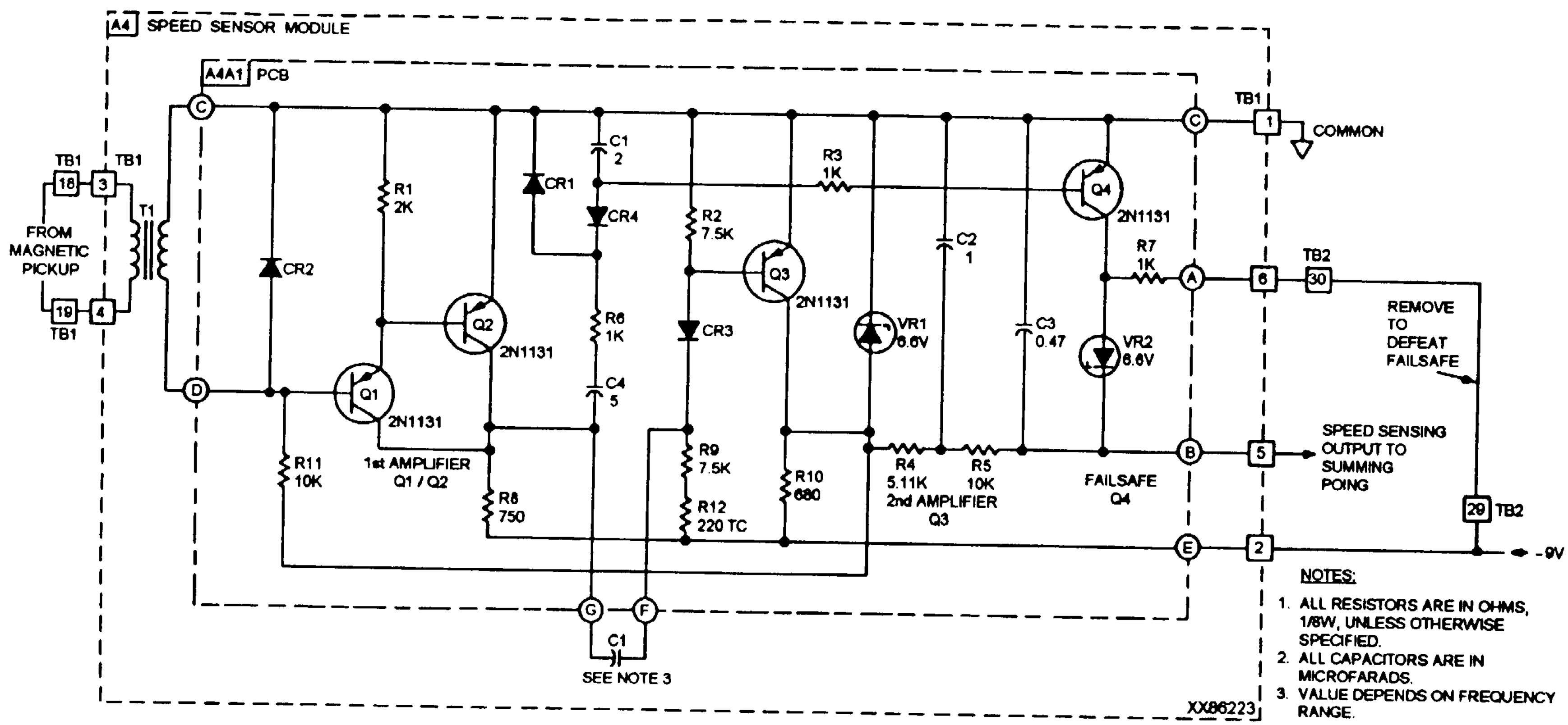

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Figure 9-18.—Speed sensor schematic.

DECELERATION MODE.— With the external switch or contacts (connected to TB1 terminals 14 and 15) open, the positive voltage from A3A1R1 forward biases current switch A3A1Q1. With Q1 turned on, -9 volts are connected through Q1 to LOW SPEED potentiometer A3R1. The LOW SPEED potentiometer sets the amount of negative speed-setting bias voltage to hold the prime mover at the desired idle speed.

ACCELERATION MODE.— Closing the external ramp switch or contacts connected to TB1 terminals 14 and 15 connects -9 volts dc to timing capacitor A1C1 and current switch A3A1Q1. This reverse biases Q1 and stops the current flow through Q1. This allows the right side of C1 to charge from -9 volt dc toward +9 volt dc his positive ramp voltage is applied through gate diode A3A1CR2 to the amplifier summing point. ACCEL potentiometer A3R2 sets the charge time constant of the circuit, thereby setting the acceleration rate of the ramp generator. The ramping output voltage continues in a positive direction until it reaches 0 volt dc As the ramp becomes more positive than 0 volt dc, gate diode A3A1CR1 forward biases and begins to conduct. This clamps the ramp generator output to +0.6 volt dc At this time the prime mover should be at or near rated speed and the reference voltage at the summing point will be 0 volt dc.

Speed Sensor

The speed input signal from the magnetic pickup is applied to interstage transformer A4T1 (see fig. 9-18). Transformer T1 provides a 1 to 3 step-up ratio of the speed input signal. The alternating input signal from T1 alternately drives first amplifier A4A1Q1/Q2 into saturation and cutoff. This clipped sine wave output signal is applied to the selectable time constant differentiator network.

Differentiator networks A4C1/A4A1R9 and R12 convert the clipped sine wave from the first amplifier to corresponding positive- and negative-going spikes. Capacitor A4C1 is selectable to set the proper time constant for the particular engine speed for which the 2301 electric control is used. The value of capacitance selected determines the decay time of the positive and negative spikes.

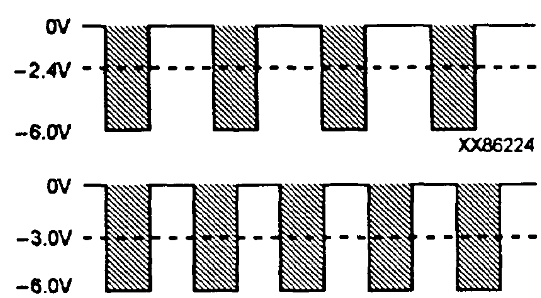
The positive- and negative-going spikes are applied to gate diode A4A1CR3. The gate diode passes only the negative-going spikes and rejects the positive spikes. These negative spikes trigger the second amplifier A4A1Q3.

Biasing for the second amplifier is such that it operates as a saturation switch. The negative trigger spikes saturate Q3 and hold Q3 saturated until the spike decays sufficiently below the threshold voltage to turn Q3 off. This produces a pulsed output with the frequency determined by the engine speed and the pulse width determined by the selected time constant. Zener diode A4A1VR1 clamps the maximum pulse excursion to 6.6 volts.

As the engine rpm increases, so does the frequency of the speed input signal (see fig. 9-19). The value of capacitance selected sets the speed range of the speed sensor to match the requirements of the engine. Higher rpm engines require a faster differentiator network time constant. This maintains the proper ratio between the pulse width and the puke period (time between pulses).

The output from second amplifier Q3 is filtered by a two stage RC filter consisting of R4/C2 and R5/C3. For all practical purposes, the filtered output voltage is proportional to the engine speed (see fig. 9-19). If the engine speed decreases, the frequency of the differentiated spikes decreases. This increases the time between pukes. Since the pulse width is determined by the differentiator time constant, the pulse width remains the same. This decreases the average dc voltage level from the filter circuit.

During normal operation the clipped sine wave output signal from the first amplifier is coupled through gate diode A4A1CR4 and charges integrating capacitor C1. When C1 charges sufficiently negative, fail-safe transistor Q4 turns on and saturates. This clamps the anode of VR2 at the dc common potential. In this mode the negative fail-safe supply voltage, which is connected through the fail-safe jumper, is dropped across R7.



NOTE: BASIC ENVELOPE DEVELOPED ACROSS A4A1R1.
DASHED LINE INDICATES AVERAGE FILTERED DC VOLTAGE OUTPUT. SHADED AREA EMPHASIZES EQUAL AREA PULSES.

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Figure 9-19.—Speed sensor output voltage.

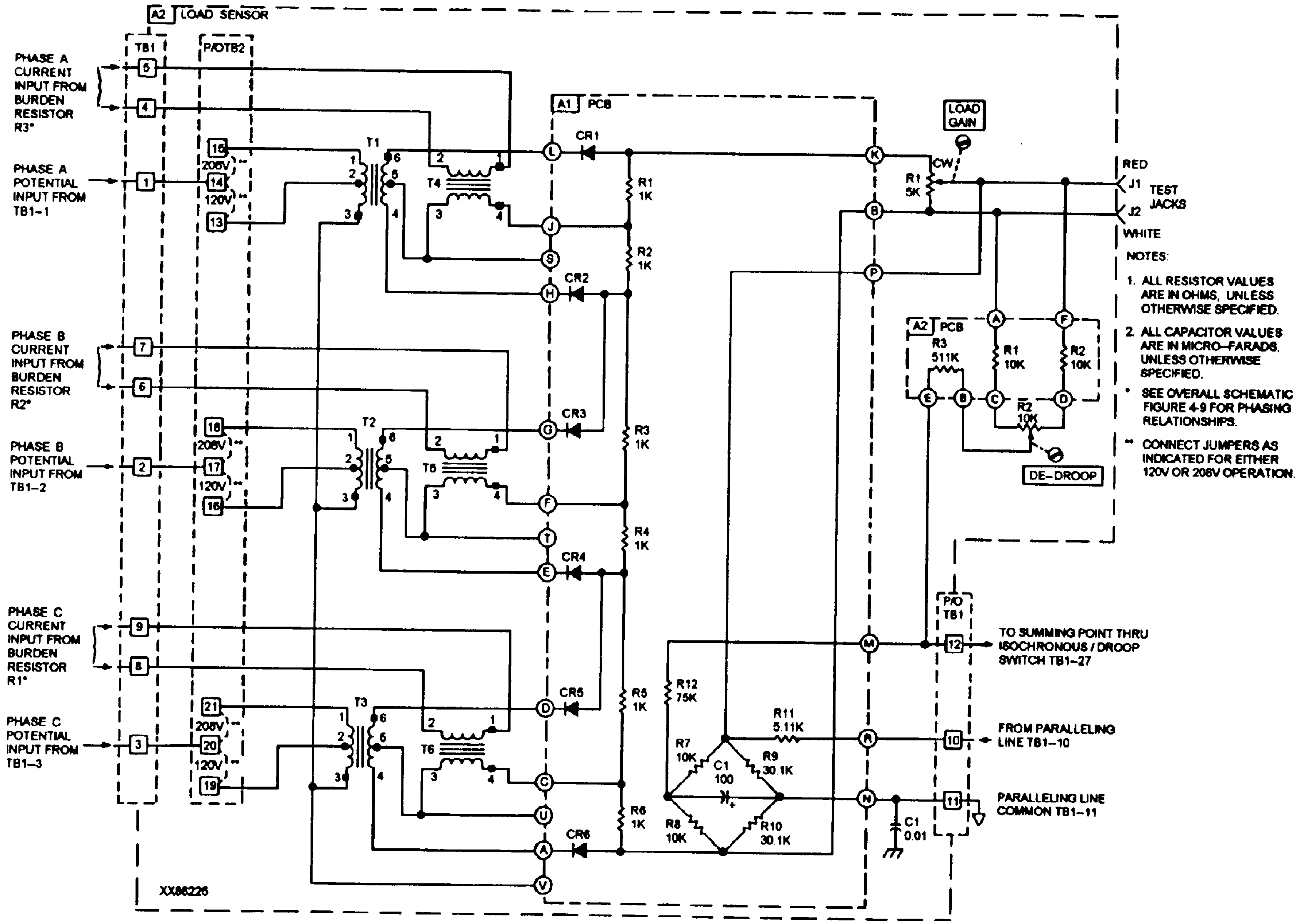

Figure 9-20.—Load sensor schematic.

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In the event that the magnetic pickup fails (or before initial start-up), capacitor C1 becomes discharged, allowing fail-safe transistor Q4 to turn off.

When this condition occurs, the fail-safe supply voltage reverse biases zener diode VR2. This clamps the speed sensor output voltage at approximately -2.4 volts. This simulates a high engine speed to the summing point to decrease the engine fuel supply to minimum.

Load Sensor

In the load sensor (fig. 9-20) A2 monitors the voltage levels from the external potential and current transformers. From these input signals, the load sensor computes the total kW load on the generator and produces a dc voltage proportionate to the load

Figure 9-21 shows one phase of the load sensor and the equivalent voltage circuits for 90° and 270° transition through the sine wave. As shown, current input transformer T4 can be represented by battery E3, the value and polarity of which is dependent on load and sine wave transition. During the positive half cycle, the following actions occur:

STEP	ACTION
1.	The E1 and E2 voltages are maximum at 90°.
2.	During this half-cycle, diode CR1 reverse biases and CR2 forward biases and conducts.
3.	At this time the polarity of E3 adds to E2 with the total voltage developed across R2.
4.	During the negative half-cycle, the E1 and E2 voltages are again maximum, only in the opposite polarity.
5.	This forward biases CR1 and reverse biases CR2.
6.	E3 also changes polarity during the negative half cycle.
7.	Since E3 and E1 are opposite in polarity, the voltage developed across R1 is E1 minus E3.

During periods of no load, voltage at E3 is 0 V and the voltage developed across R1 and R2 is equal to the voltage at E1 and E2.

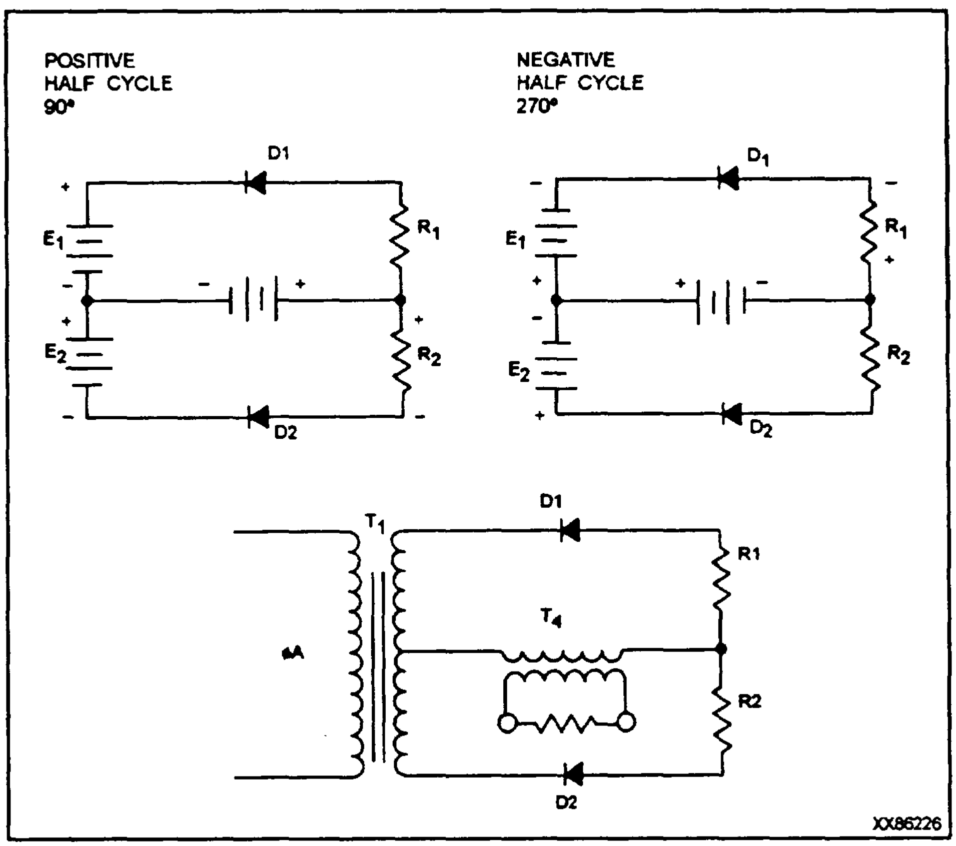

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Figure 9.21—Equivalent single-phase circuit.

During no load there is no current signal and consequently no voltage is developed across the current transformer. This results in a 0 volt load signal since the three phases cancel each other out.

LOAD GAIN control A2Rl (fig. 9-20) is connected in parallel with the voltage adder circuit. The output of the variable LOAD GAIN control (represented as variable voltage source E in fig. 9-22) is applied across the bridge circuit. This then is the load control signal for this particular prime mover.

A dc-droop circuit is connected across the output of the LOAD GAIN potentiometer and applies a portion of this load voltage as bias to the output of the load sensor. This counteracts any inherent droop in the overall system.

An optional load pulse circuit (fig. 9-22) differentiates any sudden load voltage output from the LOAD GAIN control caused by a sudden load change. The load puke provides a lead signal to the amplifier summing point and minimizes the off speed and recovery time associated with large and sudden load changes.

SINGLE UNIT ISOCHRONOUS.— During single-unit isochronous operation, the bridge circuit is balanced; thus the load sensor output is 0 volt. Under this condition the speed sensor maintains engine speed

SINGLE UNIT DROOP.— Setting the external mode switch to DROOP connects AIR11 to dc common. This unbalances the bridge network, producing a the load on the generator increases, the load voltage from the bridge circuit (terminal 12) increases negatively. This negative voltage is applied to the DROOP potentiometer which sets the amount of series resistance. In this mode the negative load voltage biases the speed setting signal downward as the load increases.

PARALLEL UNIT ISOCHRONOUS.— The load sensor provides proportional load sharing when two or more generating units are parallel in the isochronous mode. In this mode each load sensor compares the load of its generating unit with the load of other units producing power and either increases or decreases fuel to the engine to maintain its proportional share of the load.

When the mode switches are set for isochronous operation for a parallel engine combination, their load sensor bridge circuits are connected together through the paralleling lines (see fig. 9-23). In this mode of operation, the bridge circuits are balanced with terminal 11 as a common reference point.

When paralleling two or more units, each engine takes on its proportional share of the load by equalizing the load voltages across the bridge network.

As an example, assume that two units are paralleled The first unit has a 100-kW capacity and the second has 50 kW. Unit 1 is operating at 75 percent capacity and unit 2 is at rated speed with no load. The load sensor for both units is calibrated for 9 volts at full load. However, E1 for unit 1 is 6.75 volts (9 volts x 0.75) and E2 for unit 2 is 0 volt (9 volts x 0.00), caused by the different load

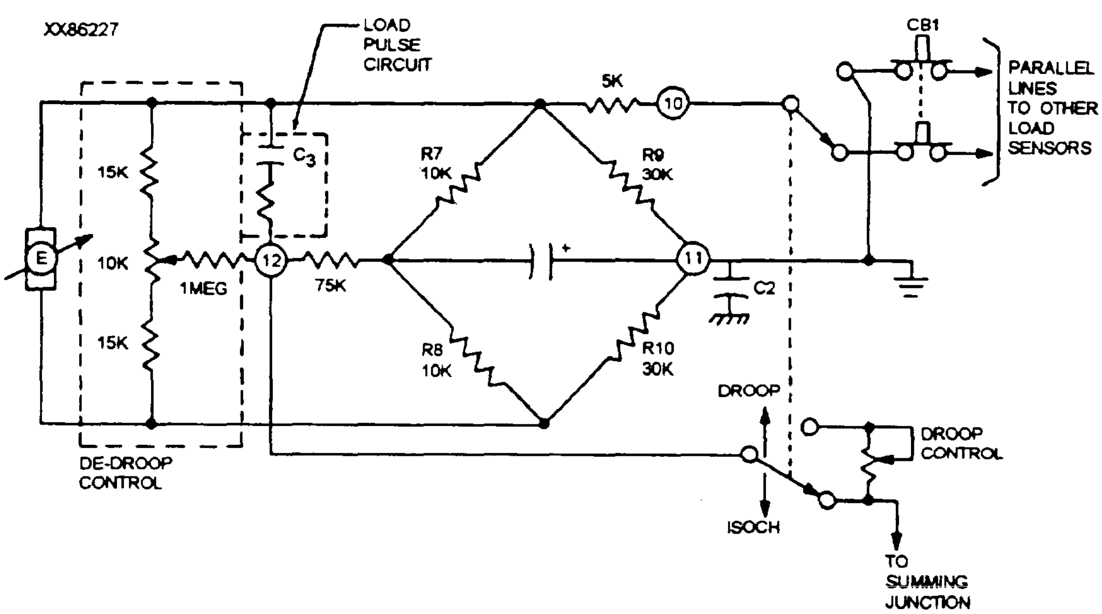

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Figure 9-22.-Basic load sensor, single-unit configuration.

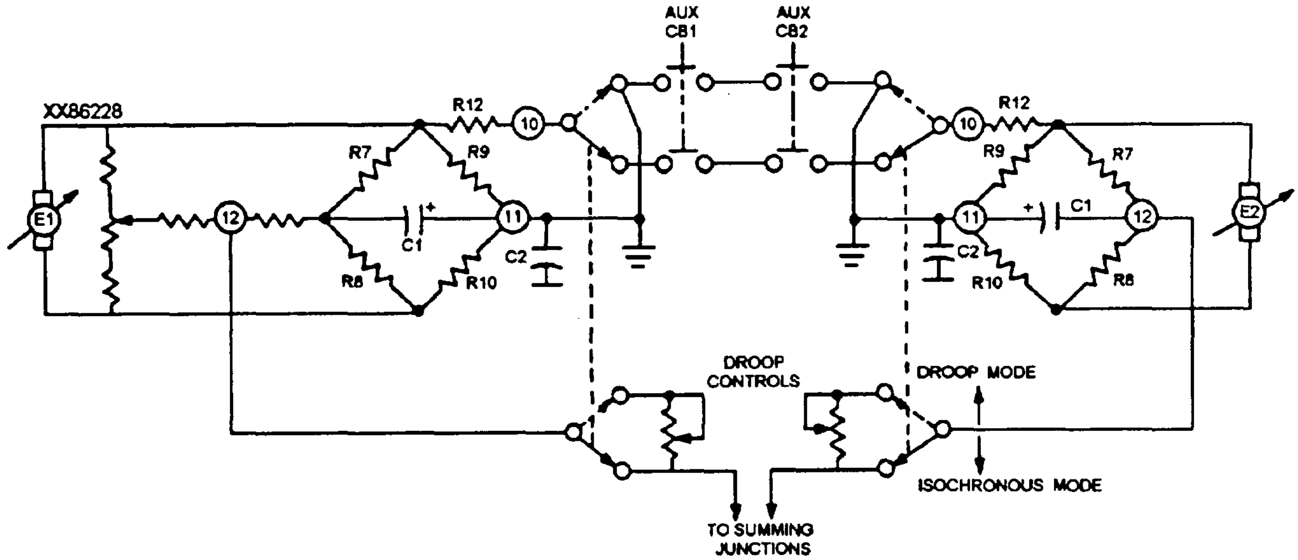

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Figure 9-23.—Basic load sensor, parallel unit configuration.

conditions. This condition exists at the moment of paralleling, causing an electrical imbalance between the two load sensor bridge networks.

STEP	ACTION
1.	The imbalance causes a circulating current between the two bridge networks and produces a positive output voltage to the summing point of unit 2 and a negative output voltage to the summing point of unit 1.
2.	This causes unit 2 to take on load and unit 1 to shed load.
3.	As unit 2 takes on load, E2 increases from 0 volts. As unit 1 sheds load, E1 decreases from 6.75 volts.
4.	The circulating current then decreases.

This continues until E1 equals E2 (4.5 volts) and both generators share the load proportionally. Unit 1 is producing 50 kW, and unit 2 is producing 25 kW for a total power of 75 kW.

The load sensors are only active during unequal had changes when a circulating current develops between the bridge networks. During an unequal change, the bridge networks are electrical y unbalanced, and the action is always toward proportional load sharing.

MAINTENANCE

Maintenance for the 2301 electric governor should be conducted on a regular basis. The first step in the procedure is to look for any obvious physical defects. Missing, loose, or damaged electrical or mechanical connections often result in more serious maintenance problems if not corrected. Other maintenance suggestions are as follows:

- Transformers. Inspect all transformers for loose or broken terminals. Check all mounting hardware.

- Controls. Inspect all controls for loose mounting, damaged wipers, or contacts and smoothness of operation. Do not disturb the setting of a screwdriver-adjusted control unless it is suspected of being faulty.

- Terminal blocks. Inspect all terminal blocks for cracks, chips, or loose mounting hardware. Check all wiring terminals for loose wires or lugs.

- Printed circuit boards. Inspect printed circuit boards for secure mounting and proper location in the unit. It is not advisable to remove circuit boards for the sole purpose of inspecting them for physical damage. Components mounted on printed circuit boards should be checked for secure mounting and poor electrical connections.

- Wiring. Inspect all wiring for frayed or burned leads. Insure that insulating sleeves are in place. Check for loose or broken lacing in harnesses.

When power is secured, dust and foreign matter can be removed by brushing with a clean dry brush. Large surfaces should be wiped with a clean, dry, lint-free cloth. Compressed air at low pressure may be used to blow dust from hard to reach areas. When using compressed air for cleaning, always direct the first blast at the deck. This will blow any accumulation of moisture from the air line.

Use a nonlubricating electrical contact cleaner when potentiometers have erratic control.

SUMMARY

After you have completed this chapter, you should understand the basic function of electrohydraulic governor control systems. There are many different types and variations in the components of the systems. This chapter has dealt with only a few. When making repairs on your system, always refer to the correct technical manual.

CHAPTER 10

DEGAUSSING

Degaussing is the method most used to reduce a ship's magnetic field to minimize the distortion of the earth's magnetic field. This, in turn, reduces the possibility of detection by these magnetic sensitive ordnances or devices.

LEARNING OBJECTIVES

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

1. *Recognize the purpose of the degaussing system.*
2. *Identify the various coils used in the degaussing system installation.*
3. *Identify the need for deperming.*
4. *State the procedures used when ranging a ship.*
5. *Recognize the differences between the types of degaussing systems.*
6. *Recognize the marking system used in degaussing system installations.*

A steel-hulled ship is like a huge floating magnet with a large magnetic field surrounding it. As the ship moves through the water, this field also moves and adds to or subtracts from the earth's magnetic field. Because of its magnetic field, the ship can act as a triggering device for magnetic-sensitive ordnance or devices. Reduction of the ships static magnetic signature is accomplished using the following means:

1. Degaussing
2. Nonmagnetic materials in construction
3. Controlling eddy current fields and stray magnetic fields caused by various items of the ships equipment

THE EARTH'S MAGNETIC FIELD

The magnetic field of the earth is larger than the magnetic field of a ship. The earth's magnetic field acts upon all metal objects on or near the earth's surface.

The existence of magnetism far out in space was determined mathematically many years ago. The first factual proof came with the launching of the Explorer and Pioneer satellites in 1958 and 1959. Radiation counters proved that the Van Allen belts, layers of high-intensity radiation existing far out in space, followed the predicted magnetic contours.

Project Argus also gave additional proof of the earth's magnetic field in space. In August of 1958, three small 1.5-kiloton nuclear explosions were detonated 300 miles above the Falkland Islands in the South Atlantic. In the virtual vacuum that exists at 300 miles above the earth's surface, free electrons, released by the explosion, were captured by the earth's magnetic field. In less than 1 second, electrons spiralled from the Southern to the Northern Hemisphere. Within an hour, they had covered the entire magnetic field at 300 miles altitude.

Figure 10-1 shows the earth as a huge permanent magnet, 6,000 miles long, extending from the Arctic to the Antarctic polar region. Lines of force from this magnet extend all over the earth's surface, interacting with all ferrous materials on or near the surface. Since many of these ferrous materials themselves become magnetized, they distort the background field into areas of increased or decreased magnetic strength. The lines of magnetic force at the earth's surface do not run in

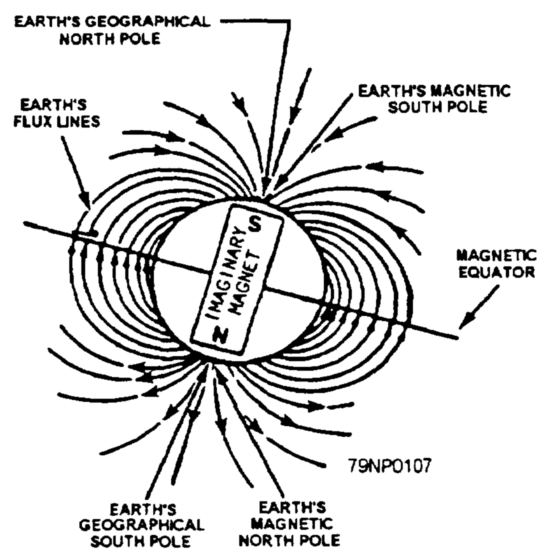


Figure 10-1.-Earth's magnetic field.

straight, converging lines like the meridians on a globe, but appear more like the isobar lines on a weather map.

By convention, the positive external direction of the magnetic field of a bar magnet is from the north pole to the south pole. However, lines of force for the earth's field leave the earth in the Southern Hemisphere and reenter in the Northern Hemisphere. For this reason, you can think of the polar region in the Arctic as the north-geographic, south-magnetic pole. The Antarctic polar region is then the south-geographic, north-magnetic pole.

Look at figure 10-1. Here, you can see that the magnetic lines of force form closed loops, arching from the earth's magnetic core to outer space, and then reentering the earth in the opposite hemisphere. Since all lines of magnetic force return to their points of origin, they form closed magnetic circuits. It is impossible to eliminate the earth's field; however, the effect a ship has on the earth's magnetic field may be lessened. The purpose of degaussing is to prevent the ship from distorting the earth's magnetic field. Some highly developed techniques are used in degaussing.

The rest of this chapter explains the fundamentals of degaussing and describes the operating principles of manual and automatic shipboad degaussing systems. Learning these knowledge factors will help the EM stand watch at the degaussing switchboard operate the degaussing equipment, and maintain the installed degaussing system.

The magnitude and direction of the earth's magnetic field at any point may be resolved into components. These components are the horizontal (H) component and the vertical (Z) component. Since the earth is spherical, an X and Y component would have little meaning; therefore, X and Y are combined into one component, the H component.

The angle of the field with the horizontal, sometimes called the dip angle, may be easily determined by a dip needle. A dip needle is a simple two-pivot compass needle held with the needle pivot axis parallel to the earth's surface. Since a compass needle always aligns itself parallel to the lines of force of a magnetic field, the dip needle indicates the angle of the earth's field to the horizontal by aligning itself with the lines of force entering or leaving the earth at that point. Both direction and strength of the field maybe determined by a mine search coil and flux-measuring equipment.

Table 10-1 shows horizontal and vertical component magnitudes and the resulting total field magnitude and direction for several representative cities in the Northern and Southern Hemispheres. As you look at this table, you can see that the vertical component is positive in the Northern Hemisphere and negative in the Southern Hemisphere. These component polarities occur because lines of force leave the earth in the Southern Hemisphere and reenter in the Northern Hemisphere. For this reason, the upward field, in the Southern Hemisphere, is assigned a negative value; and the downward field, in the Northern Hemisphere, is assigned a positive value. There are two areas of maximum vertical intensity but opposite polarity—the north and south magnetic poles. The vertical intensity at the magnetic equator is zero since the entire field is horizontal.

The vector sum of the H and Z components defines the magnitude and the direction of the total field at any point on the earth's surface.

THE SHIP'S MAGNETIC FIELD

The magnetic field of a ship is the vector sum of the ship's permanent magnetic field and the ship's induced magnetic field. The ship's magnetic field may have any magnitude and be at any angle with respect to the horizontal axis of the ship.

PERMANENT MAGNETIZATION

The process of building a ship in the earth's magnetic field develops a certain amount of permanent magnetism in the ship. The magnitude of the permanent magnetization depends on the earth's magnetic field at the place where the ship was built, the material used to construct the ship, and the orientation of the ship at the time of building with respect to the earth's field.

The ship's permanent magnetization is the source of the ship's permanent magnetic field. This permanent magnetic field can be resolved into two factors:

1. The vertical permanent field component, designated as Z
2. The horizontal permanent field component, designated as H

The horizontal permanent field component includes the longitudinal permanent field component and the athwartship permanent field component. The vertical, longitudinal, and athwartship permanent field components are constant, except for slow changes with time. They are not affected by continuous changes in heading or magnetic latitude.

Table 10-1.—Measurements of the Earth's Magnetic Field at Selected Locations Expressed in Microtesla

LOCATION	HORIZONTAL (H) COMPONENT	VERTICAL (Z) COMPONENT	TOTAL FIELD STRENGTH	DIRECTION OF TOTAL FIELD
North Pole (Magnetic)	0	+62	62	90° down
Fairbanks, Alaska	12	+56	57	78° down
Stockholm, Sweden	15	+46	49	70° down
London, England	19	+44	47	69° down
Washington, D.C.	18	+54	57	72° down
Tokyo, Japan	30	+34	46	50° down
Manila, P.I.	39	+10	41	14° down
Equator (Magnetic)	41	0	41	0° horizontal
Rio de Janeiro, Brazil	23	-08	25	20° up
Capetown, South Africa	14	-28	32	64° up
Buenos Aires, Argentina	23	-14	26	30° up
Melbourne, Australia	23	-56	61	68° up
South Pole (Magnetic)	0	-72	72	90° up

All ships that are to be fitted with a shipboard degaussing installation and some ships that do not require degaussing installations, are depermed. Deperming is essentially a large-scale version of demagnetizing a watch. The purpose is to reduce permanent magnetization and bring all ships of the same class into a standard condition so the permanent magnetization, which remains after deperming, is about the same.

INDUCED MAGNETIZATION

After a ship is built, its existence in the earth's magnetic field causes a certain amount of magnetism to be induced into it. The ship's induced magnetization depends on the strength of the earth's magnetic field and on the heading of the ship with respect to the inducing (earth's) field.

Like the ship's permanent magnetization, the ship's induced magnetization is the source of the ship's magnetic field. This induced magnetic field can be resolved into the following components:

1. The vertical induced field component.
2. The horizontal induced field component. The horizontal induced field component also includes the longitudinal induced field component and the athwartship induced field component.

The magnitude of the vertical induced magnetization depends on the magnetic latitude. The vertical induced magnetic field is maximum at the magnetic poles and zero at the magnetic equator. The vertical induced magnetization is directed down when the ship is north of the magnetic equator and up when the ship is south of the magnetic equator. Hence, the vertical induced magnetic field changes with magnetic latitude and to some extent, when the ship rolls or pitches. The vertical induced magnetic field does not change with heading because a change of heading does not change the orientation of the ship with respect to the vertical component of the earth's magnetic field.

The longitudinal induced magnetic field changes when either the magnetic latitude or the heading changes and when the ship pitches. If a ship is heading in a northerly geographical direction, the horizontal component of the earth's magnetic field induces a north pole in the bow and a south pole in the stem (fig. 10-2, view A). In other words, the horizontal component of the earth's field induces a longitudinal or fore-and aft component of magnetization. The stronger the horizontal component of the earth's magnetic field, the greater the longitudinal component of magnetization. If the ship starts at the south magnetic pole and steams toward the north magnetic pole, the magnitude of the longitudinal component of induced magnetization starts at zero at the south magnetic pole, increases to a maximum at the magnetic equator, and decreases to zero at the north magnetic pole. Hence, for a constant heading, the longitudinal component of induced magnetization changes magnitude as the ship moves to a different latitude.

If, at a given magnetic latitude, the ship changes heading from north to east, the longitudinal component of the induced magnetic field changes from a maximum on the north heading to zero on the east heading. When the ship changes heading from east to south, the longitudinal component increases from zero on the east heading to a maximum on the south heading. On southerly headings, a north pole is induced at the stem

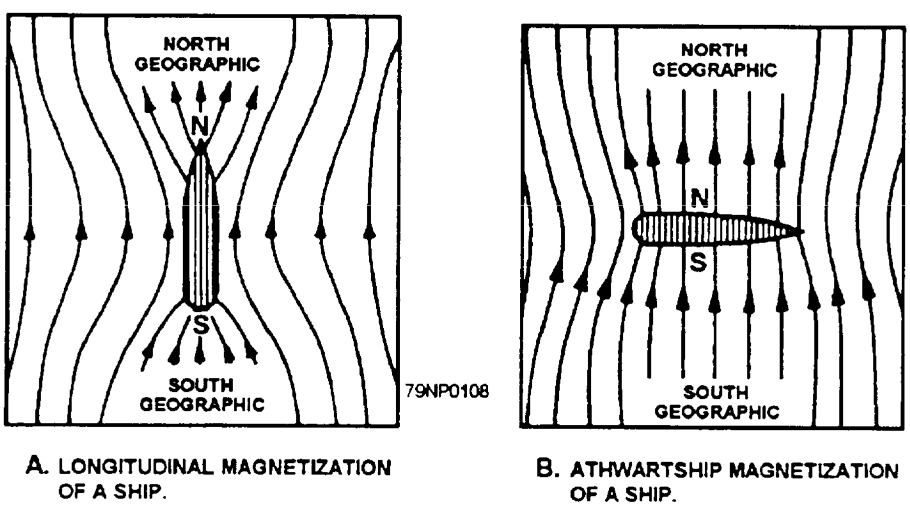


Figure 10-2.—Effect of the earth's magnetic field upon a ship.

and a south pole at the bow. This is a reversal of the conditions on northerly headings, when a north pole is induced at the bow and a south pole at the stern. The longitudinal component of induced magnetic field also changes, to some extent, as the ship pitches.

The athwartship induced magnetic field changes when either the magnetic latitude or the heading changes and when the ship rolls or pitches. When a ship is on an east heading, a north pole is induced on the port side and a south pole on the starboard side (fig. 10-2, view B), which is the athwartship component of induced magnetization. The magnitude of the athwartship magnetic field depends on the magnitude of the horizontal component of the earth's magnetic field at that latitude. The horizontal component is maximum at the magnetic equator for a ship on an east-west heading, and zero at the magnetic poles or for a ship on a north-south heading.

MAGNETIC RANGING

A ship is said to be ranged when its magnetic field is measured at a magnetic range, commonly called a *degaussing range* or *degaussing station.* A degaussing range or station measures the magnetic field of ships that pass over measuring equipment located at or near the bottom of the channel in which the ships travel.

RANGING PROCEDURES

Ships are ranged before they are depermed to determine the direction and magnitude of their fields. Magnetometer garden measurements also are required during and after the deperming process to evaluate the quality and effectiveness of the treatment. The most common ranging procedure, called check ranging, uses the coil range. Check ranging usually occurs during a ship's normal entry into port. After passing over the range, the ship receives a report of its magnetic characteristics. If the strength of its magnetic field exceeds a safe operational level, the ship is scheduled to report for calibration ranging. Here the ship makes a number of passes over the range while its shipboard degaussing coils are adjusted and calibrated from information supplied from the range hut. When the new settings for the degaussing coils have been determined, new degaussing control settings are placed in the degaussing folder.

If the ship is unable to compensate adequately for its magnetic field because of excessive permanent longitudinal or permanent athwartship magnetization or an irregular permanent vertical magnetization, the ship is scheduled to report for deperming.

FREQUENCY OF RANGING

All minesweepers and landing craft utilities (LCUs) are required to be checked quarterly by a degaussing range. All other ships that have a degaussing installation must be checked semiannually. Submarines must be checked annually. Any ship that exceeds check range limits must undergo calibration ranging or magnetic treatment as soon as possible.

SHIPBOARD DEGAUSSING INSTALLATION

A shipboard degaussing installation consists of the following items:

- One or more coils of electric cable in specific locations inside the ship's hull.
- A means of controlling the magnitude and polarity of current to these coils and therefore the magnetic field produced by them.
- The ships degaussing folder.
- A dc power source to energize these coils.
- Compass-compensating equipment, consisting of compensating coils and control boxes, to compensate for the deviation effect of the degaussing coils on the ship's magnetic compasses.

Used properly, these items will greatly reduce the magnetic signature of the ship and help to prevent detection by magnetic sensitive instruments.

DEGAUSSING COILS

The distortion of the earth's field caused by the ship's permanent magnetic field (vertical, longitudinal, and athwartship components) and the ship's induced magnetic field (vertical, longitudinal, and athwartship components) is neutralized by degaussing coils. The degaussing coils are made with either single-conductor or multiconductor cables. The coils must be energized by direct current. This current is supplied from 120-volt or 240-volt dc ship's service generators or from degaussing power supply equipment installed for the specific purpose of energizing the degaussing coils.

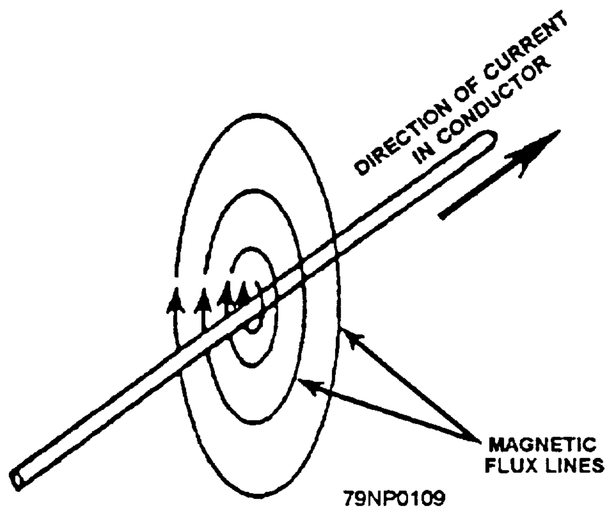


Figure 10-3.—Magnetic field around a current-carrying conductor.

Coil Function

Each of the components of the ship's magnetization (horizontal, vertical, and athwartships) produces a magnetic field in the vicinity of the ship. Current through a conductor produces a magnetic field around it (fig. 10-3). By forming the conductor into a coil, a magnetic field can be produced to surround the ship in specific areas (fig. 10-4). Strategically locating these coils and precisely controlling the magnitude and polarity of the current through these coils will effectively restore the earth's field to the undistorted condition around the ship.

Each degaussing coil has the required location and the number of turns to establish the required magnetic field strength when it is energized by direct current of the proper value and polarity. The coils will then produce magnetic field components equal and opposite

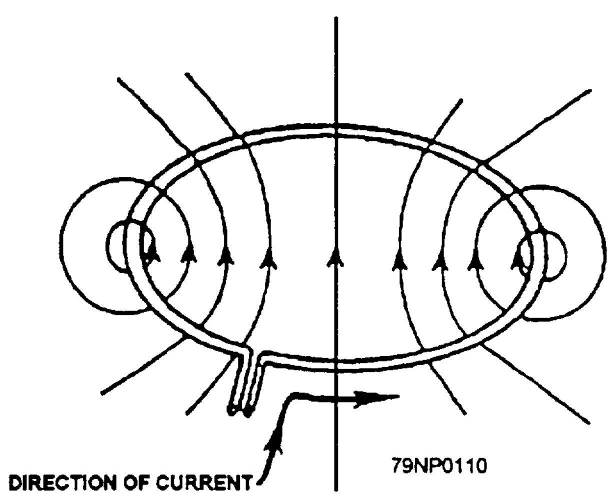


Figure 10-4.—Magnetic field of a current-carrying coil.

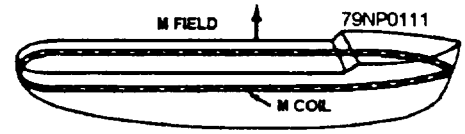


Figure 10-5.—M coil.

to the components of the ship's field. Each coil consists of the main loop and may have smaller loops within the area covered by the main loop, usually at the same level. The smaller loops oppose localized peaks that occur in the ship's magnetic field within the area covered by the main loop.

M Coil

The M (main) coil (fig. 10-5) encircles the ship in a horizontal plane, usually near the waterline. The M coil produces a magnetic field that counteracts the magnetic field produced by the vetical permanent and vertical induced magnetization of the ship.

Figure 10-6 shows the magnetic field produced by the vertical magnetization of the ship. Figure 10-7 shows the magnetic field produced by the M coil. The M-coil field opposes the magnetic field produced by the vertical magnetization of the ship. If the M-coil compensating magnetic field were everywhere exactly equal and opposite to the field produced by the vertical

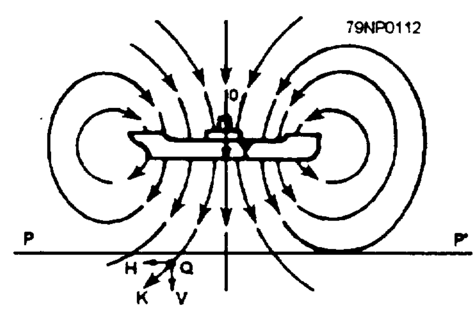


Figure 10-6.—Magnetic field due to the vertical magnetization of the ship.

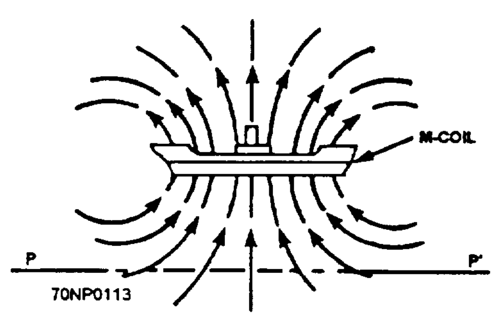


Figure 10-7.—Magnetic field produced by the M coil.

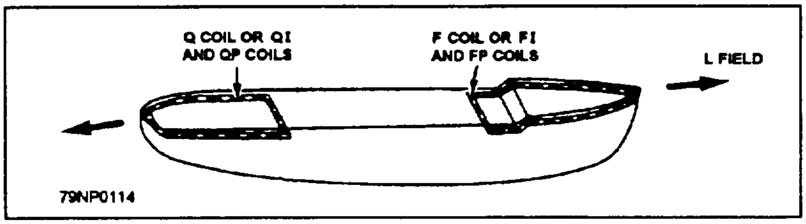


Figure 10-8.—F and Q coils.

magnetization, the result of the two magnetic fields would be equal to zero. This is not possible to attain, and as a result, the M-coil field is always considerably less than the vertical field. The vertical permanent magnetization of a ship is constant while the vertical induced magnetization varies with magnetic latitude, roll, and pitch, but not with heading. Consequently, the M-coil field strength must be changed when the ship changes magnetic latitude to keep the M-coil field as nearly equal and opposite to the field produced by the ship's vertical magnetization.

F and Q Coils

The F (forecastle) coil encircles the forward one-fourth to one-third of the ship and is usually just below the forecastle or other uppermost deck. The Q (quarterdeck) coil encircles the after one-fourth to one-third of the ship and is usually just below the quarterdeck or other uppermost deck, as shown in figure 10-8.

The F and Q coils counteract the magnetic field produced by the ship's longitudinal permanent and induced magnetization. The shape of the magnetic field produced by the ship's longitudinal permanent and longitudinal induced magnetization and the two fields are directed below the bow and stem of the ship. Look at figure 10-9. Here, you can see that the ship's longitudinal permanent magnetization is constant, but the longitudinal induced magnetization changes with heading and magnetic latitude. The F- and Q-coil field strengths must both be changed whenever the ship changes course or magnetic latitude. These field strengths must also be changed if the coil field strengths would not have the proper values to counteract the changed longitudinal induced magnetization. Note that both adjustments must be made, one for the F-coil field strength and one for the Q-coil field strength.

F1-Q1 and FP-QP Coils

In many installations the conductors of the F and Q coils are connected to form two separate circuits designated as the F1-Q1 coil and the FP-QP coil. The F1-Q1 coil consists of a F1 coil connected in series with the Q1 coil so the current is the same in both coils. The same is true for the FP-QP coils in that they are also connected in series and the same current is in both coils. Installations with both F1-Q1 and FP-QP coils are known as split-coil installations because the F and Q coils are split into two coils.

The F1-Q1 coil is used to counteract the magnetic field produced by the ship's longitudinal induced magnetization. The coil field strength depends on two factors—the ship's heading and the magnetic latitude. As the ship's heading and magnetic latitude change, the ship's longitudinal induced magnetization changes accordingly.

The FP-QP coil is used primarily to counteract the magnetic field produced by the ship's longitudinal permanent magnetization, and it is sometimes used to provide some compensation to supplement the M coil

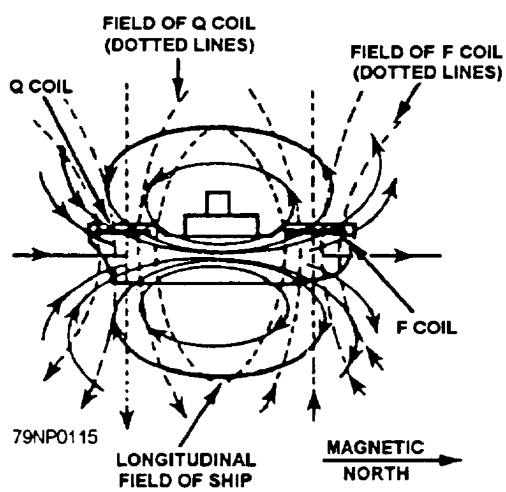


Figure 10-9.—Longitudinal field of ship and neutralizing fields of F and Q coils.

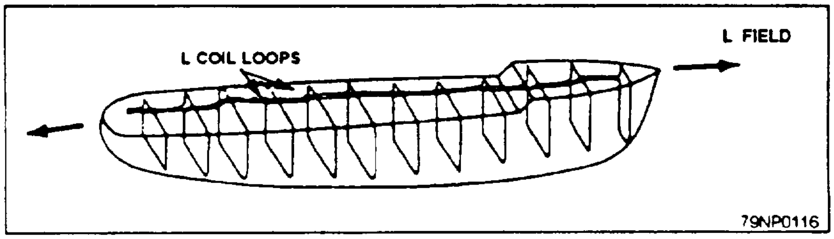


Figure 10-10.—L coil.

for vertical induced magnetization. However, if the FP-QP coil is used to provide vertical induced compensation, its coil field strength must be changed when the ship's magnetic latitude changes.

L Coil

The L (longitudinal) coil (fig. 10-10) consists of loops in vertical planes parallel to the frames of the ship. The L coil is always used when compensation for the pitch of the ship is required. The function of the L coil is to counteract the magnetic field produced by the ship's longitudinal permanent and induced magnetization. The L coil is more difficult to install than the F and Q coils or FI-QI and FP-QP coils; however, it provides better neutralization because it more closely simulates the longitudinal magnetization of the ship. The L coil is commonly used in minesweeper vessels.

The longitudinal induced magnetization changes when the ship changes heading or magnetic latitude, and the L-coil current must be changed accordingly.

A Coil

The A (athwartship) coil (fig. 10-11) has loops in the vertical fore-and-aft planes. The function of the A coil is to produce a magnetic field that will counteract the magnetic field caused by the athwartship permanent and athwartship induced magnetization. Since the athwartship induced magnetization changes when the ship changes heading, magnetic latitude, or rolls, the A-coil strength must be changed accordingly.

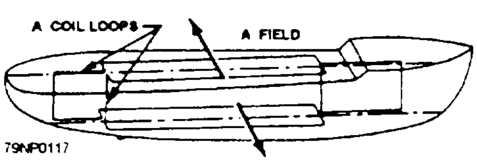


Figure 10-11.—A coil.

MANUAL CURRENT CONTROL

Many of the older (prior to the mid-1950s) three-coil degaussing installations and all installations with only an M coil have operator current control. These installations were fabricated and installed by the shipbuilders. They were never assigned type designations. Manual or operator control is necessary because an operator must adjust the degaussing coil currents when they have to be changed due to a change in the ship's heading or magnetic latitude or both. In such installations, roll and pitch compensation is not provided.

The equipment controls power obtained from constant voltage dc generators in some installations and from degaussing motor generators in other installations. Coil currents are set by adjustment of the rheostats. The rheostats cnfigured in series with the degaussing coils when power is obtained from a constant voltage source and in series with the generator field when motor-generators are used for power source. Both manually operated and motor-driven rheostats are used. For each of the ship's degaussing coils, the required coil currents, the various magnetic latitudes, and major ship's headings are obtained from the degaussing charts in the ship's degaussing folder. These current values are determined for one latitude and calculated for other latitudes during calibration ranging. The current values given in the degaussing folder for the various zones of operation represent the sum of the induced field and perm field currents.

AUTOMATIC CURRENT CONTROL

Automatic degaussing (AUTODEG) control equipment adjusts some or all of the coil currents automatically with changes in ship's attitude (heading, roll, pitch, trim, and list) or with changes in both attitude and location. AUTODEG control equipment is installed on all ships with degaussing coils installed in more than one place. Currently, the two basic types of AUTODEG control equipment currently are

(1) magnetometer-controlled equipment and (2) gyro-controlled equipment.

Magnetometer Control

Signals to control the induced field currents are obtained from a three-axis magnetometer. The magnetometer measures the components of the earth's field along the axis of the ship and automatically adjusts the coil currents in a manner that will compensate for changes in induced magnetization caused by the ship's roll and pitch and by changes in the ship's heading and geographical location. You can obtain the perm field current by biasing the magnetometer output with a perm bias component or by providing a P coil with a separate regulated current source or a combination of both methods.

Magnetometer control is used on nonmagnetic minesweepers because roll and pitch compensation and smooth or stepless zone control (magnetic latitude variations) are needed for these ships. It is also used on minesweepers because the magnetometer can be readily located so it measures the earth's field rather than a combination of earth's field, ship's field, and other interference fields.

Magnetometer control is used on some steel-hulled ships with aluminum superstructures, where the effect of the ship's field on the magnetometer can be cancelled by compensation techniques. Magnetometer control is used on these ships to eliminate operator inputs (H, Z, and magnetic variation) required with gyro-controlled equipment.

Gyro Control

Signals to control the induced field currents are obtained from the ship's gyrocompass and gyro stabilizer systems. These signals are modified by operator inputs for magnetic latitude and heading (operator sets H, Z, and magnetic variation controls). They are processed by an analog computer to provide induced field currents proportional to the calculated values of the earth's magnetic field component along the ship's axis.

You can obtain the perm field current by biasing computer output or with a separate P coil or a combination of both methods. Gyro control is presently used on ships that do not require roll and pitch compensation. On these ships, the control signal is obtained from the ship's gyrocompass, and the coil currents are adjusted automatically to compensate only for the change in induced magnetization caused by a change in ship's heading.

Emergency Manual Control

All AUTODEG control equipment is equipped with emergency manual control for use if the automatic controls become inoperative. This equipment is manually operated by the operator. The operator sets currents to values obtained from the ship's degaussing folder for the various magnetic latitudes and adjusts the eight-course heading switch as the ship's heading varies.

TYPES OF AUTOMATIC DEGAUSSING SYSTEMS

Look at table 10-2, which contains brief descriptions of the different types of AUTODEG. For detailed descriptions, you should refer to the applicable technical manuals. The first three types of equipment shown in the table are the only types being installed on new ships.

MDG DEGAUSSING EQUIPMENT

MDG degaussing equipment is installed on nonmagnetic minesweepers. This equipment consists of a fluxgate-type triaxial magnetometer probe installed on the ship's mast and a control unit containing all control and power circuits installed in the combat information center (CIC) or the pilothouse (fig. 10-12). The magnetometer probe is located and aligned so it measures the local earth's magnetic field components along each of the ship's three axes. These field components are biased and amplified by the degaussing equipment to produce required degaussing coil currents (fig. 10-13). The probe's location must be free of interference produced by the ship's magnetic field, degaussing coils, and other installed equipment. The equipment is unique in that 90 separate power amplifiers are available to supply the ship's degaussing loops.

Magnetometer-controlled AUTODEG Equipment Operation

Two modes of operation are used for magnetometer controlled AUTODEG equipment—automatic and manual.

Table 10-2.-Description of Different Automatic Degaussing Equipment

TYPE	DESCRIPTION
MDG	Electromagnetic static. Control signals from three-axis magnetometer. Solid state control circuits with as many as ninety power amplifiers available to supply the degaussing loops.
SSM	Solid-state magnetic. Control signal from heading gyro. Solid state control circuits. Silicon controlled rectifier-type power supplies.
MCD	Magnetometer-controlled degaussing. Control signals from magnetometer. Solid state control circuits. Silicon controlled rectifier-type power supplies.
EMS	Solid-State Electromagnetic. Control signals from three-axis magnetometer. Solid state control circuits. Power transistors or silicon controlled rectifiers for power control.
GEM	Generator Field (Electronic). Control signals from three-axis magnetometer. Combination of solid state and magnetic amplifier control circuits. Controls field of generator of degaussing motor generator. This equipment is type GM equipment that has been converted to magnetometer control.
SEM	Selenium Rectifier (electronic). Control signals from three-axis magnetometer. Combination of solid state and magnetic amplifier control circuits. Magnetic amplifier-type power supplies. This equipment is type SM equipment that has been converted to magnetometer control.
SM	Selenium Rectifier (Magnetic Amplifier). Control signal from heading gyro or from heading gyro and gyro stabilizer. Magnetic amplifier-control circuits. Magnetic amplifier-type power supplies.
GM	Generator Field (Magnetic Amplifier). Control signal from heading gyro or from heading gyro and gyro stabilizer. Magnetic amplifier-control circuits. Controls field of generator of degaussing motor generator. **NOTE**: All type GM equipment with roll and pitch signals from gyrostabilizer have been converted to type GEM equipment.
FM	Exciter Field (Magnetic Amplifier). Control signal from heading gyro. Magnetic amplifier-control circuits. Controls field of exciter of degaussing motor generator.
RM	Rheostat Operated (Magnetic Amplifier). Control signal from heading gyro. Magnetic amplifier-control circuits. Controls motor of motor-driven rheostat. Rheostat is in series with degaussing coil connected to constant voltage dc power supply.

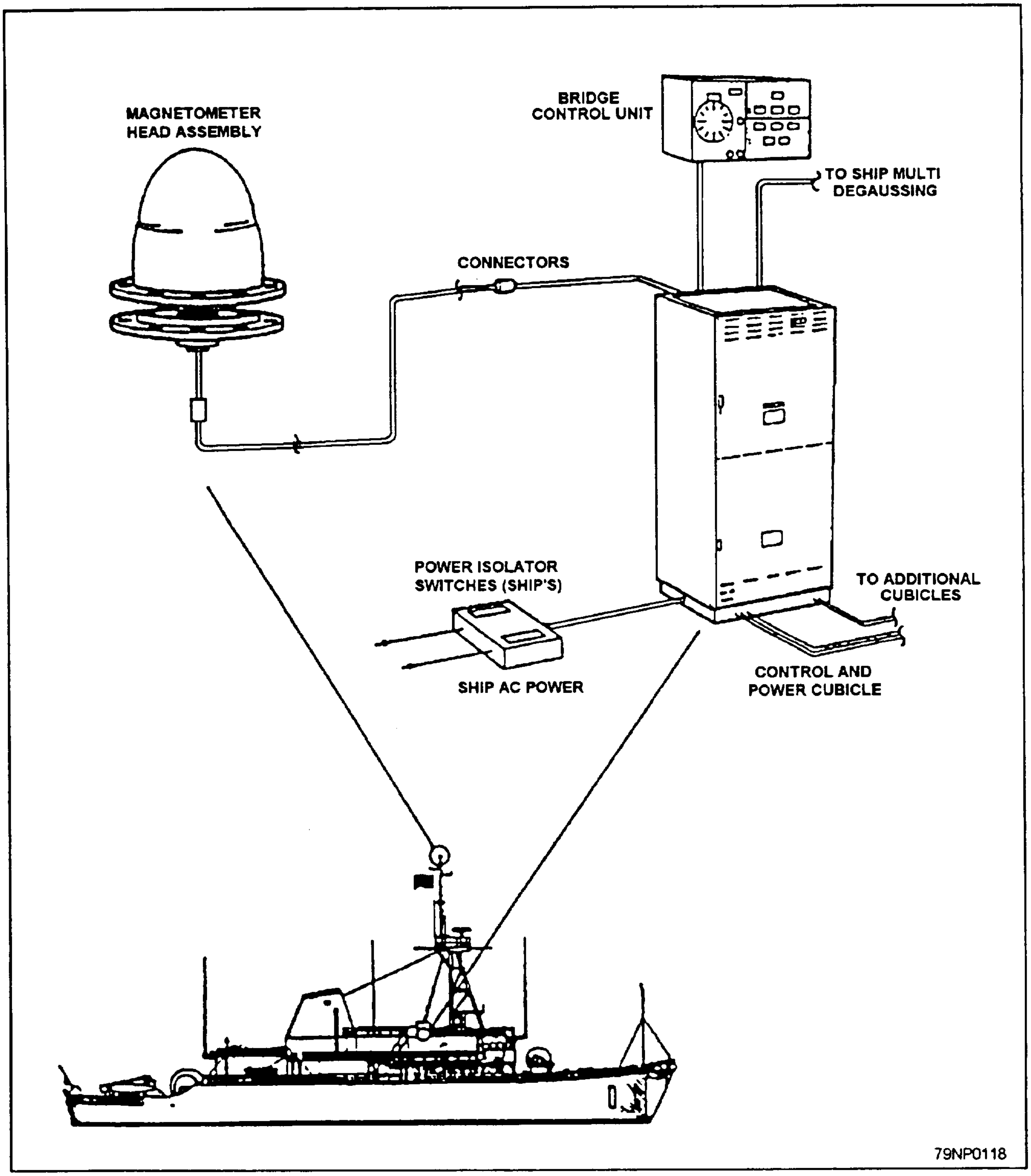


Figure 10-12.—Type MDG automatic degaussing equipment.

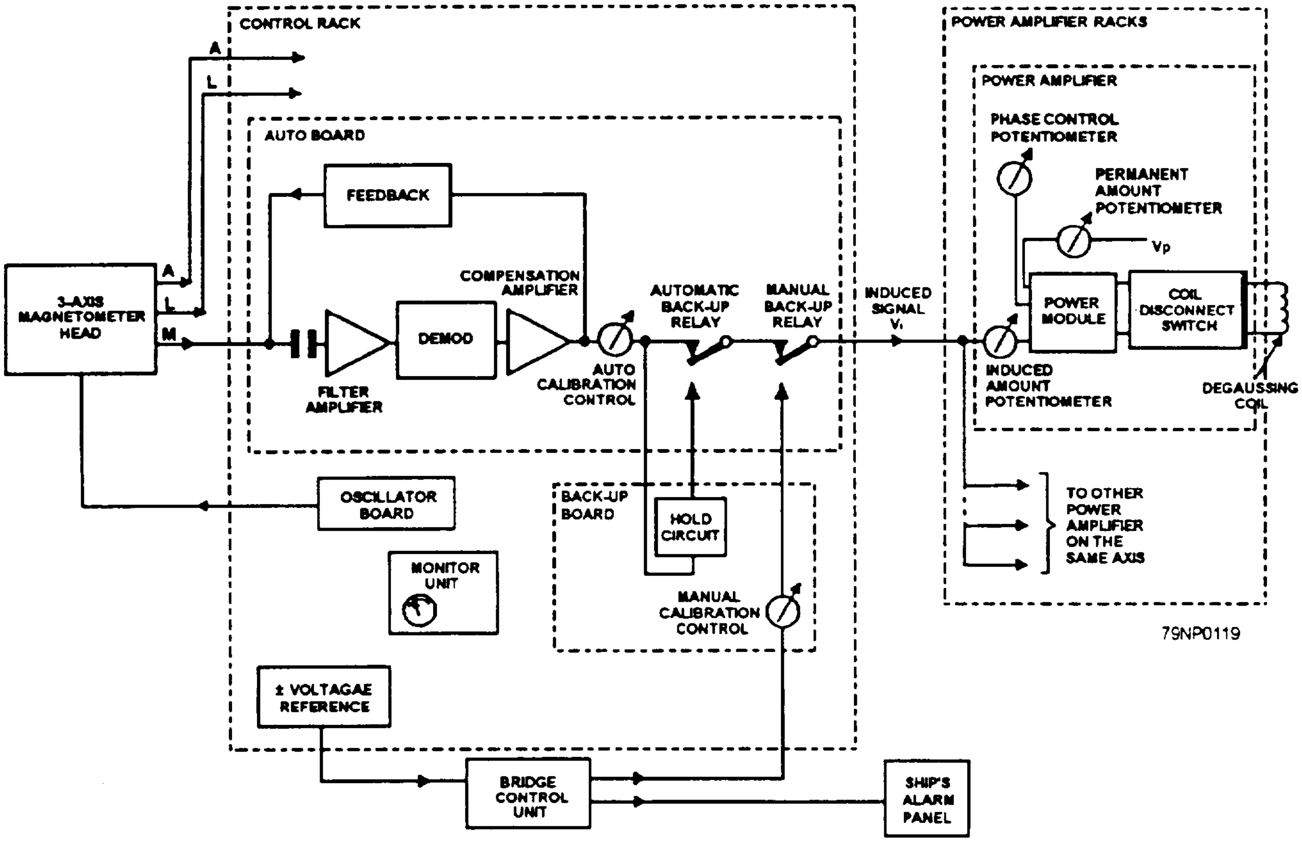


Figure 10-13.—Block diagram for type MDG degaussing system.

AUTOMATIC OPERATION.— When setup for automatic operation, magnetometer-controlled AUTODEG equipment will control the currents in the ship's degaussing coils to compensate for the ship's permanent and induced magnetism, regardless of the ship's heading, roll, pitch, or geographic location. Automatic operation is the normal mode and consists primarily of turning equipment on and periodically monitoring the front panel indicators and current outputs for indications of equipment malfunction.

During calibration of the degaussing system at a degaussing range, the number of coil turns, the current magnitude, and the polarities are established. When calibration is completed, the coils are adjusted for the proper number of turns, the equipment is adjusted for automatic operation, and all pertinent information is recorded in the ship's degaussing folder. During normal (automatic) operation, none of the controls are adjusted or reset. You should monitor the trouble indicators periodically, checking the current outputs as follows:

STEP	ACTION
1.	A. Measure the magnitude and polarity of the permanent coil (FP-QP and P) currents. B. Compare them with the values specified in the ship's degaussing folder.
2.	A. Check the magnetometer outputs by comparing the indicated field strength for each axis with the values given in the ship's degaussing folder for the ship's position. B. Make measurements with the ship on cardinal magnetic headings with little roll and pitch. This procedure will provide, at best, a rough check of magnetometer outputs as indicated field strengths are affected by roll, pitch, trim, and list of the ship. Also, only approximate values of the local earth's field can be obtained from charts in the degaussing folder.
3.	A. Measure the induced coil (M, A, L, and FI-QI) currents and compare them with the indicated field strengths. B. Ensure the magnitude of these currents is directly proportional to the field strength indicated, the induced magnitude control setting, and the perm current setting. Charts in the degaussing folder provide coil currents versus indicated field strengths for induced coils on cardinal headings. C. Check the adjustment of induced magnitude and perm current control settings by comparing the current versus field strength values specified on the chart with the current versus field strength values measured.

MANUAL OPERATION.— Magnetometer-controlled equipment provides for operator control of degaussing coil currents when a fault exists in the magnetometer group circuits. Adjustments associated with the ship's heading and the local earth's field (Hand Z zone of operation) are made during manual operation. Since operator-set heading and earth's field inputs only approximate optimum inputs and since no roll or pitch inputs are provided, compensation of the ship's induced magnetism using manual operation is not as good as the compensation obtained with automatic operation. For this reason, when normal operation is not possible, you should manually operate only the affected coil or coils. The general procedure for manual operation is as follows:

STEP	ACTION
1.	Set the eight-course heading switch for the ship's magnetic heading (not required for manual operation of the M coil)
2.	Set the M-coil polarity switch for the polarity specified in the ship's degaussing folder (positive for northern latitudes).
3.	Set the operational mode switch for manual operation.
4.	Check the coil current magnitude, and adjust the manual current control, if required (see CAUTION), for the current specified in the degaussing folder for the ship's zone of operation. **CAUTION** Setting the heading switch to positions other thanpositions corresponding to the ship's magnetic heading can result in degaussing coil currents with the wrong magnitude or wrong polarity, which can be dangerous in a magnetic mine danger area. In mine danger areas, adjust the current magnitudes without changing the heading switch position. The procedure is given in step 6.
5.	Keep the heading switch set to the position corresponding to the ship's magnetic heading and the coil current magnitude adjusted for the proper H or Z zone of operation.
6.	Adjust the manual induced magnitude controls as follows:
	a. **M COIL.** Adjust the control to obtain the current specified for the new location on the degaussing chart. (See the ship's degaussing folder.)
	b. **A COIL.** If the heading switch is set in the E or W position, adjust the control to obtain the current specified for the new location on the degaussing chart. If the switch is set for an intercardinal heading, set the control to obtain 70 percent of the current specified for the new location. If the heading switch is set in the N or S position, do not adjust the control until the ship's heading changes so the heading switch is set to a new position.
	c. **L COIL and FI-QI COIL.** Adjust the magnitude for this coil in the same manner as for the A coil, except make the adjustments with the heading switch in the N, S, and intercardinal heading positions. Do not adjust the current when the switch is set to E or W headings.

The exact procedures vary with the equipment installed. Some equipment has separate manual current controls that should be preset so that they do not have to be adjusted when the coils are switched to manual operation. On equipment with common current controls for automatic and manual operation before switching to manual operation, adjust the control to zero current (maximum CCW). When you adjust the current on the operating equipment, consult the technical manual furnished with the equipment for detailed information.

Gyro-controlled AUTODEG Equipment Operation

Like magnetometer-controlled equipment, gyro-controlled AUTODEG equipment has two modes of operation-automatic and manual.

AUTOMATIC OPERATION.— When set up for automatic operation, gyro-controlled equipment will automatically make changes in coil currents that are required because of changes in the ship's heading. Gyro-controlled equipment will not automatically make changes in coil currents that are necessary when the ship changes its magnetic latitude.

NOTE: Older equipment once automatically changed coil currents to provide for compensation of the ship's roll and pitch. This type of equipment is now obsolete and has been converted to magnetometer control or removed from service.

Automatic operation is the normal mode of operation and consists primarily of energizing the equipment, periodic monitoring for indications of malfunction, and adjusting current controls as a ship moves from one H and Z zone to another. Gyro-controlled equipment, like magnetometer-controlled equipment, is completely set up and adjusted when the ship's degaussing system is initially calibrated at the range. However, some controls on this equipment must be set each time the equipment is energized. The general procedure for automatic operation is as follows:

STEP	ACTION
1.	Set the magnetic variation, H zone, M-coil polarity, and FP-QP coil polarity controls to the settings corresponding to the ship's geographic location as obtained from the ship's degaussing folder.
2.	Set the A- and FI-QI coil operation mode switches and test switches for automatic operation. Energize the equipment by turning on all coil power switches.
3.	Adjust the M- and FP-QP coil current magnitude controls for the current specified in the degaussing folder for the ship's position.
4.	Keep the magnetic variation, H zone, M- and FP-QP coil current polarities and magnitudes set for the ship's geographic location.
5.	Monitor the trouble indicators periodically for indications of malfunctions.

with the values specified in the degaussing folder for the ship's location. Magnitude and polarity of A- and FI-QI coil currents will vary with the ship's heading. Monitor these on cardinal headings or calculate them. Ensure that the FI-QI current is equal to the value specified for the ship's location multiplied by the cosine of the ship's magnetic heading angle and that the A-coil current is equal to the value specified for the location times the sine of the magnetic heading angle.

MANUAL OPERATION.— Gyro-controlled equipment has a provision for operator control of the A- and FI-QI coil currents if there is a loss of the gyro signal or a fault in the control computer. Manual operation consists of the heading switch set for the ship's magnetic heading and the H-zone switch set for the ship's position. Since step inputs from the heading switch only approximate heading signals from the gyro and control computer, the ship's induced magnetism compensation during manual operation is not as good as that provided by automatic operation. Consequently, manual operation should be used only when normal operation is not possible.

The operator should set up the equipment for manual operation (the manual-induced magnitude current controls should be adjusted and locked) at the same time it is set up for automatic operation. This will enable the operator to switch from automatic to manual operation without having to adjust current magnitude. Incorrect current magnitudes and polarities can be dangerous in a mine danger area. The general procedure for manual operation of the FI-QI or A coil is as follows:

STEP	ACTION
1.	Set the local-remote transfer switch for local operation, the H-zone switch for the ship's position, and the eight-course heading switch for the ship's magnetic heading.
2.	Set the operational mode switch for manual operation and the power switch to ON.
3.	Keep the H-zone switch set for the position and the heading switch set for the magnetic heading.
4.	Monitor the trouble indicators and currents periodically for indications of malfunctions. The current magnitude and polarity will depend on the heading switch position. Ensure the magnitude is zero, 70, or 100 percent of the value specified in the degaussing folder for the ship's position. Monitor the currents without switching the heading switch. Indiscriminate switching of the heading switch will result in currents with incorrect magnitude and polarity. If necessary, adjust the current magnitudes 70 percent on intercardinal headings and 100 percent on cardinal headings (adjust the FI-QI coil on north-south headings and the A coil on east-west headings).
5.	Use the heading switch at the remote location for manual operation by first setting the heading switch at the remote location to the ship's magnetic heading, and then setting the local-remote transfer switch for remote operation. Indiscriminate switching of the local-remote transfer switch will also result in currents with incorrect magnitude and polarity.

TYPE SSM

SSM degaussing equipment is the standard degaussing equipment installed on all ships that require degaussing, except nonmagnetic minesweepers and patrol frigates (FFG-7 class). This equipment has a control switchboard, a remote control unit, and a power supply for each installed degaussing coil (fig. 10-14). The switchboard contains operator controls, control circuits, and status indicators for all coils. The remote control unit provides status indicators and a heading switch for emergency manual operation in a remote location (usually the pilot house). The power supplies amplify control signals from the switchboard.

The switchboard is functionally divided to operation and maintenance easier. The computer drawer contains a mechanical computer and the controls necessary to provide induced A- and FI-QI coil current magnitudes for the ship's heading and location (fig. 10-15). The automatic and manual drawers contain current controls, meters, and status indicators for the automatic coils (A and FI-QI) and the manual coils (M and FP-QP). The ground detector, temperature alarm bell, power-supply blown-fuse indicators, and power switches are located on the front panels.

The power supplies (fig. 10-16) are supplied in standard power ratings, and they differ only in output current ratings. AU are functionally identical.

TYPE MCD

MCD degaussing equipment is installed on FFG-7 class ships. This equipment consists of a fluxgate-type triaxial magnetometer, a control unit, a remote control unit, and a power supply unit for each installed degaussing coil. It is essentially a combination of EMS equipment and SSM equipment. The magnetometer and control unit are functionally similar to the EMS magnetometer and control unit. The main differences are that additional compensation features are provided to minimize the effect of the ship's magnetic field at the magnetometer and that the control unit outputs are current signals to the power supplies instead of currents to the degaussing coils. The remote control unit and the power supplies are similar to the SSM remote control unit and power supplies.

MARKING SYSTEM

For ease of maintenance by the ship's force, the degaussing installations in all types of naval vessels are marked following a standard marking system. All

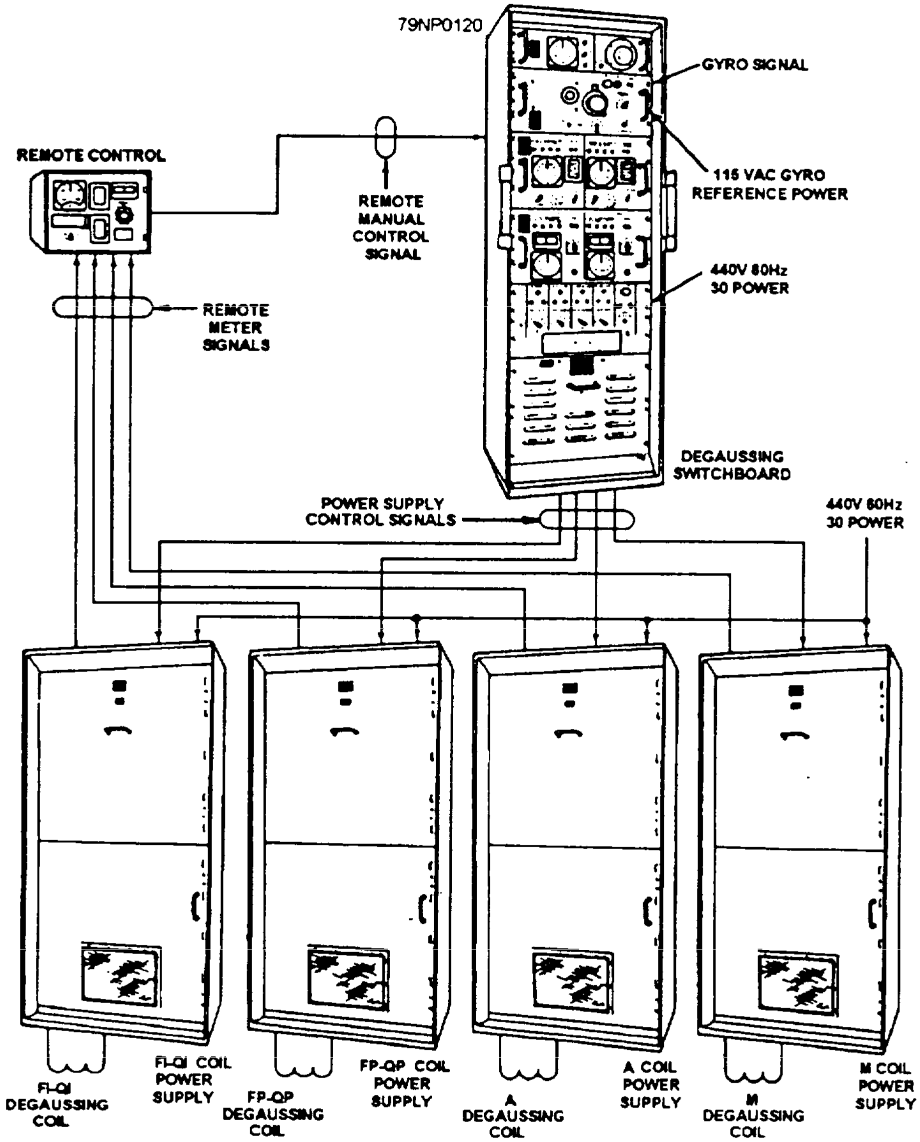


Figure 10-14.—SSM automatic degaussing equipment.

feeders, mains, and other cables supplying power to degaussing switchboards, power supplies, and control panels are designated and marked as specified for power and lighting circuits. The system of markings and designations of conductors applies specifically for a multiconductor system, but it is also applicable to single-conductor installations.

Degaussing cable identification tags are made of metal. The cables are tagged as close as practicable to both sides of decks, bulkheads, or other barriers. Degaussing conductors are marked by hot stamping (branding) insulating sleeving of appropriate size. Each end of all conductors are marked, and the conductor marking corresponds to the marking of the terminal to which they connect inside the connection box or through box. The sleeving is pushed over the conductor so the marking is parallel to the axis of the conductor. Table 10-3 shows the letters used for cable designations and cable tag markings for degaussing coil cables and circuits.

For a detailed description of the marking for degaussing-coil imps, circuits, conductors, and cables, and for degaussing feeder cable and feeder cable conductors, refer to chapter 475 of the *Naval Ships' Technical Manual.*

CONNECTION AND THROUGH BOXES

Connection and through boxes are similarly constructed watertight boxes, but they are used for different purposes.

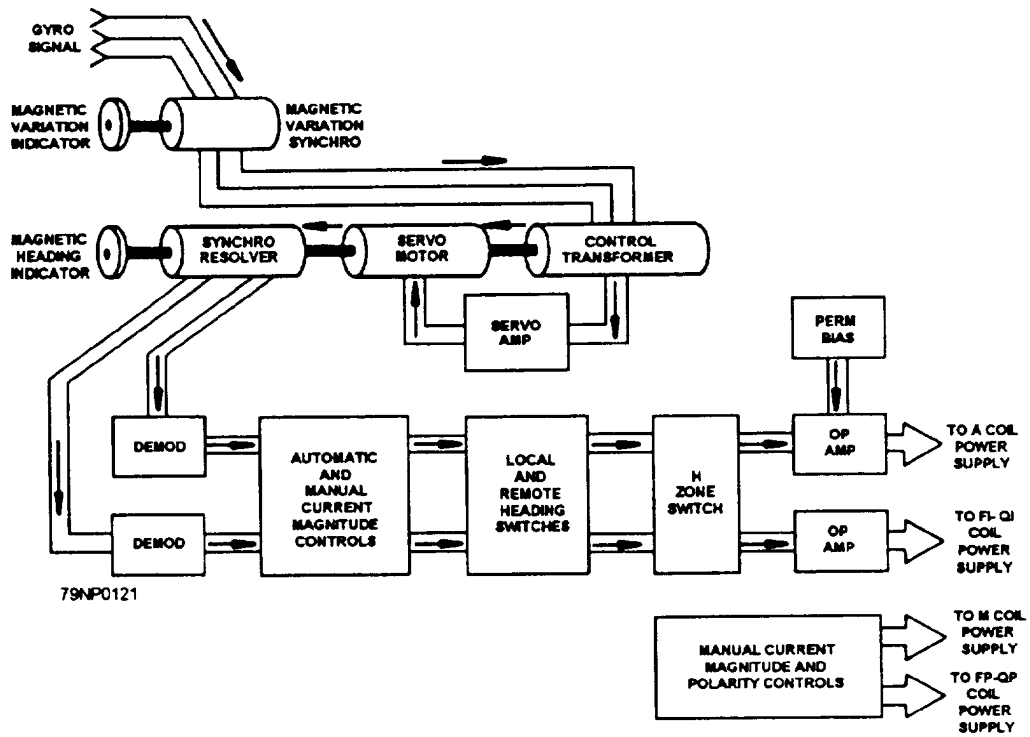


Figure 10-15.—Block diagram for an SSM degaussing switchboard.

A connection box is a watertight box with a removable cover used to connect loops together, to connect conductors in series, and to reverse turns. The power supply connection for a coil and all adjustments of ampere-turn ratios between loops are made within connection boxes. The power supply cable and interconnecting cable for the FI-QI and FP-QP coils terminate in connection boxes.

A through box is a watertight box with a removable cover used to connect conductors without a change in the order of conductor connections. Also, a through box

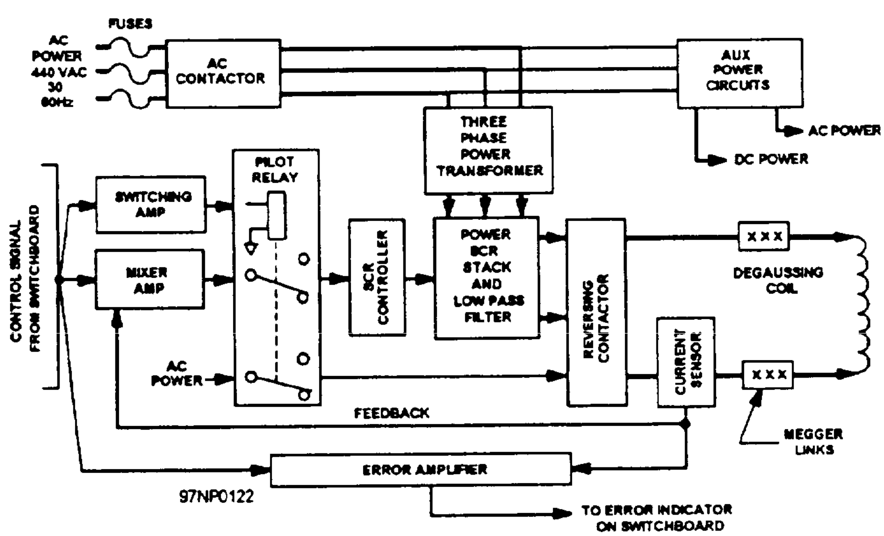


Figure 10-16.—Block diagram for a type SSM degaussing power supply.

Table 10-3.—Degaussing Installation Markings

LETTER	MEANING
A	Athwartship coil
AMM	Ammeter
AP	A coil to correct for permanent magnetism
AX	An auxiliary coil
CC	Compass compensating coil
D	Degaussing system
F	Forecastle coil to correct for permanent and induced magnetism
FDR	Feeder
FI	F coil to correct for induced magnetism
FP	F coil to correct for permanent magnetism
I	FI-QI coil-used in conjunction with feeders, compass compensating coil, and indicator light leads
IL	Indicator light
L	Longitudinal coil
LP	L coil to correct for permanent magnetism
LX	L auxiliary coil
M	Main coil
MP	M coil to correct for permanent magnetism
MX	MAUX (main auxiliary) coil
P	Used in conjunction with feeders for AP, FP-QP, LP, and MP coils
Q	Quarterdeck coil to correct for permanent and induced magnetism
QI	Q coil to correct for induced magnetism
QP	Q coil to correct for permanent magnetism
SPR	Spare conductor

is used to connect sections of cable. In some cases, splicing is used instead of through boxes.

A wire diagram of the connections in the box is pasted on the inside of the cover and coated with varnish or shellac. The wiring diagram for connection boxes should (1) designate the conductors that may be reversed without reversing the other loops, (2) indicate the arrangement of parallel circuits so equal changes can be made in all parallel circuits when such changes are required, and (3) show the spare conductors. Spare conductors should be secured to connection terminals in the connection boxes and should not form a closed or continuous circuit. All conductors in a connection box should be 1 1/2 times the length required to reach the farthest terminal within the box. Connection boxes should also have drain plugs accessible to provide for periodic removal of accumulated moisture from the boxes.

Connection and through boxes have IDENTIFICATION PLATES that include degaussing box numbers (such as D1 and D2), connection box and/or through boxes as applicable, and coil and loop designations (such as Ml, M2, and F12).

	D1	
CONNECTION BOX		THROUGH BOX
M1		F1
	M2	

This sample identified the No. 1 degaussing box serving as a connection box for the M1 and M2 loops and as a through box for the F1 loop.

DEGAUSSING FOLDER

The degaussing folder is an official ship's log. It contains information on the magnetic treatment of the ship, instructions for operating the shipboard degaussing system, degaussing charts (figs. 10-17 and 10-18) with the value of coil settings, installation information, and a log section showing the details of the action taken on the ship's degaussing system.

The folder is prepared by degaussing range personnel when the ship's degaussing system is initially calibrated.

PREVENTIVE MAINTENANCE

Preventive maintenance is extensive for automatic degaussing systems. The degaussing switchboards and remote panels require frequent cleaning and inspection as they are sensitive to heat and dirt. The removal of dirt and dust from automatic degaussing control equipment allows the natural flow of air around the components for heat dissipation. Use of a vacuum cleaner or bellows is a safe way to remove dust or dirt. Do not use compressed air.

Check the connection or through boxes for moisture. Drain plugs are installed in the bottom of connection or through boxes to help you accomplish your inspection. When you notice moisture in a box during your inspection, leave it open to dry out. At the same time, check the box cover gasket for deterioration, and replace it if necessary.

When performing any preventive or corrective maintenance on AUTODEG, observe standard electrical safety precautions.

For additional information on degaussing systems, refer to the *Naval Ships' Technical Manual,* chapters 300 and 475, and the manufacturers' instruction books.

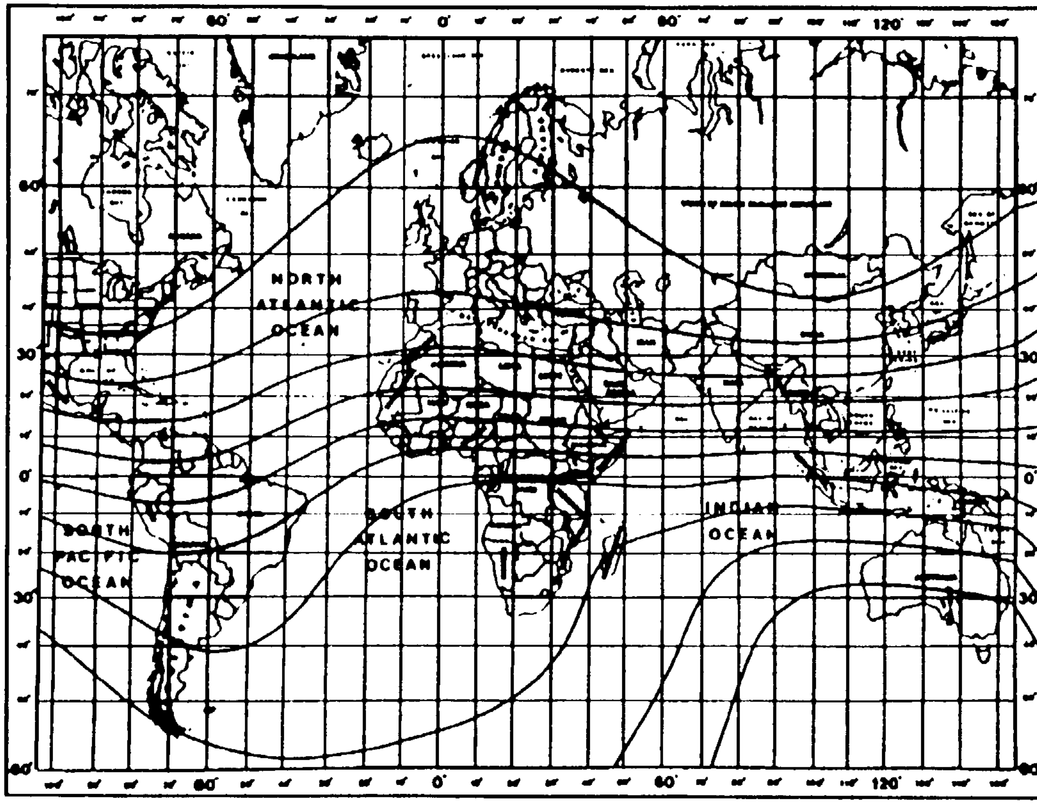
SUMMARY

In this chapter, we have discussed the degaussing systems installed aboard ships of the Navy. After studying the information, you should have a better understanding of the earth's magnetic field, ship's magnetic fields, degaussing coils, ranging procedures, operation of various types of systems, and cable markings for degaussing installations.

ATLANTIC - INDIAN OCEAN

DEGAUSSING CHART No. 1

FOR AREAS WEST OF 105° WEST AND EAST OF 155° EAST SEE PACIFIC CHART (OVER)



CLASSIFICATION DOWNGRADING/ DECLASSIFICATION

COIL SETTINGS † IN AMPERES				REGIONS	Z
M		FP-QP			ZONE
97.5				NORTHERN	.550
84.0					.440
70.5		+15			.330
57.5					.220
43.5				MIDDLE	.110
30.0		+15			000
16.5					-.110
3.0				SOUTHERN	-.220
-10.5		+15			-.330
-24.0					-.440
-37.5					-.550

79NP0123

† SETTINGS APPLY TO SPACES BETWEEN LINES, NOT TO LINES

NAVSEA 8950/8 (REV. 12-84) FRONT
M/S DG NO. 5
(PREVIOUS EDITION OF 9-81 IS OBSOLETE-DESTROY STOCK)

INFORMATION FOR ISSUING PERSONNEL ONLY, NOT FOR SHIP'S USE

CLASSIFICATION

SHIP (Name, Type, and No., AND Nation)

PORT OF ISSUE ______________ DATE ______

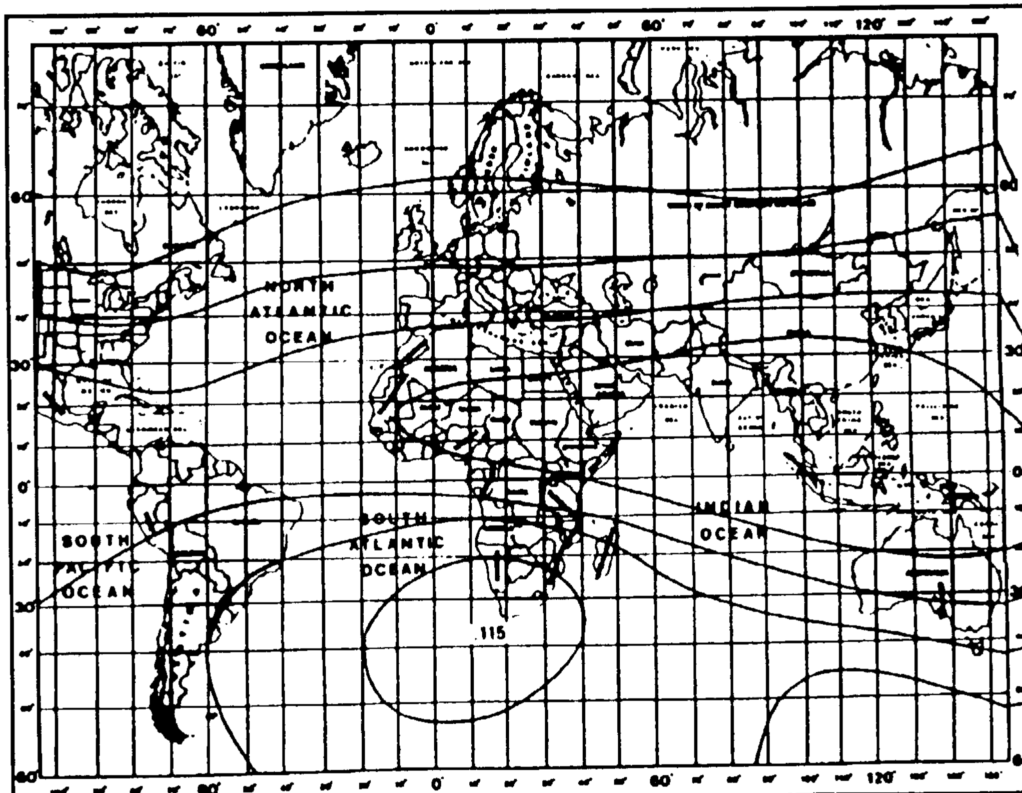
SIGNATURE OF ISSUING OFFICER ______________

Figure 10-17.—Degaussing chart No. 1.

ATLANTIC - INDIAN OCEAN

DEGAUSSING CHART No. 2

FOR AREAS WEST OF 105° WEST AND EAST OF 156° EAST SEE PACIFIC CHART (OVER)



CLASSIFICATION DOWNGRADING/ DECLASSIFICATION

COIL SETTINGS † IN AMPERES				H
	FI-QI			ZONE
	6.5			.115
	9.9			.175
	13.2			.235
	16.6			.295
	20.0			.355
	16.6			.295
	13.2			.235
	9.9			.175
	6.5			.115

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† SETTINGS APPLY TO SPACES BETWEEN LINES, NOT TO LINES

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CHAPTER 11

CATHODIC PROTECTION

This chapter contains a discussion about the cathodic protection systems installed in naval ships. there are two systems—the sacrificial anode system and the impressed current system. The two systems are different in both construction and operation.

LEARNING OBJECTIVES

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

1. *Recognize the purose of cathodic protection.*
2. *Identify the two major types of cathodic protection available.*
3. *Identify the major components of both types of cathodic protection systems.*
4. *Define various terns used to descibe cathodic protection components and processes.*

TERMS

Several terms used with this chapter may be unfamiliar to you. Because you'll need to understand them, they are defined at this point in the chapter.

Acid— A solution that contains an excess of hydrogen ions and exhibits a pH below the neutral value of 7.

Active— A state in which a metal tends to corrode (opposite to passive); freely corroding.

Amphoteric metal— A metal capable of reacting chemically either as an acid or as abase.

Anode— The electrode of an electrochemical cell circuit where corrosion occurs, and metal ions enter the solution.

Anodic polarization— The change of the electrode potential in the noble (positive) direction due to current flow.

Antifouling— The prevention of marine organism attachment or growth on a submerged metal surface through chemical toxicity. Achieved by the chemical composition of the metal, including toxins in the coating or by some other means of distributing the toxin at the areas to be kept free of fouling.

Agueous— Pertaining to water; for example, an aqueous solution is a water solution.

Base— A solution that contains an excess of hydroxyl ions and exhibits a pH above the neutral value of 7.

Cathode— The electrode of an electrochemical cell at which reduction is the principal reaction. The electrode where corrosion usually does not occur unless the electrode metal is amphoteric.

Cathodic corrosion— Corrosion of a metal when it is a cathode. Cathodic corrosion occurs on metals, such as Al, Zn, Pb, when water solution turns strongly alkaline as a result of the normal cathodic reactions. It is a secondary reaction between the alkali generated and the amphoteric metal.

Cathodic polarization— The change of the electrode potential in the negative direction due to current flow.

Cathodic protection— A technique or system used to reduce or eliminate the corrosion of a metal by making it the cathode of an electrochemical cell by means of an impressed direct current or attachment of sacrificial anodes, such as zinc, magnesium, or aluminum.

Cell— A circuit or system consisting of an anode and a cathode in electrical contact in a solid metal or liquid conducting environment.

Corrosion— The reaction between a material and its environment that results in the loss of the material or its properties. For example: when used as a material of construction, the transformation of a metal from the metallic to the nonmetallic state.

Corrosion potential— The potential that a corroding metal exhibits under specific conditions of concentration, time, temperature, or velocity in an electrolytic solution and measured relative to a reference electrode under open-circuit conditions.

Corrosion product— A product resulting from corrosion. The term applies to solid compounds, gasses, or ions resulting from a corrosion reaction.

Corrosion rate— The speed at which corrosion progresses. Frequently expressed as a constant loss or penetration per unit of time. Common units used are mils per year (mpy), millimeters per year (mm/y), and micrometers per year (µm/y). 1 mil= 0.001 inch 1 mm= 0.001 meter, 1 µm = 0.000001 meter.

Current capacity— The hours of current that can be obtained from a unit weight of a galvanic anode metal. Usually expressed in ampere hours per pound (amp-hr/lb) or ampere hours per kilogram (amp-h/kg).

Current density— The current per unit area of surface of an electrode. Commonly used units include the following:

Milliamperes per square foot $\frac{mA}{ft^2}$

Milliamperes per square meter $\frac{mA}{m^2}$

Amperes per square foot $\frac{A}{ft^2}$

Amperes per square meter $\frac{A}{m^2}$

Examples: $10\ \frac{mA}{m^2}$ $\quad 1\ \frac{mA}{ft^2}$

Current efficiency— The ratio of the actual total current measured from a galvanic anode in a given time period to the total current calculated from the weight loss of the anode and the electrochemical equivalent of the anode metal is expressed as a percentage.

Eletrochemical cell— A system consisting of an anode and a cathode immersed in an electrolytic solution. The anode and cathode may be different metals or dissimilar areas on the same metal surface. A cell in which chemical energy is converted into electrical energy under the condition of current flow between anode and cathode.

Electrode— A metal or nonmetallic conductor in contact with an electrolytic solution that serves as a site where an electric current enters the metal or nonmetallic conductor or leaves the metal or nonmetallic conductor to enter the solution.

Electrode potential— The difference in electrical potential between an electrode and the electrolytic solution with which it is in contact; measured relative to a reference electrode.

Electrolysis— The production of chemical changes in an electrolytic solution caused by the passage of electrical current through an electrochemical cell. (Should not be used to mean corrosion by stray currents.)

Electrolyte— A substance that, in solution, gives rise to ions; an ionic conductor usually in aqueous solution a chemical substance which on dissolving in water renders the water conductive.

Electrolytic cell— A system in which an anode and cathode are immersed in an electrolytic solution and electrical energy is used to bring about electrode reactions. The electrical energy is thus converted into chemical energy. **(NOTE:** The term *electrochemical cell* is frequently used to describe both the electrochemical cell and the electrolytic cell.)

Electrolytic solution— A solution that conducts electric current by the movement of ions.

Electromotive force (emf) series— A list of elements arranged according to their standard electrode potentials (the hydrogen electrode is a reference point and is given the value of zero), with noble metals, such as gold being positive, and active metals, such as zinc, being negative.

Embrittlement— Severe loss of ductility of a metal or an alloy.

External circuit— Wires, connectors, measuring devices, current sources, and so forth, that are used to bring about or measure the desired electrical conditions within the test cell. In corrosion terminology it also includes that part of an electrochemical cell external to the solution

Galvanic corrosion— Corrosion of a metal because of electrical contact with a more noble metal or nonmetallic conductor in a corrosive environment. Often used to refer specifically to bimetallic corrosion; sometimes called *couple action.*

Galvanic couple— Two or more dissimilar connductors, commonly metals, in electrical contact in the same electrolytic solution.

Galvanic series— A list of metals and alloys arranged according to their relative corrosion potentials in a given environment. **(NOTE:** This series may not be the same order as in the EMF series.)

Half-cell— One of the electrodes and its immediate environment in an electrochemical cell; an electrode and environment arranged for the passage of current to another electrode for the measurement of its electrode potential; when coupled with another half-cell, an overall cell potential develops that is the sum of both half-cell potentials.

Hydrogen blistering— *The* formation of blisterlike bulges on or below the surface of a ductile metal caused by excessive internal hydrogen pressure. Hydrogen may be formed during cleaning, plating, corrosion, or cathodic protection.

Hydrogen embrittlement— Severe loss of ductility caused by the presence of hydrogen in the metal; for example, through pickling, cleaning, of cathodic protection.

Ion— An electrically charged atom (such as Na+, C+) or group of atoms (such as NH4+, SO=, PO=).

Noble— A state in which a metal tends not to be active; the positive direction of electrode potential.

Noble metal— A metal that is not very reactive, such as silver, gold, or platinum, and that may be found naturally in metallic form on earth.

Noble potential— Apotential toward the positive end of a scale of electrode potentials.

Open-circuit potential— The potential of an electrode measured with respect to a reference electrode when essentially no current flows to or from the electrode.

Oxidation— Loss of electrons by a metal during a chemical or electrochemical reaction; as when a metal goes from the metallic state to the corroded state when acting as an anode; when a metal reacts with oxygen sulfix, and so on to form a compound such as oxide or sulfide.

pH— A logarithmic measure of the acidity or akalinity of a solution. A value of 7 is neutral; low numbers are acid (1-6); large numbers are alkaline (8-14). Each unit represents a tenfold change in concentration.

Polarization— The shift in electrode potential from the open-circuit potential value resulting from the effects of current flow.

Potential— A numerical value (measured in volts) for an electrode in a solution and defined with reference to another specified electrode.

Protective potential— A term used in cathodic protection to define the minimum potential required to mitigate or suppress corrosion. For steel in quiescent seawater a value of -0.80 volt to Ag/AgC1 reference electrode is generally used.

Reduction— Gain of electrons by a metal during a chemical or electrochemical reaction; as when a metal ion in solution goes to the metallic state at a cathode in an electrochemical cell.

Reference electrode— A half-cell of reproducible potential by means of which an unknown electrode potential can be determined on some arbitrary scale (for example, Ag/AgC1, SCE, Cu/CuSO4). A standard against which the potentials of other metal and nonconductive conductor electrodes are measured and compared.

Shield— A nonconducting coating, paint, or sheet that is used to beneficially change the current on a cathode or anode; normally used with impressed current or other high-potential cathodic protection systems to distribute the current beyond the immediate vicinity of the electrode.

Stray-current corrosion— Corrosion caused by current flow from a source (usually dc) through paths other than the intended circuit or by extraneous currents in the electrolytic solution.

CATHODIC PROTECTION

Cathodic protection reduces the corrosion or deterioration of metal caused by a reaction with its environment (ship's hull and seawater). The chemical action that is created is similar to the electrochemical action of a battery or cell. Figure 11-1 shows a dry-cell battery circuit. The positive current is indicated by a positive deflection of the voltmeter needle when the positive terminal of the meter is connected to the cathode (positive terminal) of the cell. As the electrochemical action continues, the process will eventually corrode or consume, the anode that is providing the current to light the lamp. This process is called electrochemical action.

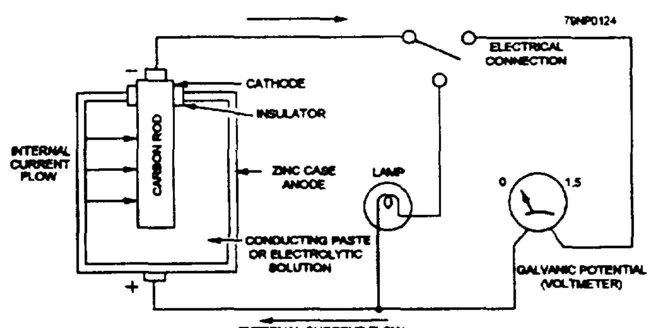


Figure 11-1.—Dry-cell battery circuit.

ELECTROCHEMICALACTION

In a marine environment, corrosion is an electrochemical process caused when two dissimilar metals are immersed in seawater, with the seawater acting as the electrolyte. This process is shown in the electrochemical corrosion cell (fig. 11-2). You must understand that in an electrochemical cell, a metal that is more corrosion prone always has a higher driving voltage than the metal that is less corrosion prone. In cathodic protection the more corrosion-prone metal is the anode (zinc, for example) and the less corrosion-prone metal is the cathode (steel hull, for example). The rate of corrosion is directly related to the magnitude of the potential difference and is referred to as the open-or half-cell potential of metals. Some of the factors affecting the amount of corrosion are stray currents, resistivity, and the temperature of the seawater.

Stray-current corrosion is caused by an external current leaving the hull of a vessel and entering the seawater. If the connection between the ship and welding machine is not correctly made (fig. 11-3) or no return lead to the welder is connected, you could have current flow between the ship's hull and the pier. This current flow causes corrosion to form on the hull.

Seawater resistivity is the concentration of ions in seawater, which acts as a resistance to current flow between two dissimilar metals. Generally, normal seawater has a nominal resistivity of 20 to 22 Ohms/cm at a temperature of 20°C (68°F). In brackish or fresh water this resistivity may vary.

TYPES OF CATHODIC PROTECTION

There are two types of cathodic protection systems—the sacrificial anode system and the impressed current system. Each system will be addressed separately.

SACRIFICIAL ANODE SYSTEM

The sacrificial anode system is based on the following principle:

> When a more reactive metal is installed near a less reactive metal and submerged in an electrolyte such as seawater, the more reactive metal will generate a potential of a sufficient magnitude to protect the less reactive metal.

In this process, the more reactive metal is sacrificed. Sacrificial anodes attached to a ship's hull slowly oxidize and generate a current (see the electrochemical corrosion cell in figure 11-2 that protects the hull and its appendages). The system shown in figure 11-2 does not

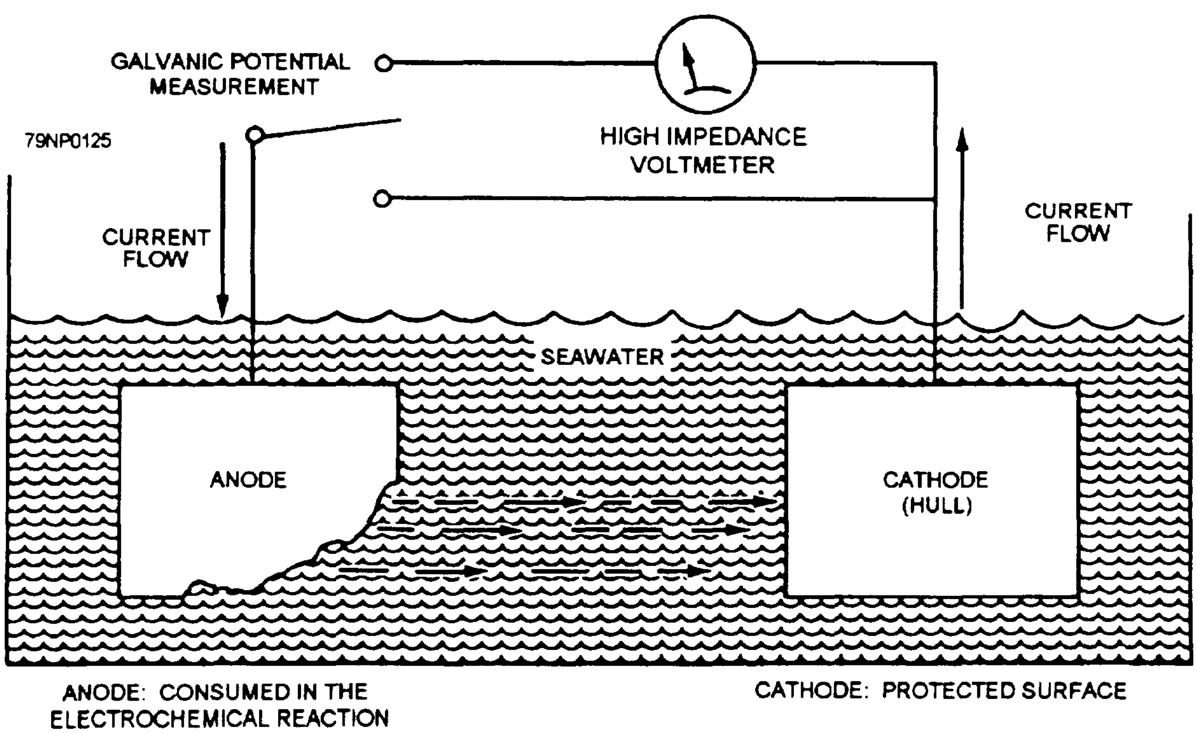


Figure 11-2.-Electrochemical corrosion cell.

have an onboard control of protecting current and depends on the limited current output of the anode. This type of system requires anode replacement on a fixed schedule (usually every 3 years on naval ships). The system is rugged and simple, requires little or no maintenance, and always protects the ship.

Types of Sacrificial Anodes

The sacrificial anodes listed below are discussed in this section.

1. zinc
2. Aluminum
3. Magnesium
4. Iron
5. Steel waster pieces

ZINC ANODES.— Zinc anodes are@ for anodic polarization on steel or aluminum surfaces. They have a half-cell potential of a negative 1.04 volts. Zinc anodes can be either bolted or welded to the hull. Welding is the preferred method because the anodes will have a secure electrical and mechanical attachment.

ALUMINUM ANODES.— Aluminum anodes are currently being tested and evaluated by the Naval Sea Systems Command (NAVSEASYSCOM).

MAGNESIUM ANODES.— Magnesium anodes have a half-cell potential of about negative 1.5 volts. They aren't used in seawater applications because of rapid loss of the anode material and overprotection due to the high driving voltage. Magnesium anodes are used in fresh or brackish water areas where the resistivity of the electrolyte is relatively high and a higher driving voltage is required to produce the proper amount of polarizing current.

IRON ANODES.— Iron anodes are installed to increase the presence of iron ions in the water. The increase of iron ions strengthens the formation of the oxide film produced on copper alloy surfaces.

STEEL WASTER PIECES.— Steel waster pieces are sleeves of mild steel installed at nonferrous metal junctions to protect sea valves and sea chests.

Uses of Sacrificial Anodes

Sacrificial anodes are used in small boats, mothballed ships, and submarines. They may be installed in piping systems, bilge pumps, valves, ballast tanks, fuel tanks, sewage collection holding tanks (CHTs), sonar domes, voids, and stem tubes.

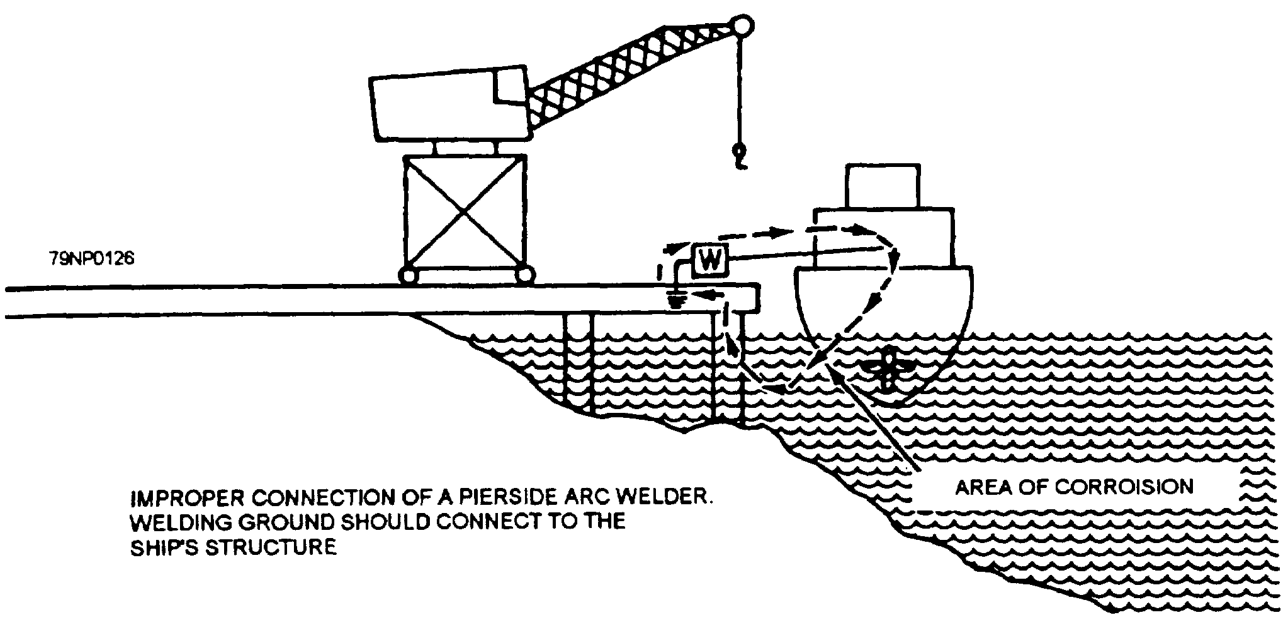


Figure 11-3.—Stray-current corrosion.

Table 11-1.—Advantages and Disadvantages of Sacrificial Anodes

ADVANTAGES	DISADVANTAGES
1. No external electrical power is required.	1. The anode current is uncontrollable.
2. Anodes are relatively fool-proof and little maintenance is required.	2. Water turbulence around the hull increases the noise level.
3. Anodes are easy to install.	3. Frequent replacement is necessary when stray dc currents are present (especially when welding machines are used).
4. Hull protection is provided at all times until the anode is completely consumed.	4. Fuel consumption is increased.
	5. Replacement is usually necessary before scheduled overhaul (every 3 years).

Advantages and Disadvantages of Sacrificial Anodes

Table 11-1 shows the advantages and disadvantages of sacrificial anodes.

IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM

The impressed current cathodic protection (ICCP) system (fig. 11-4) uses an external source of electrical power provided by a regulated dc power supply to provide the current necessary to polarize the hull. The protective current is distributed by specially designed inert anodes of platinum-coated tantalum. The principal advantage of an ICCP system is its automatic control feature, which continuously monitors and varies the current required for corrosion protection. If the system is secured, no corrosion protection is provided.

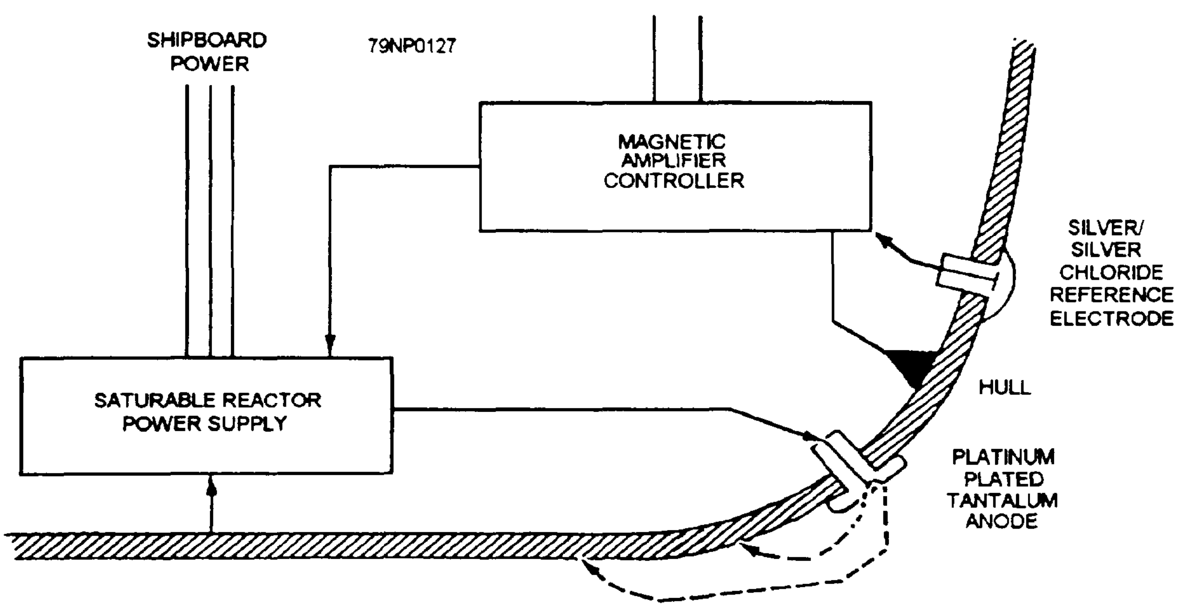


Figure 11-4.—Basic impressed current cathodic protection system.

Components of the ICCP System

The components of the ICCP system are listed below and discussed in this section.

1. Power supply
2. Controller
3. Anodes
4. Reference electrode
5. Stuffing tube
6. Shaft grounding assembly
7. Rudder ground (including stabilizer if installed)
8. Dielectic shield

POWER SUPPLY.— The power supply performs the following two functions:

1. It converts available shipboard ac to low-voltage dc.
2. It provides a means of adjusting the value of current delivered to the anodes.

CONTROLLER.— The controller (fig. 11-5) is used to monitor the control power supply outputs that maintain the hull at a preset potential versus the reference cdl. The controller is a sensitive amplifier that creates an output signal proportional to the voltage difference between the reference (electrode-to-hull) voltage and the internally set voltage. The controller should be mounted in a readily accessible area.

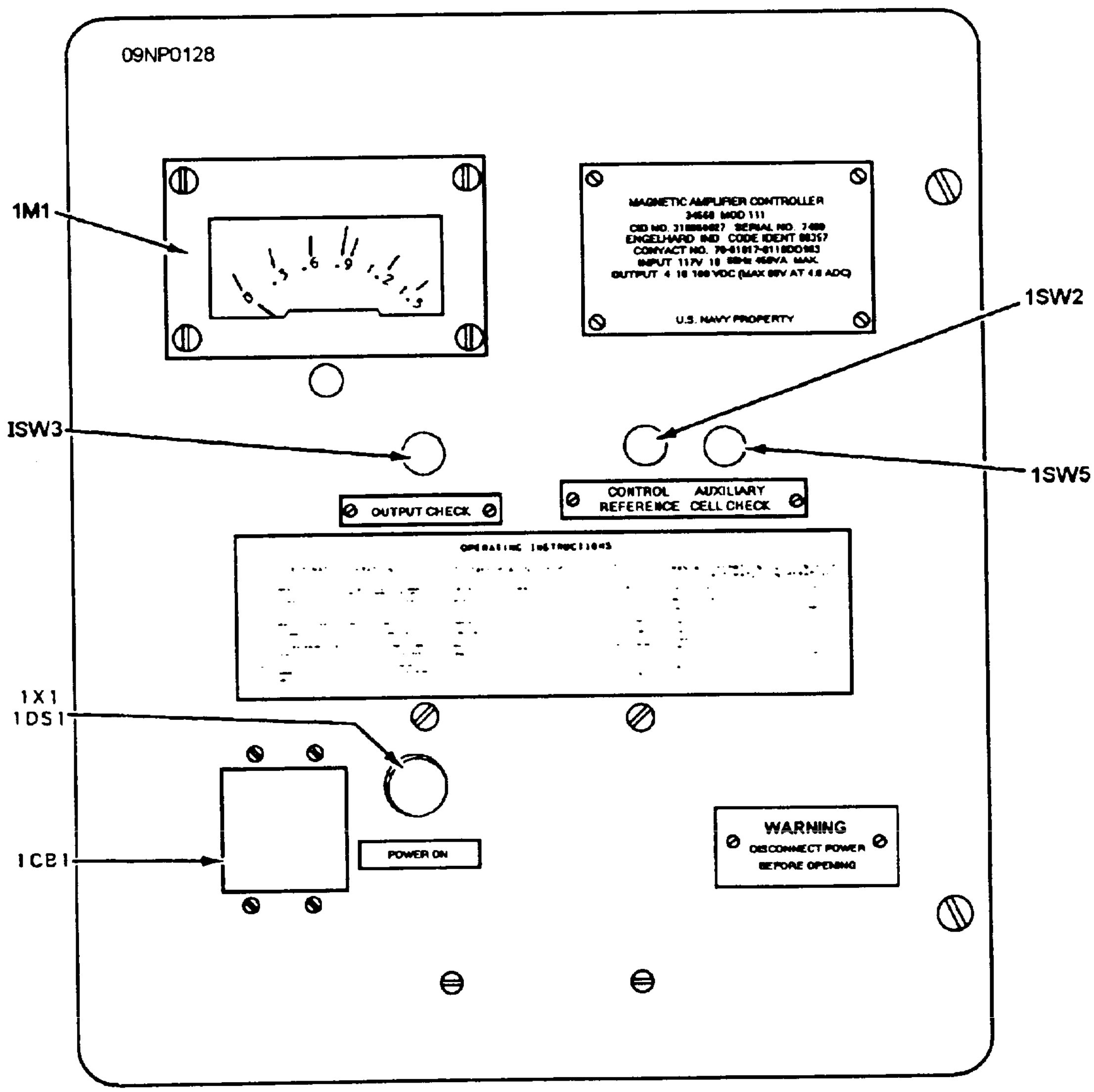
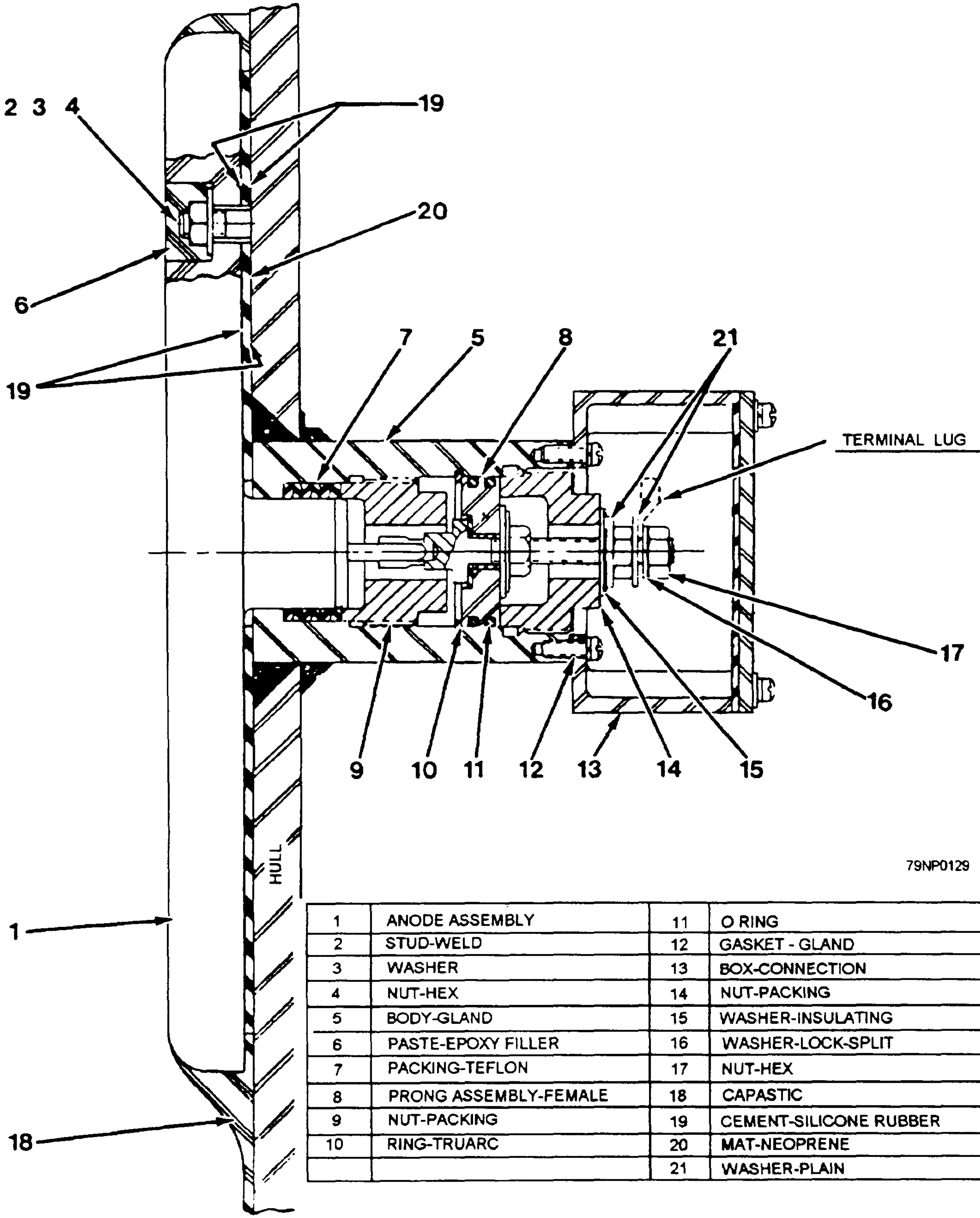


Figure 11-5.—Magnetic amplifier controller Mod III.



1	ANODE ASSEMBLY	11	O RING
2	STUD-WELD	12	GASKET - GLAND
3	WASHER	13	BOX-CONNECTION
4	NUT-HEX	14	NUT-PACKING
5	BODY-GLAND	15	WASHER-INSULATING
6	PASTE-EPOXY FILLER	16	WASHER-LOCK-SPLIT
7	PACKING-TEFLON	17	NUT-HEX
8	PRONG ASSEMBLY-FEMALE	18	CAPASTIC
9	NUT-PACKING	19	CEMENT-SILICONE RUBBER
10	RING-TRUARC	20	MAT-NEOPRENE
		21	WASHER-PLAIN

Figure 11-6.—Anode assembly.

Table 11-2.—Anode Locations on the Underwater Hull

1.	Placement should be at least 5 feet below the light-load waterline.
2.	One- and two-screw ships will have one set of anodes located more than 10 feet, but less than 50 feet, forward of the propeller plane.
3.	Four-screw ships will have two anodes located between the forward and after propeller planes, one port and one starboard.
4.	Anodes should be mounted in an area that experiences minimum water turbulence and that is protected from mechanical damage.
5.	Anode to anode, anode to electronic log equipment, and anode to reference cell separation should be a minimum of 40 feet.
6.	Anodes should not be installed within 15 feet of a sea chest or pipe discharge.

ANODES.— The anodes (fig. 11-6) are constructed of two platinum-mated tantalum rods mounted in an insulating glass-reinforced polyester holder. Anodes are bolted to the outside of the ship's hull. The dc flows into the seawater through the platinum surface of the tantalum rods. The platinum surface of the anode corrodes very slowly. The replacement period for anodes is usually 10 years or longer. Anodes are available in three sizes—2 feet (40 amperes), 4 feet (75 amperes), and 8 feet (150 amperes).

When installed (table 11-2), anodes should be placed to maintain a uniform potential throughout the underwater hull. The following is a list of anode locations:

REFERENCE ELECTRODE.— The reference electrode (fig. 11-7) is a silver/silver chloride type constructed of a silver mesh screen that has been treated with silver chloride. The reference electrode is bolted to the exterior hull of the ship and is insulated from the ship by a polyvinyl chloride holder. A stuffing tube is used to pass the cable from the electrode through the hull to the controller. The controller measures the potential of the hull versus the reference electrode, and signals the power supply to increase or decrease current output

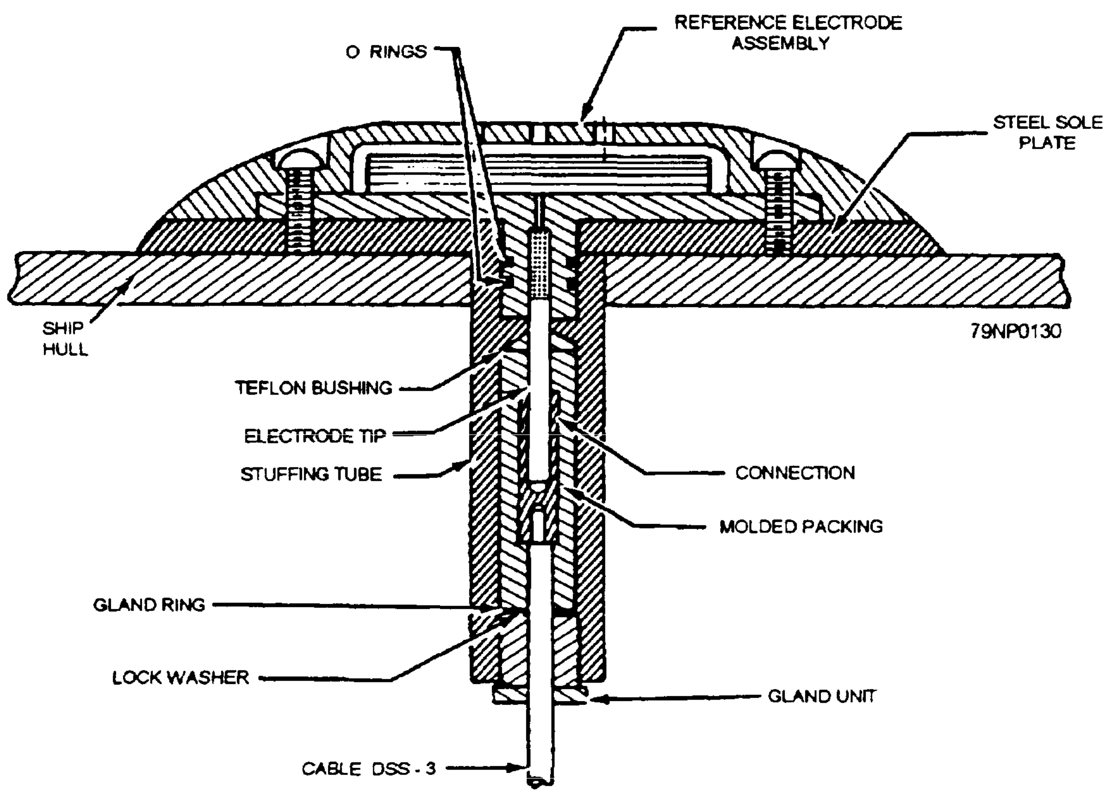


Figure 11-7.—Reference electrode assembly.

as required. Varying the current output reduces the potential difference between the hull potential and the preset desired potential. Two reference electrodes are installed for each controller—One is selected for the primary control, and the other serves as an auxiliary to verify operation of the controlling cell and seines as a backup if failure of the primary cell occurs. Reference electrodes are generally located on each side of the hull, about halfway between the anode sites. Reference electrodes are usually replaced approximate] y every 10 to 12 years.

STUFFING TUBE.— Stufflng tubes are required to insulate the electrical wires that pass through the hull to anodes or reference electrodes.

SHAFT GROUNDING ASSEMBLY.— The shaft grounding assembly (fig. 11-8) consists of a silver-alloy band, ring-fitted on the propeller shaft. The assembly is electrically bonded to the shaft and is usually located in the shaft alley. Silver-graphite brushes ride on the hard silver surface of the bands, electrically connecting the rotating propeller shaft to the hull. This assembly is necessary to permit the anode current that flows through the water to enter the propeller blades and return to the hull. A shaft grounding assembly is provided for each shaft. Ships of carrier size or larger are fitted with two brush assemblies on the silver-alloy ring.

RUDDER GROUND.— Rudders and Stabilizers are grounded by brazing a braided, tinned-copper grounding strap at least 1 1/2 inches wide between the

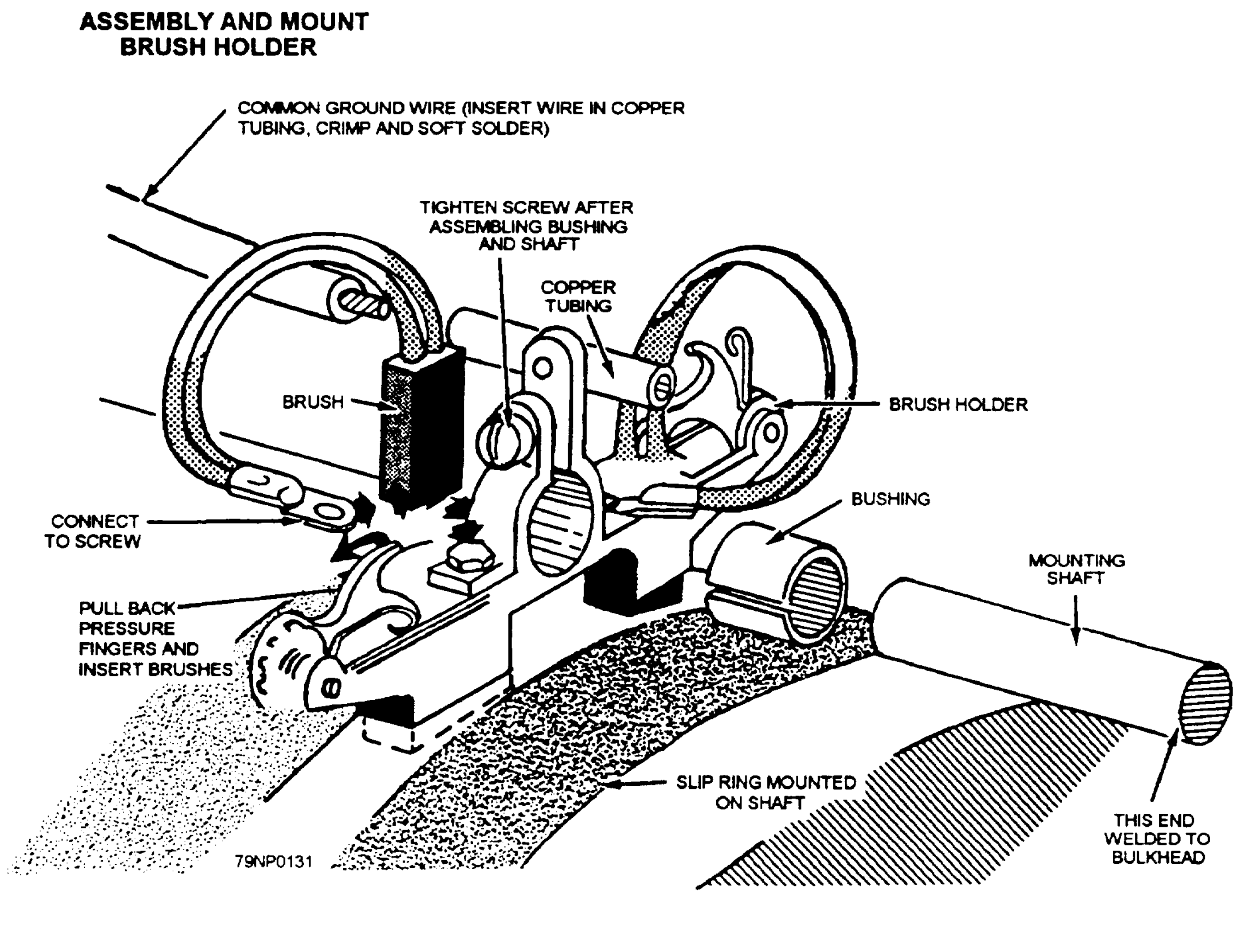


Figure 11-8.—Shaft grounding assembly.

rudder stock and the hull. To permit full rotation of the rudder stock from port to starboard, a large loop is required in the ground strap.

DIELECTRIC SHIELD.— The dielectric shield prevents shorting of the anode current to the hull and aids in wider current distribution. The dielectric shield is applied as a thick coating around each anode. It consists of a high-solids epoxy with a high-dielectric strength.

Operation

The requirements for operating the ICCP system on ships is provided in the manufacturer's technical manual. The system should be operated at all times, with the following exceptions:

1. During diving operations
2. During equipment repair
3. During planned maintenance
4. During drydocking

The system **must** be reactivated within 2 hours after the activity is completed. **Never energize the system if the ship is out of the water (drydocked).**

Before the reference electrode is connected to the controller, you should check the voltage between the reference electrode and the steel hull. The voltage should be approximately 0.6 volts dc. The hull will be negative (–), and the reference electrode will be positive (+). If the voltage is zero, the reference electrode has an open lead or the lead or electrode is shorted to the hull. When the voltage is 0.6 volts or higher, the ship is receiving cathodic protection from an external source, which could be zinc anodes or an electrical leakage.

You need to inspect the controller and power supply wiring to ensure the unit is properly grounded. Before connecting the anode leads to the power supply, check for possible shorts. The voltage developed between a disconnected platinum anode and the steel hull will range from 1.0 to 2.0 volts dc and can be read on a high-impedance voltmeter. The polarity of the anode is positive (+) and the polarity of the hull is negative (-). If this voltage is zero, you could have an open lead wire or a shorted anode. When the voltage reads between 2.0 to 5.0 volts, it indicates that the anode lead is immersed in seawater.

Hull Potential Settings

As the ship's water environment changes, so must the level of protection from the cathodic protection system. The following paragraphs address the two major differences in environment the ship encounter—seawater and brackish or fresh water.

HULL POTENTIAL SETTING OF SHIPS IN SEAWATER.—The impressed current system is designed to operate automatically and requires a minimum amount of maintenance. The operator normally sets the hull potential at -0.85 volt. When the voltage between the hull and the reference electrode is more positive than the voltage set by the operator, the output of the controller increases. This causes an increase in the anode current output from the power supply until the voltage between the hull and the reference electrode approaches the set voltage. A voltage between the hull and the reference electrode that is negative to the set voltage causes a decrease in controller output, thereby decreasing the anode current output.

The optimum range of polarization or hull-to-reference electrode potential for a ship with an ordinary steel hull is from a -0.80 to a -0.90 volt to the silver/silver chloride reference electrode. Increased anode current will result in hull potentials more negative than the optimum amount. Increasing the negative potential does not provide more protection. If exceeded, this will result in hydrogen generation at the hull surface.

HULL POTENTIAL SETTING OF SHIPS ENTERING BRACKISH OR FRESH WATER.— As a ship enters a port or bay that is riverfed, the resistivity of the water will change as the salinity changes. Operation of the ICCP system will be affected by the changing water resistivity. The operator will notice the ICCP system operating at higher voltage outputs and lower current outputs. The lower current output is caused by the higher impedance of the water. A higher voltage output is required to drive the same current in the higher-resistivity electrolyte. The operator will record this condition on the ICCP log. Do not take action to correct this condition by equipment calibration while the ship is in brackish water.

Cathodic Protection Log

Normal operating procedures require maintaining a Cathodic Protection Log, NAVSEA Form 9633/1 (fig. 11-9A and 11-9B) on ICCP system operation. The readings are recorded on these logs daily and submitted to NAVSEA monthly. Logs submitted to NAVSEA are analyzed to identify those systems that are not operating correctly. After analysis of the logs is complete, a response is sent to the ship or TYCOM indicating the operational status of the equipment as interpreted from

CATHODIC PROTECTION LOG

(NAVSEA S 9086-VF-STM-000) *(Form cont'd on back)*

Refer to NAVSEA S 9086-VF-STM-000, Chapter 633. Impressed Current Cathodic Protection (ICCP) system provides corrosion protection to underwater hull when maintained & operated properly.

NAME OF SHIP	SHIP'S HULL NUMBER	SHIP'S W/TWO CONTROLLERS *(Check One)* ☐ FORE ☐ AFT	MONTH	YEAR

DAILY (VOLTS) *(Fill In)*

AUTOMATIC CONTROL SETTING ☐ VOLTS

NORMAL OPERATION-AUTOMATIC MODE AT 065

POWER SUPPLY CURRENT (AMPERES)

TAG - OUT PERIODS

A. DIVING OPERATIONS
B. EQUIPMENT MALFUNCTION
C. MAINTENANCE*
D. DRYDOCK* E. OTHER *(Specify)**

DAY	SPEED ("X" IF PIERSIDE)	REF. CELL CHECK		OUTPUT CHECK	NUMBER				TIME		*REASON *(Specify "E")*				
		CONTROL	AUXILIARY		1	2	3	4	OFF	ON	A	B	C	D	E
1															
2															
3															
4															
5															
6															
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SIGNATURE, ELECTRICAL OFFICER	SIGNATURE, CHIEF ENGINEER	SIGNATURE, COMMANDING OFFICER

NAVSEA 9633/1 (Rev 7/84) S/N 0116-LF0096-3307 *(Previous edition obsolete, destroy stock)*

(FORM CONT'D ON BACK)

86NP0145

Figure 11-9A.—Cathodic Protection Log (front).

CATHODIC PROTECTION LOG - CONTINUATION

(NAVSEA S9086-VF-STM-000)

Refer to NAVSEA S9086-VF-STM-000, Chapter 633, Impressed Current Cathodic Protection (ICCP) system provides corrosion protection to underwater hull when maintained & operated properly

CONTROLLER

- SHALL BE OPERATED IN AUTOMATIC HULL POTENTIAL CONTROL MODE AT ALL TIMES.
- AUTOMATIC CONTROL SETTING FOR NORMAL OPERATION IS 0.85 VOLTS.
- MANUAL CONTROLLER MODE IS A FIXED POWER SUPPLY CURRENT SETTING FOR PMS TEST OR OTHER SPECIAL CONDITIONS O N L Y.
- SENSITIVITY SWITCH IS (CHECK ONE) .... > ☐ LOW ☐ MEDIUM ☐ HIGH

POWER SUPPLY

- SHALL BE OPERATED AT ALL TIMES EXCEPT DRYDOCK, DIVING OPERATIONS, AND PMS.

PMS

RECORD TEST INFORMATION FROM MRC 6332 (IC-38) IF CONTROLLER AND POWER SUPPLY PMS IS COMPLETED.

- CONTROLLER

	VOLTS NO 1	VOLTS NO 2
MAX. AUTOMATIC SETTING - OUTPUT CHECK .... >		
MIN. AUTOMATIC SETTING - OUTPUT CHECK .... >		

- POWER SUPPLIES

	AMPS NO 1	AMPS NO 2	AMPS NO 3	AMPS NO 4
FORWARD SYSTEM.. >				
AFTER SYSTEM.. >				

- INDICATE IF ANY ANODE CIRCUIT BREAKERS TRIP .... > ☐ ☐

NORMAL OPERATIONS RANGES (MIN. - MAX)

V O L T S		A M P E R E S	
REFERENCE CELL CHECK CONTROL AUXILIARY	OUTPUT CHECK	POWER SUPPLY CURRENT	
0.75-1.20	0.01-1.00	5 - 150 ± 10% 10 - 300 ± 10%	150A POWER SUPPLY 300A POWER SUPPLY

FORWARD LOGS QUARTERLY TO :

- NAVAL SEA SYSTEMS COMMAND, SEA 06M1 WASHINGTON, DC 20362

REFER QUESTIONS CONCERNING OPERATION AND MAINTENANCE TO

(In Order Of Precedence)

1 NAVSEACENS (CODE 750)	2 NAVSSES (CODE 053)	3 NAVSEA (SEA 05M1)

COMMENTS *(If applicable)*

NAVSEA 9633/1 (Rev 7/84) (BACK) S/N 0116-LF-096-3307

79NP0146

Figure 11-9B.—Cathodic Protection Log (back).

the logs. This response will recommend corrective actions to be taken, if required.

OUTPUT CHECK.— A particularly significant value recorded on the log is the output check. The values recorded will range from practically zero to 1.0 volt, representing 100 percent current output. If the values range between 0.3 and 0.5 volt, the system is operating at 30 to 50 percent capacity.

POWER SUPPLY.— The daily current output is recorded for each power supply. Ampere values may vary, depending on the power supply, maximum output, and current demand. Two capacities of power supplies are used-0 to 150 amperes and 0 to 300 amperes.

ICCP Maintenance

The ICCP maintenance is performed according to the Planned Maintenance System (PMS). You should take daily meter readings on the panel and record them on the log. A quarterly check must be performed on the shaft grounding assembly. A 24-month intervals, the panel meters are calibrated according to PMS requirements.

SUMMARY

In this chapter, you were introduced to the fundamentals of cathodic protection systems, including their operation, logs, and maintenance. An understanding of these systems will enable you to ensure that the ship's hull is maintained in a noncorrosive condition at all times. Additional information can be found in the manufacturer's technical manuals or *Naval Ships' Technical Manual,* chapter 633, "Cathodic Protection. "

CHAPTER 12

VISUAL LANDING AIDS

This chapter contains an introduction to the function, identity, and operation of the visual landing aid lighting equipment used aboard non-aviation ships for the operation and support of helicopters. The ability of a ship to safely support helicopter operations greatly increases its effectiveness in ASW operations, its supply/support functions, and makes emergent y transfer of personnel due to sickness much quicker.

LEARNING OBJECTIVES

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

1. *Identify the need for* visual *landing aids aboard ship.*
2. *Describe the operation of the stabilized platform assembly.*
3. *Describe the function of the gyroscope input to the stabilized platform assembly.*
4. *Identify the various components of the visual landing aids.*

Visual landing aids (VLA), consisting of helicopter deck area marking, lighting, and approach aids, are required on all air capable ships (ACS) to provide an environment for safe helicopter operations. Deck markings identify the limits of the helicopter operating area, provide line-up information, and identify the safe landing zone. Because of increasing demands for all-weather and night operations, special lighting systems have been designed to provide the helicopter pilot with the following data:

1. An initial visual contact with the ship
2. A safe glide path to the landing area
3. Precise information (visual cues) relative to the ship's deck position and any obstructions that may be present during launch and recovery operations
4. Visual indications for helicopter in-flight refueling (HIFR) and vertical replenishment operations (VERTREP)
5. A lighting system to signify any unacceptable landing condition aboard the ship
6. Various other lighting systems to aid the pilot in operating under the more demanding environmental conditions on ACS ships.

All components of the VLA (fig. 12-1) assist both the helicopter and the ship in completing the assigned mission.

STABILIZED GLIDE SLOPE INDICATOR SYSTEM

The stabilized Glide Slope Indicator (GSI) System is an electrohydraulic optical landing aid designed for use on ships equipped for helicopter operations. By use of the stabilized GSI, a helicopter pilot may visually establish and maintain the proper glide slope for a safe landing.

The GSI is mounted on a stable platform and provides a tricolor (red, green, and amber) display of which one color (or mixing at the interface) is seen (fig. 12-2). The color of the light bar indicates to the pilot whether the aircraft is above (green), below (red), or on (red/amber interface) the correct glide slope. In order to steady the GSI with respect to the pitching and rolling motions of the ship, the light cell is mounted on an electrohydraulic stabilization platform. The system incorporates a failure detection circuit which turns off the light in the event of stabilization failure.

The Mk 1 Mod 0 stabilized GSI system has the following six major components (fig. 12-3):

1. Electronic enclosure assembly
2. Remote control panel assembly
3. Hydraulic pump assembly
4. Transformer assembly
5. Glide slope indicator
6. Stabilized platform

Each of these components is discussed in detail in the following paragraphs.

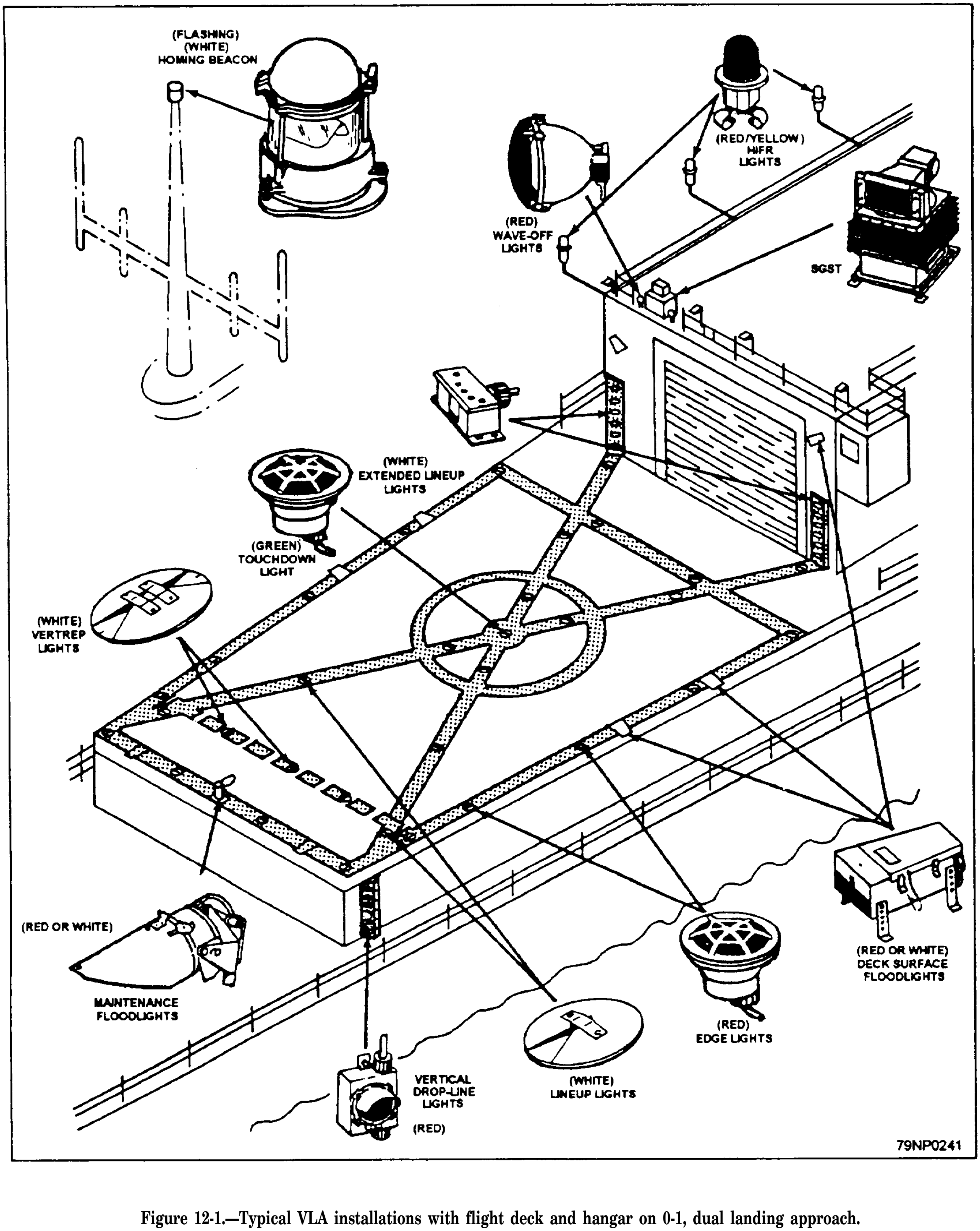


Figure 12-1.—Typical VLA installations with flight deck and hangar on 0-1, dual landing approach.

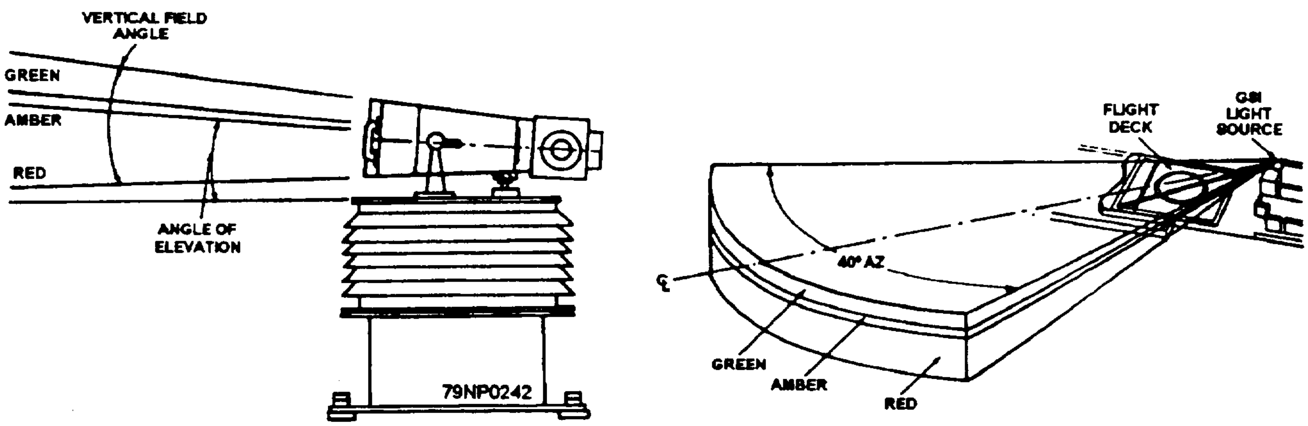


Figure 12-2.—Glide slope indicator and light beam.

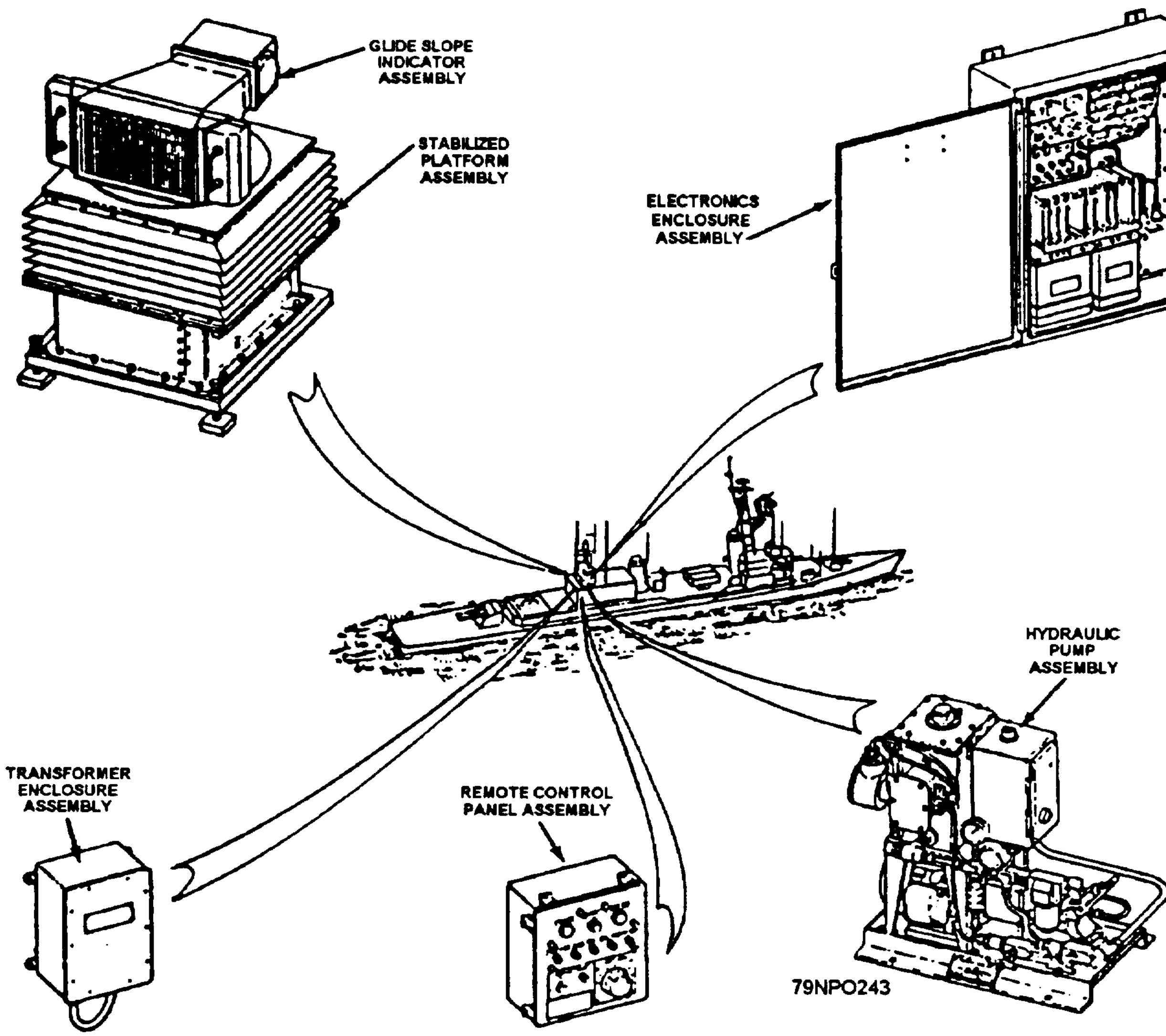


Figure 12-3.—Stabilized glide slope indicator system

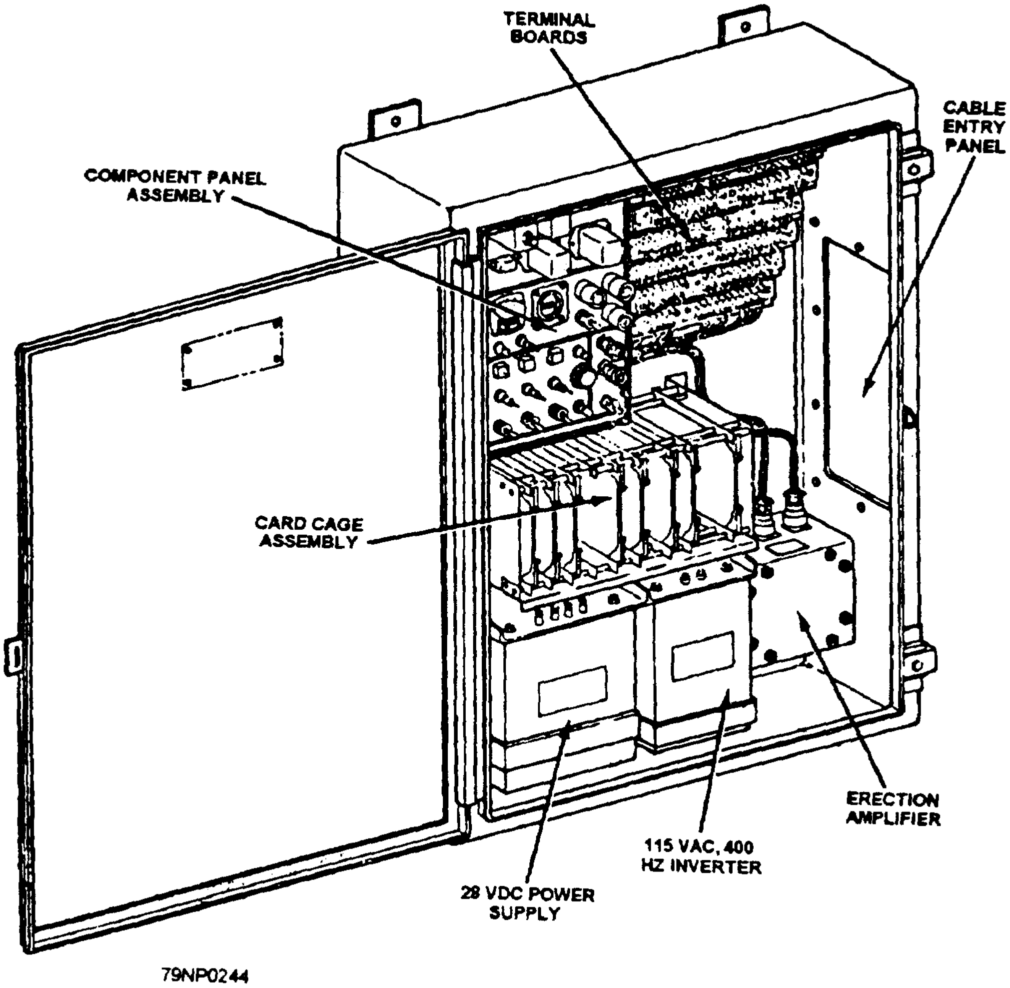


Figure 12-4.—Electronic enclosure assembly.

ELECTRONIC ENCLOSURE ASSEMBLY

The electronic enclosure assembly (fig. 12-4) contains the circuits, amplifiers, and other electrical and electronic components required to control the major components of the system. To understand the system operation, it is necessary for you to understand the operation of the feedback control systems. A feedback control system compares an input signal with a reference signal and then generates an error signal. This error signal is then amplified and used to drive the output in a direction to reduce the error. This type feedback system is often referred to as a servo loop. A gyro (fig. 12-5), mounted on the stabilized platform, acts as the reference of the system. Since the gyro is stable, synchro transmitters located on the gimbals in the gyro will sense any motion of pitch or roll. As the ship begins to pitch

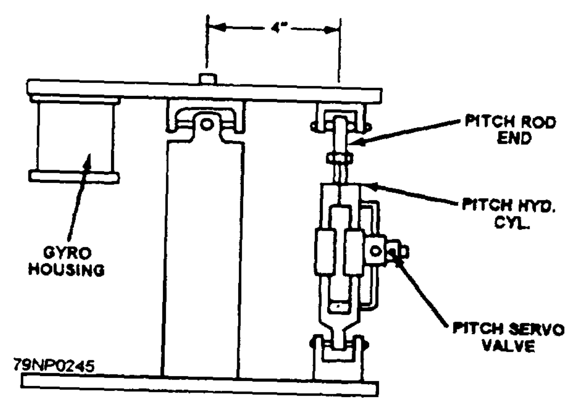


Figure 12-5.—Platform pitch drive.

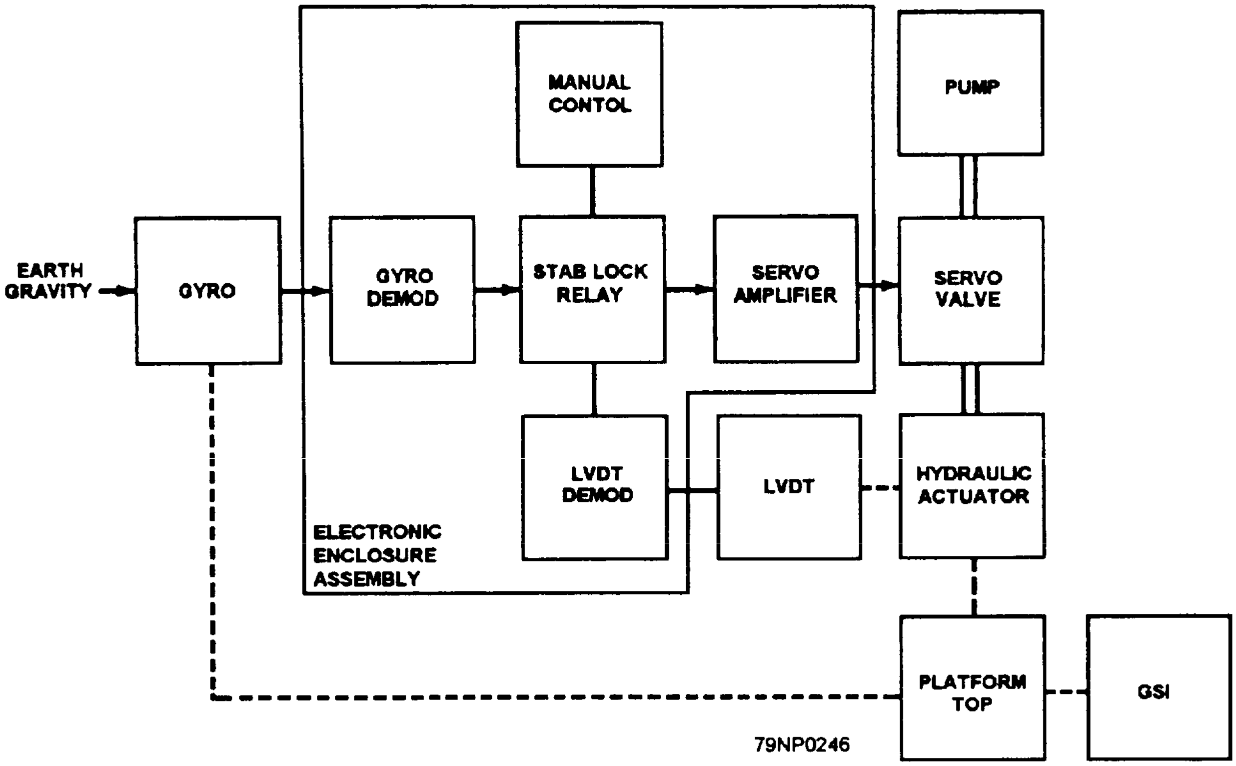


Figure 12-6.—Block diagram-stabilization circuits.

or roll, an error signal is developed by the synchro transmitter stators in the gyro. Refer to the block diagram in figure 12-6, and you can follow the path of the error signal through the electronic enclosure assembly. (The block diagram represents either the pitch or the roll control loops since they are identical electrically.) From the transmitter stators of the gyro, the error signal is sent to the gyro demodulator where the signal is changed born ac to dc The signal then goes through a stabilization lock (stab lock) relay (described later) and is amplified as it moves through the servo amplifier which in turn operates the servo valve. The servo valve opens and allows hydraulic fluid to enter the hydraulic actuator (fig. 12-7). This levels the platform and thus cancels the error signal. When this occurs, a READY light is actuated on the remote control panel. If the system develops a malfunction and the error signal is not canceled, an error-sensing circuit will light the NOT READY light on the remote control panel and turn off the glide slope indicator.

In the previous paragraph you have learned the normal mode of operation in the electronics portion of the system. The stabilization lock feature (stab lock

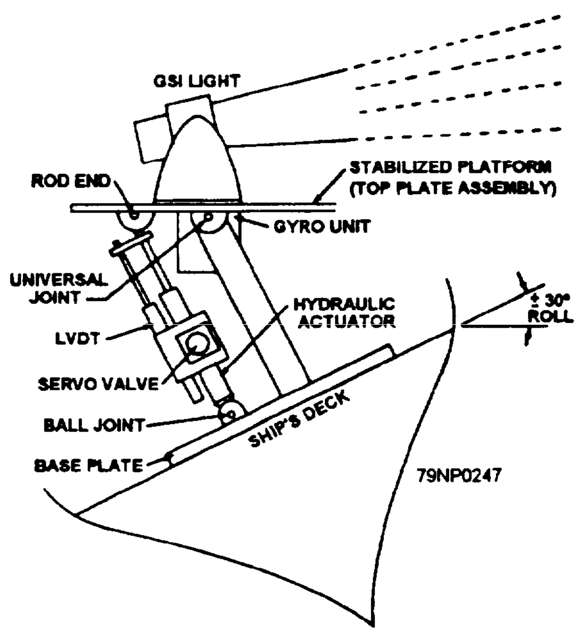
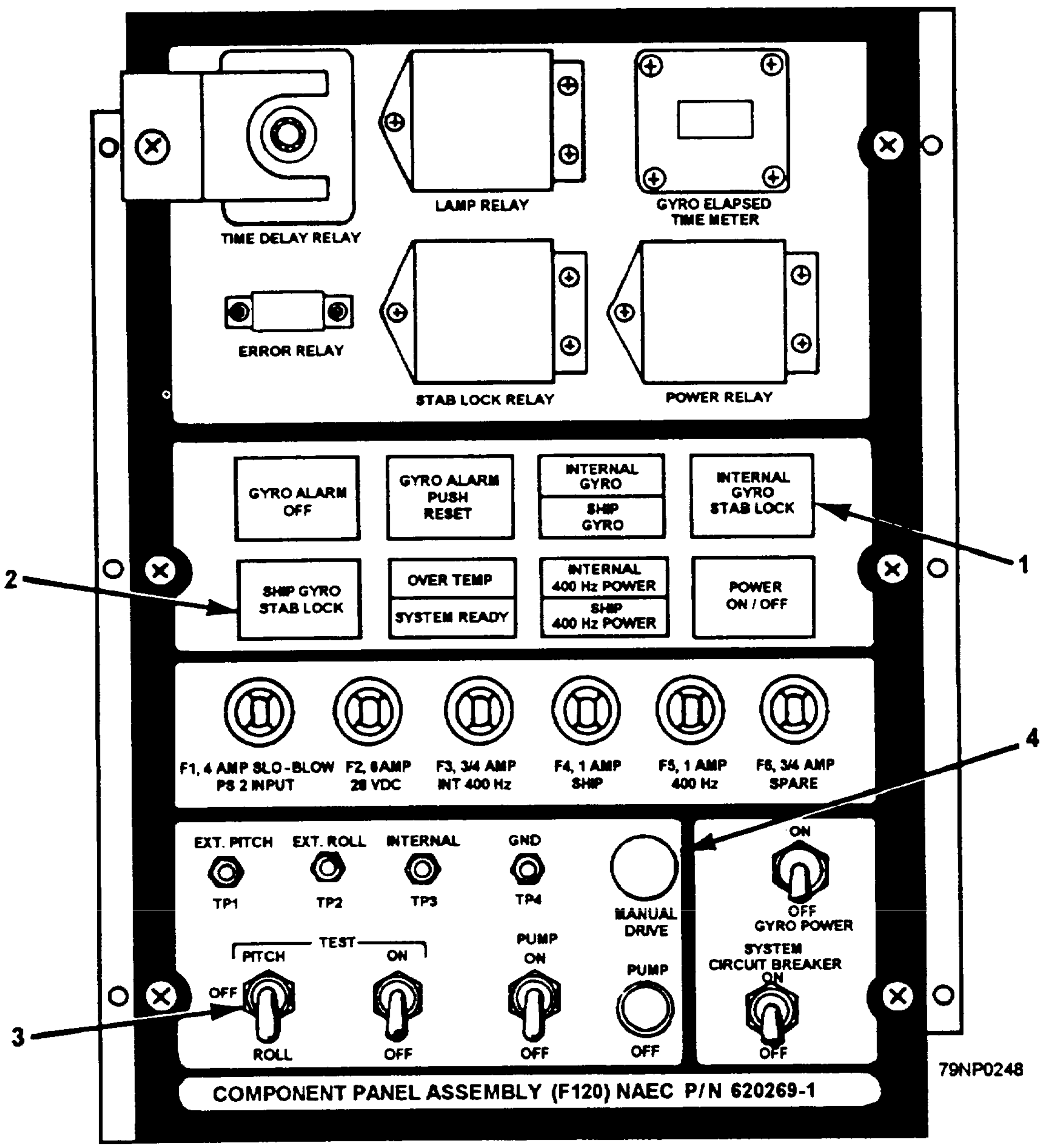


Figure 12-7.—Stabilized platform assembly-functional diagram.

relay) tests and aligns the GSI. Referring to figure 12-8, you will see the:

1. internal gyro stab lock,
2. the ship's gyro stab lock push button, and
3. two test switches

As previously mentioned the error signal in the normal mode goes through a stab lock relay. When the stab lock button is pushed, the normal error signal supplied from the gyro is stopped at this point. (See fig. 12-9.) When the stab lock button is pushed, the error signal comes from the linear voltage differential transformer (LVDT) when the test switch is in the off position. The core of the LVDT is mechanically attached to the hydraulic actuator which levels the platform. As the actuator moves, the core also moves, thereby supplying a signal proportional to the amount of roll or pitch. These signals can be measured to aid in the maintenance and alignment of the system. Provisions are also made to manually drive the platform using the test switches and the manual drive potentiometer ((4) in fig. 12-8 and may also be seen in diagram of fig. 12-10).



1. Internal Gyro Stab Lock switch-indicator
2. Ship Gyro Stab Lock switch-indicator
3. Pitch-Off-Roll Toggle switch
4. Manual Drive potentiometer

Figure 12-8.—Component panel assembly.

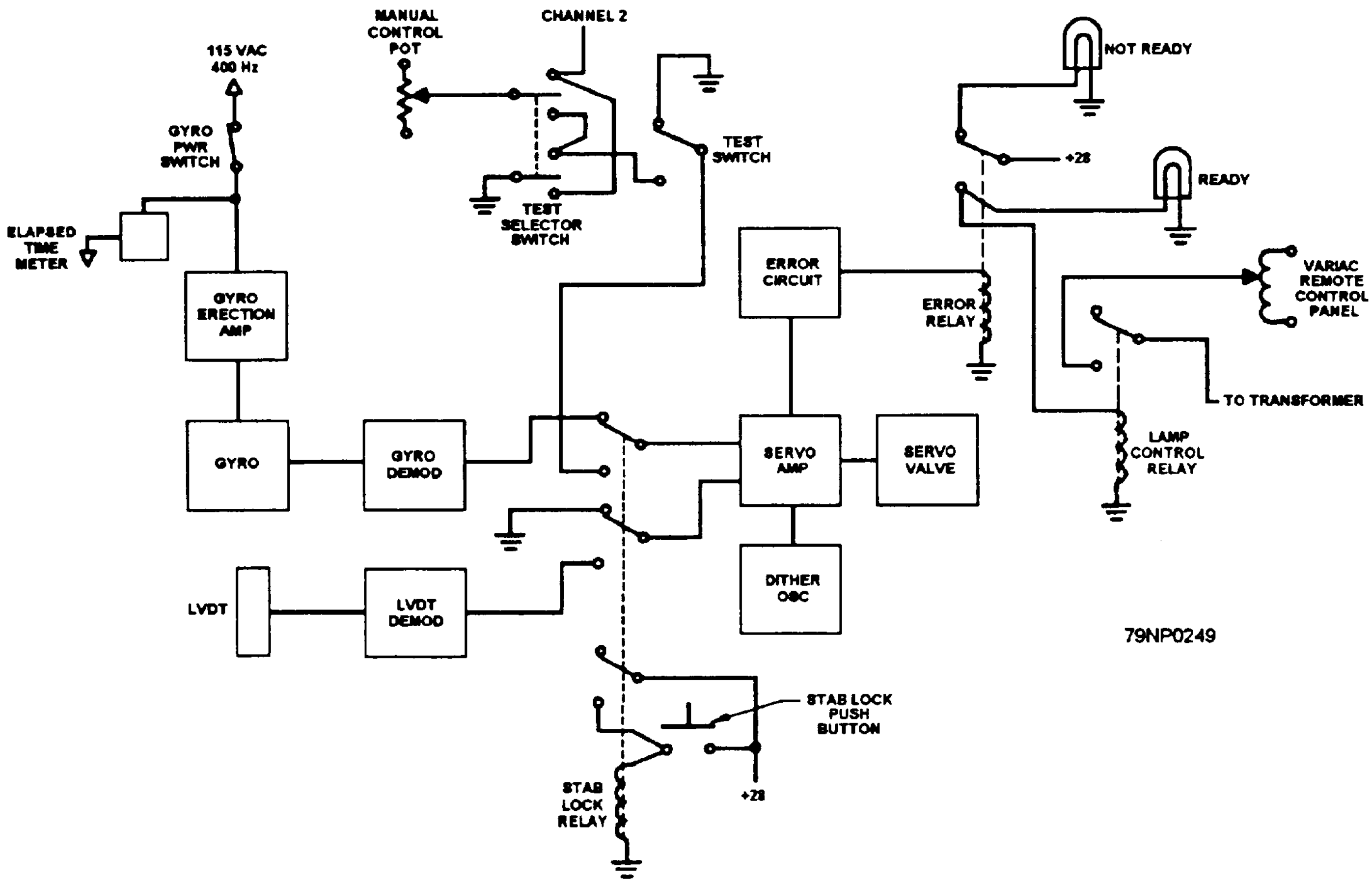


Figure 12-9.—Stabilization control circuits—signal flow.

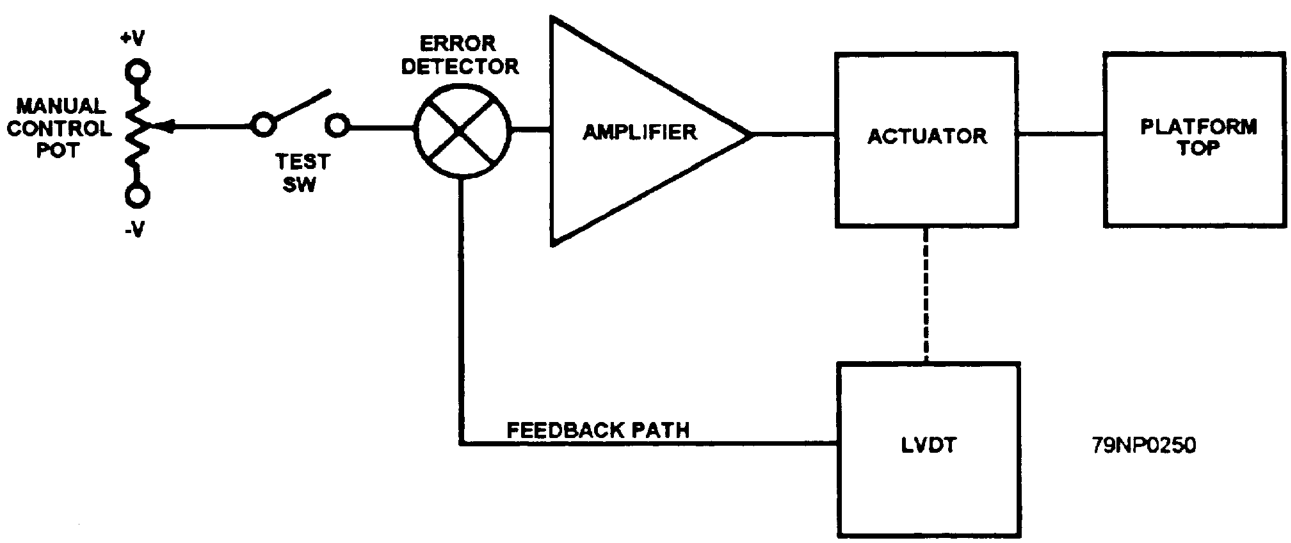
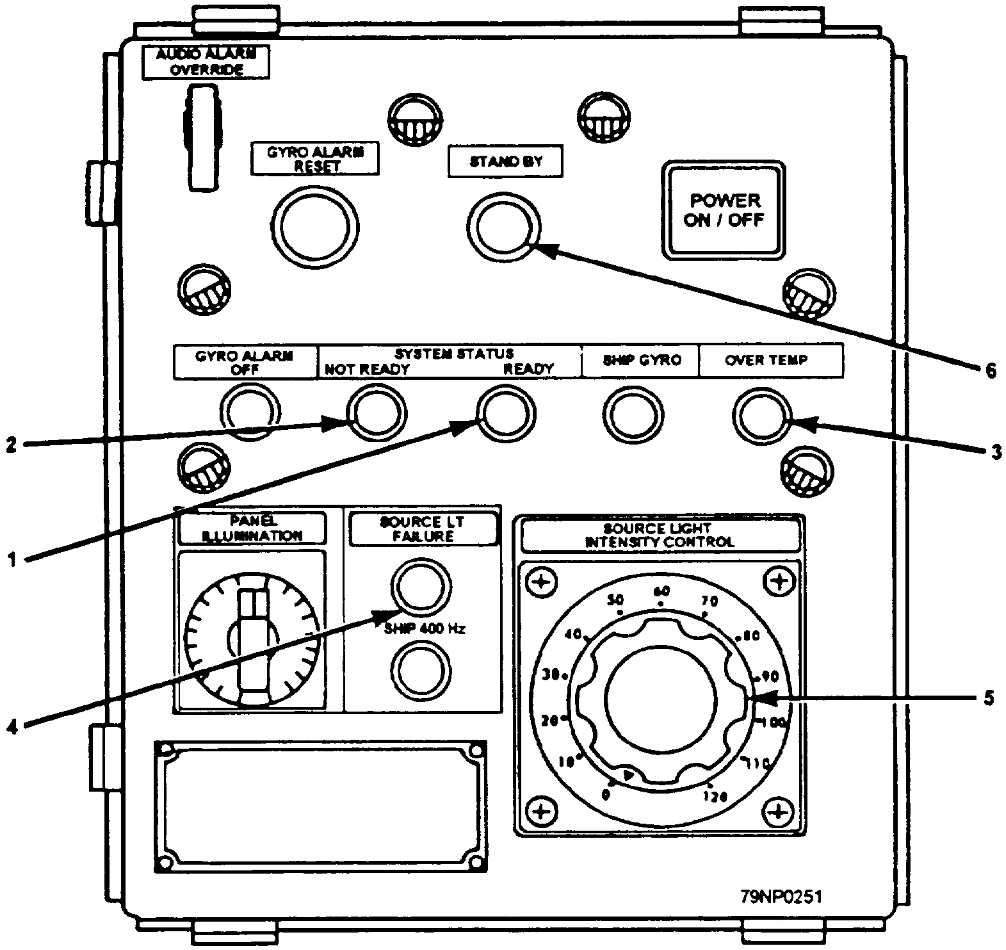


Figure 12-10.—LVDT servo loop.



1. System Status Ready indicator
2. System Status Not Ready indicator
3. Over Temperature indicator
4. Source Light Failure press-to-test indicator
5. Source Light Intensity Control variable transformer
6. Standby indicator

Figure 12-11.—Remote control panel assembly.

REMOTE CONTROL PANEL ASSEMBLY

The remote control panel (fig. 12-11) is located in the helicopter control station (HCS). This panel provides control and indicators for operating and monitoring the stabilized GSI from a remote location. It contains the following items.

Item #	Name	Purpose
1.	*READY* light	illuminates when the GSI stabilized platform is level
2.	*NOT READY* light	illuminates when there is an error signal to indicate that the GSI stabilized platform is not level
3.	*OVER TEMP* light	indicates when the hydraulic fluid is heated to a temperature higher than 135°F ±5 degrees
4.	*SOURCE FAILURE* light	illuminates when a projection lamp in the GSI indicator fails
5.	*SOURCE LIGHT INTENSITY CONTROL*	variable transformer which controls the intensity of the GSI light
6.	*STANDBY LIGHT*	energized when the main switch on the electronic enclosure assembly is on

YDRAULIC PUMP ASSEMBLY

The hydraulic pump assembly (fig. 12-12) is located as close as possible to the stabilized platform. It provides hydraulic fluid at 1,400 psi to the hydraulic actuator on the stabilized platform. 'he motor and controller operate on 440-V three phase received from the ship's normal power supply. The temperature switches (not shown) operate the HIGH TEMP light on the remote control panel. Also, a pressure switch in the hydraulic pump discharge line will close at 1,200 psi. If not closed, the pressure switch will de-energize the electronic panel assembly on low oil pressure. Hydraulic fluid heaters in the oil reservoir will warm the fluid up to 70°F ±5 degrees before use of the GSI system.

TRANSFORMER ASSEMBLY

The transformer assembly is located as close as possible to the stabilized platform. Its purpose is to step down the voltage for the source light (GSI) from 0- to 115- volts ac to 0- to 18.5-volts ac depending on the setting of the intensity control.

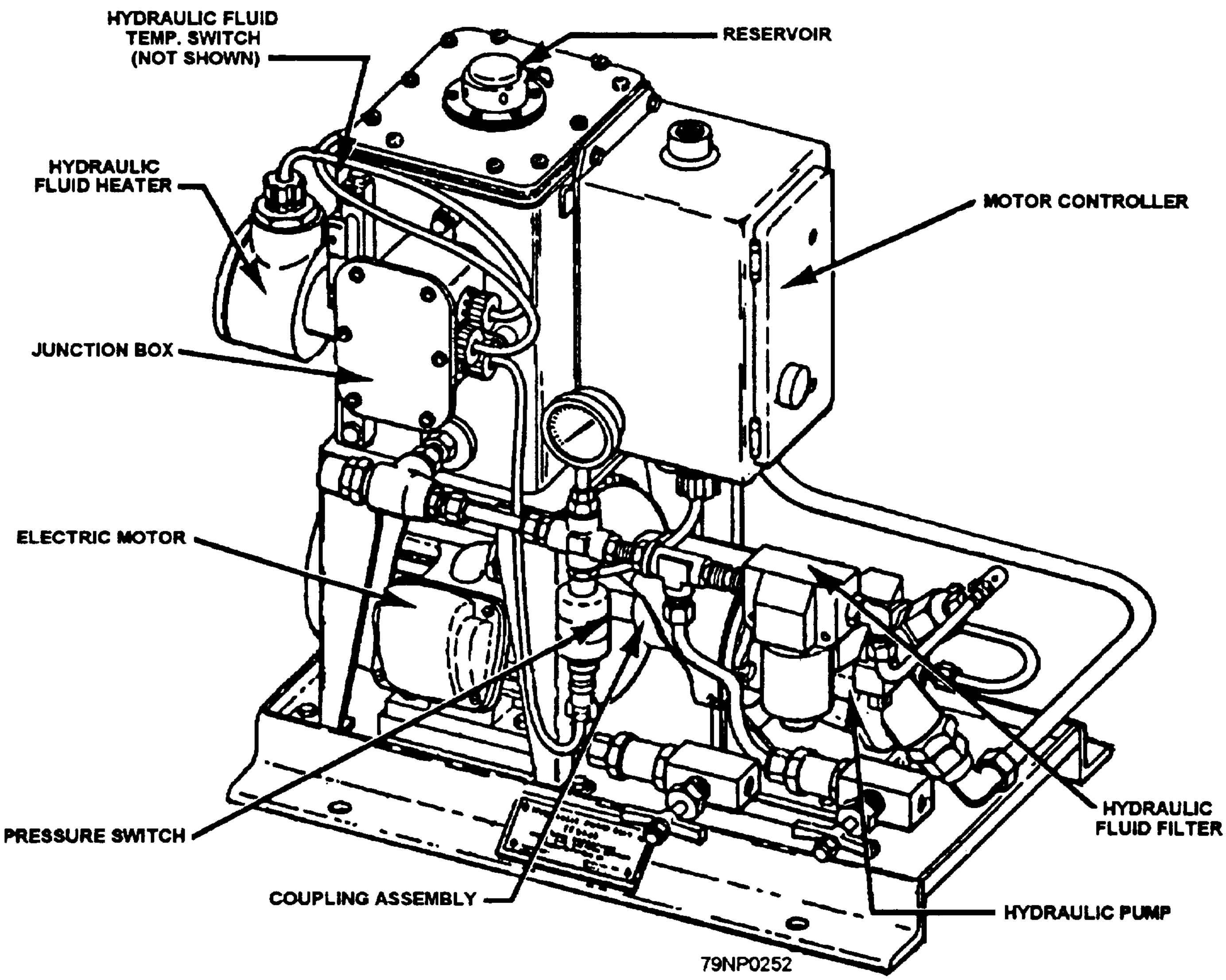


Figure 12-12.—Hydraulic pump assembly.

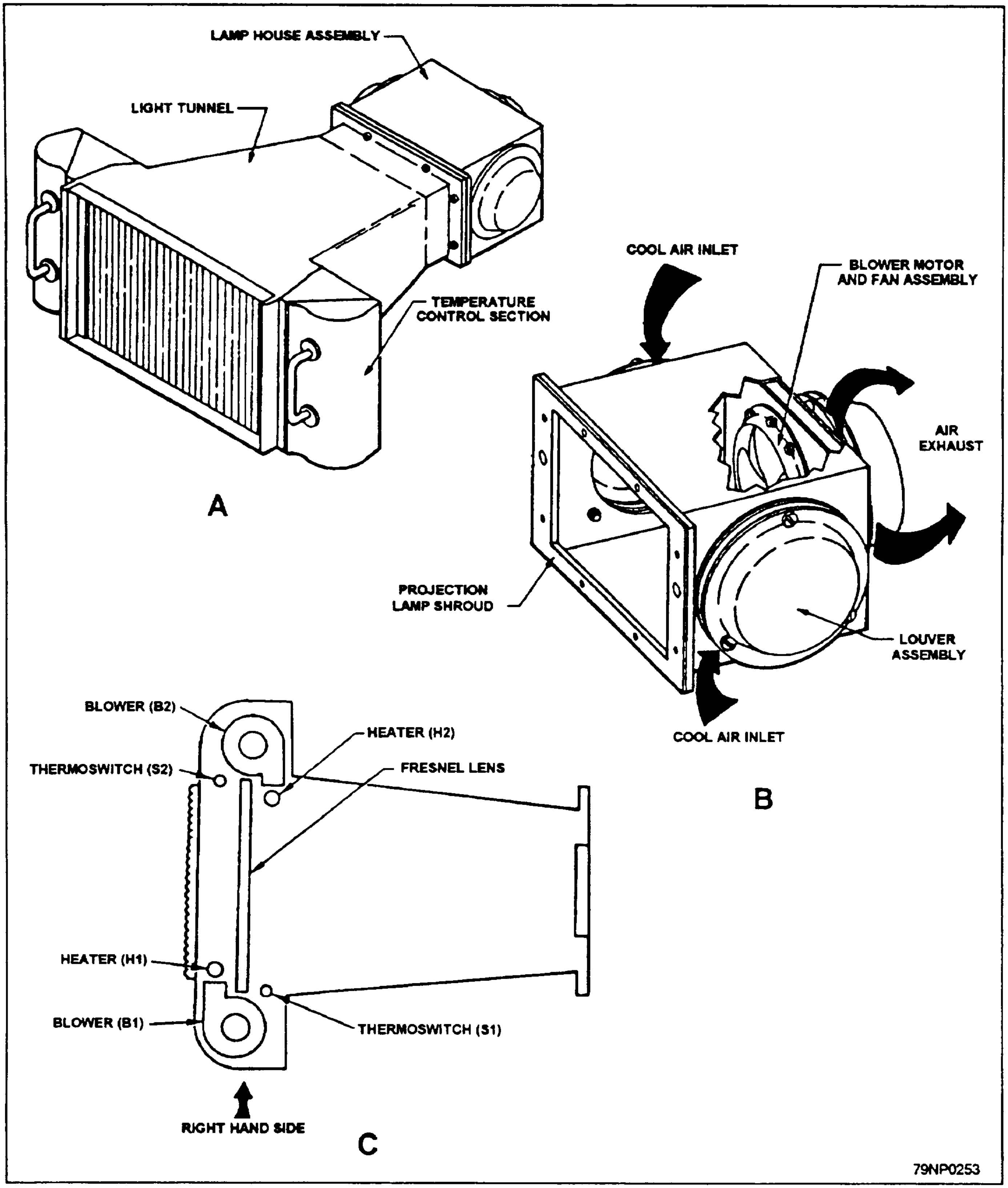


Figure 12-13.—A. Glide slope Indicator; B. Lamp house assembly; C. Temperature control section.

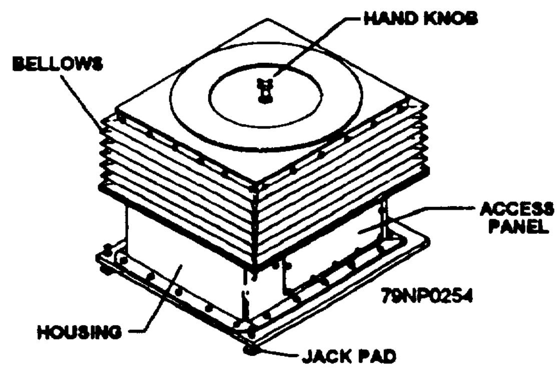


Figure 12-14.—stabilized platform assembly.

GLIDE SLOPE INDICATOR (GSl)

The glide slope indicator (fig. 12-13A) is a cell assembly made up of the following three main sections:

1. **The lamp house assembly** (fig. 12-13B)—contains three source lights, a vent fan to cool the section, an optical lens (not shown), and reflectors
2. **The light tunnel—** provides space for the focal length of the lens to be utilized
3. **The temperature control** section fig. 12-13C)—contains the Fresnel lens which is sensitive to temperature

To protect the Fresnel lens from excessive temperature variations, two heaters, each having a blower, are mounted on either side of the cell assembly in the temperature control section. Each heater is controlled by a thermostat which maintains the temperature at 115°F ±15 degrees. The blowers recirculate the heated air throughout the cell assembly.

STABILIZED PLATFORM ASSEMBLY

The stabilized platform assembly (fig. 12-14), which will remain level despite the pitch and roll attitude of the ship, provides a mount for the GSI. The assembly, shown in figure 12-15, consists of a stabilized platform attached to two hydraulic actuators (pitch and roll) which maintain the platform level at all times. The

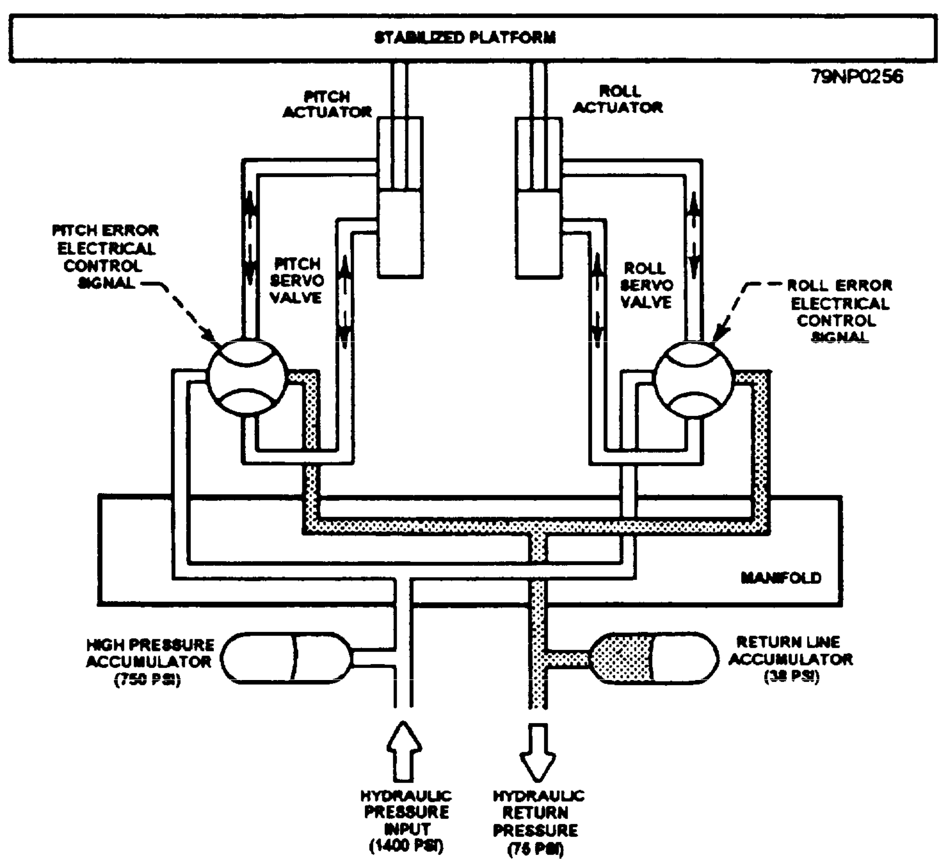


Figure 12-15.—Function diagram of the stabilized platform assembly.

block diagram in figure 12-16 shows the complete system interconnected. The stabilized GSI system cannot compensate for a ship's heave. Heave is the rise and fall of the entire ship without a change in pitch or roll angle.

VERTICAL GYROSCOPE

The vertical gyroscope is basically a mechanical device. The essential element of the gyroscope is a flywheel rotating at high angular velocity about an axis. The flywheel is mounted within gimbals which allow it 2 degrees of freedom. (See fig. 12-17.)

When the gyroscope's flywheel is rotating at high speed, its inertia is greatly increased. This causes the flywheel to remain stationary within the gyro gimbal structure. In order to align the gyroscope flywheel to the local earth's gravity vector (downward pull of gravity), a pendulum sensor is attached under the spinning flywheel. In operation, the pendulum is held suspended within a magnetic sensor. The magnetic sensor measures the difference between the pendulum axis and the spin motor axis. The sensor output is amplified and used to drive a torque motor. This motor causes the gyro flywheel to rotate in a direction that reduces the sensor output. In actual operation, the pendulum sensor is affected by lateral accelerations which cause it to oscillate about true position. To correct for this oscillation, the gyro circuit's time constants are long. The long time constants cause the gyro flywheel to ignore periodic variations of the pendulum and align itself to the average pendulum position. Figure 12-18 shows the essential elements of the gyro.

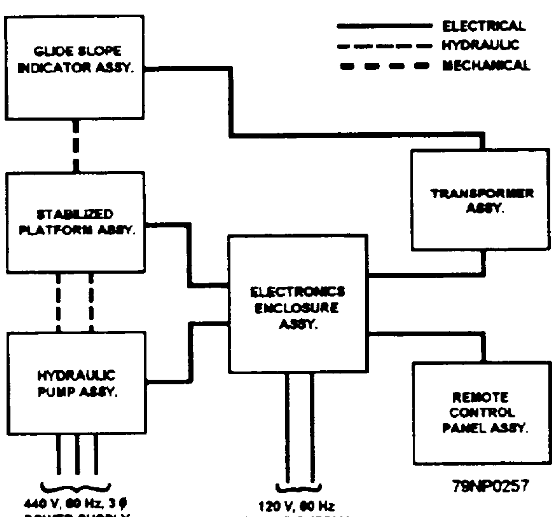


Figure 12-16.—Stabilized glide slope indicator—block diagram.

GYRO ALARM CIRCUIT

The stabilized GSI system incorporates an independent failure detection circuit. This detects any failure that results from a loss of stabilization. It does this by comparing an input from the ship's gyro with the output of the platform LVDT. When the system is operating correctly in the internal gyro mode, the output of the LVDT is directly proportional to the ship's motion. If the ship's motion from the LVDT is added out of phase (reverse polarity) to the ship's motion from the ship's gyro, the two will cancel. Any remaining voltage from the summation will be the error between the ship's gyro and the platform. The error is compared against a preset limit, and if it exceeds this limit, the platform error relay is tripped. The gyro input is required for the alarm and is also used for the ship's gyro stabilization and for the rate lead. The rate lead circuits are used to reduce velocity lag of the platform and to increase system dynamic accuracy. In the ship's gyro stabilization mode, the system operates at a reduced accuracy because of null errors and LVDT linearity error. Therefore the ship's gyro mode is to be used as a backup mode only.

HOMING BEACON

The homing beacon is a high intensity white lamp located on the mainmast or high on the superstructure. It should be visible for at least 330 degrees in azimuth. The beacon has a minimum effective intensity of 1,500 candles over a span of 7 degrees in elevation and produces approximatey 90 flashes per minute. The intensity of the beacon light can be varied from blackout to full intensity by a dimmer control on the lighting control panel. The homing beacon is wired in two circuits; the motor which turns the reflector is wired to

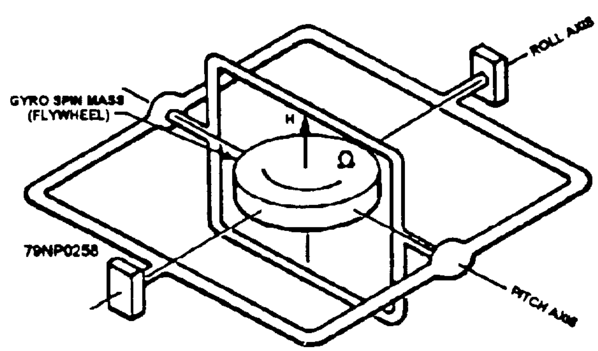


Figure 12-17.—Vertical gyro-simplified schematic.

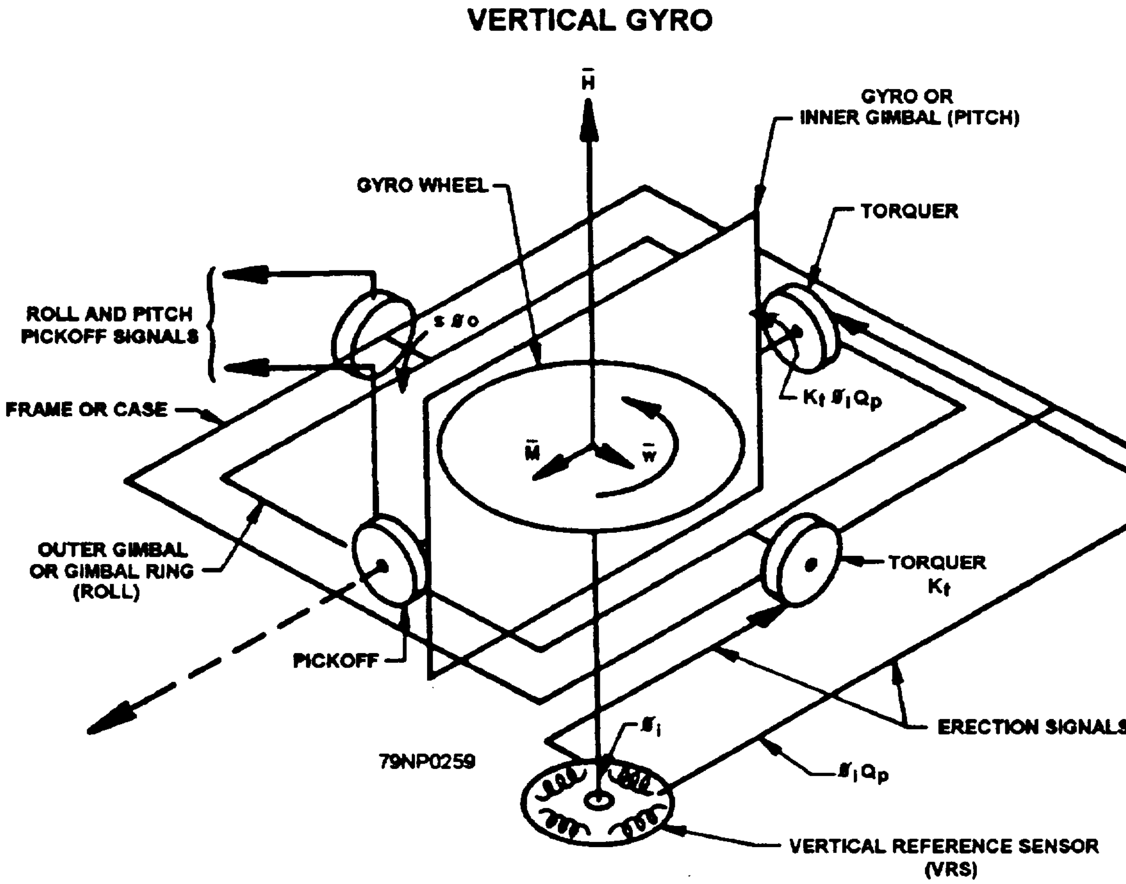


Figure 12-18.—Vertical gyro—line schematic diagram.

a fixed-voltage circuit (115 volts), while the lamp (150 watt) is wired through a step-down transformer (115/32 volts) to a variable voltage dimming circuit.

EDGE LIGHTS

The edge lights outline the periphery of the obstruction-free helicopter deck area with a minimum of four lights along each edge of the area. Edge lights are red omnidirectional lamps which can be seen in any direction above deck level. They are connected to the low voltage side of a 115/12-volt step-down transformer. The 115-volt side of each transformer (one transformer per light fixture) is connected to a motor-driven variable transformer which controls the intensity of the lights.

LINE-UP LIGHTS

The line-up lights are white and flash in sequence. They are installed in the deck along the line-up line for deck landing. Line-up lights are either unidirectional or bidirectional (LSTs only) dependent on the ship's landing capability. Each lamp is connected to the secondary side of a 115/6.5-volt step-down transformer. The primary is connected to a motor-driven, variable transformer (intensity) and a flash sequencer (fig. 12-19).

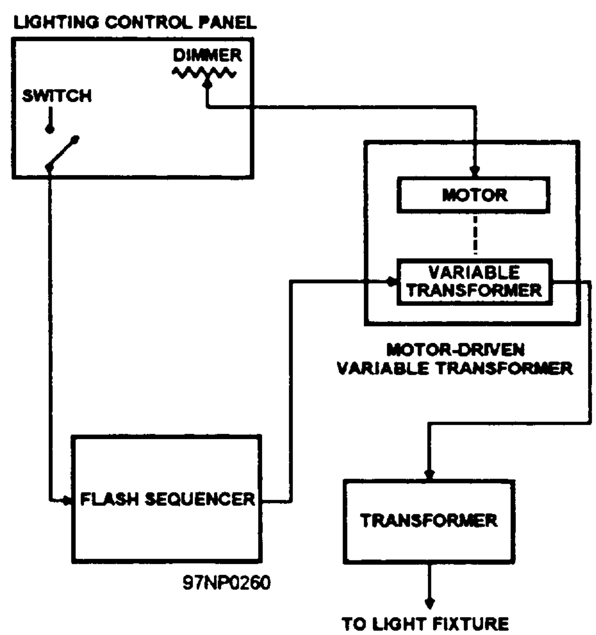


Figure 12-19.—Simplified interconnection of line-up lights.

EXTENDED LINE-UP LIGHTS

Extended line-up lights are white lights installed at the forward end of the deck-installed line-up lights and extend above the flight-deck level. These lights merely extend the line-up lights forward to provide the helicopter pilot with a better visual picture of line up with information during night landing operations. The extended line-up lights are a minimum of six individual light fixtures either mounted vertically to a bulkhead or on a light bar assembly mounted to the flight deck. Each extended line-up light fixture is connected to a 6.5-volt secondary of a 120/6.5-volt step-down transformer. The primaries of the transformers are connected to the same circuit as the deck-installed, line-up lights.

FLASH SEQUENCER

The flash sequencer (fig. 12-20) is wired into the line-up lights to provide the helicopter pilot with additional visual cues and depth perception during night landing approaches. The cam-operated unit sequentially flashes 9 to 10 line-up lights. On ships with both port and starboard approaches, the flash sequencer must be capable of producing flashes (strobing) of either port or starboard line-up lights as selected by controls on the lighting control panel.

VERTICAL DROP-LINE LIGHTS

Vertical drop-line lights are red and serve as an aft extension of the deck-installed line-up lights. The light bar assembly is installed immediately aft of the landing line-up lights and contain four to six red lights which extend below the flight deck in the vertical plane. These lights in conjunction with the extended line-up lights provide the helicopter pilot with continuous line up during night approach when deck-installed line-up lights cannot be seen because of the ship's motion. The drop-line bar assembly operates from a single 120/12-volt step-down transformer/enclosure assembly which is wired to a motor-driven, variable voltage transformer (dimmer).

FORWARD STRUCTURE/DECK SURFACE FLOODLIGHTS

White floodlights, with red filters, are provided to illuminate any structure forward of the landing area and to provide greater depth perception to the pilot during night operations. At least two fixtures, one port and one starboard, must be installed and adjusted to illuminate the aft face of the hangar as well as structures forward of the landing area. Other fixtures are installed and adjusted to illuminate the landing area itself. These fixtures are connected to a motor-driven variable transformer (intensity). Each fixture is conncted to the low voltage side of a separate 120/30-volt step-down transformer.

MAINTENANCE FLOODLIGHTS

Red maintenance floodlights are required for night preflight and postflight maintenance. The floodlight assembly consists of a light fixture, lamp, red filter, on/off switch, and support. The light is wired to the ship's 120-volt, 60Hz, single-phase power supply.

OVERHEAD FLOODLIGHTS

White overhead floodlights with yellow and red filters provide illumination of the helicopter deck for support of night operations. These lights are mounted above the landing area and are connected to a motor-driven variable transformer.

WAVE-OFF LIGHT SYSTEM

The Wave-Off Light (WOL) System (fig. 12-21) provides a visual cue to the pilot that landing conditions aboard the ship are unacceptable. The system consists of the following nine major components:

1. Master control panel assembly
2. Two remote panel assemblies
3. Two plug-in junction box assemblies
4. Terminal junction box assembly
5. Two wave-off light assemblies
6. Portable switch

Each of these components is discussed in detail in the following paragraphs.

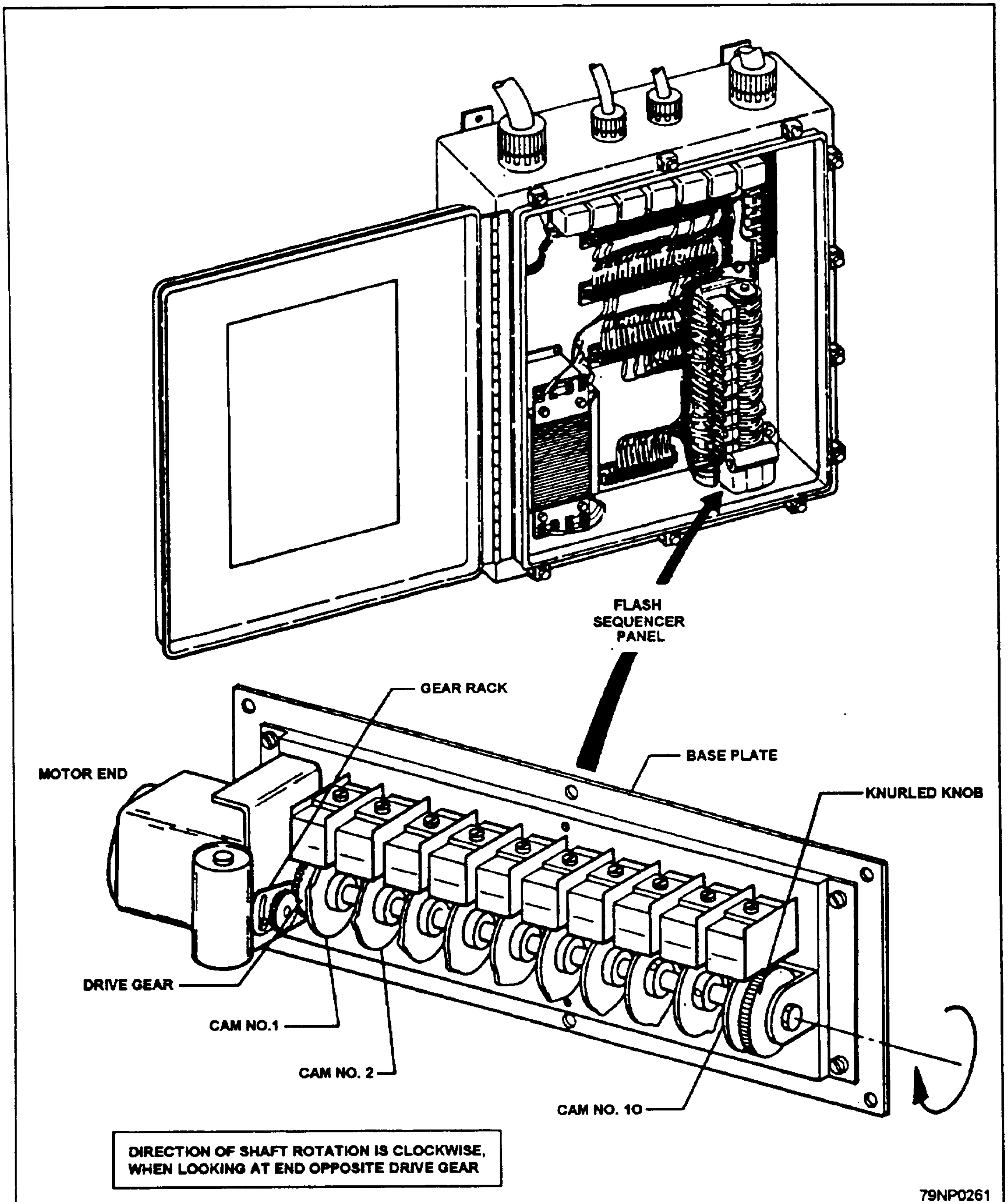


Figure 12-20.—Flash sequencer panel and timer assembly.

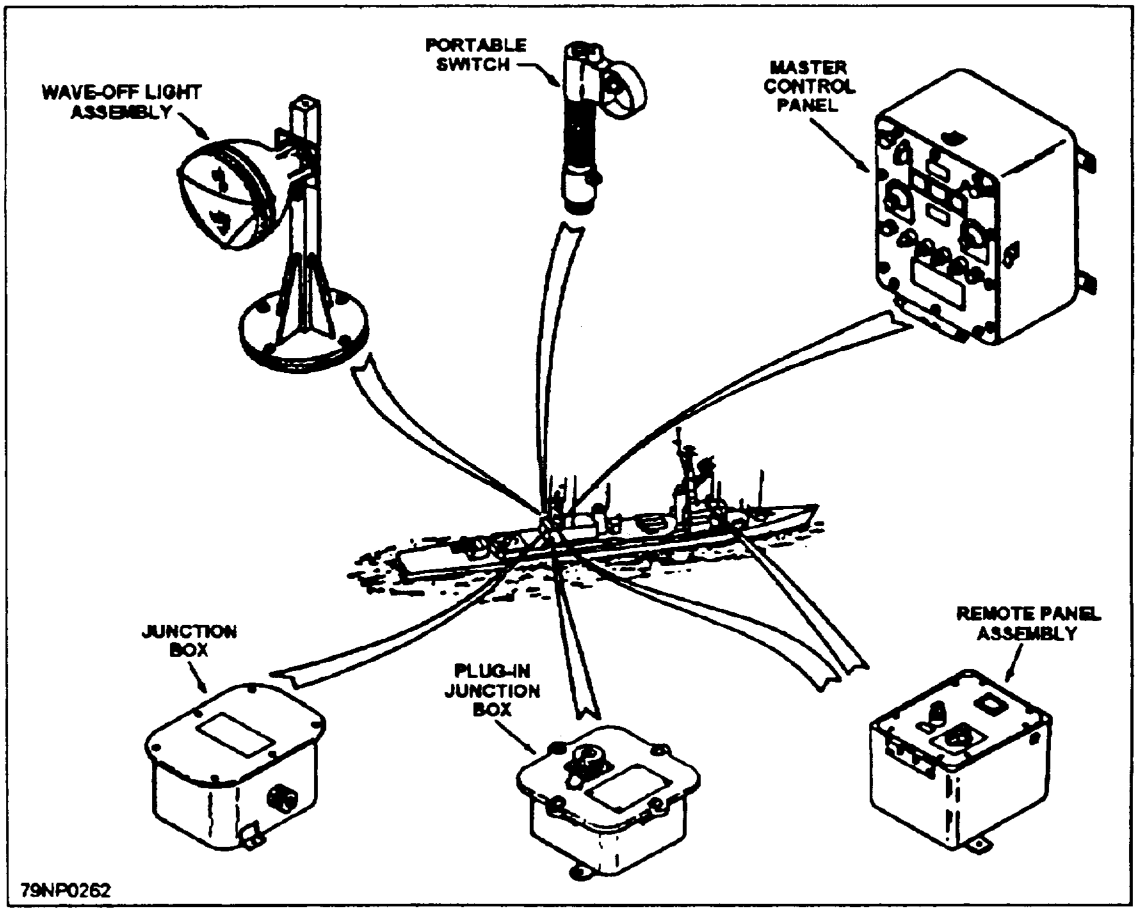


Figure 12-21.—Wave-off light system.

MASTER CONTROL PANEL

The master control panel (fig. 12-22) is located in the Helicopter Control Station. It controls the power for the WOL, houses the electronic circuitry which controls intensity and flash rate of the WOL, permits operation of the WOL, and indicates which station has control.

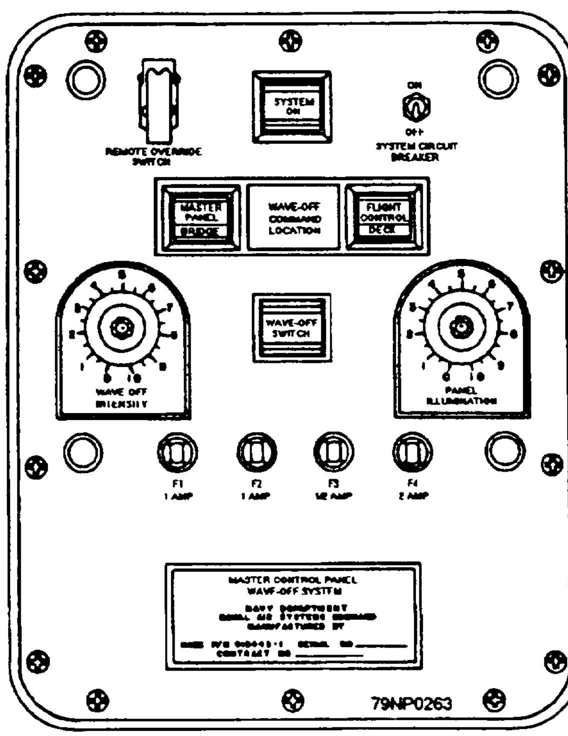


Figure 12-22.—Master control panel.

REMOTE PANEL ASSEMBLY

The remote panel assembly (fig. 12-23) allows the WOL to be operated from remote stations located at the captain's bridge and adjacent to the hanger door.

PLUG-IN JUNCTION BOX ASSEMBLY

Two plug-in junction boxes are contained in one assembly. The junction boxes are located one on either side of the hangar door to permit a plug in of a portable switch to operate the WOL on the flight deck by the landing signalman enlisted (LSE).

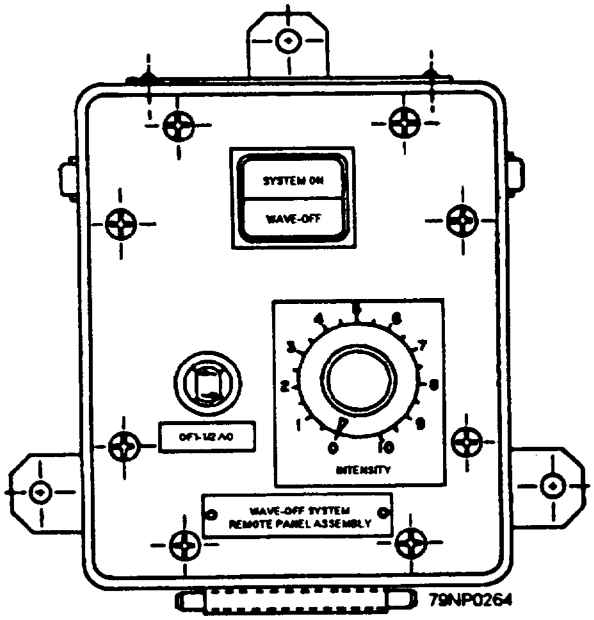


Figure 12-23.—Remote panel assembly.

TERMINAL JUNCTION BOX ASSEMBLY

The terminal junction box assembly contains the terminals for the connections to the WOL and the master control panel.

WAVE-OFF LIGHT ASSEMBLY

The wave-off lights are located on each side of the GSI. Figure 12-24 shows interconnection of the WOL system.

HELICOPTER IN-FLIGHT REFUELING LIGHTS (HIFR)

Helicopter in-flight refueling lights are yellow (red if at war or other conditions where reduced visibility is required) and are required for helicopter refueling

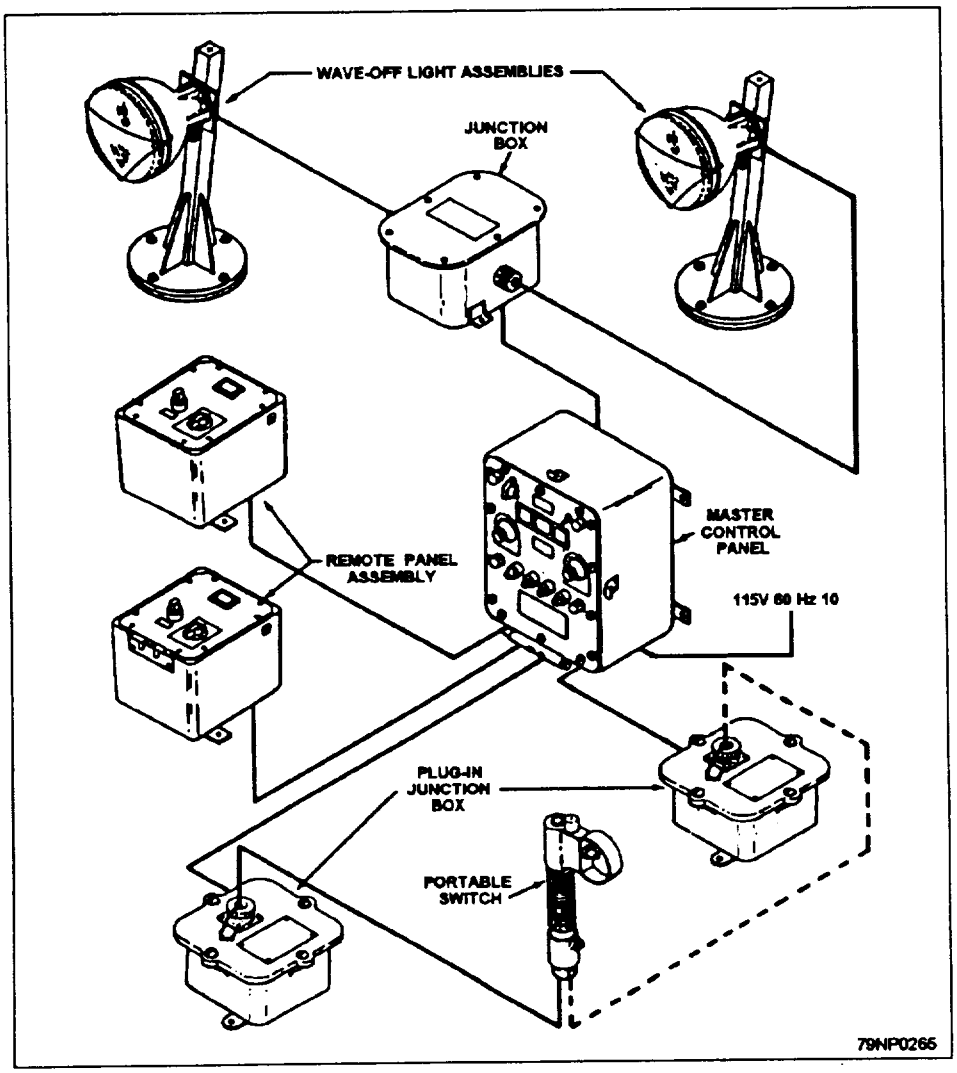


Figure 12-24.—Wave-off light system.

operations. These lights give the helicopter pilot a visual indication of the ship's heading at all times and provide a height reference during in-flight refueling operations.

Three HIFR heading lights are installed forward to aft on the port side of the ship in a line parallel to the ship's centerline (heading). Spacing between the lights is approximately 20 feet, beginning outside the rotor clearance distance and extending forward. All HIFR heading lights are installed at the same height, approximately 30 to 40 feet above the ship's waterline. All lights are controlled by a single on/off switch, located on the lighting control panel, and area standard watertight assembly consisting of a lighting fixture, yellow globe, and a 115-volt, 50-watt rough service lamp.

VERTICAL REPLENISHMENT (VERTREP) LIGHTS

VERTREP line-up lights are bidirectional fixtures for VERTREP/hover approaches, and they form an athwartship line-up path at approximately 8- to 12-foot intervals. Spacing between lights is uniform and such that the pilot's view of the lights is not obstructed during the helicopter's approach. When installed in landing areas equipped with landing approach line-up lights, the VERTREP line-up lights are connected to the same dimmer as the landing approach line-up lights. This switching arrangement prevents the simultaneous energizing of both the landing approach line-up lights and the VERTREP/hover line-up lights.

LIGHTING CONTROL PANEL

The lighting control panel (fig. 12-25) that controls the lights in the VLA package is installed on all ships

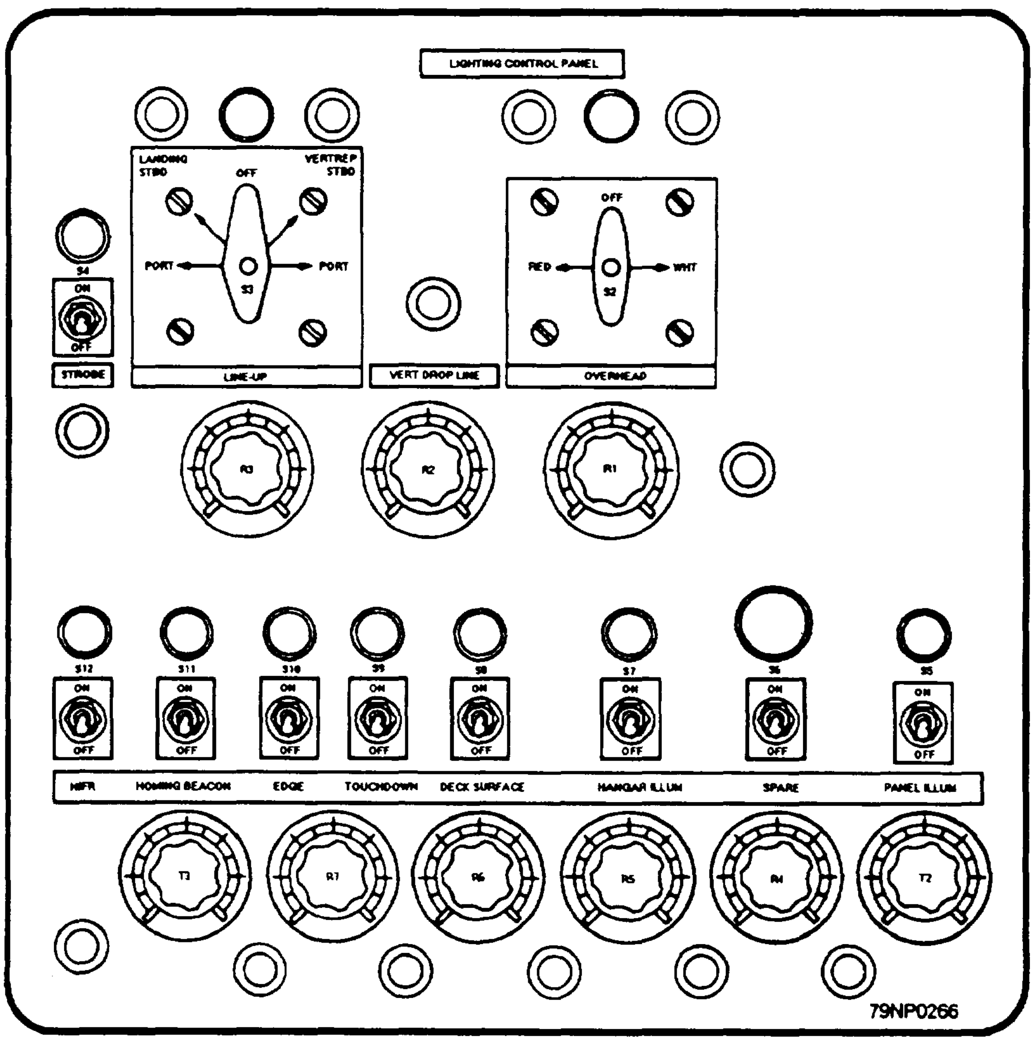


Figure 12-25.—Lighting control panel.

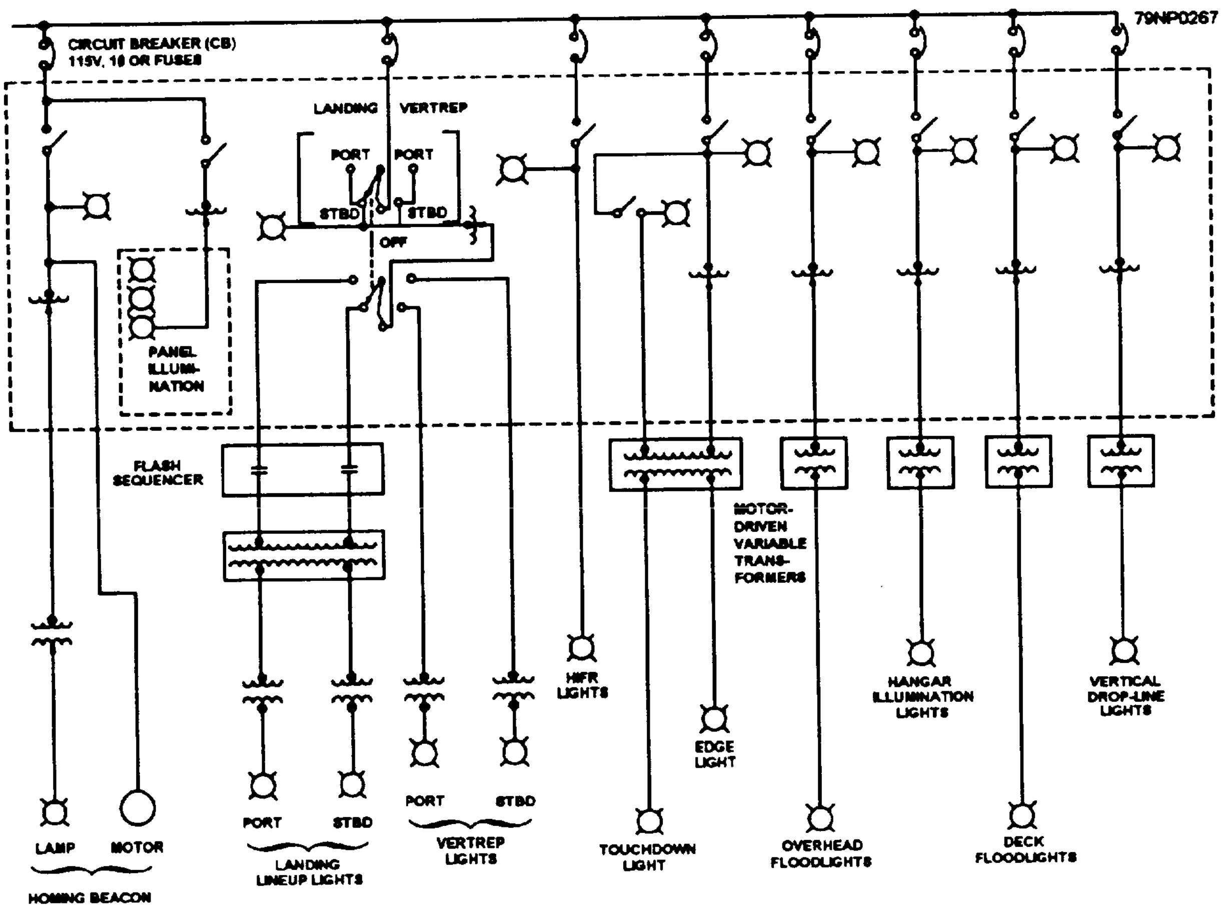


figure 12-26.—Simplified line diagram of the lighting control panel.

which conduct helicopter operations at night. This control panel is located at the helicopter control station and consists of switches, dimmers, and red indicator lamps. The dimmers are variable autotransformers mounted in the control panel. The lighting control panel requires input power at 120 volt, 60 Hz and is designed to accommodate the applicable light equipment discussed in the preceding paragraphs. Figure 12-26 is a simplified line diagram of the lighting control panel.

MOTOR-DRIVEN VARIABLE TRANSFORMERS

Motor-driven remote variable transformers (fig. 12-27) are used in the VLA lighting control system to control the intensity of the various lights. There are four 10-ampere and two 22-ampere transformers in the system. The 22-ampere transformers are used with the overhead and deck-surface floodlights and the 10-ampere transformers are used with the following lights:

1. Hangar illumination floodlights
2. Line-up lights
3. Vertical drop-line lights
4. Edge lights

Input power is applied to the variable transformer, and the controlled 0- to 120-volt-ac output is connected

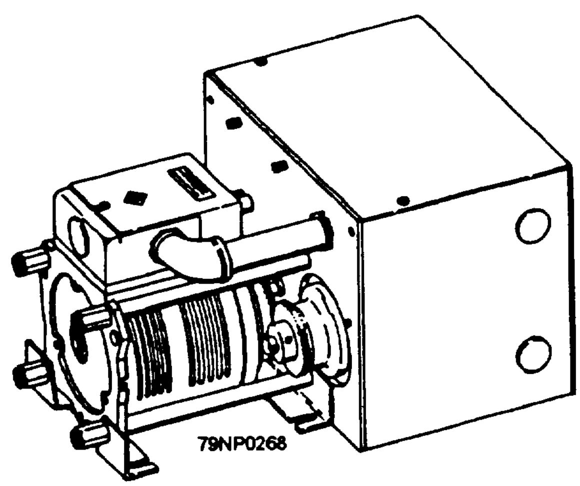


Figure 12-27.—Motor-driven variable transformer.

to the lights (fig. 12-28). The transformer wiper (secondary) is moved by the synchronous motor which is controlled by the potentiometer in the lighting control panel. The detector circuit in the position detector determines from the setting of the remote control potentiometer whether the motor turns in a direction to raise or lower the output voltage.

The reference power supply in the position detector converts ac input voltage to dc, and the potentiometer in the control panel determines the magnitude of dc reference voltage sent to the detector circuit. The feedback power supply in the position detector converts the ac output voltage from the variable transformer to a proportional dc voltage which is also sent to the detector circuit.

The detector circuit consists of a comparator and solid state switches (TRIACS) which energize either the clockwise (LOWER) or counterclockwise (RAISE) windings of the drive motor. The drive motor rotates the wiper shaft on the transformer in the proper direction until the feedback voltage equals the reference, and the motor stops at a position corresponding to the desired light intensity. Cam-operated limit switches open the motor circuit and prevent the motor from driving the wiper on the transformer beyond the upper and lower stops.

MAINTENANCE REQUIREMENTS

The VLA system contains many electrical and electronic components which require both preventive and corrective maintenance. The components that we have discussed in this chapter contain many motors, controllers, blowers, heaters, pressure switches, and lighting fixtures that are exposed to weather. The electronic portions are solid state and are primarily on printed circuit boards. As an Electrician's Mate you can realize some of the problems which will be encountered both with electrical and electronic parts. It is of utmost importance that you follow all PMS requirements carefully to keep all portions of this system operating

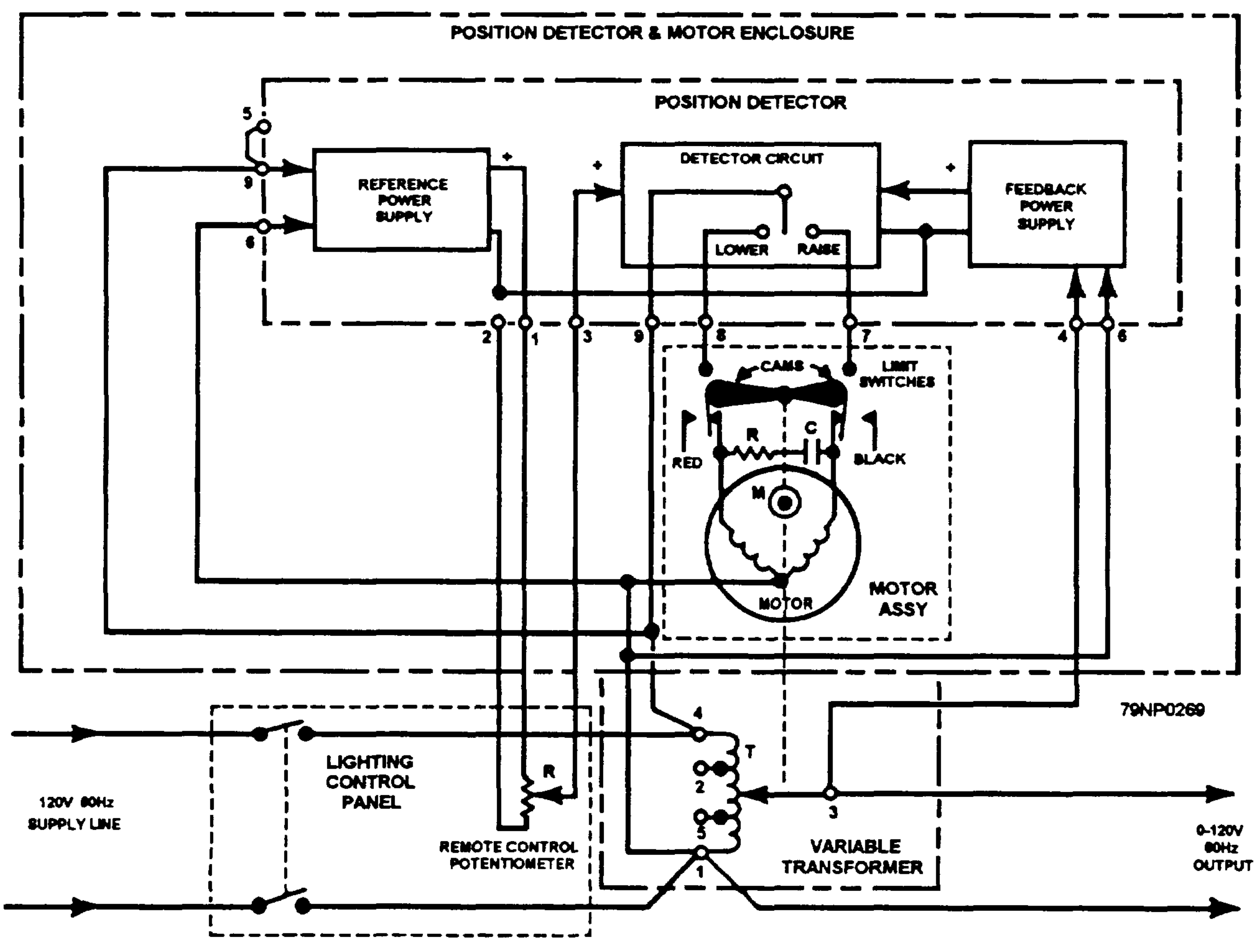


Figure 12-28.—Motor-driven remote variable transformer circuit diagram.

effectively. When performing any corrective action, always refer to the manufacturer's technical manuals.

SUMMARY

Now that you have completed this chapter, you should have a good comprehension of the various lighting systems installed on U.S. Navy air capable ships. Remember, just as we have different classes of ships, we have different types of lighting systems. As an E-6 or E-7 you may be required to supervise the maintenance of several different systems. Always refer to the correct technical manual for that particular ship.

CHAPTER 13

ENGINEERING PLANT OPERATIONS, MAINTENANCE, AND INSPECTIONS

In today's environment of decreasing resources and manpower, it is essential that equipment be well maintained and people be properly trained. This chapter will give you some idea of the scope of activity required to keep today's engineering plant operable and ready.

LEARNING OBJECTIVES

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

1. *Identify the various forms, records and reports required to operate an engineering plant.*
2. *Recognize the need for preventive maintenance.*
3. *Identify the various forms used in reporting and tracking maintenance actions.*
4. *Identify the various types of inspections conducted and realize their importance.*
5. *List the various ship trials conducted.*
6. *Identify the responsibilities of various members in and out of the command for enforcing safety guidelines.*

Although it is possible to consider operations, maintenance, and inspections as three separate areas of responsibility, it is important to remember that the three cannot be totally separated. Much of your work requires you to operate equipment, maintain it for further use, and keep auditable records on the equipment.

ENGINEERING PLANT OPERATIONS

The primary goal of a ship is to get underway. In meeting that objective, the engineering department functions to ensure that the engineering plant is fully functional, can be safely operated, and adequate watch teams are trained and qualified.

As a member of the engineering department, you will be responsible for ensuring that the equipment under your cognizance is ready to support the ship in getting underway. Once underway, the engineering department continues its job of monitoring, maintaining, and operating the various equipment needed to keep the ship functional.

OPERATION RESPONSIBILITIES

The engineering department administrative organization is set up to provide the proper assignment of duties and supervision of personnel. Personnel, including yourself, are needed to ensure that all pertinent instructions are carried out and that all machinery, equipment, and electrical systems are operated following good engineering practices. Other responsibilities include the posting of instructions and safety precautions by operational equipment and ensuring that they are obeyed by all personnel. WatchStanders must be properly supervised to ensure that the entire engineering plant is operated with maximum reliability, efficiency, and safety.

For you to monitor and record your plant's status and performance, you need to know which engineering records and reports are required. Reports regarding administration, maintenance, and repair of naval ships are prescribed by directives from authorities such as the Type Commander, Naval Ship Systems Command (NAVSEA) and the Chief of Naval Operations (CNO). These records must be accurate and up to date following current instructions.

As an EM1 or EMC, you will have supervisory duties that require you to have a greater knowledge of engineering records and administrative procedures than you had as an EM3 or EM2. Supervisory duties and responsibilities require a knowledge of engineering records as well as inspections, administrative procedures, training, preventive maintenance, and repair procedures.

Information on the most common engineering records and reports is given in this chapter. These standard forms are prepared by the various systems commands and CNO. The forms are for issue to forces afloat and can be obtained as indicated in *the Navy Stock List of Publications and Forms,* NAVSUP 2002. Since these forms are revised periodically, you must be sure that you are using the most current version. When complementary forms are necessary for local use, make sure that an existing standard form will serve the purpose.

OPERATING RECORDS

In operating equipment, care must be taken to ensure that the equipment is operated within guidelines or boundaries established by the manufacturer. Operating records (logs) allow for tracking the condition of equipment and tracking the number of hours of operation. These are legal records and must be maintained as described.

Engineering Log

The Engineering Log, NAVSEA 3120/2 (fig. 13-1), and the Log Continuation Sheet, NAVSEA 3120/2, are used to record important daily events and data pertaining to an engineering department and the operation of an engineering plant. A table is provided in the log for recording the hourly average rpm (to the nearest tenth) of all shafts and the resultant speed in knots. Additional tables and spaces are provided for recording the information that is listed below.

1. Name of the ship.
2. Date.
3. Ship's draft and displacement (upon getting under way and anchoring or mooring).
4. Total engine miles steamed for the day and the distance traveled through water.
5. Number of days out of dock.
6. Amount of fuel, water, and lubricating oil on hand, received and expended.
7. Location or route of the ship.
8. Remarks relating to important events. Remarks written in the Engineering Log must include the following information
   a. Boilers in use
   b. Engine combination in use
   c. Major speed changes (such as 1/3, 2/3, standard, and full)
   d. All injuries to personnel occurring within the department
   e. Casualties occurring to material under the responsibility of the engineering department
   f. Such other matters as may be specified by competent authority

Each entry must be a complete statement and must be written using standard phraseology. The TYCOM's directives contain other specific requirements pertaining to the remarks section of Engineering Logs for ships of the type. The engineering officer must ensure compliance with these directives.

Entries in the Engineering Log must be made following instructions given in the following documents:

- The Log Sheet, NAVSEA 3120/2B
- *U.S. Navy Regulations,* chapter 10
- *Naval Ship's Technical Manual,* chapter 090
- TYCOM directives

The original Engineering Log is a legal record. As such, it must be prepared neatly and legibly. The remarks should be prepared, **and must be signed,** by the engineering officer of the watch (EOOW) (underway) or the engineering department duty officer (in port). **No erasures are permitted in the log.** When a correction is necessary, a single line is drawn through the original entry so that the entry remains legible. The correct entry is then inserted so clarity and legibility are maintained. Corrections, additions, or changes are made only by the person required to sign the log for the watch. Corrections are initialed on the margin of the page.

The engineering officer verifies the accuracy and completeness of all entries and signs the log daily. The CO approves and signs the log on the last calendar day of each month and on the date his/her command is relinquished. The engineering officer should require the log sheets be submitted in sufficient time to allow his/her review and signature before noon of the first day following the date of the log sheet(s).

When the CO (or engineering officer) directs a change or addition to the Engineering Log, the person concerned must comply unless he/she believes the proposed change or addition to be incorrect In this event, the CO (or engineering officer) enters such remarks over his signature as deemed appropriate. After the log has been signed by the CO, no change is permitted without the CO's permission or direction.

Completed Engineering Log sheets are filed in a post-type binder. Pages of the log are numbered

ENGINEERING LOG
NAVSEA 3120/2B (REV. 10-81 S/N 0166-LF-031-2115 (9-77 EDITION IS OBSOLETE) CLASSIFICATION

U.S.S.					HULL NUMBER
CONCORD					AFS-5
DAY	MONTH	YEAR	TIME ZONE	TIME ZONE CHANGE TO	TIME ZONE CHANGE FROM
Ø4	APR	1994	+4Z		

AT/PASSAGE FROM	PASSAGE TO	TOTAL MILES TRAVELED TODAY
SEA	SEA	4ØØ

EQUIPMENT STATUS *(Need not be completed for continuing pages)*

MAIN ENGINES	PLANT STATUS	BOILERS
1	CROSS-CONNECTED	1 and 2

GENERATORS	STEERING ENGINES COMBINATION
1 and 3	PORT UNIT/PORT CABLE

DAYS OUT OF DRY DOCK	CATAPULT STATUS *(CV's only)*	DAYS SINCE LAST HULL CLEANING
4Ø		4Ø

DRAFT FWD	DRAFT AFT	DRAFT MEAN	TONS
16' 5"	2Ø' 2"	17' 4"	2Ø,2ØØ

LIQUID LOAD	PERCENT OF FULL LOAD (%)
9Ø%	

MAJOR EQUIPMENT OUT OF COMMISION
#1 L.P. AIR COMPRESSOR

EXAMINED DAILY AND CERTIFIED TO BE CORRECT

SIGNATURE OF ENGINEER OFFICER/RANK	DATE OF SIGNATURE

TIME	RECORD OF ALL EVENTS OF THE DAY (DAY 04, MONTH APR, YEAR 1994)
ØØ12	STARTED NO. 1 MAIN CONDENSATE PUMP, SECURED NO. 2 MAIN CONDENSATE PUMP
ØØ15	STARTED NO. 1 MAIN FEED PUMP, SECURED NO. 2 MAIN FEED PUMP

CLASSIFICATION PAGE NO.

(LEAVE BACK SIDE BLANK)

86NP0195

Figure 13-1.—Engineering Log—all ships.

ENGINEER'S BELL BOOK - ALL VESSELS
NAVSEA 3120/1
(formerly NAVSHIPS 3120/1)

ENGINEER'S BELL BOOK

		SHIP TYPE		HULL NUMBER	SHEET SERIAL	YEAR	MONTH	ZONE	DAY
D	A	A F	S	Ø Ø 5	Ø 1	4	Ø 4	Z	Ø 4
1	2	3 - 4		5 - 7	10 - 11	12	13 14	15	16 17

CONCORD
Ship Name

J
22

SHAFT NUMBER(S)	CLASS	HANDL
O N E	Z	Z
74 16 17 16 77	78	79

Record of all "BELLS," SIGNALS and ORDERS received regarding movement of propellers this date.

En route from SEA to SEA Clocks set back or ahead ______ hrs. ______ min., at ______

(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET	(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET	(1) TIME	(2) SIGNAL	(3) R.P.M.	(4) COUNTER OR PITCH SET
ØØØØ	CTR		925475								
ØØ1Ø	1/3	25	926415								
ØØ13	2/3	5Ø	92665Ø								

S/N 0116-LF-031-2000

86NP0196

Figure 13-2.—Engineer's Bell Book, NAVSEA 3120/1.

consecutively with a new series of page numbers beginning on the first day of each month

Engineer's Bell Book, NAVSEA 3120/1

The Engineer's Bell Book (fig. 13-2) is a record of all bells, signals, and other orders received by the throttleman regarding movement of the ship's propellers. Entries are made in the Bell Book by the throttleman (or an assistant) as soon as an order is received Entries may be made by an assistant when the ship is entering or leaving port or engaging in any maneuver which is likely to involve numerous or rapid speed changes. This procedure allows the throttleman to devote undivided attention to answering the signals. The Bell Book is maintained as shown in figure 13-3.

On ships and craft equipped with controllable reversible pitch propellers, the propeller pitch is recorded in column 4 in feed and fractions of feet. These are set in response to a signaled speed change, rather than the shaft revolution counter readings. The entries for astern pitch are preceded by the letter B. Each hour on the hour, entries are made of counter readings. This facilitates the calculation of engine miles steamed during those hours when the propeller pitch remains constant at the last value set in response to a signaled order.

Before going off watch, the EOOW signs the Bell Book on the line following the last entry for the watch. The next EOOW continues the record immediately thereafter. In machinery spaces where an EOOW is not stationed, the bell sheet is signed by the watch supervisor.

The Bell Book is maintained by bridge personnel in ships and craft equipped with controllable reversible

---

1. A separate bell sheet is used for each shaft each day, except where more than one shaft is controlled by the same throttle station. In this case, the same bell sheet is used to record the orders for all shafts controlled by the station. All sheets for the same date are filed together as a signal record.

2. The time of receipt of the order is recorded in column No. 1 (fig. 13-2).

3. The order received is recorded in column No. 2. Minor speed changes (generally received via revolution telegraph) are recorded by entering the number of rpm ordered. Major speed changes (normally received via engine order telegraph) are recorded using the following symbols:

Order	Entry
ahead 1/3 speed	1/3
ahead 2/3 speed	2/3
ahead standard speed	I
ahead full speed	II
ahead flank speed	III
stop	Z
back 1/3 speed	B 1/3
back 2/3 speed	B 2/3
back full speed	BF
back emergency speed	BEM

4. The number of revolutions corresponding to the major speed change ordered is entered in column 3.

NOTE: When the order received is recorded as rpm in column 2 (minor speed changes), no entry is made in column 3.

5. The shaft revolution counter reading (total rpm) at the time of the speed change is recorded in column 4. The shaft revolution counter reading—as taken hourly on the hour, while under way—also is entered in column 4.

Figure 13-3.—Maintaining the Engineer's Bell Book

pitch propellers and in which the engines are directly controlled from the bridge. When control is shifted to the engine room, however, the Bell Book is maintained by the engine room personnel. The last entry made in the Bell Book on the bridge indicates the time that control is shifted. The first entry made in the Bell Book in the engine room indicates the time that control is taken by the engine room. Similarly, the last entry made by the engine room personnel indicates when control is shifted to the bridge. When the Bell Book is maintained by the bridge personnel, it is signed by the officer of the

NAVSEA 9255/9 (1-79) (Front)
(Formerly NAVSEA 9510/1)

FUEL AND WATER REPORT

DATE 12 MAY 1995

TO: COMMANDING OFFICER, USS FRIGATE (FF-11ØØ)

	FUEL (GALLONS)		LUBE OIL (GALLONS)	WATER (GALLONS)	
	BOILER FUEL	DIESEL FUEL	STORAGE TANKS	POTABLE	RESERVE FEED
ON HAND LAST REPORT	224,ØØØ	15,2ØØ	1,5ØØ	9,Ø5Ø	9,Ø8Ø
RECEIVED (+)	Ø	Ø	Ø	Ø	Ø
DISTILLED (+)				7,Ø5Ø	1Ø,Ø7Ø
EXPENDED (-)	2Ø,2ØØ	Ø	1ØØ	6,8ØØ	8,57Ø
GAIN (+) LOSS (-) BY INVENTORY	+4ØØ	-2ØØ	Ø	Ø	Ø
ON HAND THIS REPORT	2Ø4,2ØØ	15,ØØØ	1,4ØØ	9,3ØØ	1Ø,58Ø
ON HAND %	91	76	7Ø	93	91

TRANSFERS/RECEIPTS (FUEL, LUBE OIL, OR WATER)
OIL
FROM ________ HRS TO ________ HRS AMOUNT (GAL) ________ SOURCE ________
WATER
FROM ________ HRS TO ________ HRS AMOUNT (GAL) ________ SOURCE ________

POTABLE WATER RECORD		
PERSONNEL ON BOARD	GALLONS USED PER PERSON	STANDARD
243	28	27

FEEDWATER CONSUMPTION	
NOT UNDERWAY (GALLONS PER HOUR)	UNDERWAY (GALLONS PER HOUR)
	357

REMARKS: Boiler water pH and phosphate low due to FWDCT contamination. Conductivity high because treated to restore pH and phosphate prior to blowdown for contamination.

DFT salinity indicator reading high due to FWDCT contamination.

Feedwater pH low due to undertreatment.

Stripped JP-5 service tank.

86NP0197

Figure 13-4.—Fuel and Water Report (front).

deck (OOD) in the same manner as prescribed for the EOOW.

Alterations or erasures are not permitted in the Bell Book. An incorrect entry is corrected by drawing a single line through the entry and recording the correct entry on the following line. Deleted entries are initialed by the EOOW, the OOD, or the watch supervisor, as appropriate.

Fuel and Water Reports, NAVSEA 9255/9

The Fuel and Water Report (figs. 13-4 and 13-5), is a report submitted daily to the commanding officer.

NAVSEA 9255/9 (1-79) (BACK)

BOILER WATER CONDITIONS

RECORD THE BOILER WATER TEST RESULTS IN THE DESIGNATED SPACES. RESULTS NOT WITHIN LIMITS MUST BE CIRCLED IN RED AND EXPLAINED IN REMARKS ON THE FRONT OF THIS REPORT.

HOURS SINCE CLEANING				LAST SAMPLE				RANGE OF RESULT					LAYUP CODE	TOTAL STEAMING HOURS
BLR NO.	FIRE-SIDE	WATER-SIDE (MECH)	WATER-SIDE (CHEM)	pH	COND.	PHOS-PHATE	CHLOR-IDE		pH	COND.	PHOS-PHATE	CHLOR-IDE		
1A	1Ø28.5	1Ø37.5	5972.6	1Ø.12	315	45.Ø	1.32	MAX	1Ø.19	51Ø	5Ø	2.52		48.5
								MIN	9.41	85	17.5	.12		
1B	1Ø99.1	1Ø77.1	5894.3					MAX					STM	Ø
								MIN						
								MAX						
								MIN						
								MAX						
								MIN						
								MAX						
								MIN						
								MAX						
								MIN						
								MAX						
								MIN						
								MAX						
								MIN						

DEAERATED FEEDWATER CONDITIONS

SYSTEM		DISSOLVED OXYGEN (PPB)				SALINITY INDICATOR (EPM CHLORIDE)				pH			
		1	2	3	4	1	2	3	4	1	2	3	4
RANGE OF RESULTS	MAX	1Ø				.Ø5				8.99			
	MIN					.Ø1				8.46			

BOILER WATER LIMITS:

	TYPE A	TYPE B
pH	10.20 - 10.60	9.80 - 10.20
CONDUCTIVITY (µMHOS/CM)	600 MAX	400 MAX
PHOSPHATE (PPM)	50 - 120	25 - 60
CHLORIDE (EPM)	NOTE 1	NOTE 1

NOTE 1: SHOULD NOT NORMALLY EXCEED 1.00 EPM (CONTAMINATION NOT OCCURRING)

FEEDWATER LIMITS:

	ALL SHIPS
DISSOLVED OXYGEN (PPB)	15 PPB BY METER, 15 PPB BY CHEMICAL TEST
SALINITY (EPM CHLORIDE)	0.02
pH	8.60 - 9.00

BOILER LAYUP

DRY
- DES DESICCANT
- HTD HEATED AIR

WET
- STM 150 PSI STEAM (SHIP)
- STS 150 PSI STEAM (SHORE)
- NIT NITROGEN
- DFT HOT DFW FILL
- HYD HYDRAZINE

PREPARED BY: (OIL KING) BT1 Flash A. Brush	REVIEWED: (MPA) Lt. John Doe	REVIEWED: (ENGINEER OFFICER) Jack Frost

86NP0198

Figure 13-5.—Fuel and Water Report (back).

This report indicates the amount of fuel oil and water on hand as of midnight, the previous day. The Fuel and Water Report also includes the previous day's feed and potable water performance and results of water tests. The original and one copy are submitted to the OOD in sufficient time for submission to the commanding officer or command duty officer with the 1200 reports.

Monthly Summary, CINCLANTFLT 3100-4

The Monthly Summary of Fuel Inventory and Steaming Hours Report is a comprehensive monthly report of engineering data. From this report the operating efficiency and general performance of the ship's engineering plant can be calculated (see fig. 13-6). Requirements for this report are contained in Fleet Commander Instructions. This report is prepared by the engineer officer and verified, as to fuel receipts, by the supply officer. It is then approved and fowarded by the CO directly to the fleet commander. A copy is retained on board in the files of the engineering department. An additional copy of the report may be provided to the type commander.

MONTHLY SUMMARY OF FUEL INVENTORY AND STEAMING HOURS REPORT
LANTFLT 3100/1 (Rev. 7/73) 0109-LF-6311-0011

CINCLANTFLT REPORT 3100-4
(No letter of transmittal required. Submit by 3rd of following month.)

FROM (Name, type, hull no.)		UIC	MONTH/YEAR
USS FRIGATE FF-1100		12347	04/84
TO COMMANDER IN CHIEF U.S. ATLANTIC FLEET (CODE 042) NORFOLK, VA. 23511	MAIN PROPULSION FUEL TYPE (Check one) ☐ NSFO ☐ JP-5 ☐ DIESEL ☒ DISTILLATE	OPR CDR CODE (SEE REVERSE)	DAYS UNDERWAY

	NAFO (GALLONS)	DIESEL (GALLONS)	JP-5 (GALLONS)	DISTILLATE (GALLONS)
FUEL INVENTORY ON BOARD BEGINNING OF MONTH			6,525	173,500
RECEIPTS DURING MONTH (+)			2,500	64,700
GAIN BY INVENTORY (+)			0	1,000
LOSS BY INVENTORY, STRIPPING, CONTAMINATION (-)			75	0
TOTAL MONTHLY DELIVERIES TO SHIP, HELO, ETC. (-)			1,300	0
FUEL CONSUMED UNDERWAY (-)			0	71,300
FUEL CONSUMED NO UNDERWAY (-)			0	5,900
FUEL CONSUMED FOR BOATS, AUX. ETC. (-)			60	0
FUEL INVENTORY ON BOARD END OF MONTH (Bal)			7,590	162,000

	STEAMING UNDERWAY	STEAMING NOT UNDERWAY	NOT UNDERWAY COLD IRON	TOTAL HOURS FOR MONTH
HOURS	224	24	472	720

FUEL RECEIPTS - DETAIL FROM ISSUING SHIP OR SHORE ACTIVITY

Date	From	Type	Gallons
4-2-84	YO-241	JP5	2,500
4-09-84	AO-177	Dist	64,700

FUEL DELIVERIES - DETAIL AND DOCUMENT NUMBERS

Date	To	Type	Gallons
4-7	TWR-1, N4200-NI-0960	JP5	100
4-8	HSL 37, DET 2 N 4600-N2-1073	JP5	1,200

SUBMITTED	RECEIPTS/DELIVERIES VERIFIED	FORWARDED APPROVED
LT USN	USN	CDR, USNR
CHIEF ENGINEER	SUPPLY OFFICER	COMMANDING OFFICER

86NP0199

Figure 13-6.—Monthly Summary of Fuel and Steaming Hours Report, CINCLANTFLT Report 3100-4.

AC/DC Electric Propulsion Operating Record, NAVSEC 9622/1

The AC/DC Electric Repulsion Operating Record, NAVSEC 9622/1, is a daily record for each operating propulsion generator and motor in ships (except submarines) equipped with ac or dc electric propulsion machinery. A separate sheet is used for each shaft, except on ships with more than two generators or two motors per shaft. In this case, as many sheets as needed are used.

Information is entered in the record and the remarks are written and signed by the EM of the watch. Accuracy is checked by the EM in charge of the electric propulsion equipment and the electrical officer. Space is provided on the record for the approval and signature of the engineer officer on a daily basis.

Electrical Log, NAVSEC 9600/1

The Electrical Log (fig. 13-7) is a complete daily record maintained for each operating ship's service and

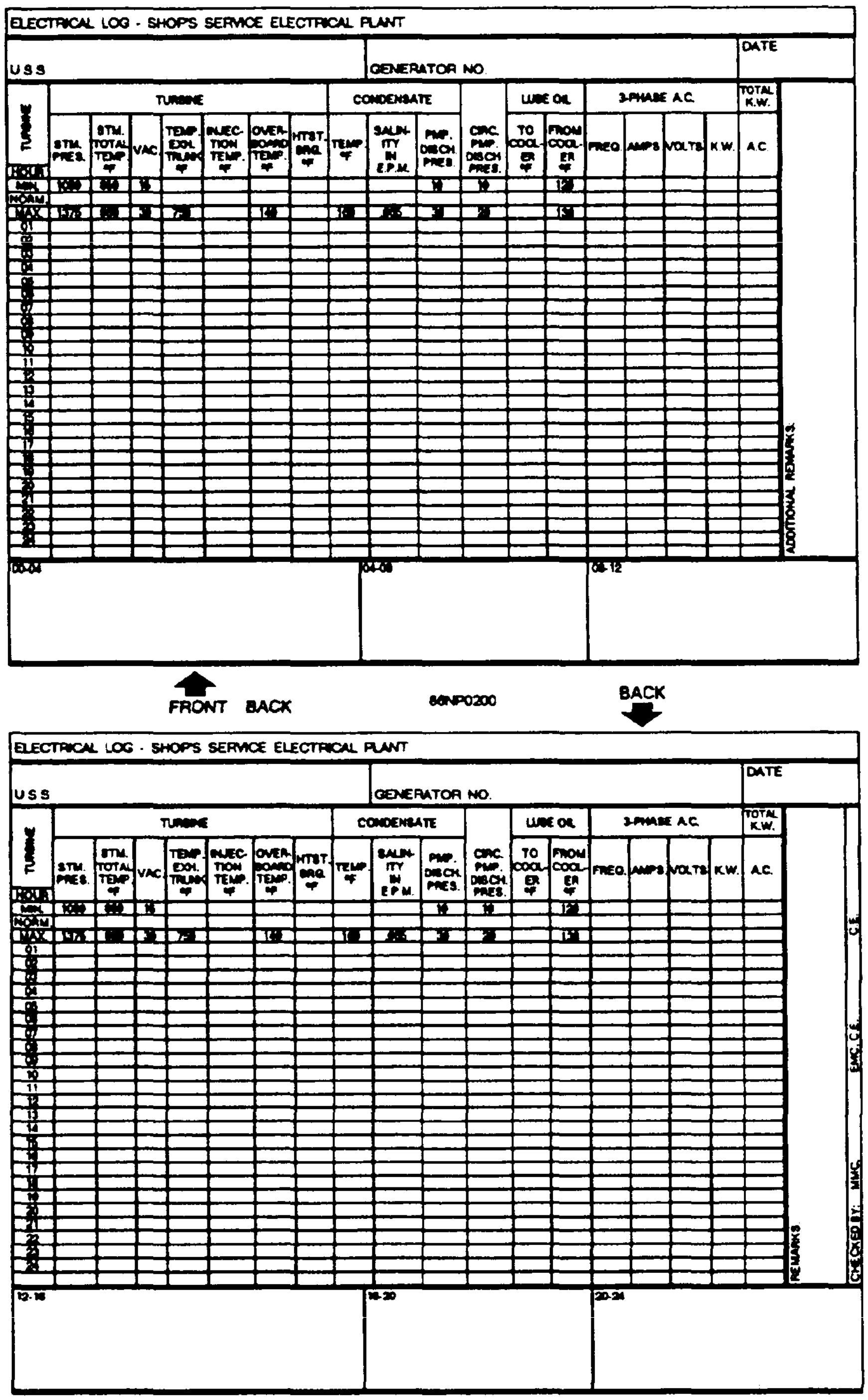


Figure 13-7.—Electrical Log—Ship's Service Electric Plant.

emergency generator. It is a complete daily record (from midnight to midnight) of the operating conditions of the ship's service electric plant. Any corrections or changes to entries for a watch must be made by the person who signs the log for that watch. However, corrections or additions must not be made after the log sheet has been signed by the engineering officer without his or her permission or direction. The station logs are turned into the logroom every morning for the engineering officer's signature and for filing.

The back of the log is a continuation of the front, and it also provides spaces for the engineering officer's and senior Electrician's Mate's signatures. Entries concerning the prime movers are generally recorded by the generator watch (MM). Electrical information is recorded by the switchboard watch (EM) who signs the remarks for the watch.

The accuracy of the entries is checked by the EM in charge of the ship's service generators. Both the M and E division officers check the record for accuracy and any evidence of impending casualties. Each officer initials the record to indicate that it has been checked. The engineering officer notes the content and signs the record in the space provided on a daily basis.

Gyrocompass Operating Record

The Gyrocompass Operating Record (Gyrocompass Log) is a locally prepared, complete daily record maintained for each operating master gyrocompass. The form for the log is prepared following the type commander's directives. Columns in the log should provide space for recording the times of starting and stopping the gyrocompass, total hours of operation since delivery of the gyrocompass, and important operating data pertaining to the gyrocompass installation. The petty officer in charge of the interior communications (IC) equipment checks the accuracy of the log, and the electrical officer notes its contents on a daily basis.

IC Room Operating Record

The IC room operating record is a daily record of major electrical equipment in operation in the IC room and is maintained by the IC watch. The form for the record is prepared locally following the type commander's directives. On small ships the Gyrocompass Log and the IC room record may be maintained on the same form. Important data such as voltages and currents of major units of IC equipment (IC switchboard, telephone switchboard, and motor generator sets) should be recorded on the form. The IC room operating record is checked and approved in the manner described for the Gyrocompass Operating Record.

ADDITIONAL RECORDS

The engineering records and reports discussed in this section serve to inform responsible personnel of coming events (including impending casualties), supply data for the analysis of equipment performance, and provide a basis for design comparison and improvement. They also provide information for the improvement of maintenance techniques and the development of new work methods. The records are those papers required to be compiled and retained on board (in original or duplicate form) for prescribed periods of time. This is primarily for reference in administrative and operational matters. The reports are of either a onetime or recurring nature. Recurring reports are required at prescribed or set intervals. Onetime reports need be made when a given situation occurs.

Engineering Officer's Night Order Book

The engineering officer keeps a Night Order Book (fig. 13-8) which is preserved as a part of the engineering records. Entered into the Night Order Book are the engineer officer's orders with respect to the following:

1. Operation of the engineering plant
2. Any special orders or precautions concerning the speed and operation of the main engines
3. All other orders for the night for the EOOW.

The Night Order Book is prepared and maintained following instructions issued by the type commander. Some instructions specify that the Night Order Book use a specific format that is standard for ships of the type. Other commands allow use of a locally prepared form **but** specify certain contents of the book

The Engineering Officr's Night Order Book must contain orders covering routine situations of a recurring nature (engineering department standing orders) as well as orders for the night for the EOOW. Standing orders are issued by the engineer officer as a letter-type directive (instruction) following the ship's directives system. A copy of the instruction is posted in the front of the Night Order Book Orders for the night for the EOOW generally specify the boilers and other major items of machinery to be used during the night watches.

ENGINEER OFFICER'S NIGHT ORDERS Date 6 JUNE 19 --

USS SAMPLE (CAG-132)

At or enroute from NAPLES, ITALY to GENOA, ITALY

Standard speed is 15 knots 141 rpm, or as ordered.

Anticipated speed changes: ______ knots at ______ : ______ at ______

Be prepared for ______ knots with Boilers ______ at ______

Boilers in use 1 AND 4 ; Standby Boilders 2 AND 3

Sprayer plates in use: (saturated side) 17/2 ; (superheater) 17/2

Standby sprayer plates: (saturated side) 36/2 ; (superheater) 36/2

Operate with engineering plant SPLIT and superheaters lighted/~~secured~~

Maintain main steam temperature at 825° F. in accordance with superheat control policy in standing night orders.

Operate ship's service generators 1 AND 4 ; generators 2 AND 3 in standby condition.

Evaporators 1 AND 2 distill to ship's tanks/~~reserve feed banks~~ until 0200 and then shift to RFT

Carry out standing night orders published in the front of this book.

REMARKS:

CARRY OUT NORMAL STEAMING WATCH ROUTINE AND KEEP BILGES DRY. CALL ME AT 0600 IF NOT NEEDED THERETOFORE.

In case of trouble or doubt, call me in room 112, telephone 222 ;

and LT. CORLEY in room 118, telephone 236

INITIALS

20-24	______	______	______
00-04	______	______	______
00-08	______	______	______

Jack P. Frost, LCDR, USN
Engineer Officer

86NP0201

Figure 13-8.—Sample Engineering Officer's Night Orders.

U. S. S. SPEEDWELL CV-333
ENGINEERING DEPARTMENT
STEAMING ORDERS

DATE 17 August , 19XX

The ship is scheduled to get underway at 14ØØ, 18 August , 19XX

1. The Engineering Department shall report ready to get underway at 1345 (zero time).

2. Boilers nos. 1, 2, 3, 4, 6, 8 shall be used.

3. Steaming watches (3rd steaming section) below as follows:

SPACE	BOILERS	MACHINERY
No. 1 Machinery Space		
No. 2 Machinery Space		
No. 3 Machinery Space		
No. 4 Machinery Space		

4. Light Boiler Nos. 1, 2 at Ø8ØØ ; Cut - in 1Ø3Ø .
Boiler Nos. 3, 4 at 1ØØØ ; Cut - in 123Ø .
Boiler Nos. _____ at _____; Cut - in _____ .

5. Commence warming - up main engines at 113Ø , and follow warming - up schedule.

6. Warm up Nos. 2 125Ø - K.W. generators at Ø8ØØ ; cut in (idle) Ø9ØØ .
Nos. 4 125Ø - K.W. generators at 12ØØ ; cut in (idle) 1245 .
Nos. _____ 125Ø - K.W. generators at _____; cut in (idle) _____.

7. Test main engines at 133Ø . Report the Engineering Department ready to get underway to the Engineer Officer .

8. Have all burners made up with 32Ø8 sprayer plates and in use by _______.
Standby 25Ø8 sprayer plates .

9. Operate 2 set(s) evaporators, and distill as directed by E. O. O. W. .

10. Calls

Calls	
Engineer Officer	Ø7ØØ
Assistant Engineer Officer	Ø63Ø
Main Propulsion Assistant	Ø6ØØ

On Station:

On Station:	
Duty Officer	R. E. Caldwell
Junior Duty Officer	G. E. Holt
Duty MMC	Miller, MMC
Duty MMC	Smith, MMC
Duty BTC	Walters, BTC
Duty EMC	Land, EMC

11.

Watch	E. O. O. W.	J. O. O. W.
ØØØØ-04ØØ	D. D. Harper, Lt(jg)	R. S. Smith, Ensign
Ø4ØØ-Ø8ØØ	R. C. Johnson, Lt.	E. E. Robertson, Ensign
Ø8ØØ-12ØØ	C. C. Smart, Ch. Mach.	D. F. Edwards, Ensign
12ØØ-16ØØ	R. E. Caldwell, Lt(jg)	G. E. Holt, Mach.
16ØØ-18ØØ	D. F. Harper	R. S. Smith,
18ØØ-2ØØØ	R. C. Johnson	E. E. Robertson
2ØØØ-24ØØ	C. C. Smart	D. F. Edwards

Unless notified otherwise, standard speed will be 15 knots, 115 rpm .

Jack R. Frost , LCDR
(Engineer Officer)

Copies: Duty Officer and C. P. O. 's, Steaming M. S. ,
Div. B. B.'s, File .

86NP0202

Figure 13-9.—Steaming Orders (sample).

A form similar to the one shown in figure 13-8 is in use in some ships for the issuance of the engineering officer's night orders.

The Night Order Book is maintained in port and at sea. In the temporary absence of the engineer officer in port the book may be maintained by the engineering department duty officer. When the ship is under way, the Night Order Book is delivered to the EOOW before 2000 and is returned to the log room before 0800 of the following day. In addition to the EOOW, principal engineering watch supervisors and the oil king should read and initial the night orders for the watch. In port, the night orders should be read and initialed by the leading duty petty officer of each engineering division as well as by the principal watch supervisors.

Steaming Orders

Steaming Orders are written orders issued by the engineering officer. These list the major machinery units and readiness requirements of the engineering department based upon the time set for getting the ship under way. Generally, a locally prepared form similar to the one illustrated in figure 13-9 is used for issuance of the Steaming Orders. The orders normally specify the following information:

1. The engine combinations to be used
2. Times for lighting fires and cutting-in boilers
3. Times for warming up and testing main engines
4. Times for starting and paralleling ship's service generators
5. Standard speed, and (6) EOOW and principal watch supervisors

Early posting of Steaming Orders is essential to getting a ship with a large engineering plant underway with a minimum of confusion.

Gyrocompass Service Record

The Gyrocompass Service Record Book is furnished the ship with each gyrocompass (except the Mk 22) installed. The book is a complete record of inspections, tests, and repairs to the gyrocompass. **The Gyrocompass Service Record must always remain with its associated gyrocompass.** Complete instructions for maintaining the record are outlined in the front of the book and must be carefully followed. In the event of loss of, or damage to, the Gyrocompass Service Record Book, a replacement book can be obtained as indicated in the *Navy Stock List of Publications and Forms,* NAVSUP 2002. The requisition for the new book must show the mark, modification and serial numbers of the gyrocompass for which the book is intended.

Degaussing Folder

The ship's Degaussing Folder is a record of the degaussing installation in the ship. The folder contains the following information:

1. A description of the degaussing installation
2. A record of inspection, tests, and repairs performed by repair activities
3. The values of all coil currents for the ship's positions and headings
4. A record of the degaussing range runs.

The Degaussing Folder is necessary for the operation of the degaussing system and must be safeguarded against loss. Generally, the Degaussing Folder is in the possession of the navigator. The engineer officer provides the navigator with the names of the engineering personnel who will require access to the folder.

The Ship's Force Degaussing Maintenance Record, NAVSHIPS 1009, is provided for recording maintenance of the degaussing system performed by the ship's force. When they are completed, the forms are inserted in the degaussing folder.

Situation Reports

Situation reports (SITREPS) are onetime reports required in certain situations. Table 13-1 is a summary of onetime reports (not previously described) pertaining to the engineering department.

Gas Turbine Service Records

The gas turbine propulsion plants are unique in that service and maintenance records are similar to aircraft propulsion plants. *Naval Ship's Technical Manual,* chapter 234 (9416), gives a description of these service records and full instructions for maintaining them.

DISPOSAL OF ENGINEERING RECORDS AND REPORTS

Before any of the engineering department records are destroyed, the *Disposal of Navy and Marine Corps Records,* USN and USNS vessels, SECNAVINST

Table 13-1.—Summary of Situation Reports

NAVSEA REPORT NUMBER	TITLE	FORMAT	FREQUENCY CODE	REFERENCE NSTM CHAPTER
9070-2	Docking Report	NAVSEA 9070/1 9070/2 9070/3 9070/4 9070/5	S	094,997
9000-1	Delivery Report upon Delivery of any Ship to any Government	Letter	S	094
9880-2	Storm Damage to Ships—report of	Letter	S	100
4710-2	Examination of Structure by Shipyards; report of	Letter or mess	S	100
4730-1	Periodic Cargo Tank Inspections & Tests (AO, AOR, & AOG)	Letter	S	100
9080-1	Report of Deep Dive	Letter	S	100
3530-2	Magnetic Compass Table	NAVSEA 3120/4	S or every 12 months	100,252
9291-2	Report of Solid Ballast Installation or Changes	Letter, Drawing or Sketch	S	096
9290-1	Report of Excessive Rolling, Heeling or Pounding or Inadequate Propeller Immersion	Letter & 2 Dta Sheets	S	096
9410-1	Main Propulsion Turbines; condition of	Letter	S	231
9410-2	Turbine Lifting and Repair Report	NAVSEA 9410/4 9410/5 9410/6 9410/7 9410/8 9410/9	S	231
9430-1	Bent or Cracked Shafts	Letter	S	100,243
9440-1	Report of Propeller Measurements	NAVSEA 420	S	245
3960-1	Fuels & Lubricants, Testing of, by Naval Shipyards Laboratories	Letter	S	262
9510-1	Boiler Settings on Safety Valve	Letter	S	221
9500-1	Auxiliary Steam Turbines; Protection Against Excessive Pressure, relief valves	Letter	S	551
9510-6	Boiler Maintenance of Brickwork; Refractory Lining, Provision for Vibration	Letter	S	221
9610-1	Submarine Battery Quarterly Report	NAVSEA 149	Q	223
9620-6	Battery Water Analysis	Letter	S	223
9620-1	Inspection of Submarine Battery Elements; report of	Letter	S	223
9620-3	Battery Deficiency Report	Letter	S	223
9720-5	Ammunition Handling & Stowage	Letter	S	700
4440-4	Report of Change in Boats Status	NAVSEA 215	S	583

LEGEND: Frequency Code Letters:

D - Daily	BM - Bimonthly
W - Weekly	Q - Quarterly
BW - Biweekly	SA - Semiannually
SM - Semimonthly	A - Annually
M - Monthly	S - Situation

P5212.5(revised), should be studied. This publication informs ships of the Navy of the procedures used for disposing records. For each department aboard ship, these instructions list the permanent records that must be kept and the temporary records which may be disposed of following an established schedule.

Both the Engineering Log and Engineer's Bell Book must be preserved as permanent records on board ship for a 3-year period unless they are requested by a Naval Court or Board or by the Navy Department. In such case, copies (preferably photostatic) of such sheets or parts of these records that are sent away from the ship are certified by the engineering officer as being true copies for the ship's files.

At regular intervals, such as each quarter, the parts of those records that are over 3 years old are destroyed. When a ship that is less than 3 years old is decommissioned, the current books are retained. If a ship is scrapped, the current books are forwarded to the nearest Naval Records Management Center.

All reports forwarded to and received from NAVSEA or other higher echelon commands may be destroyed when 2 years old, if no longer required.

Only those reports which are required or serve a specified purpose should be maintained on board ship. However, any report or record that may help personnel schedule or make repairs and that will supply personnel with information not contained in publications or manuals should also be kept on board.

ENGINEERING PLANT MAINTENANCE

Naval ships, submarines, and aircraft are becoming more and more complex. To ensure these craft are ready to fulfill their assigned mission, the engineering plant of each must be kept operational.

The purpose of maintenance is to ensure that the equipment is ready for service at all times. The three fundamental rules for the maintenance of electrical equipment are as follows:

1. Keep equipment clean and dry.
2. Keep electrical connections and mechanical fastenings tight.
3. Inspect and test at sufficiently short intervals to ensure that the equipment is in operating condition.

PREVENTIVE MAINTENANCE SYSTEM (PMS)

The primary objective of the Navy Ship's Maintenance and Material Management Systems (3-M Systems) is to provide a means for managing maintenance and maintenance support so that equipment is maintained in a state of maximum equipment operational readiness. OPNAVINST 4790.4, contains all of the detailed procedures and instructions for the effective operation of the 3-M Systems. Other instructions on the 3-M Systems are found in the type commander's maintenance manuals.

This section of the chapter contains a discussion of the most cpmmon records of the 3-M Systems that must be kept current in the engineering department.

PLANNED MAINTENANCE SCHEDULES

In an effective Planned Maintenance System (PMS) Program, careful attention must be given to the PMS schedules to ensure that they are accurately filled out and posted in a timely manner. PMS schedules are categorized as cycle, quarterly, and weekly.

Cycle Schedule

The Cycle PMS Schedule (fig. 13-10) displays the planned maintenance requirements to be performed between major overhauls of the ship. The following information must be filled in on the cycle schedule: ship's name and hull number, work center designator code, maintenance index page (MIP) number, component or systems name, and maintenance scheduled in each quarter after overhaul.

The engineering officer must supervise all cycle scheduling of engineering departmental maintenance, then sign and date the Cycle PMS Schedule before it is posted.

If the need to rewrite the Cycle PMS Schedule arises, the old schedule should be filed with the last quarterly schedule with which it was used.

Quarterly schedule

The Quarterly PMS Schedule (fig. 13-11) is a visual display of the workcenter's PMS requirements to be performed during a specific 3-month period. Spaces are provided for entering the work center, quarter after overhaul, department heads signature, data prepared, and the months covered. Thirteen columns, one for each week in the quarter, are available to permit scheduling

CYCLE PMS SCHEDULE (CONVENTIONAL)
OPNAV FORM 4790/13 (3-71) S/N 0107-LF-770-3220

SHIP	WORK CENTER	SCHEDULE QUARTER AFTER OVERHAUL AS INDICATED				APPROVAL SIGNATURE
USS LEXINGTON AVT-16	EE04 (PAGE 2 OF 2)	1 13 / 5 17 / 9 21	2 14 / 6 18 / 10 22	3 15 / 7 19 / 11 23	4 16 / 8 20 / 12 24	J. Frost LCDR, USN DATE 3-30-XX
MIP	COMPONENT					EACH QUARTER
EL-5/170	REVERSE POWER RELAY		S-1R		S-1R	S-1R
EL-7/45	NO. 1 SSTG				A-1	M-1, M-3R
EL-7/45	NO. 2 SSTG	A-1				M-1, M-3R
EL-7/45	NO. 3 SSTG		A-1			M-1, M-3R
EL-7/45	NO. 4 SSTG			A-1		M-1, M-3R
EL-8/14	NO. 5 EMERGENCY DZL	S-1 (#M-1)		S-1 (#M-1)		M-1, R-1
EL-8/14	NO. 6 EMERGENCY DZL	S-1 (#M-1)		S-1 (#M-1)		M-1, R-1
EL-10/20	ABT & MBT EGL Z-1		18M-2(6, 18)		18M-2(12, 24) 48M-1(12, 28) (A-2)	Q-1R
EL-11/128	NO. 1 400HZ MG					M-1, Q-5R
EL-11/128	NO. 2 400HZ MG					M-1, Q-5R
EL-12/18	CASUALTY POWER Z-1		A-1, A-2			
EL-12/18	CASUALTY POWER Z-1			A-1, A-2		
EL-37/1	V/R NO. 1 SSTG		S-1		S-1	Q-7
EL-37/1	V/R NO. 2 SSGT	S-1		S-1		Q-7

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Figure 13-10.—Cycle PMS Schedule.

QUARTERLY PMS SCHEDULE (CONVENTIONAL) M-1, Q-5R
OPNAV 4790/14 (REV 5-73) S/N 0107-LF-770-3241

WORK CENTER EE04 (PAGE 2 OF 2) | YEAR 19XX | QUARTER AFTER OVERHAUL 1 st | APPROVAL SIGNATURE J. Frost | DATE 3-30-XX

MIP	APR 4	11	18	25	MAY 2	9	16	23	30	JUN 6	13	20	27	RESCHEDULE
EL-5/170-85	S1-R													
EL-7/45-47		M-1 ~~M3-R~~	~~M-1~~				M-1, M3-R				M-1, M3-R			
EL-7/45-47		~~M-1~~ ~~M3-R~~					M-1, M3-R				M-1, M3-R			
EL-7/45-47		~~M-1~~ ~~M3-R~~					M-1, M3-R				M-1, M3-R			
EL-7/45-47		~~M-1~~ ~~M3-R~~					M-1, M3-R				M-1, M3-R			
EL-8/14-A7		~~M-1~~					M-1				M-1			
EL-8/14-A7		~~M-1~~					M-1				M-1			
EL-10/20-97					Q-1R				Q-1R					
EL-11/128-65		~~M-1~~					M-1, Q-5R				M-1			
EL-11/128-65		~~M-1~~					M-1, Q-5R				M-1			
EL-12/18-86														
EL-12/18-86														
EL-37/1-47						Q7								
EL-37/1-47	S1								Q7					

86NP0204

UPDATE THIS SCHEDULE EVERY WEEK

Figure 13-11.—Quarterly PMS Schedule.

of maintenance requirements on a weekly basis throughout the quarter. There are also columns to enter the MIP number and PMS requirements that may require rescheduling. There are "tick" marks across the top of the scheduling columns for use in showing the in-port/underway time of the ship for the quarter.

The engineering officer must supervise scheduling of PMS on the quarterly schedule for his/her department, then sign and date the schedule before it is posted. At the end of each quarter, the engineer officer must review the quarterly schedule, check the reasons for PMS actions not accomplished, and sign the form in the space provided on its reverse side. The division officer is responsible for updating the quarterly schedule every week. Completed quarterly schedules should be kept on file for 1 year.

Weekly Schedule

The Weekly PMS Schedule (fig. 13-12) is a visual display of the planned maintenance scheduled for accomplishment in a given workcenter during a specific week. The weekly schedule is used by the workcenter supervisor to assign and monitor the accomplishment of required PMS tasks by workcenter personnel.

The Weekly PMS Schedule contains blank spaces for the following information: work center code, date of current week, division officer's signature, MIP number minus the date code, component names, names of personnel responsible for specific maintenance items, periodicity codes of maintenance requirements, outstanding major repairs, and situation requirements.

The workcenter supervisor is responsible for completing the Weekly PMS Schedule and for updating it every day.

SCHEDULING WORK

Careful planning is required to keep up with all maintenance and repair work within your division. You should already have in your workcenter the following documents to help you schedule your work:

- The Current Ship's MaintenanceProject (CSMP)
- The Job Control Number (JCN) Log
- The Quarterly PMS Schedule
- The Weekly schedule

WEEKLY PMS SCHEDULE (CONVENTIONAL)
OPNAV FORM 4790/15 (3-70)
S/N 0107-LF-770-3280

WORK CENTER	PMS SCHEDULE FOR WEEK OF	APPROVAL SIGNATURE
EE04 (PAGE 2 OF 2)	16 - 20 MAY	John Doe LT, USN

MIP	COMPONENT	MAINTENANCE RESPONSIBILITY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY SUNDAY	OUTSTANDING REPAIRS AND PM CHECKS DUE IN 4 WEEKS
EL-5/170	REVERSE POWER RELAY								S-1R
EL-7/45	NO. 1 SSTG	GRIER	M-1, M-3R						M-1, M-3R
EL-7/45	NO. 2 SSTG	GRIER	M-1, M-3R						M-1, M-3R
EL-7/45	NO. 3 SSTG	OWENS			M-1, M-3R				M-1, M-3R
EL-7/45	NO. 4 SSTG	OWENS			M-1, M-3R				M-1, M-3R
EL-8/14	NO. 5 EMERGENCY DZL	HARRISON		M-1					M-1, R-1
EL-8/14	NO. 6 EMERGENCY DZL	EDWARDS		M-1					M-1, R-1
EL-10/20	ABT & MBT EQL Z-1	NOVAC							Q-1R
EL-11/128	NO. 1 400-HZ MG	GRIER				M-1, Q-5R			M-1, Q-5R
EL-11/128	NO. 2 400HZ MG	GRIER				M-1, Q-5R			M-1, Q-5R
EL-12/18	CASUALTY POWER Z-1								
EL-12/18	CASUALTY POWER Z-1								
EL-37/1	VR NO. 1 SSTG								
EL-37/1	VR NO. 2 SSGT								

UPDATE THIS SCHEDULE DAILY

86NP0205

Figure 13-12.—Weekly PMS Schedule.

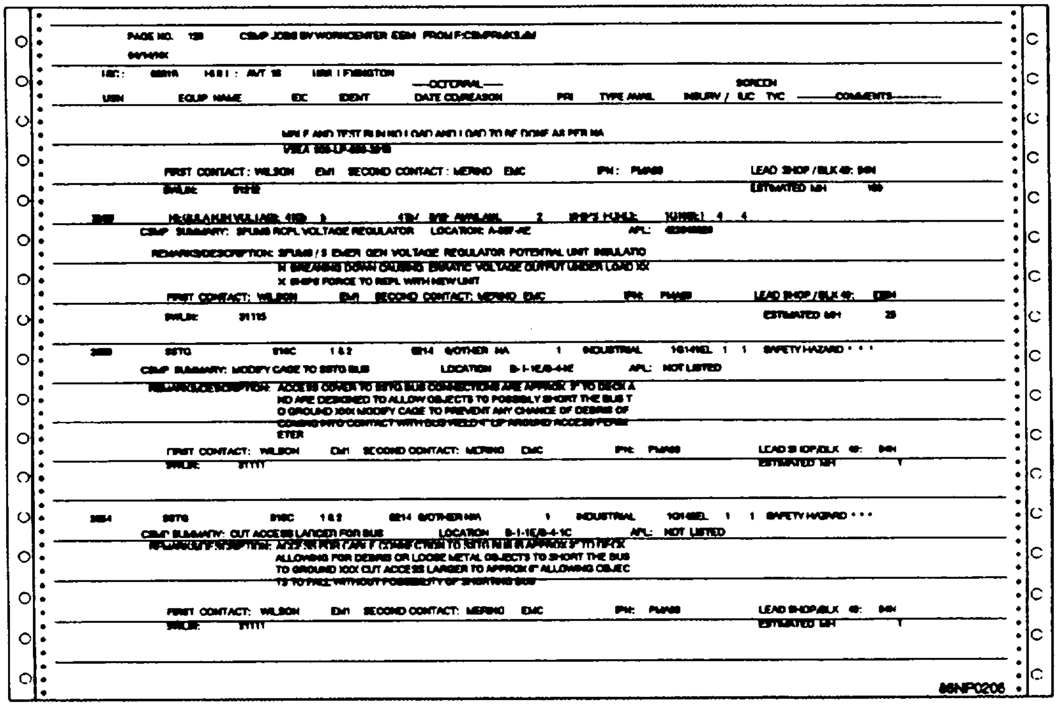


Figure 13-13.—Current Ship's Maintenance Project (CSMP).

- The Maintenance Data Collection Subsystem (MDCS) Forms, such as OPNAV 4790/2K, OPNAV 4790/2L, and OPNAV 4790/2Q.

Current Ship's Maintenance Project (CSMP)

The CSMP (fig. 13-13) is a computer generated document listing the maintenance actions that have been entered into the Maintenance Data System (MDS) for a particular unit. The CSMP can be divided by unit, department, division, and workcenter. It is a valuable tool for the workcenter supervisor when scheduling work to conform to the ship's schedule.

EMØ1

WORK CENTER

JSN	DEFERRALS				COMPLETIONS				REMARKS
	DATE	4790/2L	TRANSMITTAL LTR DATE*	ENTERED IN COMPUTER*	DATE	TRANSMITTAL LTR DATE*	ENTERED IN COMPUTER*	**	* * *
Ø624	6249	✓	6251	6252	6254	6255	6256		
Ø625	6249		6251	6252	6253	6255	6256		
Ø626	6251	✓	6252	6253	6263	6264	6266		
Ø627	6263		6263	6264	6266	6267	6269	YES	
Ø628	6266		6266	6267					

* FOR 3-M Coordinator only

* * If parts are required, have 1250-1/1348's been submitted?

* * * Include information regarding documents returned, resubmission transmittal ltr ser & dates

86NP0207

Figure 13-14.—Recommended format for the job control number log.

Job Control Number (JCN) Log

The JCN log (fig. 13-14) is a locally generated log used by the workcenter to assign workcenter Job Sequence Numbers (JSNs) to maintenance actions required within the workcenter. These numbers enable each work item to individually tracked and its progress to be monitored.

Ship's Maintenance Action Form (OPNAV 4790/2K)

OPNAV Form 4790/2K (fig. 13-15) is used to show completion of specific PMS requirements; to request repair of equipment or services from IMAs or shipyards; or can be used to describe equipment malfunctions. Once submitted, the information from the 4790/2K will

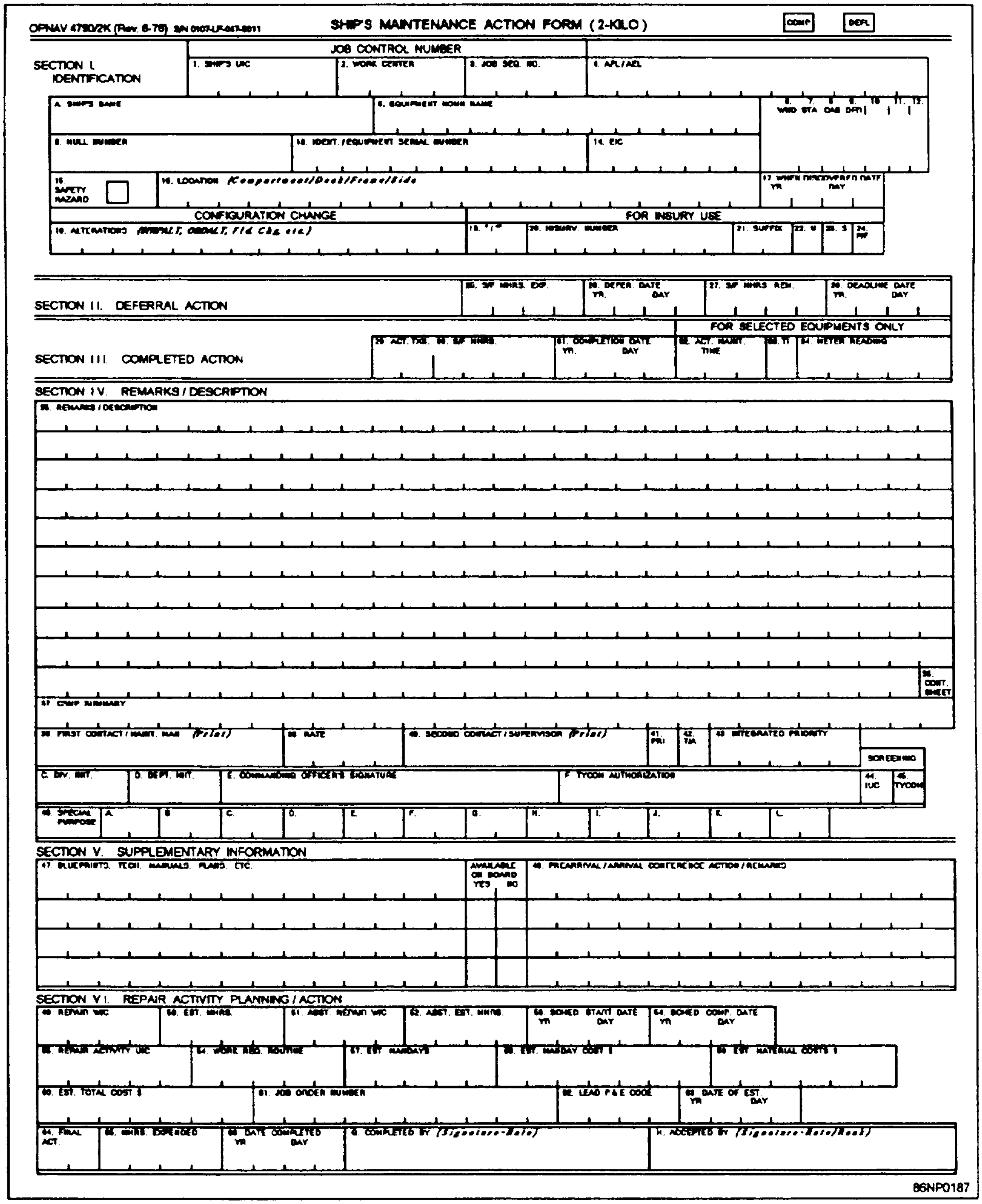

OPNAV 4790/2K (Rev. 6-78) S/N 0107-LF-047-8011
SHIP'S MAINTENANCE ACTION FORM (2-KILO)
COMP DEFL
JOB CONTROL NUMBER
SECTION I. IDENTIFICATION
1. SHIP'S UIC
2. WORK CENTER
3. JOB SEQ. NO.
4. APL/AEL
A. SHIP'S NAME
5. EQUIPMENT NOUN NAME
HULL NUMBER
13. IDENT./EQUIPMENT SERIAL NUMBER
14. EIC
15. SAFETY HAZARD
16. LOCATION (Compartment/Deck/Frame/Side)
17. WHEN DISCOVERED DATE YR. DAY
CONFIGURATION CHANGE
FOR INSURV USE
19. ALTERATION (SHIPALT, ORDALT, Fld Chg, etc.)
20. INSURV NUMBER
21. SUFFIX
SECTION II. DEFERRAL ACTION
25. S/F MHRS. EXP.
26. DEFER. DATE YR. DAY
27. S/F MHRS. REM.
28. DEADLINE DATE YR. DAY
FOR SELECTED EQUIPMENTS ONLY
SECTION III. COMPLETED ACTION
29. ACT. TKN.
30. S/F MHRS.
31. COMPLETION DATE YR. DAY
32. ACT. MAINT. TIME
34. METER READING
SECTION IV. REMARKS / DESCRIPTION
35. REMARKS / DESCRIPTION
36. CONT. SHEET
37. CSMP SUMMARY
38. FIRST CONTACT/MAINT. MAN (Print)
39. RATE
40. SECOND CONTACT/SUPERVISOR (Print)
41. PRI
42. T/A
43. INTEGRATED PRIORITY
SCREENING
C. DIV. INIT.
D. DEPT. INIT.
E. COMMANDING OFFICER'S SIGNATURE
F. TYCOM AUTHORIZATION
44. IUC
45. TYCOM
46. SPECIAL PURPOSE
A. B. C. D. E. F. G. H. I. J. K. L.
SECTION V. SUPPLEMENTARY INFORMATION
47. BLUEPRINTS, TECH. MANUALS, PLANS, ETC.
AVAILABLE ON BOARD YES NO
48. PREARRIVAL/ARRIVAL CONFERENCE ACTION/REMARKS
SECTION VI. REPAIR ACTIVITY PLANNING / ACTION
49. REPAIR UIC
50. EST. MHRS.
51. ASST. REPAIR UIC
52. ASST. EST. MHRS.
53. SCHED START DATE YR DAY
54. SCHED COMP. DATE YR DAY
55. REPAIR ACTIVITY UIC
56. WORK REQ. ROUTINE
57. EST. MANDAYS
58. EST. MANDAY COST $
59. EST. MATERIAL COSTS $
60. EST. TOTAL COST $
61. JOB ORDER NUMBER
62. LEAD P & E CODE
63. DATE OF EST. YR DAY
64. FINAL ACT.
65. MHRS. EXPENDED
66. DATE COMPLETED YR DAY
G. COMPLETED BY (Signature-Rate)
H. ACCEPTED BY (Signature-Rate/Rank)
86NP0187

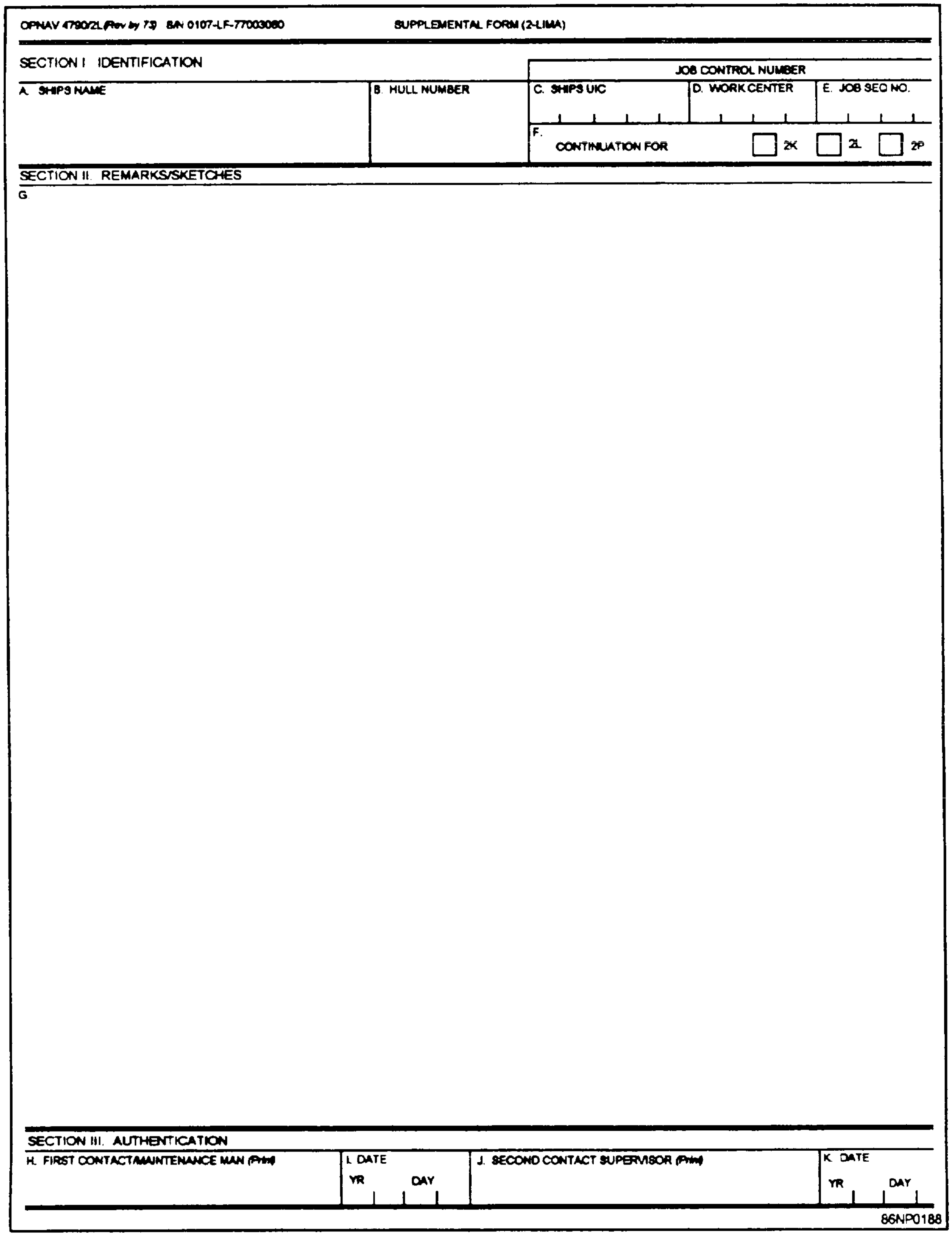
Figure 13-15.—Ship's Maintenance Action Form, OPNAV 4790/2K.

be entered into the MDS to appear on the units CSMP for that workcenter which reported the action.

If the information is used to defer a maintenance action for outside assistance, the responding repair facility will use this information to perform repairs required.

Supplemental Form (OPNAV 4790/2L)

OPNAV Form 4790/2L (fig. 13-16) is a supplemental form which you use to provide amplifying information relating to a maintenance action described on a corresponding 4790/2K. The OPNAV 4790/2L



OPNAV 4790/2L (Rev by 73) S/N 0107-LF-77003060 SUPPLEMENTAL FORM (2-LIMA)

SECTION I IDENTIFICATION

JOB CONTROL NUMBER

A. SHIPS NAME | B. HULL NUMBER | C. SHIPS UIC | D. WORK CENTER | E. JOB SEQ NO.

F. CONTINUATION FOR 2K 2L 2P

SECTION II. REMARKS/SKETCHES

G.

SECTION III. AUTHENTICATION

H. FIRST CONTACT/MAINTENANCE MAN (Print) | I. DATE YR DAY | J. SECOND CONTACT SUPERVISOR (Print) | K. DATE YR DAY

86NP0188

Figure 13-16.—Supplemental Form, OPNAV 4790/2L.

may also be used to list multiple-item serial numbers and locations for which identical maintenance requirements exist from an outside activity. It may also be used to list drawings and sketches.

Automated Ship's Maintenance Action Form, OPNAV 4790/2Q

OPNAV Form 4790/2Q is an automated work request produced by an IMA with computer capabilities. The 2Q is produced from the original 4790/2k, which is in your CSMP suspense file. For more detailed information about these forms and schedules and how to fill them out, review OPNAVINST 4790.4 (fig. 13-17).

Methods for Scheduling Work

Some of the proven methods you should follow when scheduling maintenance and repair work are listed below.

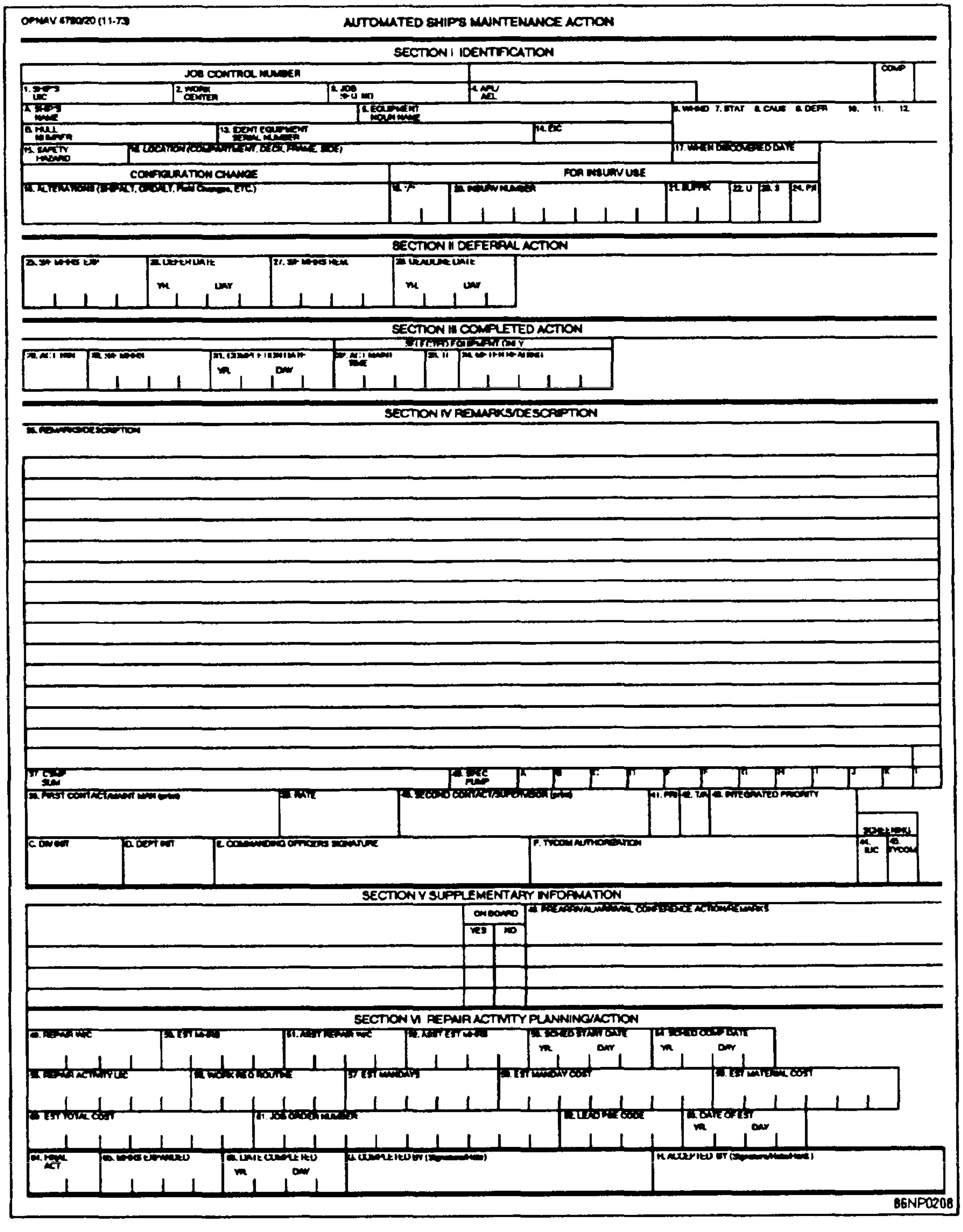


Figure 13-17.—Automated Ship's Maintenance Action Form, OPNAV 4790/20.

1. Size up each job before you let anyone start working on it. Check the applicable Maintenance Requirement Cards (MRCs) so that you will know exactly what needs to be done. Also, check all applicable drawings and manufacturer's technical manuals.

2. Check on materials before you start. Be sure that all required materials are available before your personnel start working on any job. Do not overlook small items—nuts, bolts, washers, packing and gasket materials, tools, measuring devices, and so forth. A good deal of labor can be saved by making sure that materials are available before beginning the job. An inoperable piece of machinery may be useless, but it can become a nuisance and a safety hazard if it is spread around the engine room in bits and pieces while you wait for the arrival of repair parts or materials.

3. Check the priority of the job and that of all other work that needs to be done.

4. When assigning work, carefully consider the capabilities and experience of your personnel. As a rule, the more complicated jobs should be given to the more skilled and more experienced people. However, when possible, less experienced people should be given difficult work to do under supervision so that they may acquire skill in such jobs.

Be sure that the person who is going to do a job is given as much information as necessary. An experienced person may need only a drawing and a general statement concerning the nature of the job. A less experienced person is likely to require additional instructions and, as a rule, closer supervision.

5. Keep track of the work as it is being done. In particular, check to be sure that proper materials and parts are being used, that the job is properly laid out or set up, that all tools and equipment are being used correctly, and that all safety precautions are being observed.

6. After a job has been completed, make a careful inspection to be sure that everything has been done correctly and that all final details have been taken care of. Check to be sure that all necessary records and reports have been prepared. These job inspections serve at least two important purposes—first, they are needed to make sure that the work has been properly performed; and second, they provide for an evaluation of the skills and knowledge of the person who has done the work. Don't overlook the training aspects of a job inspection. When your inspection of a completed job reveals any defects or flaws, explain what is wrong, why it is wrong, and how to avoid similar mistakes in the future.

ESTIMATING WORK

Often, you'll be required to estimate the amount of time, the number of personnel, and the amount of material required for specific repair jobs. Actually, you are making some kind of estimate every time you plan and start a repair job as you consider such questions as the following:

How long will it take?

Who can best do the job?

How many people will be needed?

Are all necessary materials available?

However, there is one important difference between the estimates you make for your own use and those that you make when your division officer asks for estimates. When you give an estimate to someone in authority over you, you cannot tell how far up the line this information will go. It's possible that an estimate you give to your division officer could ultimately affect the operational schedule of the ship; therefore, it's essential that such estimates be as accurate as you can possibly make them.

Many of the factors that apply to scheduling all maintenance and repair work apply also to estimating the time that will be required for a particular repair job. You cannot make a reasonable estimate until you have sized up the job, checked on the availability of materials, checked on the availability of skilled personnel, and checked on the priority of the various jobs for which you are responsible. To make an accurate estimate of the time required to complete a specific repair job, you must also consider what part of the work must be done by other shops and what kinds of interruptions and delays that may occur. Although these factors are also important in the routine scheduling of maintenance and repair work, they are particularly important when estimates of time may affect the operational schedule of the ship.

If part of the job must be done by other shops, you must consider not only the time actually required by these shops but also time that may be lost if one of them holds up your work and the time spent to transport the material between shops. Each shop should make a separate estimate, and the estimates should be combined to obtain the final estimate. **Don't** attempt to estimate the time required by other personnel. Attempting to estimate what someone else can do is risky because you can't possibly have enough information to make an accurate estimate.

Consider all the interruptions that might cause delay, over and above the time required for the work itself. Such things as drills, inspections, field days, and working parties can have quite an effect on the number of people who will be available to work on the job at any given time.

Estimating the number of personnel required for a certain repair job is, obviously, closely related to estimating time. You will have to consider not only the nature of the job and the number of people available, but also the maximum number of people who can work effectively on a job or on part of the job at the same time. Doubling the number of personnel will not cut them time in half instead, it will result in confusion.

The best way to estimate the time and the number of personnel needed to do a job is to divide the total job into the various phases or steps that will have to be done. Then, estimate the time and the personnel required for each step.

Estimating the materials required for a repair job is often more difficult than estimating the time and labor required for the job. Although your own past experience will be your best guide for this kind of estimating, a few general considerations should be noted.

1. Keep accurate records of all materials and tools used in any major repair job. These records serve two purposes—first, they provide a means of accounting for materials used; and second, they provide a guide for estimating materials that will be required for similar jobs in the future.

2. Before starting any repair job, plan the job carefully and in detail. Make full use of manufacturers' technical manuals, blueprints, drawings, and any other available information, and find out in advance all the tools and materials that will be required for the accomplishment of each step of the job.

3. Make a reasonable allowance for waste when calculating the amount of material you will need.

INSPECTIONS

Naval ships and shore installations are required to be inspected to ensure that their operation, administration, and equipment reflects a high standard of readiness. The frequency with which the various types of inspections are held is determined by the CNO, fleet commanders, and type commanders. As far as any specific ship is concerned, the cognizant type commander usually designates the type of inspection and when it will be held.

Your command will usually be notified in advance when various inspections are to be held. However, preparations for such inspections should not be postponed until notices are received. It is a mistake to think that a poorly administered division or department can, by a sudden burst of energy, be prepared to meet the inspector's eagle eye. By using proper procedures and keeping up to date on such items as repair work, maintenance work, operating procedures, training of personnel, engineering casualty control drills, maintenance records, and reports, you will always be ready for any type of inspection at any time.

Since your ship may be designated to provide personnel to perform an inspection on another command, you, as a PO1 or CPO, may be assigned the duty as an assistant inspector. Therefore, you should know something about the different types of inspections and trials and how they are conducted.

There are a variety of types of inspections, each with a specific purpose. Since the Electrician's Mate rating is an engineering rating, we will focus on those inspections which most directly affect the engineering department.

ADMINISTRATIVE INSPECTIONS

Administrative inspections cover administrative methods and procedures normally used by the ship. Each inspection is divided into two general categories—the general administration of the ship as a whole and the administration of each department. This TRAMAN only discusses the engineering department.

The purpose of an administrative inspection is to determine whether or not the department is being administered within the guidelines established by the standard organization and regulations manual of the United States Navy, *Engineering Department Organization Manual,* and other pertinent instructions.

Inspecting Party

It is a routine procedure for one ship to conduct an inspection of a similar division on another ship. General instructions for conducting the inspection are usually given by the division commander; however, the selecting and organizing of the inspecting party are done aboard the ship that must conduct the inspection.

The chief inspector, usually the commanding officer of the ship, will organize the assisting board. The organization of the assisting board, in general conformance with the departmental organization of the ship, is divided into appropriate groups. Eacvh group is headed by an inspector with as many assistant inspectors as necessary. Chief petty officers and petty officers first class may be assigned as assistant inspectors.

The engineering department inspecting group (or party) is organized and supervised by the engineer officer. The manner in which an individual inspection is carried out depends to a great extent upon the knowledge and ability of the members of the group (or party).

General Inspection of the Ship as a Whole

One of the two categories of administrative inspection is the general administration of the ship as a whole. Items of this inspection that have a direct bearing on the engineering department, and for which the report of inspection indicates a grade, are shown below:

1. Appearance, bearing, and smartness of personnel

2. Cleanliness, sanitation, smartness, and appearance of the ship as a whole

3. Adequacy and condition of clothing and equipment of personnel

4. General knowledge of personnel in regard to the ship's organization ship's orders, and administrative procedures

5. Dissemination of all necessary information among the personnel

6. Indoctrination of newly reported personnel

7. General education facilities for individuals

8. Comfort and conveniences of Living spaces, including adequacy of light, heat, ventilation, and fresh water

9. Economy of resources

Engineering Department Inspection

The engineering department administrative inspection is primarily the inspection of the engineering department paperwork, including publications, bills, files, books, records, and logs. Additionally, this inspection includes other items with which the chief petty officers and petty officers first class must be concerned. Some of these items are the cleanliness and preservation of machinery and engineering spaces; the training of personnel; the assignment of personnel to watches and duties; the proper posting of operating instructions and safety precautions; the adequacy of warning signs and guards; the marking and labeling of lines and valves; and the proper maintenance of operating logs.

Administrative Inspection Checkoff Lists

Administrative inspection checkoff lists are usually furnished to the ship by the type commander. These lists are used as an aid for inspecting officers and inspecting party personnel to assist them in ensuring that no important item is overlooked. The inspecting personnel, however, should not accept these lists as being all-inclusive because additional items develop that must be considered or observed during an inspection. be considered or observed (fig. 13-18).

As a petty officer, you should be familiar with the various checkoff lists used for inspections. These checkoff lists will give you a good understanding of how to prepare for an inspection as well as how to carry out your daily supervisory duties. You will find it helpful to obtain copies of the various inspection checkoff lists from the log room and to carefully look them over. They will give detailed information about what type of inspection you may expect for your type of ship.

The following is an abbreviated sample of an engineering department checkoff list. You should get a better understanding of the scope and purpose of administrative inspections by reviewing this list.

OPERATIONAL READINESS INSPECTION

The operational readiness inspection is conducted to ensure that the ship is ready and able to perform the operations which might be required of it in time of war. This inspection consists of the conduct of a battle problem and of other operational exercises. A great deal of emphasis is placed on antiaircraft and surface gunnery, damage control, engineering casualty control, and other appropriate exercises. Various drills are held and observed, and the ship is operated at full power for a brief period of time.

The overall criteria of performance include the following questions:

1. Can the ship as a whole carry out its operational functions?

1. **BILLS FOR BOTH PEACE AND WAR**

a. Inspect the following, among others, for completeness, correctness, and adequacy.

(1) Department Organization
(2) Watch, Quarter, and Station Bills
(3) Engineering Casualty Bill
(4) Fueling Bill

2. **ADMINISTRATION AND EFFECTIVENESS OF TRAINING**

a. Administration and effectiveness of training of personnel for current and prospective duties.

(1) Are sufficient nonrated personnel in training to replace anticipated losses?
(2) NAVEDTRA training courses.
(a) Number of personnel enrolled
(b) Percentage of personnel in department enrolled
(c) Number of personnel whose courses are completed

(3) Are personnel concerned familiar with operating instructions and safety precautions? (Question personnel at random.)
(4) Are personnel concerned properly instructed and trained to handle casualties to machinery?
(5) Are personnel properly instructed and trained in damage control?
(6) Are training films available and used to the maximum extent?
(7) Are training records of personnel adequate and properly maintained?

3. **DISSEMINATION OF INFORMATION WITHIN DEPARTMENT**

a. Is necessary information disseminated within the department and divisions?
b. Are the means of familiarizing new personnel with department routine orders and regulations considered satisfactory?

4. **ASSIGNMENT OF PERSONNEL TO STATIONS AND WATCHES**

a. Are personnel properly assigned to battle stations and watches?
b. Are sufficient personnel aboard at all times to get the ship under way?
c. Are personnel examined and qualified for important watches?
d. Does it appear that personnel on watch have been properly instructed? (Question personnel at random.)

5. **OPERATING INSTRUTIONS, SAFETY PRECAUTIONS, PMS, AND CHECKOFF LISTS**

a. Inspect completeness of the following:

(1) Operating instructions posted near machinery
(2) Posting of necessary safety precautions

b. Are PMS schedules properly posted and maintained in the working spaces?
c. Is the Master PMS Schedule posted and up to date?
d. Are responsible personnel familiar with Current instructions regarding routine testing and inspections?
e. Are starting-up and securing sheets properly used?

Figure 13-18.—Engineering inspection checkoff sheet.

6. **PROCEDURES FOR PROCUREMENT, ACCOUNTING, INVENTORY, AND ECONOMY IN USE OF CONSUMABLE SUPPLIES, REPAIR PARTS, AND EQUIPAGE**

a. Is an adequate procedure in use for replacement of repair parts?
b. Are there adequate measures used to prevent excessive waste of consumable supplies?
c. Is there proper supervision in the proper supply of, care of, and accountability for hand tools?
d. Are inventories taken of repair parts which are in the custody of the engineering department?
e. How well are repair parts preserved and stowed?
f. What type of system is used to locate a repair part carried on board? (Have a chief or first class petty officer explain to you how a repair part for a certain piece of machinery is obtained.)
g. Are custody cards properly maintained for accountable tools and equipment?

7. **MAINTENANCE OF RECORDS AND LOGS**

a. Inspect the following for compliance with pertinent directives, completeness, and proper form.

(1) Engineering Log
(2) Bell Book
(3) Operating Records
(4) Maintenance Records
(5) Alteration and Installation Program
(6) Daily Oil and Water Records
(7) Engineering Reports
(8) Training Logs and Records
(9) Work Books for Engineering Spaces

8. **AVAILABILITY AND CORRECTNESS OF PUBLICATIONS, DIRECTIVES, AND TECHNICAL REFERENCE MATERIAL**

a. Engineering Blueprints Recommended
(1) Ship's Plan Index (SPI)
(2) Proper indexing of blueprints
(3) Completeness and condition

b. Manufacturers' Instruction Books
(1) Proper indexing
(2) Completeness and condition

c. Type Commanders Material Letters
d. NAVSEA Technical Manual
e. General Information Book
f. Booklet Plans of Machinery

9. **CLEANLINESS AND PRESERVATION**

a. Preservation and cleanliness of space (including bilges)
b. Preservation and cleanliness of machinery and equipment
c. Neatness of stowage
d. Condition of ventilation
e. Condition of lighting
f. Compliance with standard painting instructions

Figure 13-18.—Engineering inspection checkoff sheet—Continued.

2. Is the ship's company well trained, well instructed, competent, and skillful in all phases of the evolutions?

3. Is the ship's company stationed following the ship's Battle Bill, and does the Battle Bill meet wartime requirements?

Observing Party

The personnel and organization of the operational readiness observing party are similar to those of the administrative inspection party. However, more personnel are usually required for the operational readiness observing party. These additional personnel are often chief petty officers and first class petty officers.

The observing party members are briefed in advance of the scheduled exercises and drills that are to be conducted. They must have sufficient training and experience so that they can properly evaluate the exercises and drills that are to be held. Each observer is usually assigned to a specific station and should be well qualified in the procedure of conducting drills and exercises for that station. That each observer be familiar with the type of ship to be inspected is also highly desirable.

Battle Problems

The primary purpose of a shipboard battle problem is to provide a medium for testing and evaluating the ability of all divisions of the engineering department to function together as a team in simulated combat operations.

The discussion of the battle problem in this TRAMAN is from the viewpoint of the observer and presents some general information about the requirements and duties of a member of the engineering department observing party. The knowledge of the viewpoint and duties of an observer should help you prepare yourself and your personnel for a battle problem and other appropriate exercises.

PREPARATION OF A BATTLE PROBLEM.— The degree of perfection achieved in any battle problem is reflected in the skills and applications of those who prepare it. A great deal depends upon the experience of officers and chief petty officers. The element of surprise in the conduct of a battle problem significantly increases its value.

Battle problems are the most profitable and significant of all peacetime training experience. They demonstrate a department's readiness for combat. The degree of realism of this test determines its value: the more nearly it approximates actual battle conditions, the more valuable it is.

CONDUCT OF A BATTLE PROBLEM.— Before a battle problem is conducted, the ship is furnished specific information such as that listed below.

1. Authority for conducting the inspection
2. Time of boarding of the inspecting party
3. Time the ship is to get under way
4. Time for setting the first material readiness condition
5. Time for conducting the inspection to zero problem time conditions
6. Zero problem time
7. End of problem time
8. Time of critique

Observers must be proficient in the proper methods of introduction of information. In general, when practical, the information delivered to ship's personnel should be verbal and should contain only that information which would help the ship's personnel develop adequate procedures for the search and investigation of the imposed casualty. If the ship's personnel fail to locate the casualty, the observer may resort to coaching, but a notation should be made on the observer's form as to the time allowed before coaching and information were furnished. Special precautions should be taken to give the symptoms of casualty the same degree of realism that they would have if the casualty were actual rather than simulated.

To impose casualties, ship's personnel must close valves, open switches, or stop machinery. In each case, the observer should inform responsible ship's personnel of the action desired, and the ship's personnel should operate the designated equipment.

NOTE: A casualty should be simulated, or omitted entirely, if there is danger that personnel injury or material damage might result.

NOTE: The supply of lubricating oil to the main engines or the supply of feedwater to the boilers MUST NOT be stopped to simulate casualties.

An emergency procedure should be set up by the observing party and ship's company to ensure proper action in case actual casualties, as distinguished from simulated or problem casualties, should occur.

Although the general amounting system (the 1MC circuit) may be used by the ship's company, observers, normally, have priority in its use. The problem-time announcer uses the general announcing system to announce the start of the battle problem, the problem time at regular intervals, the conclusion of the problem, and the restoration of casualties. The general announcing system is kept available at all times for use in case of actual emergency. All other announcing system circuits and other means of interior communications are reserved for the use of the ship.

Engineering telephone circuits should be monitored by one or more observers. A check should be made for proper procedure, for circuit discipline, and for proper handling of information or casualties.

An inspection should be made to see that the engineering plant is properly split following current directives. Fire hazards, such as paint, rags, or oil; and missile hazards, such as loose gear, loose floor plates, toolboxes; and repair parts boxes should be noted. The condition of firefighting, damage control, and remote-control gear should be carefully inspected.

ANALYSIS OF THE BATTLE PROBLEM.— The maximum benefit obtained from conducting a battle problem lies in pinpointing existing weaknesses and deficiencies and in resulting recommendations for improvement in organization and training. Every effort should be made by the observers to emphasize strong points as well as deficiencies. Knowledge of existing strong points is helpful to boost the morale of the ship's personnel.

Analysis of the battle problem gives the observers an opportunity to present to the ship's company their opinion of its performance and for the ship's company to comment on the observers' remarks as well as to consider suggested improvements.

Analysis is conducted in two steps—the critique and the observers' report.

Critique of the Battle Problem.— A critique of the battle problem is held on board the observed ship before the observing party leaves so the problems and the actions taken may be reviewed when they are fresh in the minds of all concerned. The critique is attended by all the ship's officers, appropriate chief and first class petty officers, the chief observer, and all senior observers. The various points of interest of the battle problem are discussed. The chief observer comments on the overall conduct of the problem after the senior observers complete their analysis of the battle problem as reported in their observers' reports.

Observers' Reports.— The observers' reports are prepared in the form prescribed by the type commander and include any additional instructions given by the chief observer. The reports of the observers are collected by the senior observer for each department and are submitted to the chief observer. All observers' reports are reviewed by the senior observers before the critique is held.

The observers' reports (fig. 13-x.—An example of an engineering observer's report) provide the inspected ship with detailed observations of the battle problem which because of time limitations, may not have been brought out during the critique. The inspected ship receives a copy of all observers' reports; in this way, each department is given the opportunity to review the comments and set up a training schedule to cover the weak points.

The blank parts of the observers' report forms are filled as applicable to the individual observer's station. Items that were not observed are either left blank or crossed out. Additional information, if required for a certain exercise or condition, may be written on the reverse side of the form. A separate form or sheet is used for each exercise or drill. Remarks or statements made by the observer should be clear and legible.

MATERIAL INSPECTION

The purpose of material inspection is to determine the actual material condition of the ship. On the basis of what the inspection discloses, it may be necessary to recommend repairs, alterations, changes, or developments that will ensure the material readiness of the ship to carry out the mission for which it was designed. In addition, the material inspection determines whether or not proper procedures are being carried out in the care and operation of the machinery and the equipment. Administrative procedures and material records that are inspected include maintenance records and routine tests and inspections. The requirements prescribed for material readiness are as follows:

1. Established routines for the conduct of inspection sand tests, schedule for preventive maintenance, and a system which will ensure timely and effective repairs.

2. Adequate material maintenance records, kept in accordance with current directives, that give the history and detailed description of the condition of the machinery and the equipment.

Engineering observer ____________________
Location ____________________

1. The engineering department's evaluation is based on the following: (a)extent of the department's preparation and fulfillment of the ordered conditions of readiness as appropriate to the problems, (b) extent of correct utilization of the engineering damage control features built into the ship, (c) extent to which proper engineering casualty control is accomplished, (d) extent to which on station personnel take corrective action for control of damage, (e) adequacy of reports and dissemination of information, and (f) the general handling of the plant following good engineering practice and the ability of the department to ensure maximum mobility and maneuverability of the ship and to supply all necessary services to other departments in fighting the ship.

2. Hit ____________________
Exercise ____________________

a. Preparation and status of the plant.
b. Fulfillment of proper conditions of readiness.
c. Fire and missile hazards.
d. Condition of fire fighting and damage control gear.
e. Condition of personnel clothing and protection.
f. Stationing and readiness of personnel.
g. Investigation and interpretation of casualty.
h. Promptness and effectiveness in taking care of casualty.
I. Were proper doctrine and procedures used?
j. Were prompting and additional information given by observer?
k. Were proper reports made?
l. Readiness of standby units.
m. Readiness of alternate and emergency lighting and power.
n. Were proper safety precautions observed?
o. Material deficiencies.
p. Coordination of personnel.
r. Coordination of engineering spaces.

3. Main engine control. Receipt of vital interior communications, origination and transmission of required reports to Conn, Damage Control Central, and other stations.

4. Action taken by main engine control.

a. Correct action
b. Sound judgment based on good practice
c. Assurance
d. Speed

5. Recommendations.

Figure 13-19.—Observer's checklist.

3. Planned and effective utilization of the ship's facilities for preservation, maintenance, and repair.

4. Correct allocation of necessary work to the following categories:

a. The ship's force

b. The tenders and repair ships

c. The naval shipyards or other shore repair activity

The scope of the material inspection is similar to that of the inspection made by the Board of Inspection and Survey (discussed later in this chapter). These inspections should be thorough and searching. They should cover in detail, maintenance and repair not general appearance. The distinction between administrative inspections and material inspections should be readily recognized, and there should be as little duplication as possible. Examination of the material maintenance records and reports should be made to determine the material condition of the machinery and the equipment. General administrative methods, general appearance, cleanliness of compartments, and cleanliness of machinery are not part of this inspection, except in cases where they have a direct bearing on material condition.

The composition of the inspecting party for the material inspection is similar to that of the administiative inspection party.

Preparation for the Material Inspection

At an appropriate time before the date of the inspection, the chief inspector furnishes the ship with advance instructions. These instructions will include the following information:

1. A list of machinery and major equipment to be opened for inspection. The limit to which a unit of machinery or equipment should be opened is that which is necessary to reveal known or probable defects. The units selected to be opened should be representative and, in case of a multiple-shaft ship, should not disable more than one half of the propulsion units. Proper consideration must be given to the ship's operational schedule and safety.

2. A list of equipment to be operated. Auxiliary machinery such as the anchor windlass, winches, and steering gear are normally placed on this list.

3. Copies of the condition sheets. These are checkoff lists which are used for the material inspection.

4. Any additional instructions considered necessary by the type commander or other higher authority.

Each department must prepare work lists showing the items of work to be accomplished and the recommended means for accomplishment (shipyard, tender or repair ship, or ship's force during an overhaul or upkeep period). The items are arranged in the recommended order of importance and are numbered. A list of the outstanding alterations is also made up for the inspection. Work lists usually consist of 5- by 8-inch cards with one repair or alteration item on each card. The work list should include all maintenance and repair items, because if material deficiencies are found during the inspection they will be checked against the work list. If the item does not appear on the work list, a discrepancy in maintaining the required records will be noted by the inspector.

Condition Sheets

Condition sheets are made up by the needs of the different material groups. The engineering department is primarily concerned with the machinery, the electrical, the damage control, and the hull condition sheets. Condition sheets contain checkoff sheets and material data sheets and consist of a large number of pages. Items for data and checkoff purposes are listed for all parts of the ship and for all machinery and equipment on board ship.

In advance of the inspection, a preliminary copy of the condition sheets of the ship to be inspected must be filled in. Detailed data for the preliminary copy is obtained from the maintenance records and reports.

An entry for any known fault or abnormal condition of the machinery or equipment is made in the proper place on the condition sheets. Details and information are given, as necessary, to indicate the material condition to the inspecting party. If corrective work is required in connection with a unit or space, a reference is made to the work list item. Data and information requested in the condition sheets should be furnished whenever possible. The preliminary copy, if properly filled out, represents the best estimate of the existing material condition of the ship.

When the condition sheets have been completed, they are turned over to the respective members of the inspecting party upon their arrival on board ship. During the inspection the inspectors fill in the various checkoff sections of the condition sheets. These sheets are then used to prepare the final inspection report on the condition of the ship.

For more detailed information concerning a ship, you should obtain a copy of the applicable condition sheets from the engineering log room.

Opening Machinery for Inspection

The ship will open machinery as previously directed by the chief inspector to obtain the inspector's opinion concerning known or probable defects. The information given in *Naval Ship' s Technical Manual,* chapter 090, is used as a guide in opening particular machinery units. More detailed information on opening machinery for material inspections is found in the administrative letters of the type commander.

A list of machinery, tanks, and major equipment opened, and the extent of opening, should be supplied to the inspecting party on its arrival. Test reports on samples of lubricating oil should be furnished to the machinery inspector.

Ship's company should have portable extension lights rigged and in readiness for the units of machinery opened up for inspection. The lighting of the spare should be in good order. The inspectors should be furnished flashlights, chipping hammers, file scrapers, and similar items. Precision-measuring instruments should be readily available.

Assembly of Records and Reports

The material inspection also includes an inspection of various material records and reports. These documents are assembled so as to be readily available for inspection. Records must be kept up to date at all times. Check over all records to make sure that they are up to date and that nothing has been overlooked. The individual records should be filled out and maintained following current directives. Where applicable, the petty officer in charge of an engineering space should check all records or reports that concern the material or the maintenance procedures of that space.

Conduct of the Inspection

The inspecting group for the engineering department should conduct a critical and thorough inspection of the machinery and equipment under the responsibility of the department. The condition sheets supplied by the type commander serve as a guide and a checkoff list in making the inspection. Appropriate remarks, comments, and recommendations are entered on the condition sheets for any particular unit of machinery or equipment.

Inspection

The inspectors should conduct the inspection together with the ship's personnel. No attempt must be made to follow a predetermined inspection schedule, and different units should be inspected as they are made available by the ship's company. If the ship is prepared for the inspection, there should be no delay between the inspection of the different units of machinery. It is not necessary that all machinery of one type be inspected simultaneously. Also, its not necessary to complete the inspection of one space before going to another.

Important items to be covered by the inspection are indicated below:.

1. All opened machinery and equipment are carefully inspected especially where the need of repair work is indicated on the work list.

2. Investigations are made to locate any defects, in addition to those already known, which may exist in material condition or design.

3. Operational tests of machinery and equipment conducted in accordance with the furnished list.

4. Electrical equipment is checked to ensure that it is not endangered by salt water from hatches, doors, or ventilation outlets. Possible leaks in piping flanges are checked.

5. Equipment in the engineering spaces is inspected to ensure that it is properly installed and maintained.

6. Supports and running gear of heavy suspended material are inspected.

7. Hold-down bolts, plates, and other members of machinery foundations are inspected. Hammers may be used for sounding, and file scrapers may be used for removing paint to disclose any condition of metal corrosion.

8. Condition sheets are checked to see that the inspector, after receiving the reports from the inspectors, makes up a report on evaluating and grading the inspection. The chief inspector discusses, with appropriate comment, the following items:

   a. Those conditions requiring remedial action which should be brought to the attention of the commanding officer of the ship inspected and to higher authority

b. Those conditions of such excellence that their dissemination will be of value to other ships

c. Those suggestions or recommendations which merit consideration by higher authority

The final smooth report is written up in a detailed procedure following the type commander's directives.

BOARD OF INSPECTION AND SURVEY INSPECTION (INSURV)

The INSURV is under the administration of the CNO. This board consists of a flag officer, as president, and other senior offficers as required to assist the president in carrying out the duties of the board. Regional boards and subboards are established, as necessary, to assist the INSURV in the performance of its duties. In this chapter, the discussion centers on shipboard inspections made by suboards. These subboards consist of the chief inspector and 10 or more members, depending on the type of ship that is to be inspected.

Material Inspections Made by the Board

The inspection made by the INSURV is similar to the material inspection that has just been discussed. In fact, the INSURV's inspection procedures, condition sheets, and reports are used as guidelines in establishing directives for the material inspection. The primary difference is that the material inspections conducted by Forces Afloat, usually a sister ship, while the INSURV inspection is conducted by a specially appointed board. This distinction, however, refers only to routine shipboard material inspection. It must be remembered that the Board of Inspection and Survey conducts other types of inspections.

Inspections of ships are conducted by the Board of Inspection and Survey, when directed by CNO, to determine their material condition. Their inspection usually takes place four to six months before regular overhaul. Whenever practical, such inspections are held sufficiently in advance of a regular overhaul of the ship so as to include in the overhaul all the work recommended by the Board following the inspection. Upon the completion of its inspection, the Board reports the general condition of the ship and its suitability for further naval service, together with a list of the repairs, alterations, and design changes which, in its opinion, should be made.

Acceptance Trials and Inspections

Trials and inspections are conducted by the Board of Inspection and Survey on all ships before final acceptance for naval service to determine whether or not the contract and authorized changes there to have been satisfactorily fulfilled. The builder's trials and acceptance trials are usually conducted before a new ship is placed in commission. After commissioning, a final contract trial is held. Similar inspections are made on ships that have been converted to other types. All material, performance, and design defects and deficiencies found, either during the trials or as a result of examination at the completion of trials, are reported by the Board, together with its recommendations as to the responsibility for correction of defects and deficiencies. The Board also recommends any changes in design which it believes should be made to the ship itself or other ships of its type. These recommendations are made to the Secretary of the Navy.

Unless war circumstances prevent it, an acceptance trial takes place at sea over an established trial course. The tests include full power runs ahead and astern, quick reverse, boiler overload, steering, and anchor engine tests. During the trial, usually the builder's personnel operate the ship and its machinery. Ship's personnel who are on board to observe the trial carefully inspect the operation and material condition of machinery and equipment. They note all defects or deficiencies and bring them to the attention of the division or engineer officer so that each item can be discussed with the appropriate members of the Board of Inspection and Survey.

Survey of Ships

Survey of a ship is conducted by the Board of Inspection and Survey whenever a ship is deemed by the CNO to be unfit for further service because of material condition or obsolescence. The Board after a thorough inspection, renders an opinion to the Secretary of the Navy as to whether the ship is fit for further naval service or can be made so without excessive cost.

When the Board believes that the ship is unfit for further naval service, the Board makes appropriate recommendations as to the ship's disposition.

SHIP TRIALS

There are a number of different types of trials which are carried out under specified conditions. A list including most of them is given here:

1. Builder's trial
2. Acceptance trials
3. Final contract trials
4. Postrepair trials
5. Laying up or preoverhaul trial
6. Recommissioning trials
7. Standardization trials
8. Tactical trials
9. Full power trials
10. Economy trials

The trials that are considered to be routine ship's trials are numbers 4, 9, and 10 of the above list. Postrepair, full power, and economy trials are the only ones discussed in this chapter. Information on the other types of trials can be found in, *Naval Ship's Technical Manual,* chapter 094.

Postrepair Trial

The postrepair trial should be made whenever the machinery of a vessel has undergone extensive overhaul, repair, or alteration, which may affect the power or capabilities of the ship or the machinery. A postrepair trial is usually made when the ship has completed a routine naval shipyard overhaul period (the trial is optional whenever machinery has undergone only partial overhaul or repair). The object of this trial is to determine whether the work has been satisfactorily completed and efficiently performed and if all parts of the machinery are ready for service.

The postrepair trial should be held as soon as practical after the repair work has been completed, the preliminary dock trial made, and the persons responsible for the work are satisfied that the machinery is, in all respects, ready for a full power trial. The conditions of the trial are largely determined by the character of the work that has been performed. The trial should be conducted in such manner as the commanding officer and commander of the shipyard may deem necessary. A full power trial is not required in cases where repairs have been slight, and the commanding officer is satisfied that they have been satisfactorily performed and can be tested by other means.

Any unsatisfactory conditions found to be beyond the capacity of the ship's force should be corrected by the naval shipyard. When necessary, machinery should be opened up and carefully inspected to determine the extent of any injury, defect, or maladjustment that may have appeared during the postrepair trial.

A certain number of naval shipyard personnel, such as technicians, inspectors, and repairmen, accompany the ship on a postrepair trial. They check the operation of machinery that has been overhauled by the yard. If a unit of machinery does not operate properly, the yard technicians carefully inspect it to determine the cause of unsatisfactory operation.

Full Power and Economy Trials

Trials are necessary to test engineering readiness for war. Except while authorized to disable or partially disable, ships are expected to be able to conduct prescribed trials at anytime. Ships normally should be allowed approximately a 2-week period after tender overhauls and a 1-month period after shipyard overhaul to permit final checks, tests, and adjustments of machinery before being called upon to conduct competitive trials.

Trials are also held from time to time to determine machinery efficiency under service conditions, the extent, if any, of repairs necessary, the sufficiency of repairs, and the most economical rate of performance under various conditions of service.

Inspections and Tests Before Trials

The full power and the economy trials, as discussed in this chapter, are considered in the nature of competitive trials. It is assumed that the ship has been in full operational status for sufficient time to be in a good material condition and to have a well-trained crew.

Before the full power trial, inspections and tests of machinery and equipment should be made to ensure that no material item will interfere with the successful operation of the ship at full power. The extent of the inspections and the tests largely depends on the recent performance of the ship at high speeds, the material condition of the ship, and the time limits imposed by operational commitments.

Not later than one day before a trial, the engineer officer must report to the commanding officer the condition of the machinery, stating whether or not it is in proper condition and fit to proceed with the trial.

General Rules for Trials

During all full power trials and during other machinery trials, the following general rules should be observed:

1. Before a power trial, the machinery should be thoroughly warmed up; this can be accomplished by operating at a high fractional power.

2. The speed of the engines should be gradually increased to the speed specified for the trial.

3. The machinery should be operated economically, and designed pressures, temperatures, and number of revolutions must not be exceeded

4. The full power trial should not be conducted in **shallow water,** which is conducive to excessive vibration, loss of speed, and overloading of the propulsion plant.

5. If a full power trial should continue beyond the length originally specified, then all observations should be continued until the trial is finished.

6. The trial should be continuous and without interruption. If a trial at a constant rpm must be discontinued for any reason, that trial should be considered unsatisfactory and a new start made.

7. No major changes of the plant setup or arrangement should be made during economy trials.

Underway Report Data

Reports of trials include all the attending circumstances, to include the following:

Ž Draft forward, draft aft, mean draft, and corresponding displacement of the ship at the middle of the trial

- The condition of the ship's bottom
- The last time the ship was dry-docked
- The consumption of fuel per hour
- The average speed of the ship through the water

The average revolutions of the propelling engines. The methods by which the speed was determined should also be described.

Reports should also include tabulations of gauge and thermometer readings of the machinery in use and the revolutions or strokes of pertinent auxiliaries. The auxiliaries in use during the trial should be stated. Each report should state whether the machinery is in a satisfactory condition. If the machinery's condition is found to be unsatisfactory, all defects and deficiencies should be fully described and recommendations made for correcting them.

Trial Requirements

Trial requirements for each ship cover the rpm for full power at various displacements and injection temperatures. They are furnished to commanders and units concerned by the CNO Operations Readiness Division).

As far as reports are concerned, full power trials have a 4-hour duration. The usual procedure is to operate the ship at full power for a sufficient length of time until all readings are constant, and then start the official 4-hour trial period Economy trials have a 6-hour duration, with a different speed being run at each time a trial is made.

Once scheduled, trials should be run unless prevented by such circumstances as the following:

1. Weather conditions which might cause damage to the ship

2. Material troubles that force the ship to discontinue the trial

3. Any situation where running or completing the trial would endanger human life

If a trial performance is **unsatisfactory,** the ship concerned will normally be required to hold a retrial of such character as the type commander may consider appropriate.

The fact that a ship failed to make the required rpm for any hour during the trial and the amount by which it failed, should be noted in the trial report.

Observation of Trials

When full power trials are scheduled, observing parties are appointed from another ship whenever practical. When a ship is scheduled to conduct a trial while proceeding independently beween ports or under the other conditions where it is considered impactical to provide observers from another ship, the ship under trial may be directed to appoint the observers.

The number of personnel assigned to an observing party varies according to size and type of ship. The duties of the observing party are usually as follows:

1. The chief observers organize, instruct, and station the observing party. They check the ship's draft,

either at the beginning of the trial or before leaving port; supervise the performance of the engine room observers; check the taking of counter readings; render all decisions following current directives; and check and sign the trial reports.

2. The assistant chief observers assist the chief observers as directed; supervise the performance of the observers; check the taking of fuel oil soundings and meter readings; and make out the trial reports.

3. Assistant observers take fuel soundings, meter readings, counter readings, the ship's draft, and collect all other data that may be required for the trial reports.

The following items should be accomplished or considered before the trial is started.

1. When requested by the observing party, the ship under trial should provide or designate a suitable signaling system so that fuel soundings and the readings of counters and meters maybe taken simultaneously.

2. The ship under trial should furnish the chief observer with a written statement of the date of last undocking and the authorized and actual settings of all main machinery safety devices and dates when last tested.

3. The ship should have its draft, trim, and loading conform to trial requirements. In case a least draft is not specified, the liquid loading should equal at least 75 percent of the full load capacity.

4. The chief observer should determine draft and trim before and after the trial, verify the amount of fuel on board, and correct the amount of time at the beginning of the trial. The draft observer should also determine the rpm required for the full power trial at the displacement and injection temperature existing at the start of the trial.

5. The observing party should detect and promptly correct any errors in recording data, since it is important that the required data be correct within the limits of accuracy of the shipboard instruments.

6. The chief observer should instruct members of the observing party to detect any violation of trial instructions, of or of good engineering practice, and then verify any such report and provide the commanding officer a detailed account of each violation.

Manner of Conducting Trials

Some of the requirements in regards to the manner of conducting full power and economy trials are as follows:

1. Unless otherwise ordered a full power trial may be started at any time on the date set.

2. The trial should be divided into hourly intervals, but readings should be taken and recorded every half hour. Data are submitted as hourly readings in the trial report.

3. Fuel expenditures for each hourly interval of the trial should be determined by the most accurate means practical, normally by meter readings corrected for meter error and verified by soundings.

4. The appropriate material condition of the ship should be set during the different trials.

5. During all trials, the usual housekeeping and auxiliary loads should be maintained. The minimum services provided should include normal operation of the distilling plant, air compressor, laundry, galley, ventilation systems, elevators (if installed), and generators for light and power under load conditions similar to those required for normal operations at similar speeds under the prescribed material condition

6. All ships fitted with indicators, torsion meters, and other devices for measuring shaft or indicated horsepower should make at least two observations during the fullpower trial to determine the power being developed.

7. The chief observer's report of the trial should state whether all rules for the trial have been complied with.

There are special forms used for full power and economy trial reports. Illustrations of these forms are not given in this TRAMAN; however, you can obtain copies from your log room and, in this way, get an idea of the data and readings that are required for full power and economy trials.

Trial forms, and such items as tachometers, stopwatches, and flashlights, should be available to the observing party and to the personnel who take the readings. Any gauges or thermometers, which are considered doubtful or defective, should be replaced before trials are held. A Quartermaster must check and adjust all clocks in the engineering spaces and on the bridge before any trials are held.

Careful inspections and tests of equipment and items of machinery must be made that may cause difficulties during full power operation, since it is possible that unknown defects or conditions may go undetected during operation at fractional powers—the normal operating condition of the ship most of the time.

A common practice among many commanding officers when making full power trials is first to bring the ship up to a speed of 1 or more knots below the trial run speed of the ship and then turn the control of the speed (except in cases of emergency nature) over to the engineer officer. The control engine room, under the supervision of the engineer officer, brings the speed up slowly, depending on the conditions of the plant, until the specified speed has been reached.

NOISE POLLUTION INSPECTIONS

Hearing loss problems have been and continue to be a source of concern within the Navy, both ashore and afloat. In the Navy the loss of hearing can occur from exposure to impulse or blast noise (that is, gunfire, rockets, and so forth) or from continuous or intermittent sounds such as jet or propeller aircraft, marine engines, boiler equipment operations, and any number of noise sources associated with industrial activities (such as shipyards). Hearing loss may be temporary and will disappear after a brief period of nonexposure, or it may become permanent through repeated exposures to intense noise levels. The loss of hearing sensitivity is generally in the higher frequencies of 4,000 to 6,000 hertz (Hz) with many people sustaining extensive impairment before the all important speech range of 500 to 3,000 Hz is appreciably affected.

The Navy recognized noise pollution to be a problem and started to combat it through the Hearing Conservation Program. The main purpose of this program is to establish and implement an effective occupational noise control and hearing conservation program which has as its goal the elimination/prevention of hearing loss.

Hearing Conservation program

Hearing loss associated with exposure to hazardous noise and the high cost of compensation claims have highlighted a significant problem which requires action to reduce or eliminate hazardous occupational noise levels. An effective occupational noise control and hearing conservation program will prevent or reduce the exposure of personnel to potentially hazardous noise. Such programs will incorporate the following elements:

1. Identification of hazardous noise areas and their sources

2. Elimination or reduction of noise levels through the use of engineering controls

3. Periodic hearing testing of noise-exposed personnel to evaluate program effectiveness

4. Education of all hands in the command's program and their individual responsibilities

5. Strict enforcement of all prescribed occupational noise control and hearing conservation measures including disciplinary action for violators and supervisors, as necessary

Responsibilities

The Secretary of the Navy policy, contained in SECNAVINST 5100.1, emphasizes that occupational safety and health are the responsibilities of all commands. Accordingly, the following actions and responsibilities are assigned.

NAVAL MEDICAL COMMAND (BUMED).— The Commander of the Naval Medical Command must manage the hearing conservation program and maintain the program's currency and effectiveness. It must provide audiometric support to all military and civilian personnel who are included in a hearing conservation program, professional and technical assistance to commands responsible for assuring that the hearing of military and civilian personnel is protected, and appropriate professional and technical hearing conservation guidance and assistance to the Chief of Naval Education and Training (CNET).

It must develop guidelines and issue certifications following 0PNAVINST 6260.2 enclosure for personnel conducting sound level measurements, personnel performing hearing conservation audiometry, audiometric test chambers, audiometers, and all sound level measuring equipment. It must support a research and development effort in medical aspects of hearing conservation to ensure existing technology represents the most advanced state of the art.

CHIEF OF NAVAL MATERIAL.— The Chief of Naval Material (CHNAVMAT) must, in coordination with CHBUMED, provides technical assistance and engineering guidance to commands as indicated in OPNAVINST 6260.2 and periodically updates to maintain currency and effectiveness. Guidance must ensure consistent and required military capabilities, and that noise abatement is considered, designed, and engineered into all (both existing and future) ships and aircraft, weapons and weapon systems, equipment, materials, supplies, and facilities which are acquired, constructed, or provided through the Naval Material Command; and it must provide appropriate technical and engineering control methodology guidance and assistance to CNET.

THE CHIEF OF NAVAL EDUCATION AND TRAINING.— The Chief of Naval Education and Training (CNET) must, with the assistance of CHBUMED and CHNAVMAT, incorporate hearing conservation and engineering control guidance information in the curricula of all appropriate training courses. It must provide specialized hearing conservation and engineering control training and education, as required, and serve as the central source for the collection, publication, and dissemination of information on specialized hearing conservation and engineering control training courses.

NAVAL INSPECTOR GENERAL.— The Naval Inspector General (NAVINSGEN) must evaluate hearing conservation and engineering control procedures during conduct of the Navy's Occupational Safety and Health Inspection Program (NOSHIP) oversight inspections of activities ashore.

PRESIDENT, BOARD OF INSPECTION AND SURVEY.— The President of the Board of Inspection and Survey (PRESINSURV) must be directly responsible for oversight inspection aspects of shipboard hearing conservation and engineering control compliance. Inspections of fleet units must be incorporated into existing condition inspection programs.

COMMANDER, NAVAL SAFETY CENTER.— The Commander of the Naval Safety Center (COMNAVSAFECEN) must provide program evaluation, as requested, provide program promotion through NAVSAFECEN publications, and review program compliance during the conduct of surveys.

FLEET COMMANDER IN CHIEF.— Fleet Commanders in Chief and other major commanders, commanding officers, and officers in charge must ensure that all Navy areas, work sites, and equipment under their responsibtity are identified as potentially hazardous and labeled following OPNAVINST 6260.2 where noise levels are 85 dBA or greater or where impulse or impact noise exceeds a peak sound pressure level of 140 dB. Where necessary, surveys must be conducted in compliance with the guidance outlined in OPNAVINST 6260.2, enclosure (l). Enclosure (3) of OPNAVINST 6260.2 provides a listing of activities where industrial hygiene assistance may be obtained.

Where a potential noise hazard has been identified, a hearing conservation program must be instituted following OPNAVINST 6260.2, and a roster will be maintained on personnel placed in the program. Noise levels will be eliminated or reduced through the use of engineering controls.

Personal hearing protective devices will be provided and used properly by personnel where administrative or engineering controls are infeasible or ineffective. All military and civilian personnel whose duties expose them to potentially hazardous noise will receive instruction regarding the command occupational noise control and hearing conservation programs, the undesirable effects of noise, the proper use and care of hearing protective devices, and the necessity of periodic hearing testing. Emphasis will be placed upon leadership by example as regards the wearing of hearing protective devices. Command policy must be enforced including the initiation of disciplinary measures for repeated failure to comply with the requirements of the hearing conservation program.

ENGINEERING OFFICER.— OPNAVINST 6260.2 outlines the shipboard program for hearing conservation. Although the medical department representative has primary responsibility over this program, there are elements that the engineer officer must monitor and which are subject to periodic review. Periodic surveys must be accomplished to properly identify those areas within the propulsion spaces that fall into the category "Noise Hazardous Area." These areas must be marked, and personnel tasked with working in these areas must have available to them and use the prescribed aural protective devices. Training and discussion should emphasize the need for wearing these devices and should stress the medical elements of hazards to hearing resulting from "nonuse." The following paragraphs outline the specific actions to be taken by the engineering officer and subordinates to ensure the effectiveness of the command program.

The engineering officer will do the following:

1. Ensure that all newly reporting personnel have received a baseline audiogram and that each individual's medical record reflects the results of this examination.

2. Ensure that all engineering department personnel receive an annual reexamination by a medical activity.

3. Advise the medical department representative, by memorandum, of personnel by name who are working or standing watches in areas determined to be "high noise areas" and defined in OPNAVINST 6260.2.

4. Arrange for a noise survey to be taken initially by an industrial or IMA activity, and ensure that surveys are redone at least annually.

5. Designate "high noise areas" from the survey and ensure that areas are properly marked or labeled with prescribed markings. Advise the medical department of areas so designated and of any changes that may occur.

6. Issue aural protective devices to all personnel tasked to work in designated "high noise areas." These devices will be made available through the medical department for individual fitting and issue. Issue of these devices will be recorded in the individuals' medical records.

7. Ensure that sufficient training is provided to operating personnel concerning the hazards and preventive elements of the program, stressing the use of available protective devices.

8. The main propulsion assistant should be designated as the department officer to monitor and assist the engineer offficer in all elements of the program.

WORK CENTER SUPERVISOR.— As a work center supervisor, you are responsible for ensuring that safety signs are posted in your spaces which are high noise areas, that your personnel are trained and counseled as to the effects of noise pollution, and that they have the proper hearing protection as required for that area.

For additional information on the Hearing Conservation Program, refer to OPNAVINST 6260.2.

SUMMARY

Now that you have completed this chapter, you have an idea of just how many inspections and different types of maintenance you will deal with while in the Navy. Remember, most inspections are designed to help you in your work by pointing out problem areas before they become major problems.

CHAPTER 14

ENGINEERING CASUALTY CONTROL

The operating efficiency of a ship depends largely on the ability of the engineering department to continue its services both during normal operations and during casualties. Casualty control is concerned with the prevention, minimization, and correction of the effects of operational and battle casualties. Casualties are used in this chapter as defined in *Naval Ship's Technical Manual,* chapter 079, volume 2.

LEARNING OBJECTIVES

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

1. *Recognize the purpose of casualty control training.*
2. *Identify the purpose of the Engineering Casualty Control Evaluation Team (ECCET).*
3. *Recognize the purpose and identify the use of the Engineering Operational Sequencing System (EOSS).*
4. *Identify the casualty control organization.*
5. *List the duties and responsibilities of personnel within the casualty control organization.*
6. *Recognize some engineering casualties and identify the procedures for handling them.*

This chapter contains a discussion about casualty prevention, training, and restoration. These actions provide a ship with a well-rounded casualty control program.

CASUALTY PREVENTION

Casualty prevention is the most effective phase if casualty control. It concerns the quality of preventive maintenance on machinery and systems as an effort toward counteracting the effects of operational and battle casualties. Proper preventive maintenance greatIy reduces casualties caused by material failures. Continuous detailed inspection procedures are necessary. These inspections are necessary to disclose partially damaged parts that may fail at a critical time and to eliminate the underlying conditions that cause them. Some conditions that can cause failures include misadjustment, improper lubrication, and corrosion. These conditions are detrimental to machinery and cause early failure.

Casualty prevention requires constant training. Casualty control training must be a continuous step-by-step procedure. It should provide for study time and refresher drills. Any realistic simulation of casualties must be preceded by adequate preparation. You must impress upon your watch sections the full consequences of any error that may be made in handling real or simulated casualties.

Most engineering plant casualties are caused by lack of knowledge of correct procedures on the part of watch station personnel. If a simple problem is allowed to continue, the ship may be disabled. The following chart contains the causes of ineffective casualty control and their prevention:

CAUSE	PREVENTION
Lack of positive control	1. The engineering officer of the watch (EOOW) must maintain positive control of every situation that arises. 2. The EOOW must possess thorough knowledge of the correct procedures and systems operation.
Lack of effective communications	1. Maintain communications throughout the engineering plant at all times. 2. The *repeat back* technique for watch standers is the only means of ensuring that communications are received and understood.
Lack of systems knowledge	1. Watch sections must be familiar with the theory and operation of all vital engineering systems.

In the past, primary emphasis in casualty control training was placed on speed. Now, with the development and implementation of the Engineering Operational Casualty Control (EOCC) portion of the Engineering operational Sequencing System (EOSS), there is a more methodical and organized approach to casualty control. Because the approach is more methodical and organized, there is an increase in control, a decrease in plant disablements, and an increase in overall safety to plants and personnel. EOCC and EOSS will be discussed in more detail later.

To ensure maximum engineering department operational readiness, a ship must be self-sufficient in conducting propulsion plant casualty control drills. The management required for such drills involves the establishment of the Engineering Casualty Control Evaluation Team (ECCET). Preliminary administrative support for the training program must also be established.

ENGINEERING CASUALTY CONTROL EVALUATION TEAM (ECCET)

An ECCET should be developed for each underway watch section. Also, a sufficient number of personnel should be assigned to evaluate each watch station during the drills.

The engineering officer must ensure the development of an accurate, comprehensive drill package. It should be adequate to exercise the engineering department in all phases of casualty control procedures. The drill package should contain a complete file of drill scenarios and drill cards for each type of casualty that could possibly occur to the propulsion plant. Scenarios should contain the following information:

1. Drill title
2. Scenario number (if assigned)
3. General description of the casualty
4. Method of imposing the drill
5. Cause (several causes should be listed if plausible)
6. Estimated time of repair (ETR)
7. Cautions to prevent personnel hazards or machinery damage
8. Any simulations to be used in the drill

The purpose of the drill cards is to give the ECCET members ready reference to procedures to be followed. Therefore, the drill cards must give the correct procedure to be followed by each watch team member; and the procedure should be in the proper sequence for the drill. The engineering officer must ensure that adequate research is done and that each scenario is accurate. EOCC, if installed, should be the prime information source. The main propulsion assistant (MPA) should have custody of a master drill card package. This package should have appropriate copies of applicable drill scenarios. It should also include drill cards for each space.

Planning and scheduling casualty control drills should receive equal priority with other training evolutions conducted during normal working hours. When a specified time for the conduct of casualty control drills is authorized by the CO, the engineer officer must prepare a drill plan. Careful preplanning and sequencing of events are mandatory.

After the proposed drill plan is approved by the CO, designated ECCET personnel meet. The meeting is held to make sure that all members of the team understand the procedures and the sequencing of events. In preparing the drill plan, consideration is given to the following items:

- General condition of the engineering plant
- Machinery and safety devices out of commission
- Length of time set aside for the drill
- State of training of the watch section
- Power to be provided to vital circuits

Within the constraints of these items, three priorities are considered.

1. The **first priority** on drill selection is given to boiler casualty drills and/or propulsion space fire drills. These drills represent the greatest danger. They involve the largest number of propulsion plant watch team personnel.

2. The **second priority** is given to lube oil system casualties. This is because of the inherent danger to main and auxiliary equipments that these casualties represent.

3. The **third priority** is given to other main engine casualties.

NOTE: In selecting drills, the engineering officer must give emphasis to the development of watch team proficiency in handling priority one casualties.

Normally, ECCET members arrive on station shortly before the drills begin. Team members make sure that communications are established throughout the plant. With the officer of the deck's (OOD's) permission, the drill initiator imposes a casualty according to the drill plan. With regard to safety of personnel and equipment, drills are conducted as realistically as possible. Simulations are kept to an absolute minimum. Any time a hazardous situation develops, ECCET members assist the watch section in restoring the plant to proper operation. ECCET members also complete a drill critique form during the course of the drill.

As soon as possible, following the drill, a critique is conducted. Personnel of the applicable watch section attend. ECCET members and the engineering officer also attend. The ECCET leader gives the result of the drill. All other ECCET members then read their drill critique forms. Drills are evaluated as satisfactory or unsatisfactory by the ECCET leader. The evaluation is based on a review of the critique sheets before the critique. The following deficiencies form a basis for a finding of unsatisfactory:

1. Loss of plant control by the EOOW or space supervisor when either is unaware of overall plant status. It is also unsatisfactory if they are unable to restore the plant to a normal operating condition utilizing EOSS/EOCC or other issued casualty control procedures.

2. Safety violations that may cause a hazard to personnel or result in serious machinery derangement.

3. Significant procedural deficiencies that indicate a lack of knowledge of the proper procedures to be followed in correcting a casualty.

ENGINEERING OPERATIONAL SEQUENCING SYSTEM (EOSS)

The Navy has developed a system known as the Engineering Operational Sequencing System (EOSS). Essentially, the EOSS is to the operation of equipment as PMS is to maintenance.

In ships of today's modern Navy, main propulsion plants are becoming more technically complex as each new class of ship is built and joins the fleet. Increased complexity requires increased engineering skills for proper operation. Ships that lack the required experienced personnel have material casualties. These casualties have jeopardized the ship's operational readiness. Rapid turnover of engineering personnel who man and operate the ships further compounds the problem of developing and maintaining a high level of operator and operating efficiency.

The Navy is aware of these problems. Studies have been done to evaluate the methods and procedures presently used in operating complex engineering plants. The results of these studies have shown that in many instances sound operating techniques were not followed. Some of the problems found in engineering plants are described in the following paragraphs:

- The information needed by the watch stander was scattered throughout publications that were generally not readily available.

- The bulk of the publications were not systems oriented. Reporting engineering personnel had to learn specific operating procedures from *old hands* presently assigned. Such practices could ultimately lead to misinformation or degradation of the transferred information. These practices were costly and resulted in nonstandard operating procedures, not only between adjoining spaces but also between watch sections within the same space.

- Posted operating instructions did not apply to the installed equipment. They were conflicting or incorrect. No procedures were provided for aligning the various systems with other systems.

- The light-off and securing schedules were prepared by each ship and were not standardized between ships. The schedules were written for general, rather than specific, equipment or system values. They did not include alternatives between all the existing modes of operation.

Following these studies, NAVSEA developed the EOSS, which is designed to help eliminate operational problems. The EOSS consists of a set of systematic and detailed written procedures. The EOSS is made up of charts, instructions, and diagrams that are developed specifically for the operational and casualty control function of a specific ship's engineering plant. EOSS involves the participation of all personnel from the department head to the watch stander.

EOSS is designed to improve the operational readiness of the ship's engineering plant. It does this by increasing its operational efficiency and providing better engineering plant control. It also reduces operational casualties and extends the equipment life by (1) defining the levels of control (2) operating within the engineering plant, and (3) providing each supervisor and operator with the information needed. This is done by putting it in words they can understand at their watch station.

The EOSS is composed of three basic parts.

1. The *User's Guide*
2. The Engineering Operational Procedures (EOP)
3. The Engineering Operational Casualty Control (EOCC)

EOSS User's Guide

The *User's Guide* is a booklet explaining the EOSS package and how it is used to the ship's best advantage. The booklet contains document samples and explains how they are used. It provides recommendations for training the ship's personnel in using the specified procedures.

EOSS documentation is developed using work-study techniques. All existing methods and procedures for plant operation and casualty control procedures are documented. These include the actual ship procedures as well as those procedures contained in available reference sources. The resulting sequencing system provides the best tailored operating and EOCC procedures available pertaining to a particular ship's propulsion plant.

Engineering Operational Procedures (EOP)

The operational portion of the EOSS contains all information necessary for proper operation of a ship's engineering plant. It also contains guides for scheduling, controlling, and directing plant evolutions through operational modes from receiving shore services, to various modes of in-port auxiliary plant steaming, to underway steaming.

The EOP documentation is prepared for specifically defined operational stages—stages I, II, and III.

STAGE I.— Stage I deals with the total engineering plant under the direct responsibility of the plant supervisor (EOOW). The EOOW coordinates placing all systems and components (normally controlled by the various space supervisors) in operation and securing them. This person also supervises functions that affect conditions internal to the engineering plant, such as jacking, testing, and spinning main engines. The EOP documentation assists the plant supervisor to ensure optimum plant operating efficiency, properly sequencing of events in each operational evolution, and the training of newly assigned personnel. During a plant evolution, the EOOW designates control and operation of the following systems and components:

- Systems that interconnect one or more engineering plant machinery spaces and electrical systems
- Major components, such as boilers, main engines, and electrical generators
- Systems and components required to support the engineering plant or other ship functions, such as distilling plants, air compressors, fire pumps, and auxiliaries that are placed in operation or secured in response to demand upon their services

To help the plant supervisor with stage I, the EOP section contains the following documents:

Index pages	Lists each document in the stage I station book by identification number and title.
Plant procedure charts (fig. 14-1)	Lists the step-by-step procedures for each engineering plant evolution. The example shows the types of EOSS charts used regardless of equipment.
Plant status boards (fig. 14-2)	A systematic display of the major systems and cross-connect valves as well as a graphic presentation of the major equipment in each machinery space. These boards are used to maintain a current plot of systems alignment and equipment operating status.
A diagram for plant steaming conditions versus optimum generator combinations	The preferred electric power generator combinations for the various plant operating conditions.
System alignment diagrams (fig. 14-3)	The preferred initial and final alignment for each engineering plant.
A diagram for equipment versus speed requirement	The equipment normally required for various ship speeds.
A diagram for shore services connection locations	The location of shore service connections for steam, electrical power, feedwater, potable water, salt water, and fuel oil.
Training diagrams (fig. 14-4)	Each major piping system to aid in plant familiarization and training of newly assigned personnel. These diagrams indicate the relative locations of lines, valves, and equipment.

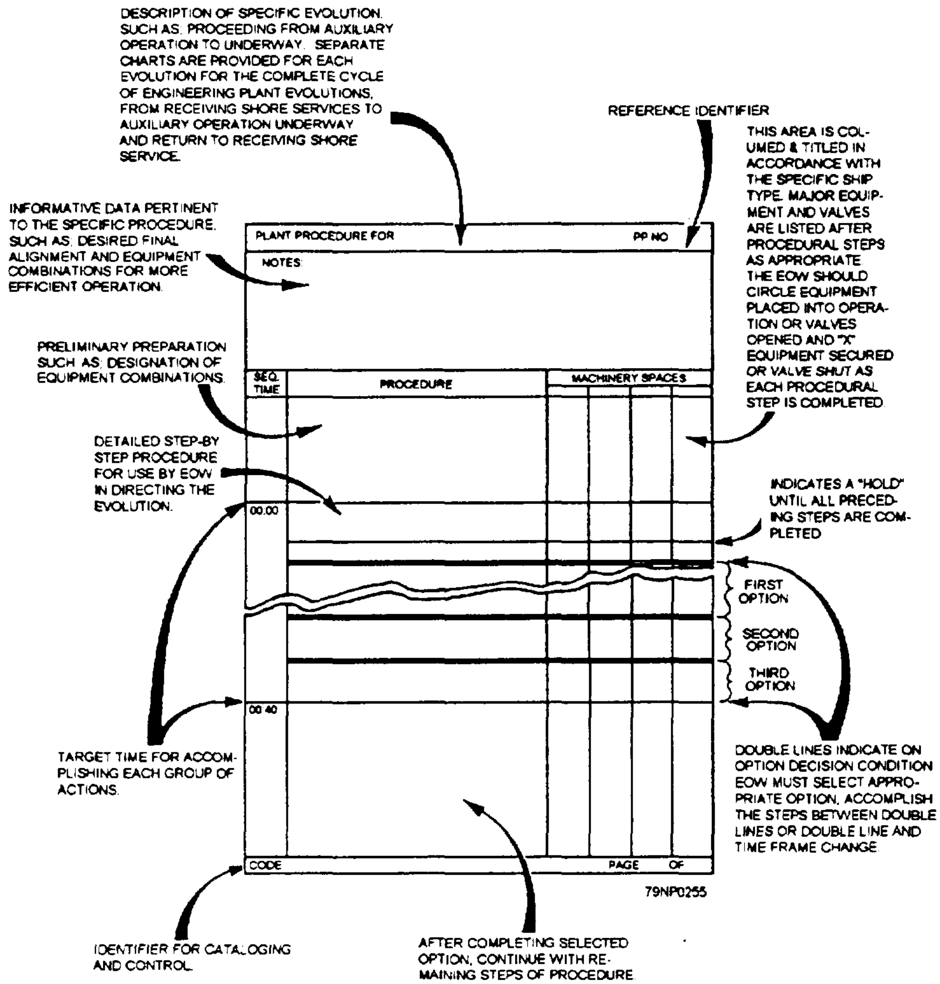


Figure 14-1.-Sample plant procedure chart.

STAGE II.— Stage II deals with the system component level under supervision of the space supervisor in each engine room and fireroom and the electrical plant supervisor (electrical load dispatcher). In stage II, the space supervisor accomplishes the tasks delegated by the plant supervisor. The EOP documentation helps the space supervisor to properly sequence events, to control the operation of equipment, to maintain an up-to-date status of the operational condition of the equipment assigned, and to train newly assigned personnel. To assist the space supervisor in this effort, the EOP section provides the following stage II documents:

Index pages	Lists each document by identification number and title for each specified operating group, such as engine room, fireroom, or electrical system.
Space procedure charts (similar to the plant procedure chart)	The step-by-step procedure to be accomplished within a space to satisfy and support the requirements of the plant procedure charts.
A space status board	A schematic of major systems and a tabular listing of the major equipment within the individual machinery spaces for maintaining a plot of system alignments and equipment operating status. This board is similar in configuration to that provided for the stage I documentation (fig. 14-5).
A diagram for electrical plant status (DLS)	The generators, switchboards, and shore-power connections within the electrical distribution systems. The DLS is provided in both the electrical operating group and in the stage I (EOOW) documentation for maintaining a plot of the system alignment.
A diagram for plant steaming conditions versus optimum generator combinations	The electrical operating group documentation. This diagram specifies the preferred electric power generator combination. (**NOTE**: This diagram is the same as that provided in the stage I documentation.)
Training diagrams of each major piping system	Stage I, plus diagrams of such systems as fuel-oil service and main engine lube oil that are normally located within the machinery spaces.

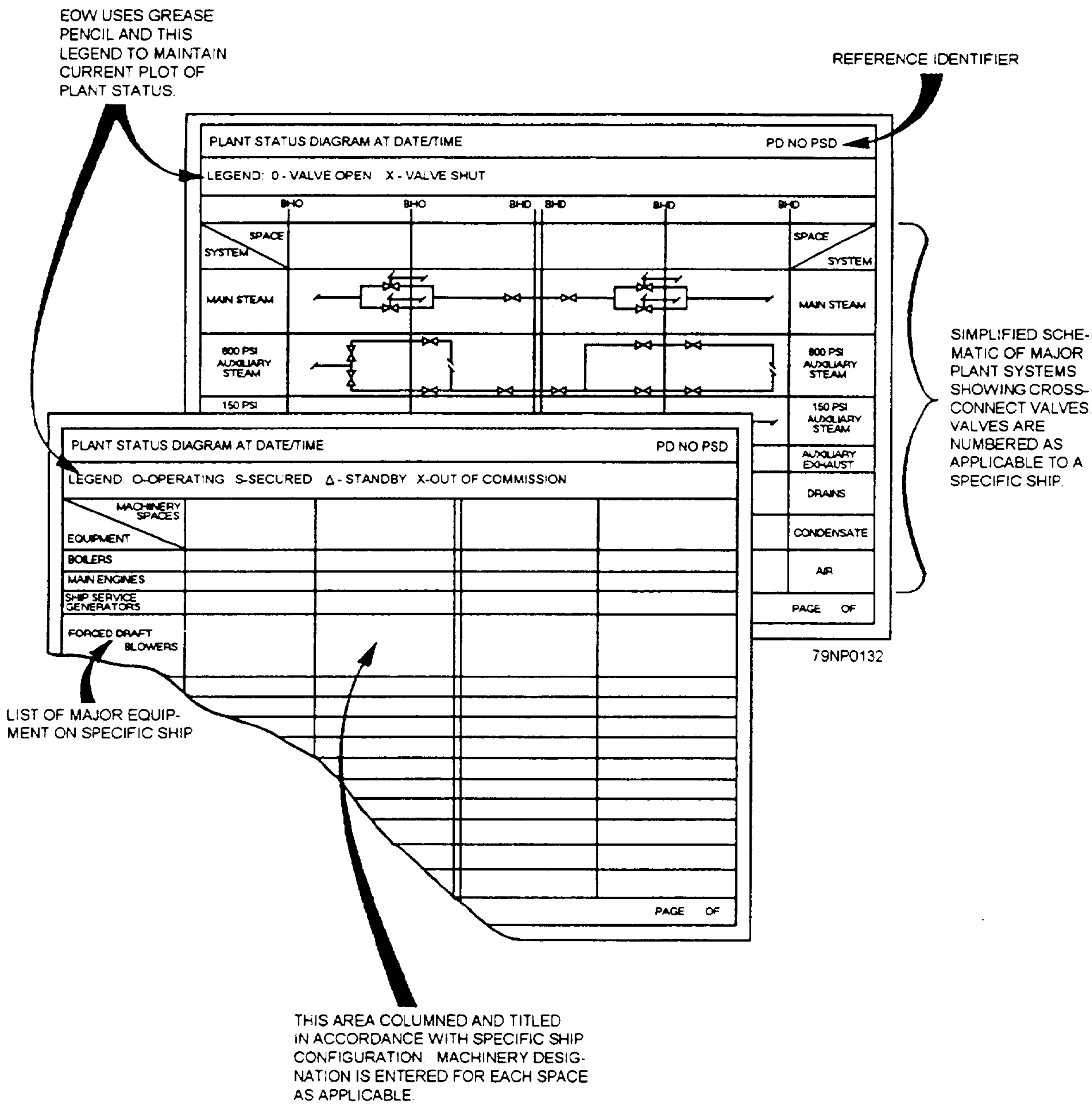


Figure 14-2.-Sample plant status diagram.

STAGE III.— Stage III deals with the system component level under the supervision of component operators. The component operators place equipment in and out of operation, align systems, and monitor and control their operation. This is done by manipulating required valves, switches, and controls. Stage III documentation includes the following:

Index pages	Lists each document by identification number and title for each specified system, such as the fuel-oil service system and the lube oil service system.
Component procedure cards	The step-by-step procedures for systems alignment or component operation.
Component procedure cards (as required)	These cards support each operation or alignment.
Alignment diagrams (fig. 14-6)	These diagrams amplify the written procedure to help the component operator in proper systems alignment. Alignment diagrams are provided whenever two or more alignment conditions exist for a given system or component.

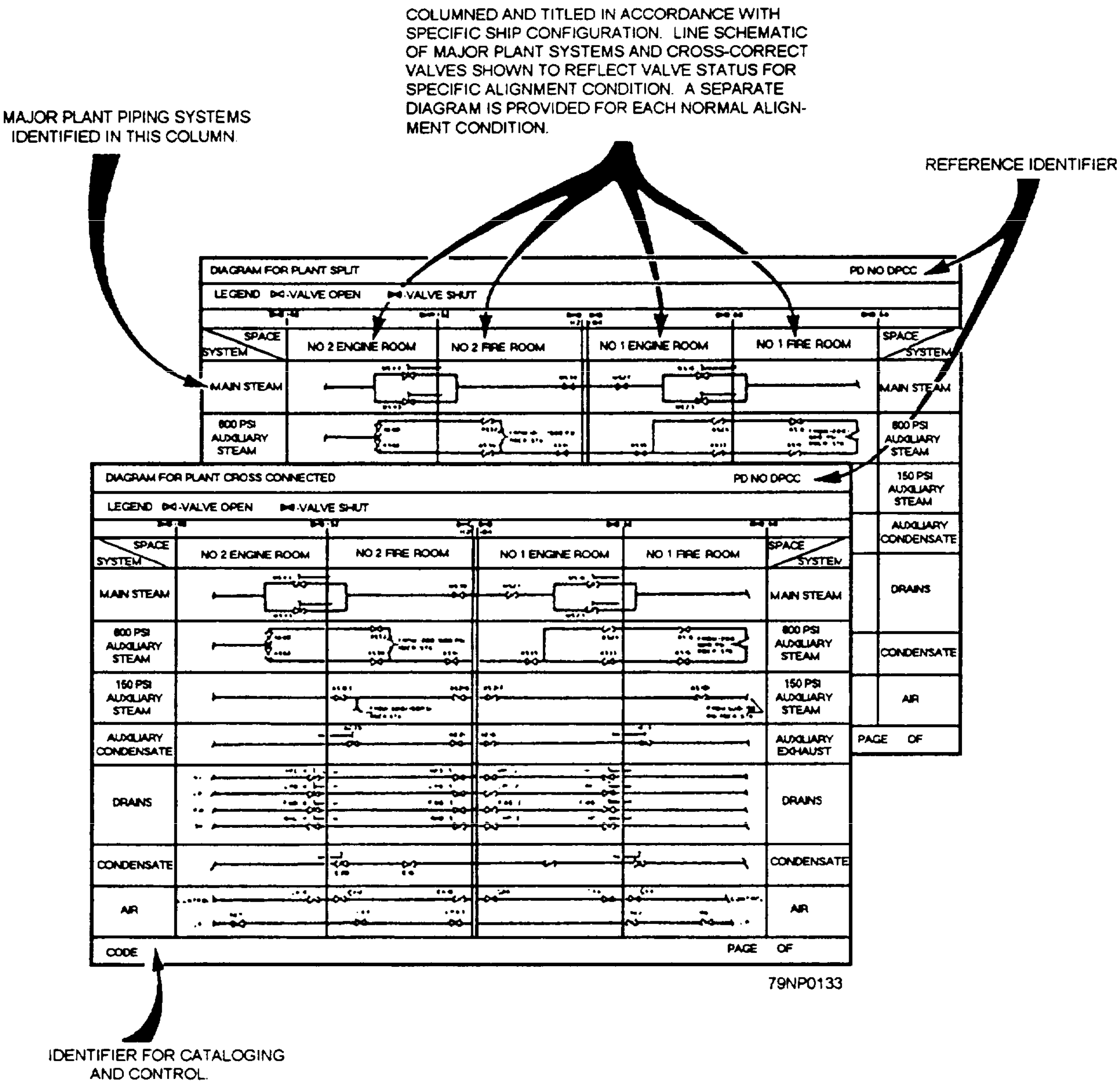


Figure 14-3.—Sample preferred alignment diagrams.

The operational use of EOP documentation is of primary importance at all levels in controlling, supervising, and operating the evolutional functions of the engineering plant.

Engineering Operational Casualty Control (EOCC)

The casualty control portion of EOSS contains information related to the recognition of casualty symptoms and their probable causes and effects. In addition, the EOCC contains information on preventive actions to take to prevent a casualty. It also specifies procedures for controlling single- and multiple-source casualties.

Casualty prevention is the concern of everyone on board. Proper personnel training provides adequate knowledge and experience in effective casualty prevention. The EOCC manual contains efficient, technically correct casualty control and prevention procedures. These procedures relate to all phases of an engineering plant. The EOCC documents possible casualties that may be caused by human error, material failure, or battle. The EOCC manual describes proven methods for controlling a casualty. It also provides

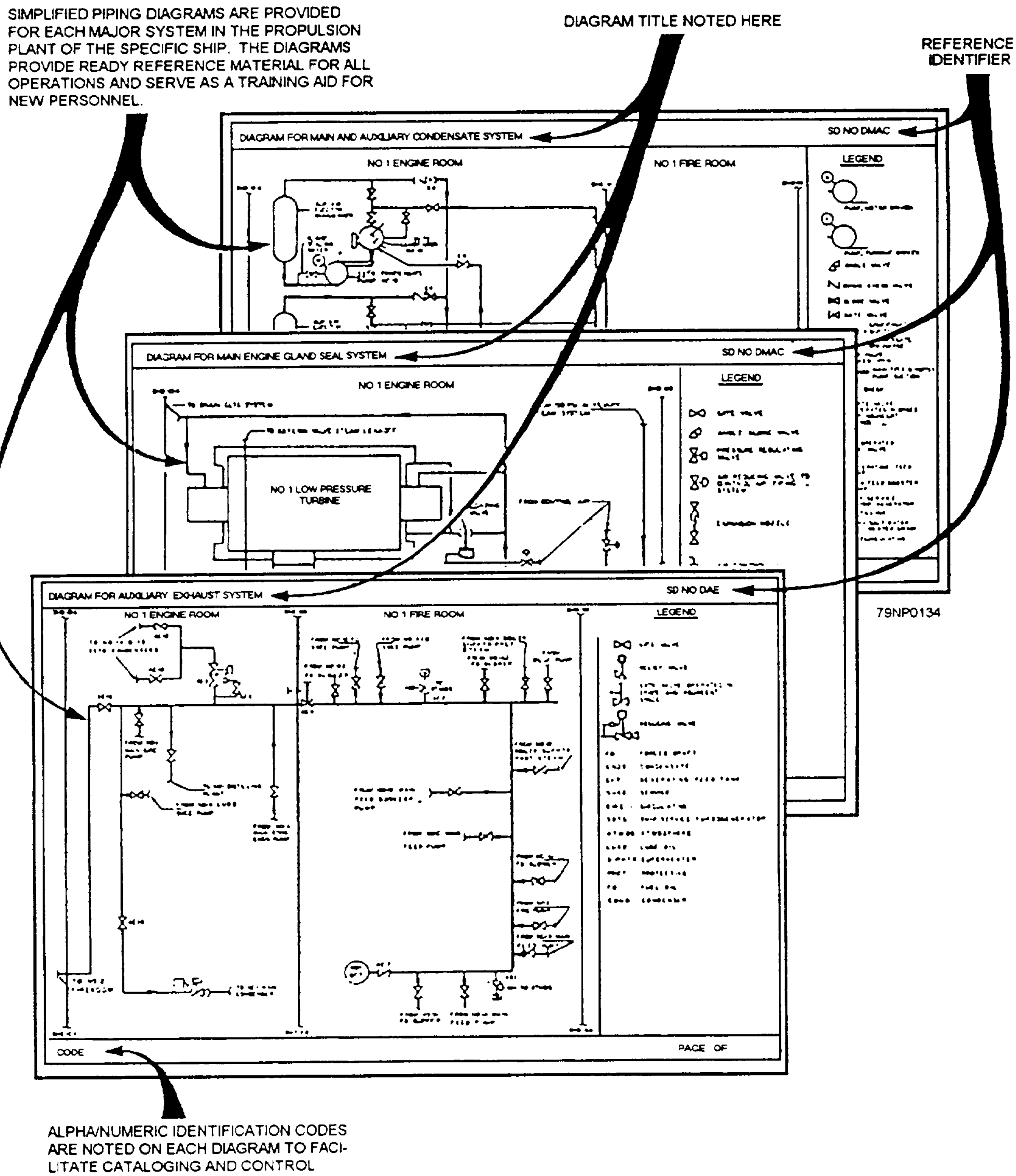


Figure 14-4.-Sample training diagram.

information for preventing further damage to the component, the system, or the engineering plant.

The EOCC manuals are available to personnel in their own machinery space so that they can be used as a means of self-indoctrination for newly assigned personnel. The EOCC can also be used as an instrument to improve casualty control procedure techniques for all watch standers. The manual contains documentation to help engineering personnel develop and maintain maximum proficiency in controlling casualties to the ship's propulsion plant.

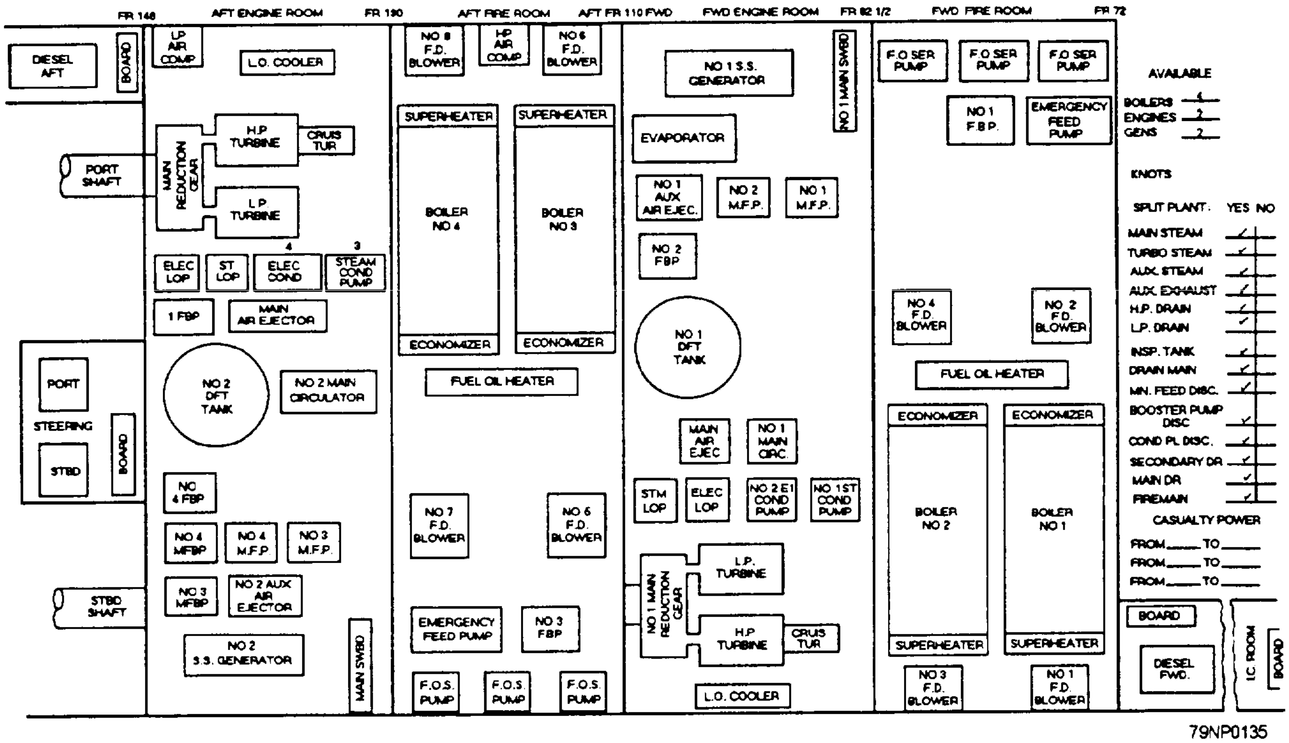


Figure 14-5.—Casualty control board.

Proficiency in EOCC procedures is maintained through a well-administered training program.

- **Primary training** concentrates on the control of single-source casualties. These are casualties that can be caused by the failure or malfunction of a single component or the failure of piping at a specific point in a system.
- **Advanced training** concentrates on the control of multiple casualties or on conducting a battle problem.

An effective, well-administered EOOW training program must contain, as a minimum, the following elements:

- Recognition of the symptoms
- Probable causes
- Probable effects
- Preventive actions that may be taken to reduce, eliminate, or control casualties

An EOSS package is not intended to be forgotten once it is developed and installed aboard a ship. It offers many advantages to the ship's operational readiness capabilities and provides detailed step-by-step sequencing of events for all phases of the engineering plant operation. Because it is developed through work study and is system oriented, the EOSS provides the basic information for the optimum use of equipment and systems. It does this by specifying correct procedures tailored for a specific plant configuration.

The EOSS does not eliminate the need for skilled plant operators. No program or system can achieve such a goal. The EOSS is a tool for better use of manpower and skills. Although the EOSS is an excellent tool for training shipboard personnel, it is primarily a working system for scheduling, controlling, and directing plant operations and casualty-control procedures.

CASUALTY CORRECTION

Casualty correction deals with correcting the effects of operational and battle damage to minimize the effect of the casualty on the ship's mobility, offensive capability, and defensive power. Casualty correction consists of actions taken at the time of the casualty to prevent further damage to the affected unit and actions taken to prevent the casualty from spreading through secondary effects.

The speed with which corrective action is applied to an engineering casualty is often of paramount importance. The extent of the damage must be

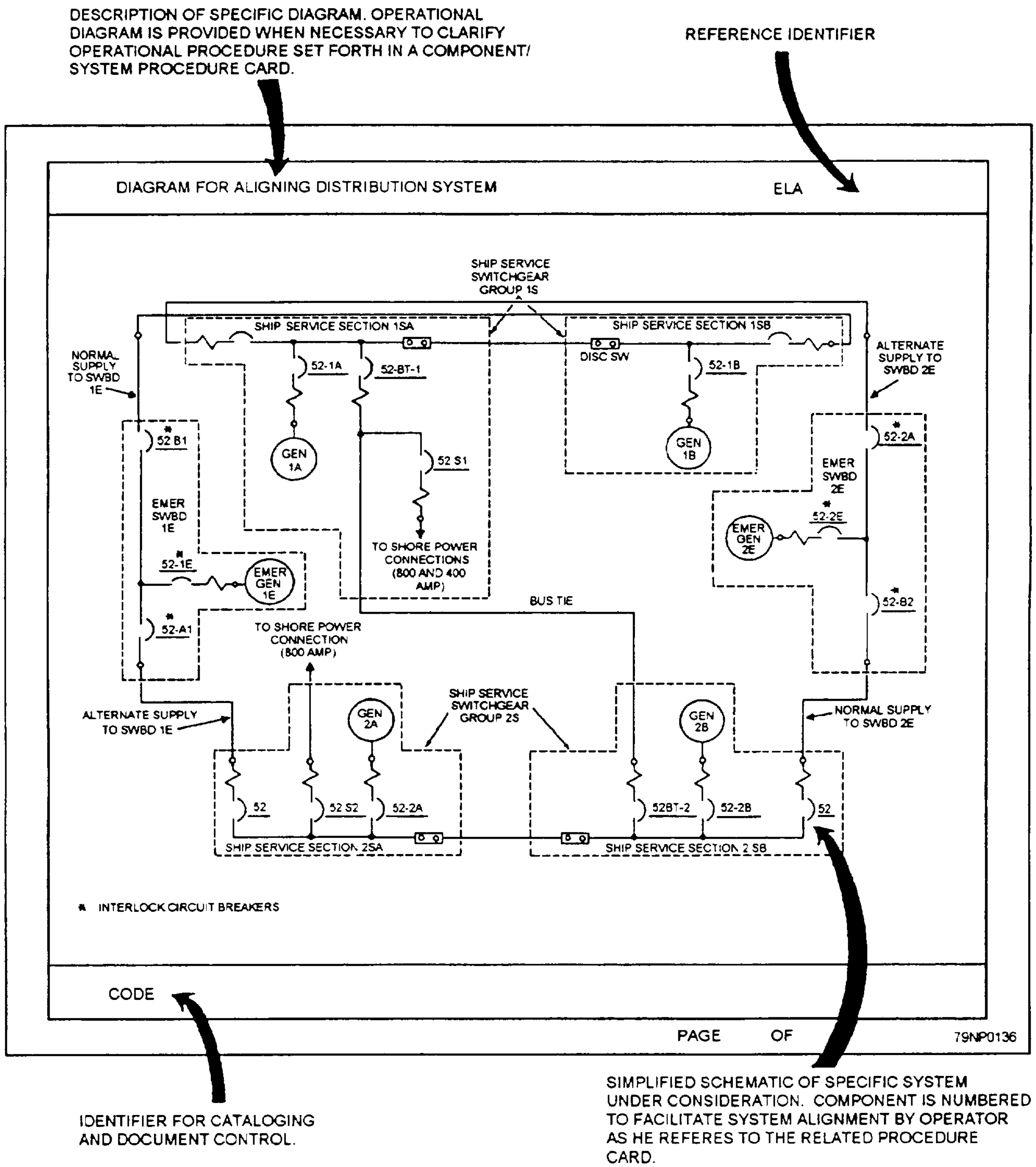


Figure 14-6.-Sample component/system alignment diagram.

thoroughly investigated and reported to the engineer officer. To maintain maximum available speed and services, the engineer officer must be informed at all times of the condition of the plant.

The CO has the responsibility of deciding whether to continue operation of equipment under casualty conditions. Such a decision carries the possible risk of permanent damage and can be justified only when the risk of greater damage or loss of the ship may occur if the affected unit is immediately secured.

CASUALTY CONTROL ORGANIZATION

The speed with which corrective action is applied depends on how well your casualty control organization is set up and on the amount of training that has been conducted.

Engineering Officer of the Watch (EOOW)

The EOOW is the officer on watch in charge of the main propulsion plant and associated auxiliaries. On most types of ships, the EOOW is normally a senior petty officer. As an EM1 or EMC, you will be primarily responsible for the safe and efficient performance of the engineering department watches (except damage control). The engineer officer determines who is qualified to perform the duties of the EOOW, and makes his/her recommendation to the CO for final qualification.

When the engineer officer considers you qualified in all respects, you will be assigned to the watch. The engineer officer or, in his/her absence, the MPA is authorized to direct the EOOW concerning the duties of the watch when such action is necessary. Other duties you should perform as EOOW are listed as follows:

1. Make frequent inspections of the machinery (boilers, engines, generators, evaporators, and auxiliaries) in the engineering department to make sure that machinery is being operated under current instructions. Ensure required logs are properly maintained, machinery and controls are properly manned, applicable inspections and tests are being performed, and all applicable safety precautions are being observed.

2. Frequently monitor IC circuits to ensure required circuits are proper] y reamed. Ensure circuit discipline is maintained and correct message procedures and terminology are used.

3. Ensure that all orders received from the OOD concerning the speed and direction of rotation of the main propulsion shafts are promptly and properly executed. Also, ensure the engineering log and the engineer's bell book are properly maintained.

4. Immediately execute all emergency orders concerning the speed and direction of rotation of the main propulsion shafts.

5. Keep the OOD and the engineer officer informed of the condition of the main propulsion plant and the maximum speed and power available with the boiler and machinery combinations that are in use.

6. Ensure that all directives and procedures issued by higher authority are observed.

7. Know the power requirements for all possible operations. Determine that the boiler and machinery combinations in use effectively meet current operational requirements. Advise the engineer officer and the OOD when modification of the machinery combinations in use is considered appropriate. Inform the OOD of any necessary changes in the operation of boilers, main engines, generators, and other major auxiliaries.

8. Supervise the training of the personnel on watch. To ensure effective training is held, it is necessary for the EOOW to understand specific operation and maintenance of engineering plant equipment. Refer to *Machinist's Mate 3 & 2,* NAVEDTRA 12144, chapters 2, 3, 4, 9, and 10, and *Boiler Technician 3 & 2,* NAVEDTRA 12140, chapters 2, 3, 4, 7, 8, 9, and 10 for this information. The EOOW should insist that each person in charge of an engineering watch station carefully instruct the personnel under their charge in specific duties and in the duties of all persons on the same watch station.

9. Perform such other duties as the engineer officer may direct. The EOOW reports to the OOD for changes in speed and direction of rotation of the main propulsion shafts and for requirements of standby power and other engineering services anticipated or ordered. The EOOW reports to the engineer officer for technical control and matters -affecting the administration of the watch.

Watch Teams

The basic organization for engineering casualty control is the watch team in each main space.

Watch teams should be thoroughly organized. Each person should be assigned duties for watch standing and casualty control for fire, flooding, and setting material conditions. The petty officer in charge of each team should maintain complete control to avoid confusion that could disrupt organization and coordination of the team.

In effectively controlling engineering casualties, it is extremely important that information be given to all stations. The engineer officer must receive brief, clear, and concise information from all stations. This information is needed to properly administer the operation of the engineering plant and to promptly order corrective measures for the control of casualties.

The sound-powered telephone (circuit 2JV) is the principal means of transmitting engineering casualty information. The telephone talker has an important job and is the key to good communications. If a message is not relayed promptly and correctly, it may place the ship in danger. In battle, the safety of the ship and the crew depends on how well the talker uses his/her voice and equipment. **Officers and petty officers must be proficient in using proper engineering terms and phraseology.** It isn't the responsibility of the talker to decipher, translate, or rephrase improperly transmitted orders; this is the responsibility of the person issuing the order or originating the message. It is the duty of the talker to relay messages as given.

Standard wording makes communication easier both within and between teams. Standard wording minimizes confusion by reducing the amount of conversation so that transmissions are easily relayed and understood. When it is practical, one command should initiate an entire casualty procedure.

It is much more effective within the team and between teams to pass the command

CROSS-CONNECT THE PLANT, or CROSS-CONNECT MAIN FEED, PORT SIDE

than it is to say

OPEN VALVES MAIN STEAM 15, MAIN STEAM 8, AUXILIARY STEAM 79 AND 80, AND AUXILIARY 44.

If the command from main engine control is CROSS-CONNECT MAIN FEED, STARBOARD SIDE, the petty officers in charge of No. 1 and No. 2 firerooms will repeat CROSS-CONNECT MAIN FEED, STARBOARD SIDE. The crew already assigned this procedure will open the correct valves with no further command and report back when a job is done. This is because the engineer officer often has to wait for a report before giving another command. The use of good talker procedure and standard wording will show immediate results.

Casualty Control Board

The casualty control board (fig. 14-5) is essential to effective casualty control during battle conditions. It furnishes a complete picture of the machinery available to the engineer officer at general quarters and watch personnel during normal watches.

For optimum results, a casualty control board should be installed at the main engine control, the after engine room, and at the main propulsion repair party station. The 2JV talkers at these stations should be responsible for maintaining the boards. The status of machinery is indicated by marking the affected unit with a grease pencil on the Plexiglass front of the casualty control board.

NOTE: The casualty control board in figure 14-5 is an example and is not suitable for all ship types.

Repair Party

In *Manual of Navy Enlisted Manpower and Personnel and Occupational Standards,* NAVPERS 18068-D, one of the requirements for an EM1 or EMC is to supervise a damage control repair party. Being the leader, you must be familiar with all the equipment used and its function. You must train your personnel in the use of the equipment and the functions of the repair party. The functions that each repair party should be capable of making and that are common to all repair parties is listed as follows:

1. Making repairs to electrical and sound-powered telephone circuits.

2. Giving first aid and transporting injured personnel to battle dressing stations without seriously reducing the damage control capabilities of the repair party.

3. Detecting, identifying, and measuring dose and dose-rate intensities from radiological contamination. They must be able to survey and decontaminate contaminated personnel and areas, except where specifically assigned to another department as in the case of nuclear weapons accident/incident.

4. Sampling and/or identifying biological or chemical agents. They must be able to decontaminate areas and personnel affected as a result of biological or chemical attack, except where this responsibility is assigned to the medical department.

5. Controlling and extinguishing all types of tires.

6. Each party must be organized to evaluate and correctly report the extent of damage in its area, to include maintaining the following:

   a. Deck plans showing locations and safe routes to NBC decontamination, battle dressing, and personnel cleaning stations.

   b. A casualty board for visual display of structural damage.

c. A graphic display board showing damage and action taken to correct disrupted or damaged systems. The use of standard damage control symbology and the accompanying preprinted message format are recommended to facilitate the recording and transmittal of damage control information. Use standard damage control symbology, as shown in figures 14-7, 14-8, and 14-9, to write and read message

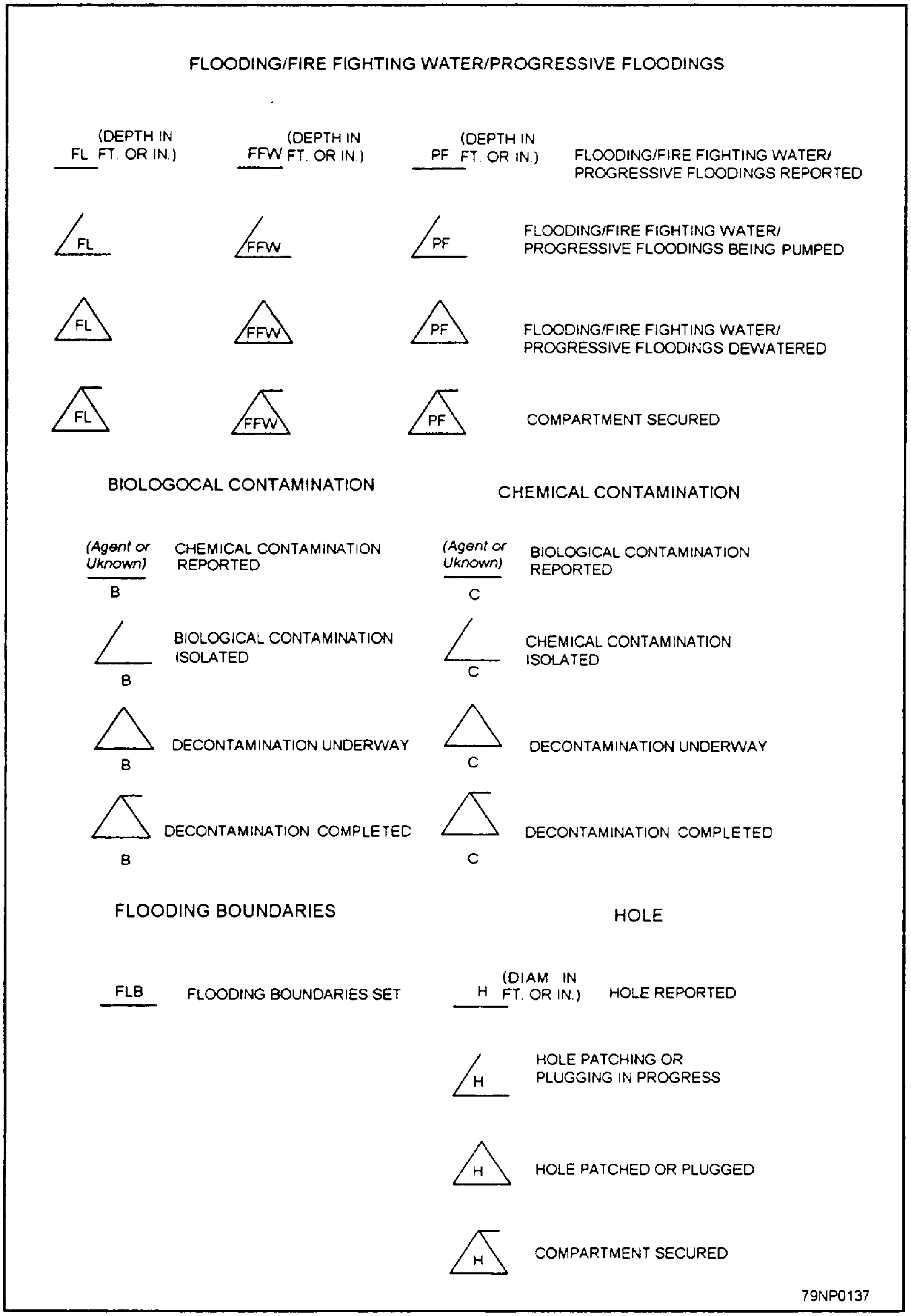


Figure 14-7.—Navy standard damage control symbology.

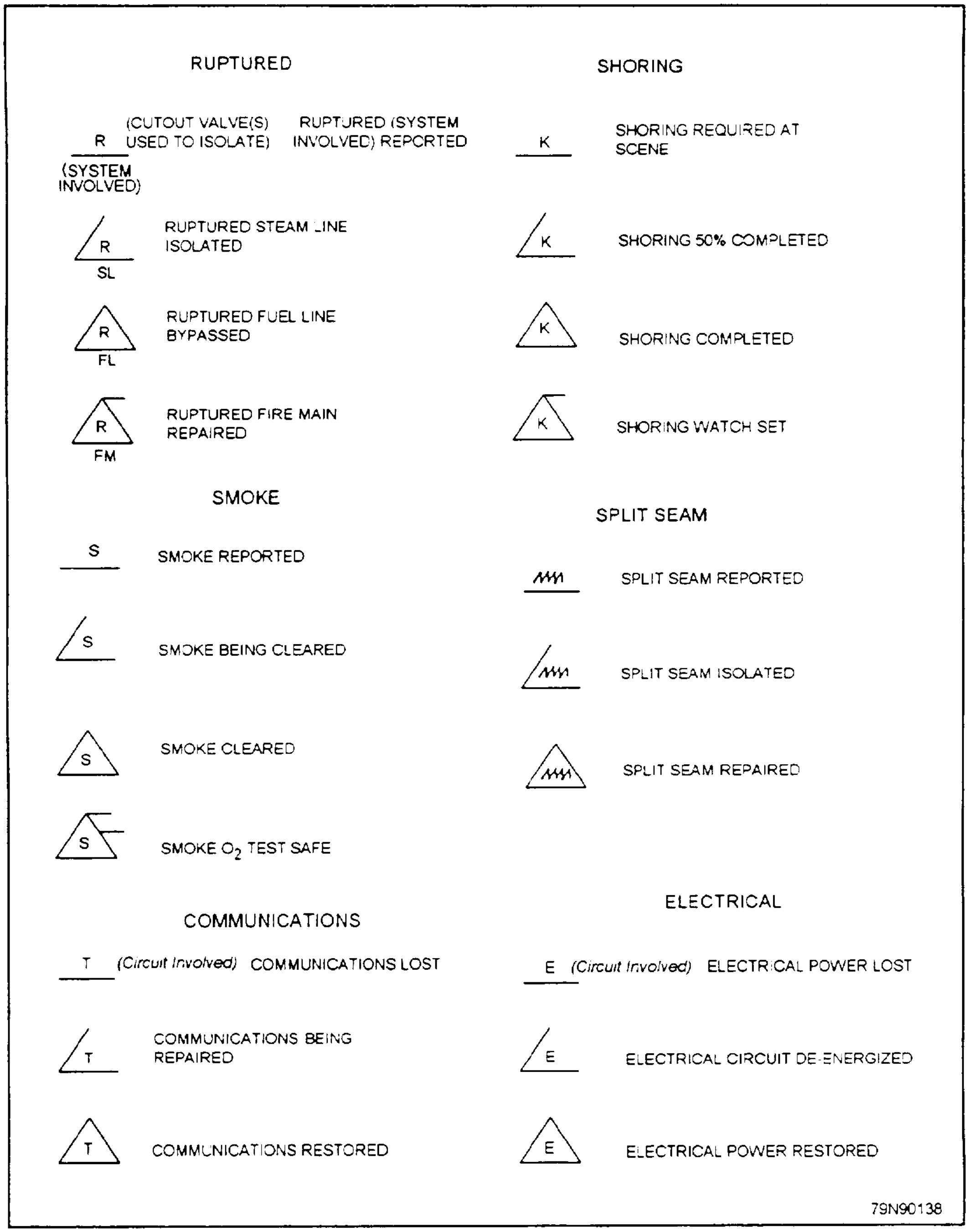


Figure 14-8.—Navy standard damage control symbology—Continued.

formats, such as those shown in figure 14-10. In reading this message, you should have come up with the following information: An 8-inch hole, 4 feet up from the deck at frame 38, starboard side of compartment 2-35-0-L.

While techniques of damage control are identical among the repair parties, each repair locker is responsible for an area of the ship. One of the more demanding areas of responsibility is Repair 5, which is responsible for the main engineering spaces. Some of the specific functions for which Repair 5 is responsible in its own assigned area include the following:

1. Maintenance of stability and buoyancy. Members of the repair party must meet the following criteria:

   a. Be stationed so that they can reach all parts of their assigned area with a minimum opening of watertight closures.

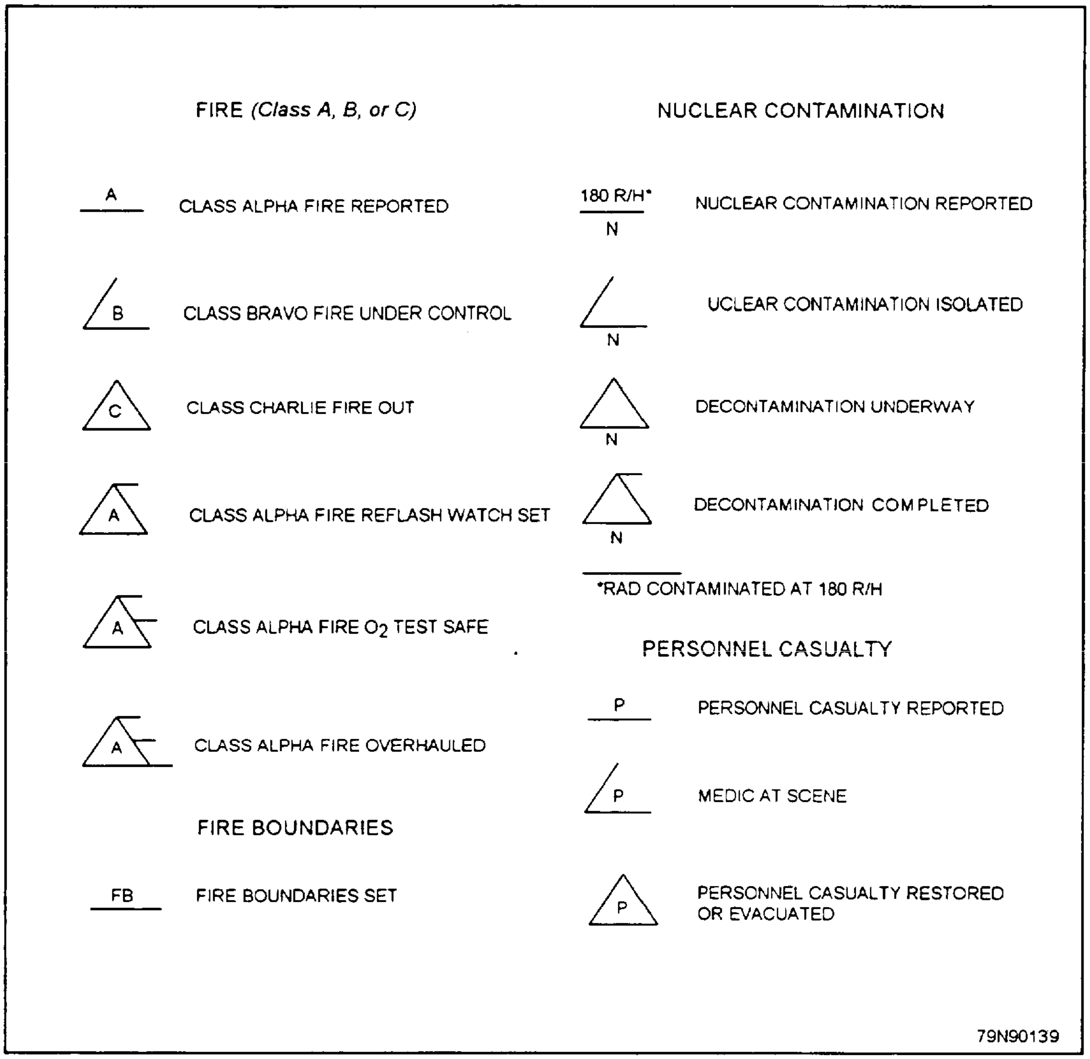


Figure 14-9.—Navy standard damage control symbology—Continued.

b. Be able to repair damage to structures, closures, or fittings that are designed to maintain watertight integrity, by shoring, plugging, welding, or caulking bulkheads and decks, resetting valves, and blanking or plugging lines through watertight subdivisions of the ship.

c. Be prepared to sound, drain, pump, counterflood, or shift liquids in tanks, voids, or other compartments; and be thoroughly familiar with the location and use of all equipment and methods of action.

d. Maintain two status boards for accurate evaluation of underwater damage:

(1) The stability status board (flooding effects diagram) used to visually display all flooding, flooding boundaries, corrective measures taken, and effects on list and trim

(2) The liquid load status board is to show the current status of all fuel and water tanks and the soundings of each tank in feet and inches.

2. Maintenance of ship's propulsion. The personnel in the repair party must be able to take the following actions:

a. Maintain, repair, or isolate damage to main propulsion machinery and boilers.

b. Operate, repair, isolate, modify, or segregate vital systems.

c. Assist in the operation and repair of the steering control systems.

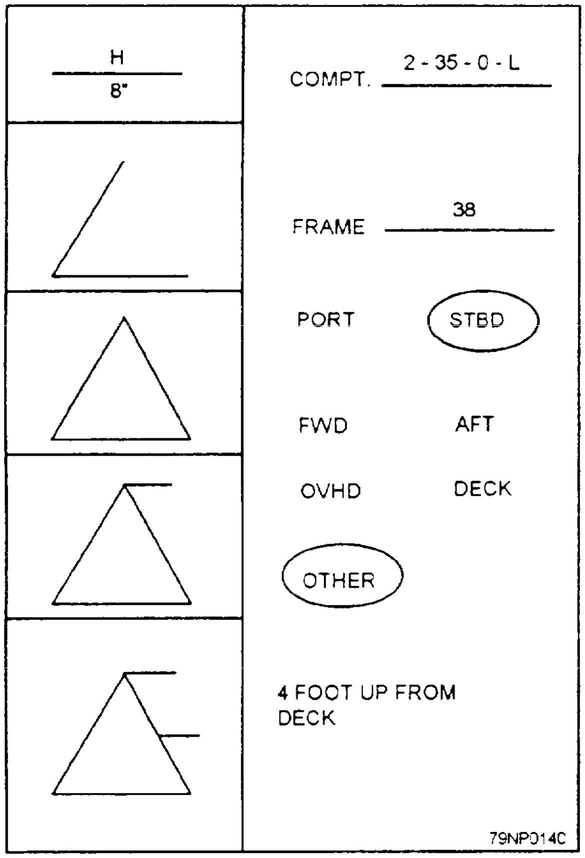


Figure 14-10.—Preprinted message format.

d. Assist in the maintenance and repair of communications systems.

e. Assist repairs 1, 2, 3, and 4 and the crash and salvage team when required.

FIREROOM CASUALTIES

The fireroom watch section supervisor should always notify the EOOW of fireroom casualties. Engine room action is based on reports given by the fireroom supervisor. When a fireroom casualty affects the operation of the engine room, cooperation and communication between personnel of both the spaces are extremely important.

Some of the fireroom casualties that affect the engine room and the procedures for controlling them include high water, low water, failure of forced draft blowers, and loss of fuel oil in suction.

High Water

If the fireroom casualty **high water in the boiler** occurs during split plant operation, the following procedures should be carried out simultaneously by all watch standers:

STEP	ACTION
1.	Trip the ship's service generator circuit breaker and close the ac and dc bus ties.
2.	Close the main engine throttle and trip the ship's service turbogenerator.
3.	Open all steam line drains and all turbine drains to ensure that all water is drained from the steam lines and turbines before the cross-connect valve is opened.
4.	Cross-connect the plant to receive steam from another boiler.
5.	The fireroom watch should take the following actions: a. Close the feed check valve. b. Secure the burners and stop the blowers. c. Close the main, the turbogenerator, and the auxiliary boiler steam stop valves.

After the boiler is secured, the fireroom watch should run down the water to the steaming level, relight fires, and bring the boiler back on the line.

Low Water

The fireroom casualty **low water in boiler** also requires that the affected boiler be secured. It is not necessary to trip the ship's service generator as in the case of high water unless the boiler is secured. However, speed in cross-connecting is important to maintain steam to the turbines.

Failure of Forced Draft Blower

Failure of a forced draft blower can be serious, depending on existing conditions. If two blowers are in use and the speed of the ship is high, the ship will have to be slowed. If only one blower is in use, its failure will necessitate securing the boiler until another blower can be started. If there is only one boiler furnishing steam to a space, the MM should cross-connect the space and take steam from another boiler.

Loss of Fuel Oil Suction

The loss of fuel oil suction will cause boiler burners to sputter, fires to die out, and possible racing of the fuel-oil service pump. Upon a loss of fuel oil suction, the following actions should be accomplished:

STEP	ACTION
1.	The watch notifies the engine room of the casualty and that the fires are secured.
2.	Secure all burners, leaving at least one air register on each side (superheated and saturated) open to expel any gases and to supply air for combustion of any oil that may have accumulated on the boiler floors.
3.	Keep the forced draft blowers running to purge the furnace (use purge chart applicable to ship's boilers).
4.	Start the standby pump with suction on the standby service tank.
5.	If unable to regain fires before steam pressure drops to a predetermined value, the watch notifies the engine room that the boiler is being secured.
6.	The main, turbo, and auxiliary boiler steam stops are then closed and the fireroom watch notifies the EOOW that the boiler is secured.
7.	The cross-connect valves are opened when so directed.
8.	The service pump discharge pressure should be observed. If the pump races and the noise level increases, there is water in the oil. If no pressure is indicated, the pump is air bound. If there is water in the oil, the watch should run the oil to the contaminated oil tank through the recirculating line until the service line is free of water. If the pump is air bound, the priming cock should be opened and the system vented.
9.	Fireroom personnel should close the air registers and slow down the forced draft blower after all oil has been burned from the furnace deck and all combustible gases expelled.

After it has been determined that good oil is available, the engineers should carry out the procedure for placing a boiler on the line. The engineers should then investigate and correct the cause of the trouble and sound the tank to determine the quantity of oil in the tank. If the oil is above the suction line, the fuel oil is contaminated or the suction line is clogged. If the fuel oil contains water, the tanks should be sounded or tests performed to find the source of the contamination.

ENGINE ROOM CASUALTIES

The operational engine room casualties that might occur include excessive vibration of a shaft, vibration of a turbine, loss of lube oil, and many others.

Excessive Shaft Vibration

If a shaft develops excessive vibration, watch personnel should take the following actions:

STEP	ACTION
1.	Notify the CCS/EOOW of the casualty.
2.	Obtain permission to slow the engine until the vibration ceases.
3.	If vibration continues at all speeds, obtain permission to stop and lock the shaft to investigate the shaft bearings.
4.	Shift and inspect the lube oil strainers.

The other engine should be speeded up to maintain speed if the tactical situation requires. If the cause for the unusual noise is undetermined, inspect the propeller, fairwaters (sleeves), and rope guards at the first opportunity.

Turbine Vibration

If a turbine begins to vibrate, the individuals on watch should take the following actions:

STEP	ACTION
1.	Notify the CCS/EOOW of the casualty and keep them informed.
2.	Obtain permission and slow down the engine and reduce the superheat temperature.
3.	A rumbling noise probably indicates the presence of water in the casing. Crack open the steam drains to remove any water from the turbine casing.

If the turbine has been standing idle for more than 5 minutes without being spun, it is probable that the rotor has been bowed temporarily. Upon restarting the turbine, vibration may be evident. If so, a brief slowing of the turbine will usually permit the rotor to straighten.

Loss of Lube Oil

All personnel should know that even a momentary loss of lubricating oil can result in localized overheating and probable slight wiping of one or more bearings. Such wiping may result in only a momentary rise in the temperature of the lubricating oil discharged from the bearing(s). Damage can be prevented or minimized by stopping the shaft rotation and quickly restoring the lubricating oil flow. Continued operation with wiped bearings can cause serious derangement to the shaft packing, oil seals, and blading.

Upon indication of a loss of lube oil to the main engine, the following actions should be taken:

STEP	ACTION
1.	Notify the CCS/EOOW of the casualty and keep them informed.
2.	Stop and lock the shaft.
3.	Shift and inspect the lube oil strainer.
4.	Check the lube oil piping for leaks, misalignment, and blockage.
5.	Check the lube oil pump for proper operation.

Loss of lubricating oil pressure may be caused by failure of the system itself. This includes failure of the main lubricating oil pumps, failure of steam or electrical power supply to the main lubricating oil pumps, or damage to boilers, steam lines, or electrical equipment.

Failure of component parts of the lube oil system may be caused by the presence of dirt, rags, or other foreign matter. This is usually the result of improper cleaning. Failure of the system may be caused by a piping failure, a failure of the operating pump, or failure of the standby pump to start. Standby pumps should be maintained ready to start the moment the pressure drops below a prescribed operating value. If automatic starting devices are not available on steam-driven pumps, the pumps should be lined up so that opening the throttle is the only action required. Steam supply lines to standby pumps should be drained continuously. Where electrical pumps are installed, personnel should be thoroughly familiar with alternate sources of power.

If steam pressure is lost in one engine room during split plant operation and the tactical situation permits, take way off the ship by backing the other engine. Determine the nature of the casualty causing the loss of steam. If a loss of steam pressure in the engine room will not cause a loss of steam to the other plant, open the auxiliary and the main steam cross-connections immediately. If the damage caused a loss of steam to the other plant, isolate the damage and then open the auxiliary and the main steam cross-connections as soon as possible. Stop and lock the affected shaft as soon as steam is available.

ELECTRIC PLANT CASUALTIES

Knowing the maximum operating limits of the electric plant is of prime importance during casualty operation. You must know the maximum allowable bearing temperatures, generator winding temperatures, maximum generator loads, and so forth.

Supplying vital power during casualty operation may require that generators be operated under overload conditions. Assuming that the prime mover can handle the overload, the temperature of the generator windings is the determining factor during sustained overloads. A portable blower may be used on open-type machines to keep the winding temperature within safe limits.

Operational electric plant casualties that might occur include loss of generator, electrical fires, loss of lube oil, and overloaded generator.

Electrical Fires

The proper procedure in the event of an electrical fire is as follows:

STEP	ACTION
1.	De-energize the power supply (normal, alternate, and emergency) to the affected controller, power panel, or switchboard.
2.	Report the fire to the CCS, EOOW, and the OOD on the bridge.
3.	Use a CO_2 fire extinguisher on the fire, and secure all ventilation.
4.	Once the fire is out, set a reflash watch until the danger of a reflash has passed.

Do not stand directly in front of the panel that is on fire. Keep low and to one side while using the CO2 extinguisher. Once the fire is out and the danger of reflash has passed, the electrician should open the panel wearing rubber gloves (use a rubber mat or boots as additional insulation) to determine the source of trouble and effect repairs.

If an electrical fire occurs in a switchboard with a generator on the line, trip the appropriate circuit breakers (fig. 14-6). The MM should actuate the overspeed trip on the generator and notify the EOOW. The EOOW then notifies the OOD and the engineering officer.

The EM should secure the voltage regulator, trip the bus-tie circuit breaker, and open the feedback circuit breaker. If the fire is in the forward switchboard, the EM should notify the after switchboard watch to open the after bus tie circuit breaker and should then use a C02 fire extinguisher on the fire. The damaged section of the switchboard should not be reenergize until repairs have been made.

If an electrical fire occurs in a generator, the generator should be secured immediately. If the fire occurs while operating split plant, the EM should trip the generator circuit breaker for the affected generator and close the bus tie. Use a C02 fire extinguisher on the fire. If a generator fire occurs during operation with a single generator, the switchboard should be stripped of all nonvital circuits after opening the generator breaker. The vital circuits should then be supplied from the emergent y diesel generator.

Loss of Lube Oil

Upon failure of generator lube oil pressure, take the following actions:

STEP	ACTION
1.	Trip the generator circuit breaker, taking it off the line.
2.	Close the bus-tie and the generator turbine throttle valve.
3.	Switch the voltage regulator to the MANUAL position and reduce the output voltage to zero.
4.	The hand-operated lube oil pump should be used to maintain lube oil pressure to the bearings until the turbine is completely stopped.

After the turbine has completely stopped, investigate and correct the casualty.

Overloaded Generator

Overload on a generator is reduced by removing nonvital loads. (**NOTE:** Power should not be interrupted to vital machinery and circuits unless absolutely necessary.)

Vital machinery and circuits include the steering gear, IC switchboard, fire pumps, drainage pumps, vital auxiliaries in the fire and engine rooms, gun mounts, and navigational lights.

DIESEL ELECTRIC DC DRIVE (FLEET TUG) CASUALTIES

Operational casualties that may occur to this type of drive include casualties to any one of the four main propulsion generators or exciters. It can also occur to the main propulsion motors, control equipment, and associated circuits.

Propulsion Generator Casualty

A casualty to one of the main propulsion generators or exciters requires cutting the affected generator out of the series propulsion loop. It is not necessary to turn the speed controller to the STOP position when cutting the generator into or out of the propulsion circuit. Normally, the controller should be brought to. a position not higher than the 11th (engine operating at 350 rpm). When it is required, a generator may be cut out of the circuit while the engine speed is in excess of 350 rpm. The generator setup switches are designed for such service. Wait several seconds between the opening of the generator's control switch and its setup switch. This reduces arcing at the setup switch contacts. It also prevents flashover of the generator commutator.

Control Console Casualty

A casualty to the pilothouse control console or associated circuitry requires a shift in control of the engines to the engine room station. Perform the following actions to shift control to the engine room:

STEP	ACTION
1.	Place the controllers at both control stations in the STOP position.
2.	Turn the excitation control switch to OFF.
3.	Turn the engine room-pilothouse control transfer switch to the ENGINE ROOM position.
4.	Turn the excitation control switch in the engine room to ON.

Note that the control transfer switch and the excitation control switch are interlocked so that the excitation control switch has to be in the OFF position before the control transfer switch can be operated.

BATTLE CASUALTIES

Shell or torpedo hits in engineering spaces usually result in multiple casualties to machinery systems and personnel. The corrective action for any particular casualty depends on the location and extent of damage. While battle casualties differ in many respects, the following procedures can be applied to most casualties of this type:

REQUIRED	ACTION
Always	Secure the space or isolate damaged sections, as practical.
When possible	Cross-connect systems or plants.
In the event of: a. turbine damage b. reduction gear damage c. main shaft damage, or d. loss of lubricating oil pressure to the main engine	Stop and lock the shaft.
If a ruptured steam line prevents the entry of repair party personnel into a space	Secure the space by using remote controls.
Always	Take all precautions to prevent flooding of the space. Put all available pumps on the bilges of the damaged space. Plug all holes, and, if possible, prevent flooding of other spaces.
Always	Extinguish fires and investigate damage. Make necessary repairs to return the machinery and the space back to service as soon as possible.
Always	Keep communication lines open. Keep main engine control advised of existing conditions.

DAMAGED CABLE AND EQUIPMENT

In any casualty involving damage to electrical cable and equipment, electrical circuits may be a hazard if they remain energized. The circumstances surrounding each case of damage will dictate action to be taken. In cases of serious damage, remove electrical power, when necessary, from all cables in the damaged area. This is to prevent the ignition of combustible liquids and gases. Continued operations, however, may require the reestablishment of power to undamaged circuits. This may include cables that extend through damaged areas.

In some cases, splices may be made or temporary jumpers may be run to reestablish power to the required circuits. Lighting circuits are not to be disregarded. This is because damage control activities can be seriously handicapped or rendered impossible by inadequate lighting.

Damaged electrical equipment should be isolated from all available sources of power. In the case of a damaged switchboard, all circuits feeding to the switchboard from remote sources should be de-energized. They should be tagged out of service at the source.

CASUALTY POWER SYSTEM

The casualty power system is limited to minimal electrical facilities required to keep the ship afloat in the event of damage and to get it out of a danger area. Important features of the casualty power system include the following:

- Preservation of the watertight integrity of the ship
- Simplicity of installation and operation
- Flexibility of application
- Interchangeability of parts and equipment, minimum weight and space requirements
- The ability to accomplish the desired functions

The casualty power system is a temporary means of providing power. It is not a means of making temporary repairs. The system is purposely limited in its scope to retain effectiveness. The more equipment added and the more the system is expanded, the greater the possibility of error in making connections. Also, the possibility of faults at relatively unimportant equipment can cause loss of power at vital equipment. It is also probable that the casualty power system, if expanded, would be burdened with miscellaneous loads at a time when its use would be essential for vital loads.

The schematic diagram for an electrical casualty power system in a typical destroyer is shown in figure 14-11. The system contains no permanently installed cables, except for vertical risers and bulkhead terminals. The risers are installed to carry circuits through decks without impairing the watertight integrity of the ship. A riser consists of a LSTSGU-75 cable extending from one deck to another with a riser terminal connected to each end for attachment of portable cables.

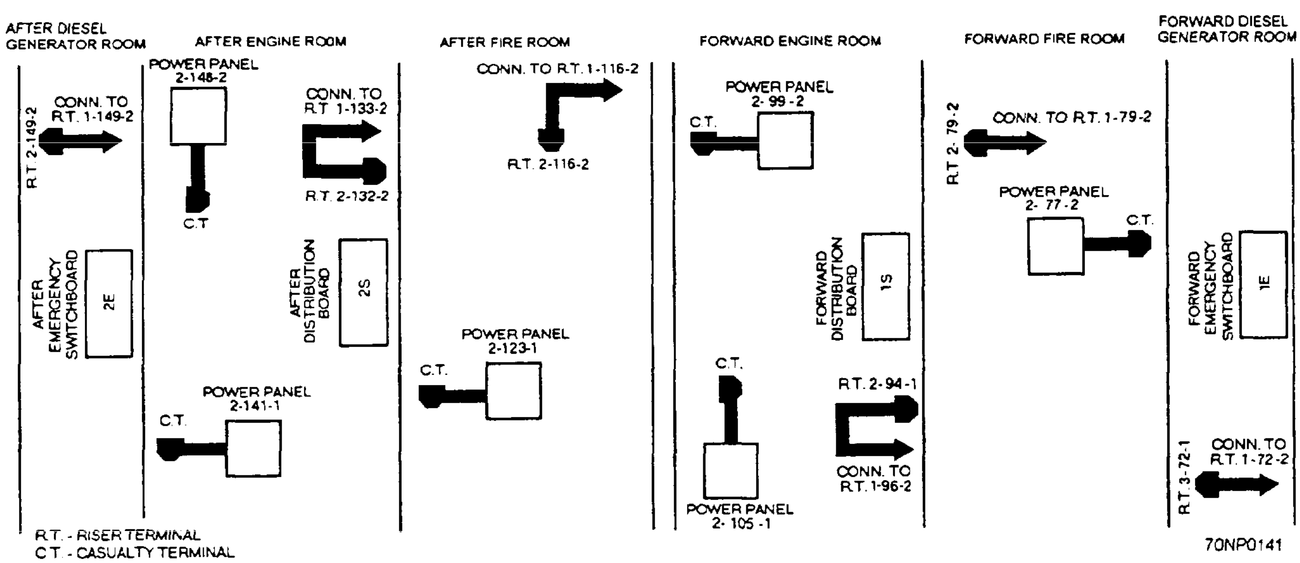


Figure 14-11.—Electrical casualty power system.

Portable LSTHOF-42 cables in suitable lengths form all the circuits required to supply power to equipment designated to receive casualty power. While the normal current-carrying capacity of LSTHOF-42 cables is 93 amperes, its casualty rating is 200 amperes. Under normal conditions, this cable will carry 200 amperes for 4 hours without damage to the cable.

The bulkhead terminals carry circuits through bulkheads without impairing the watertight integrity of the ship.

Power panels supplying equipment designated for casualty power service are equipped with terminals so that casualty power can be fed into the panels. These panels can also be used as a source of power for the casualty power system if power is still available from the permanent feeders to the panels. However, the decision to take power from the panel instead of the switchboard should be based on knowledge that equipment on that panel will not be required for the safety of the ship. Operating the equipment normally supplied by the panel plus the equipment to be supplied with casualty power may cause an overload on the circuit breaker supplying the panel. Portable switches are located in several strategic positions throughout the ship for use with the casualty power system.

In general, the casualty power system provides a horizontal run of portable cable along the damage control deck with risers for the power supply and for loads extending to and from this level. Rigging and unrigging casualty power cables are described in chapter 3 of this manual.

In figure 14-11, the ship's service switchboards (1S and 2S) and the emergency switchboards (1E and 2E) are provided with casualty power terminals installed on the back of the switchboard. Each casualty power terminal is connected to the buses through a standard 250-ampere AQB circuit breaker. The circuit breakers have an instantaneous (magnetic) trip element setting to prevent tripping of the generator breaker or fusing of the casualty power cable under short-circuit conditions. Connections to the buses are between the generator circuit breaker and the disconnect switch.

MARINE GAS TURBINE CASUALTIES

Normally, any casualty to a marine gas turbine unit will require that the unit be secured. Therefore, you

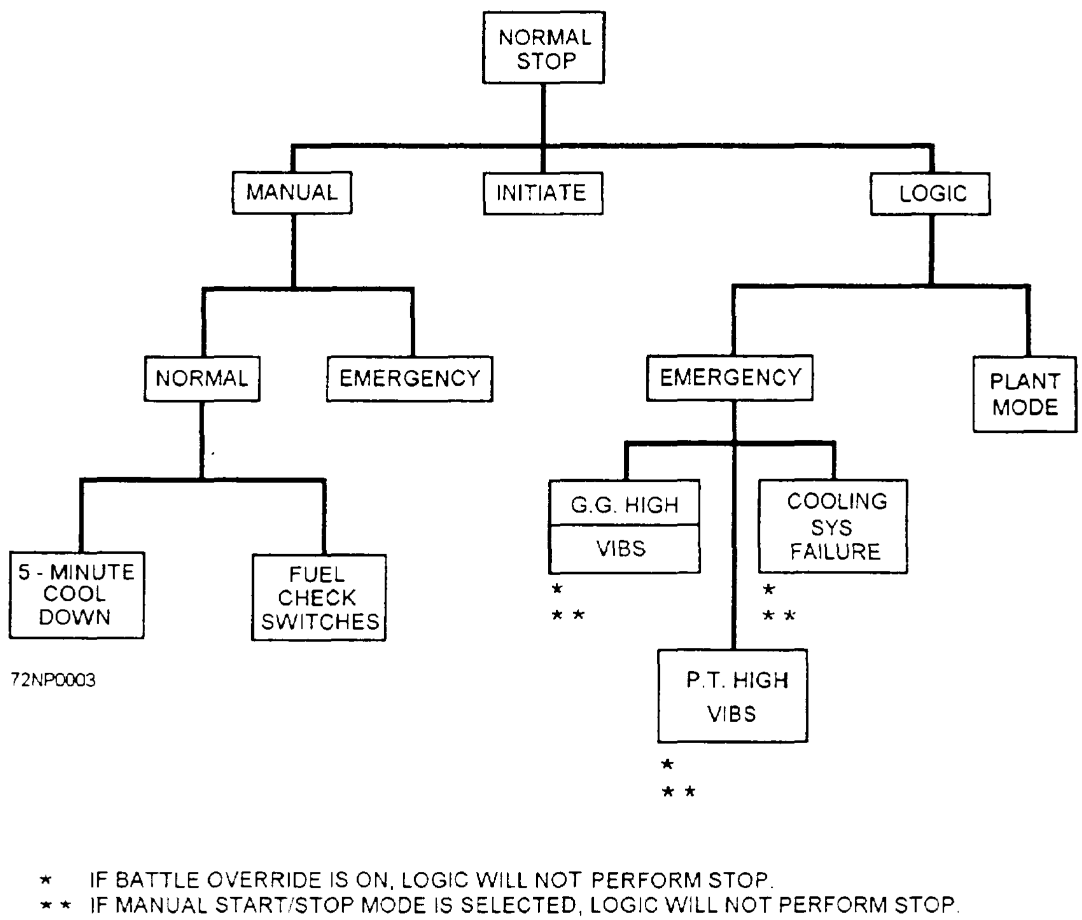


Figure 14-12.—Normal stop modes.

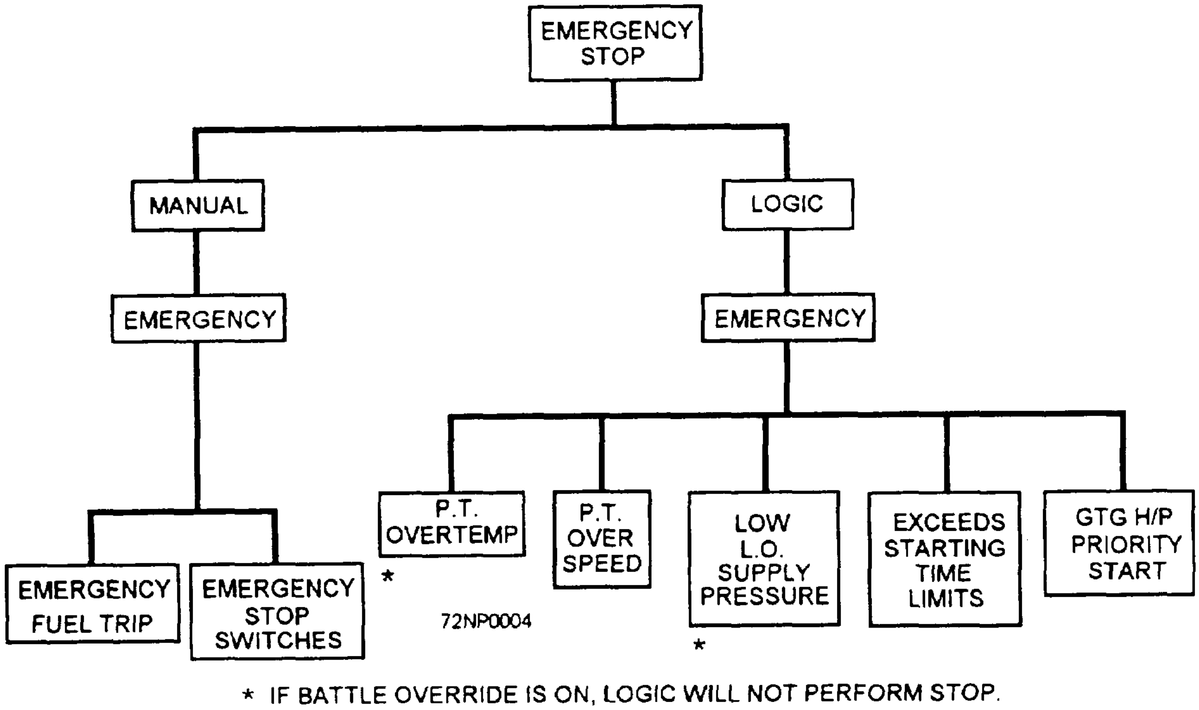


Figure 14-13.—Emergency stop modes.

need to know the casualty control procedures for marine gas turbine casualties. In this section, you will learn some of the procedures for securing a gas turbine engine. The three most common methods for securing gas turbine engines are (1) normal stop (normal 5-minute cool down and stabilization period), (2) emergency stop (operator or logic initiated by hazardous out-of-limits parameter), and (3) fire stop (operator- or logic-sensed fire).

Normal Stop Mode

The normal stop mode is the most common method used to stop a gas turbine. Referring to figure 14-12, you can see that there are three submodes to the normal stop:

1. Manual—refers to the actual operator-induced actions
2. Initiate—refers to the STOP initiate PUSH BUTTON on the STAR/STOP panel of the operating console
3. Logic—refers to the electronic logic as Programmed into the control console

Emergency Stop Mode

The emergency stop mode (fig. 14-13) is the most commonly used method to stop a gas turbine when a hazardous, out-of-limits parameter is sensed. An out-of-limits parameter may be sensed by either the control system or b y the operator. If the control system senses an out-of-limits parameter, electronic logic causes the engine to stop. If the operator senses the out-of-limits parameter, the operator should manually stop the gas turbine by using the manual emergency stop switches.

NOTE: Certain logic stop functions may be disabled if battle override is on.

Fire Stop Mode

The fire stop mode is used when a fire is detected inside the gas turbine module (GTM). Figure 14-14 shows the two methods by which the fire stop mode may be used.

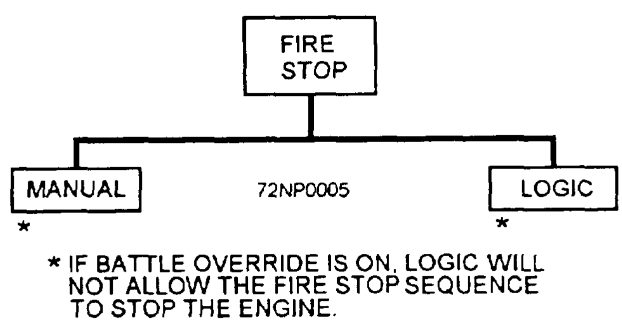


Figure 14-14.—Fire stop modes.

1. In the manual submode the operator can manually activate the fire stop and thereby stop the GTM when a fire is detected.
2. In the logic submode the system electronics activates the fire stop sequence once it detects a fire.

NOTE: The fire stop sequence is disabled when the system is in battle override.

Regardless of which mode is used to stop a gas turbine engine, the EOOW/CCS must be notified immediately when any casualty to equipment in the engineering spaces occurs. Quick, clear communications among the watch station are the best defense to avoiding turning any situation from bad to worse.

Some of the casualties that can affect gas turbine systems are very closely related to those of ships with different propulsion and power generating systems. Some of those casualties are listed in the following paragraphs.

GAS TURBINE GENERATOR CASUALTIES

Procedures for handling generator casualties among different types of ships differ because of differences in their prime movers. The following casualties are representative of the types you might find when working with gas turbine generators. When there is a difference in procedures, you must follow the EOSS/EOP for your command.

Unusual Noise or Vibration in the Gas Turbine Generator

Any unusual noise or vibration in the gas turbine generator (GTG) must be investigated immediately, An untended condition could cause further damage or complete loss of a unit that has only needed minor repairs.

Once unusual noise or vibration is reported, the following steps should be taken:

STEP	ACTION
1.	Notify CCS/EOOW of the casualty and keep them informed.
2.	Remove the electrical load from the affected generator.
3.	Change the system configuration to remove the affected generator from the line.
4.	Stop the GTG.
5.	Waterwash the GTG engine.
6.	Motor the turbine when the waterwash is completed.
7.	Check for proper lubrication.
8.	Check bearing temperatures for high readings.
9.	Observe oil pressure gages for normal oil pressures.
10.	Shift and inspect lube oil strainers.

Once all procedures have been carried out and the reason for the casualty has been identified and corrected, start and test the affected GTG according to your local EOP.

Class B Fire in the Gas Turbine Generator Module

When a class B fire is discovered in the GTG module, the following actions should be taken:

STEP	ACTION
1.	Notify CCS/EOOW of the casualty.
2.	Trip the affected generator circuit breaker.
3.	Shut the emergency fuel trip valve and stop the affected GTG.
4.	See that the installed CO_2 system is activated.
5.	Start the standby generator and place it on the line.

Quick action on the part of watch standers can avoid the loss of the GTG and prevent reduced electrical capability.

Loss of Lube Oil Pressure to the Gas Turbine Generator

A loss of lubricating oil is one of the most serious casualties that can occur on rotating machinery, especially machinery that rotates at very high speeds. A loss of lube oil can be indicated by the following:

1. Below normal lube oil pressure to bearings
2. Audible and/or visual low lube oil pressure alarm
3. High bearing temperature alarm

Once a loss of lube oil casualty has occurred, the following actions should be taken:

STEP	ACTION
1.	Notify CCS/EOOW of the casualty and keep them informed.
2.	Remove the electrical load from the affected generator.
3.	Stop the gas turbine; change the system configuration.
4.	Shift and inspect lube oil strainers.
5.	Monitor the lube oil sump level.
6.	Inspect lube oil piping and fittings for leaks.
7.	Inspect all bearings.
8.	Inspect the lube oil pressure relief valve for malfunction.

Once the cause has been identified and corrected, the unit should be tested according to your ship's EOP.

PROPULSION GAS TURBINE CASUALTIES

Propulsion gas turbine casualties are treated in much the same as casualties to the GTG.

Excessive Vibration

Excessive vibration can be caused by a number of things, including internal part failure, misalignment, faulty turbine mounts, or bent high speed coupling shaft.

Once excessive vibration is indicated, the following actions should be taken:

STEP	ACTION
1.	Notify CCS/EOOW of the casualty and keep them informed.
2.	Shut down the turbine.
3.	Investigate the vibration sensors.
4.	Waterwash the compressor.
5.	Check turbine mounts.
6.	Check the turbine hold-down bolts.
7.	Investigate for misalignment.
8.	Check for internal failure.
9.	Check the electrical system for shorts in the vibration indication circuitry.
10.	Check the signal conditioner for malfunction.

Once the cause for vibration has been identified and corrected, start the engine according to your EOP for testing.

High Lube Oil Temperature

High lube oil temperature can lead to a lubrication breakdown within the engine, which can result in fire. Immediate steps to be taken once high lube oil temperature is indicated include the following:

STEP	ACTION
1.	Notify CCS/EOOW of the casualty.
2.	Slow the propulsion engine (change to another engine if available).
3.	Shift the synthetic oil filter elements.
4.	Monitor the oil level in the storage tank.
5.	Monitor the reduction gear lube oil pressure and temperature.
6.	Check the coolant oil system for proper alignment.
7.	Obtain the gas turbine module and lube oil data printout for the affected propulsion turbine to look for clues as to the problem.
8.	Check the temperature control valve for proper setting and operation.
9.	Check the synthetic oil for traces of coolant oil.
10.	Check the lube oil consumption rate.

Once the problem has been identified and corrected, use your EOP to light off the engine and test for proper operation.

Loss of Lube Oil

A loss of lube oil to a gas turbine engine can cause the same type of damage whether the engine is used for generating electricity or propulsion. The rotating parts of the engine must be kept lubricated. When a loss of lube oil is indicated, the following actions should be taken:

STEP	ACTION
1.	Notify CCS/EOOW by stating: "SHUTTING DOWN AND CHANGING TURBINES" and keep them informed.
2.	Monitor the following conditions: a. Lube oil supply pressure b. Gas turbine module lube oil scavenge temperatures c. Gas turbine module gearbox lube oil scavenge temperatures
3.	Check the oil level in the tank.
4.	Check the lube oil system for proper alignment.
5.	Check the lube oil piping for leaks.
6.	Shift the lube oil supply filters.
7.	Check the lube oil piping for obstructions.

Once the cause for the loss of lube oil has been determined and corrected, the rotating elements should be inspected for damage caused by lack of lubrication. Once all parts have been inspected and/or replaced, start the engine according to your EOP for testing.

Class B Fire in the Gas Turbine Module

A class B fire in an engineering space is the most dangerous condition. Since there is no time for delay, training is essential to minimize danger to personnel and equipment. Once a class B fire is detected, the following steps should take place automatically:

STEP	ACTION
1.	Notify CCS/EOOW and keep them informed.
2.	Shut down the affected turbine.
3.	Ensure the fire stop is activated.
4.	Ensure the emergency fuel trip valve is shut.
5.	Ensure that the following events have occured: a. The module vent fan is stopped. b. The vent damper is closed. c. The module doors are shut.
6.	Ensure that the inert gas system is activated.
7.	Close the fuel valve to the gas turbine module.
8.	Once the fire is out, open the ventilation doors and start the module fan.
9.	Check the module for combustible/toxic gases.
10.	Stop the ventilation fan.
11.	Check for fuel leaks.
12.	Check for lube oil leaks.
13.	Check the module for interior damage.
14.	Test the turbine when the interior damage has been corrected, using your ship's EOP.
15.	Ensure that all doors are shut and latched.
16.	Motor the turbine for testing.
17.	Monitor the motoring rpm.
18.	Check the turbine for unusual noise.
19.	Place the turbine out of commission (OOC) until repairs are made if motoring is unsatisfactory.

Once repairs are completed the unit must be tested extensively using your ship's EOP.

SUMMARY

You must remember that a casualty control program is only as good as you make it. The key word is "training."

The EOSS, EOP, and EOCC will take you a long way in correcting any casualties you might sustain. Your ECCET should include your very best personnel so they can pass along their knowledge to others. As has been stated in the past, "the more you sweat in peace, the less you bleed in war!".

APPENDIX I

GLOSSARY

A

AFTER STEERING CONTROL UNIT— A rudder command generator that electrically controls rudder angle.

AIR-CORE TRANSFORMER— A transformer composed of two or more coils, which are wound around a nonmetallic core.

AMMETER— An instrument for measuring the amount of electron flow in amperes.

AMPERE (A)— The basic unit of electrical current. 1 volt across 1 ohm of resistance causes a current flow of 1 ampere.

AMPLIFIEIR, FLUID— A fluidic element that enables a flow or pressure to be controlled by one or more input signals that are of a lower pressure or flow value than the fluid being controlled.

ANODE— A positive electrode of an electrochemical device (such as primary or secondary electric cell) toward which the negative ions are drawn.

APPARENT POWER— That power apparently available for use in an ac circuit containing a reactive element. It is the product of effective voltage times effective current expressed in voltamperes. It must be multiplied by the power factor to obtain true power available.

ARMATURE— In a relay, the movable portion of the relay.

AUTOMATIC BUS TRANSFER (ABT) SWITCH— Normal and alternate power sources are provided to vital loads. These power sources are supplied from separate switchboards through separated cable runs. Upon loss of the normal power supply, the ABT automatically disconnects this source and switches the load to the alternate source.

AVERAGE VALUE OF AC— The average of all the instantaneous values of one-half cycle of ac.

B

BATTERY— A device for converting chemical energy into electrical energy.

BATTERY CAPACITY— The amount of energy available from a battery. Battery capacity is expressed in ampere-hours.

BIMETALLIC ELEMENT— Two strips of dissimilar metals bonded together so a change of temperature will be reflected in the bending of the element.

BURNISHING TOOL— A tool used to clean and polish contacts on a relay.

C

CAPACITIVE REACTANCE— The opposition to the flow of an alternating current caused by the capacitance of a circuit, expressed in ohms and identified by the symbol X_C.

CATHODE— The general term for any negative electrode.

CHARGE— Represents electrical energy. A material having an excess of electrons is said to have negative charge. A material having an absence of electrons is said to have a positive charge.

CIRCUIT— The complete path of an electric current.

CIRCULAR MIL— An area equal to that of a circle with a diameter of 0.001 inch. It is used for measuring the cross-sectional area of wires.

CONDUCTANCE— The ability of a material to conduct or carry an electric current. It is the reciprocal of the resistance of the material, and is expressed in mhos or siemens.

CONDUCTIVITY— Ease with which a substance transmits electricity.

CONDUCTOR— (1) A material with a large number of free electrons. (2) A material that easily permits electric current to flow.

COULOMB— A measure of the quantity of electricity. One coulomb is equal to 6.28×10^{18} electrons.

COULOMB'S LAW— Also called the law of electric charges or the law of electrostatic attraction. Coulomb's Law states that charged bodies attract or repel each other with a force that is directly proportional to the product of their individual charges and inversely proportional to the square of the distance between them.

CPR— Cardio-pulmonary resuscitation.

CROSS-SECTIONAL AREA— The area of a "slice" of an object. When applied to electrical conductors it is usually expressed in circular mils.

CURRENT— The drift of electrons past a reference point. The passage of electrons through a conductor. Measured in amperes.

D

DAMPING— The process of smoothing out oscillations. In a meter, damping is used to keep the pointer of the meter from overshooting the correct reading.

D'ARSONVAL METER MOVEMENT— A name used for the permanent-magnet moving-coil movement used in most meters.

DIELECTRIC FIELD— The space between around charged bodies in which their influence is felt. Also called Electric Field of Force or an Electrostatic Field.

DIRECT CURRENT (dc)— An electric current that flows in one direction only.

DOMAIN THEORY— A theory of magnetism based on the electron-spin principle. Spinning. electrons have a magnetic field. If more electrons spin in one direction than another, the atom is magnetized.

DROOP— Mode of governor operation normally used only for paralleling with shore power. Since shore power is an infinite bus (fixed frequency, droop mode is necessary to control the load carried by the generator. If a generator is paralleled with shore power and one attempts to operate in isochronous mode instead of droop mode, the generator governor speed reference can never be satisfied because the generator frequency is being held constant by the infinite bus. If the generator governor speed reference is above the shore power frequency, the load carried by the generator will increase beyond capacity (overload) in an effort to raise the shore power frequency. If the speed reference is below the shore power frequency, the load will decrease and reverse (reverse power) in an effort to lower the shore power frequency. The resulting overload or reverse power will trip the generator breaker.

DRY CELL— An electrical cell in which the electrolyte is in the form of a paste.

E

EDDY CURRENT— Induced circulating currents in a conducting material that are caused by a varying magnetic field.

EDDY CURRENT LOSS— Losses caused by random current flowing in the core of a transformer. Power is lost in the form of heat.

EFFICIENCY— The ratio of output power to input power, generally expressed as a percentage.

ELECTRIC CURRENT— The flow of electrons.

ELECTRIC PLANT CONTROL CONSOLE (EPCC)— Contains the controls and indicators used to remotely operate and monitor the generators and the electrical distribution system.

ELECTRICAL CHARGE— Symbol Q, q. Electric energy stored on or in an object. The negative charge is caused by an excess of electrons; the positive charge is caused by a deficiency of electrons.

ELECTROCHEMIC— The action of converting chemical energy into electrical energy.

ELECTRODE— The terminal at which electricity passes from one medium into another, such as in an electrical cell where the current leaves or returns to the electrolyte.

ELECTRODYNAMICS METER MOVEMENT— A meter movement using freed field coils and moving coil; usually used in wattmeters.

ELECTROLYTE— A solution of a substance that is capable of conducting electricity. An electrolyte may be in the form of either a liquid or a paste.

ELECTROMAGNET—An electrically excited magnet capable of exerting mechanical force, or of performing mechanical work.

ELECTROMAGNETIC— The term describing the relationship between electricity and magnetism. Having both magnetic and electric properties.

ELECTROMAGNETIC INDUCTION— The production of a voltage in a coil due to a change in the number of magnetic lines of force (flux linkages) passing through the coil.

ELECTROMOTIVE FORCE (EMF)— The force that causes electricity to flow between two points with different electrical charges or when there is a difference of potential between the two points. The unit of measurement in volts.

ELECTRON— The elementary negative charge that revolves around the nucleus of an atom.

ELECTRON SHELL— A group of electrons which have a common energy level that forms part of the outer structure (shell) of an atom.

ELECTROSTATIC— Pertaining to electricity at rest, such as charges on an object (static electricity).

ELECTROSTATIC METER MOVEMENT— A meter movement that uses the electrostatic repulsion of two sets of charges plates (one freed and the other movable). This meter movement reacts to voltage rather than to current and is used to measure high voltage.

ELEMENT— A substance, in chemistry, that cannot be divided into simpler substances by any means ordinarily available.

F

FERROMAGNETIC MATERIAL— A highly magnetic material, such as iron, cobalt, nickel, or alloys, that makes up these materials.

FIELD OF FORCE— A term used to describe the total force exerted by an action-at-a-distance phenomenon such as gravity upon matter, electric charges acting upon electric charges, magnetic forces acting upon other magnets or magnetic materials.

FIXED RESISTOR— A resistor having a definite resistance value that cannot be adjusted.

FLUX— In electrical or electromagnetic devices, a general term used to designate collectively all the electric or magnetic lines of force in a region.

FLUX DENSITY— The number of magnetic lines of force passing through a given area.

FREQUENCY METER— A meter used to measure the frequency of an ac signal.

G

GALVANOMETER— A meter used to measure small values of current by electromagnetic or electrodynamics means.

GROUND POTENTIAL— Zero potential with respect to the ground or earth.

H

HENRY (H)— The electromagnetic unit of inductance or mutual inductance. The inductance of a circuit is 1 henry when a current variation of 1 ampere per second induces 1 volt. It is the basic unit of inductance. In radio, smaller units are used such as the millihenry (mH), which is one-thousandth of a henry (H), and the microhenry (µh), which is one-millionth of a henry.

HERTZ (Hz)— A unit of frequency equal to one cycle per second.

HORSEPOWER (hp)— The English unit of power, equal to work done at the rate of 550 foot-pounds per second. Equal to 746 watts of electrical power.

HOT WIRE METER MOVEMENT— A meter movement that uses the expansion of heated wire to move the pointer of a meter; measures dc or ac.

HYDROMETER— An instrument used to measure specific gravity. In batteries, hydrometers are used to indicate the state of charge by the specific gravity of the electrolyte.

HYSTERESIS— The time lag of the magnetic flux in a magnetic material behind the magnetizing force producing it, caused by the molecular friction of the molecules trying to align themselves with the magnetic force applied to the material.

HYSTERESIS LOSS— The power loss in an iron-core transformer or other ac device as a result of magnetic hysteresis.

I

INDUCED CURRENT— Current caused by the relative motion between a conductor and a magnetic field.

INDUCED ELECTROMOTIVE FORCE— The electromotive force induced in a conductor caused by the relative motion between a conductor and a magnetic field. Also called INDUCED VOLTAGE.

INDUCTIVE REACTANCE— The opposition to the flow ac current caused by the inductance of a circuit, expressed in ohms and identified by the symbol X_L.

INSULATION— (1) A material used to prevent the leakage of electricity from a conductor and to provide mechanical spacing or support to protect against accidental contact. (2) Use of material in which current flow is negligible to surround or separate a conductor to prevent loss of current.

ISOCHRONOUS— Mode of governor operation normally used for generator operation. This mode provides a constant frequency for all load conditions. When operating two or more generators in parallel, use of the isochronous mode also provides equal load sharing between units.

K

KILO— A prefix meaning one thousand.

KINETIC ENERGY— Energy that a body possesses by virtue of its motion.

KIRCHHOFF'S LAWS— (1) The algebraic sum of the currents flowing toward any point in an electric network is zero. (2) The algebraic sum of the products of the current and resistance in each of the conductors in any closed path in a network is a equal to the algebraic sum of the electromotive forces in the path.

L

LEAD-ACID CELL— A cell in an ordinary storage battery, in which electrodes are grids of lead containing an active material consisting of certain lead oxides that change in composition during charging and discharging. The electrodes or plates are immersed in an electrolyte of diluted sulfuric acid.

LINE OF FORCE— A line in an electric or magnetic field that shows the direction of the force.

LOAD— (1) A device through which an electric current flows and that changes electrical energy into another form. (2) Power consumed by a device or circuit in performing its function.

M

MAGNETIC FIELD— The space in which a magnetic force exists.

MAGNETIC POLES— The section of a magnetic where the flux lines are concentrated; also where they enter and leave the magnet.

MAGNETISM— The property possessed by certain materials by which these materials can exert mechanical force on neighboring masses of magnetic material and can cause currents to be induced in conducting bodies moving relative to the magnetized bodies.

MANUAL BUS TRANSFER (MBT) SWITCH— Provides selection between normal and alternate power sources for selected equipment. This transfer switch is used for controllers with low voltage protection that requires manual restarting after voltage failure and for electronic power distribution panels.

MEGA— A prefix meaning one million, also Meg or M.

MHO— Unit of conductance; the reciprocal of the ohm.

MICRO— A prefix meaning one-millionth.

MILLI— A prefix meaning one-thousandth.

MOVING-VANE METER MOVEMENT— A meter movement that uses the magnetic repulsion of the like poles created in two iron vanes by current through a coil of wire; most commonly used movement for ac meters.

MULTIMETER— A single meter combining the functions of an ammeter, a voltmeter, and an ohmmeter.

N

NEGATIVE TEMPERATURE COEFFICIENT— The temperature coefficient expressing the amount of reduction in the value of a quantity, such as resistance for each degree of increase in temperature.

NEUTRAL— In a normal condition; therefore neither positive nor negative. A neutral object has a normal number of elections.

NONTRIP-FREE CIRCUIT BREAKER— A circuit breaker that can be held ON during an over current condition.

O

OHM (Ω)—The The unit of electrical resistance. It is that value of electrical resistance through which a constant potential difference of 1 volt across the resistance will maintain a current flow of 1 ampere through the resistance.

OHMIC VALUE— Resistance in ohms.

OHM'S LAW— The current in an electric circuit is directly proportional to the electromotive force in the circuit. The most common form of the law is E=IR, where E is the electromotive force or voltage across the circuit, I is the current flowing in the circuit, and R is the resistance of the circuit.

P

PARALLAX ERROR— The error in meter readings that results when you look at a meter from some position other than directly in line with the pointer and meter face. A mirror mounted on the meter face aids in eliminating parallax error.

PARALLEL CIRCUIT— Two or more electrical devices connected to the same pair of terminals so separate currents flow through each; electrons have more than one path to travel from the negative to the positive terminal.

PERMEABILITY— The measure of the ability of material to act as a path magnetic lines of force.

PHASE— The angular relationship between two alternating currents or voltages when the voltage or current is plotted as a function of time. When the two are in phase, the angle is zero, and both reach their peak simultaneously. When out of phase, one will lead or lag the other; at the instant when one is at its peak, the other will not be at peak value and (depending on the phase angle) may differ in polarity as well as magnitude.

PHASE ANGLE— The number of electrical degrees of lead or lag between the voltage and current waveforms in an ac circuit.

PHASE DIFFERENCE— The time in electrical degrees by which one wave leads or lags another.

PHOTOELECTRIC VOLTAGE— A voltage produced by light.

PICO— A prefix adopted by the National Bureau of Standards meaning 10^{-12}.

PIEZOELECTRIC EFFECT— The effect of producing a voltage by placing a stress, either by compression, expansion, or twisting, on a crystal and, conversely, producing a stress in a crystal by applying a voltage to it.

POLARITY— (1) The condition in an electrical circuit by which the direction of the flow of current can be determined. Usually applied to batteries and other dc voltages sources. (2) Two opposite charges, one positive and one negative. (3) A quality of having two opposite magnetic poles, one north and the other south.

POLARIZATION— The effect of hydrogen surrounding the anode of a cell which increases the internal resistance of the cell.

POTENTIAL ENERGY— Energy due to the position of one body with respect to another body or to the relative parts of the same body.

POTENTIOMETER— A three-terminal resistor with one or more sliding contacts, which functions as an adjustable voltage divider.

POWER— The rate of doing work or the rate of expending energy. The unit of electrical power is the watt.

PRIMARY WINDING— The winding of a transformer connected to the electrical source.

R

RECIPROCAL— The value obtained by dividing the number 1 by any quantity.

RECTIFIER— A device used to convert ac to pulsating dc.

REFERENCE POINT— A point in a circuit to which all other points in the circuit are compared.

RELAY— An electromagnetic device, with one or more sets of contacts, that changes contact position by the magnetic attraction of a coil to an armature.

RELUCTANCE— A measure of the opposition that a material offers to magnetic lines of force.

REPULSION— The mechanical force tending to separate bodies having like electrical charges or like magnetic polarity.

RESIDUAL MAGNETISM— Magnetism remaining in a substance after removal of the magnetizing force.

RETENTIVITY— The ability of a material to retain its magnetism.

RHEOSTAT— (1) A resistor whose value can be varied. (2) A variable resistor that is used for the purpose of adjusting the current in a circuit.

RLC CIRCUIT— An electrical circuit that has the properties of resistance, inductance, and capacitance.

RMS— Abbreviation of root mean square.

ROOT MEAN SQUARE (RMS)— The equivalent heating value of an alternating current or voltage, as compared to a direct current or voltage. It is 0.707 times the peak value of a sine wave.

ROTARY SWITCH— A multicontact switch with contacts arranged in a circular or semicircular manner.

S

SCHEMATIC CIRCUIT DIAGRAM— A circuit diagram in which component parts are represented by simple, easily drawn symbols. May be called a schematic.

SCHEMATIC SYMBOLS— Letters, abbreviations, or designs used to represent specific characteristics or components on a schematic diagram.

SECONDARY— The output coil of a transformer.

SELF-INDUCTION— The production of a counter-electromotive force in a conductor when its own magnetic field collapses or expands with a change in current in the conductor.

SENSITIVITY— (1) For an ammeter: the amount of current that will cause full-scale deflection of the meter. (2) For a voltmeter: the ratio of the voltmeter resistance divided by the full-scale reading of the meter, expressed in ohms-per-volt.

SERIES CIRCUIT— An arrangement where electrical devices are connected so that the total current must flow through all the devices; electrons have one path to travel from the negative terminal to the positive terminal.

SERIES PARALLEL CIRCUIT— A circuit that consists of both series and parallel networks.

SINE WAVE— The curve traced by the projection on a uniform time scale of the end of a rotating arm, or vector. Also known as a SINUSOIDAL WAVE.

SOLENOID— An electromagnetic device that changes electrical energy into mechanical motion; based upon the attraction of a movable iron plunger to the core of an electromagnet.

T

THERMAL-MAGNETIC TRIP ELEMENT— A single circuit breaker trip element that combines the action of a thermal and a magnetic trip element.

THERMOCOUPLE— A junction of two dissimilar metals that produces a voltage when heated.

THERMOCOUPLE METER MOVEMENT— A meter movement that uses the current induced in a thermocouple by the heating of a resistive element to measure the current in a circuit; used to measure ac or dc.

THETA— The Greek letter (θ) used to represent phase angle.

TIME CONSTANT— (1) The time required to charge a capacitor to 63.2% maximum voltage or discharge to 36.89% of its final voltage. (2) The time required for the current in an inductor to increase to 63.2% of maximum current of decay to 36.8% of its final current.

TOLERANCE— (1) The maximum error or variation from the standard permissible in a measuring instrument. (2) A maximum electrical or mechanical variation from specifications that can be tolerated without impairing the operation of a device.

TRANSFORMER— A device composed of two or more coils, linked by magnetic lines of force, used to transfer energy from one circuit to another.

TRANSFORMER EFFICIENCY— The ratio of output power to input power, generally expressed as a percentage.

$$Efficiency = \frac{P_{out}}{P_{in}}$$

TRANSFORMER, STEP-DOWN— A transformer so constructed that the number of turns in secondary winding is less than the number of turns in the primary winding. This construction provides less voltage in the secondary circuit than in the primary circuit.

TRANSFORMER STEP-UP— A transformer so constructed that the number of turns in the secondary winding is more than the number of turns in the primary winding. This construction provides more voltage in the secondary circuit than in the primary circuit.

TRIP-ELEMENT— The part of a circuit breaker that senses any overload condition and causes the circuit breaker to open the circuit.

TRIP-FREE CIRCUIT BREAKER— A circuit breaker that will open a circuit even if the operating mechanism is held in the ON position.

TRUE POWER— The power dissipated in the resistance of the circuit, or the power actually used in the circuit.

TURN— One complete loop of conductor about a core.

TURNS RATIO— The ratio of number of turns of primary winding to the number of turns in the secondary winding of a transformer.

V

VOLT— The unit of electromotive force or electrical pressure. 1 volt is the pressure required to send 1 ampere of current through a resistance of 1 ohm.

VOLTAGE— (1) The term used to signify electrical pressure. Voltage is a force that causes current to flow through an electrical conductor. (2) The voltage of a circuit is the greatest effective difference of potential between any two conductors of the circuit.

VOLTAGE DIVIDER— A series circuit in which desired portions of the source voltage may be tapped off for use in equipment.

VOLTAGE DROP— The difference in voltage between two points. It is the result of the loss of electrical pressure as a current flows through a resistance.

W

WATT— The practical unit of electrical power. It is the amount of power used when 1 ampere of dc flows through a resistance of 1 ohm.

WATTAGE RATING— A rating expressing the maximum power that a device can safety handle.

WATT-HOUR— A practical unit of electrical energy equal to 1 watt of power for 1 hour.

WEBER'S THEORY— A theory of magnetism that assumes that all magnetic material is composed of many tiny magnets. A piece of magnetic material that is magnetized has all of the tiny magnets aligned so that the north pole of each magnet points in one direction.

APPENDIX II

REFERENCES USED TO DEVELOP THIS NRTC

NOTE: Although the following references were current when this NRTC was published, their continued currency cannot be assured. When consulting these references, keep in mind that they may have been revised to reflect new technology, revised methods, practices, or procedures. Therefore, you need to ensure that you are studying the latest references.

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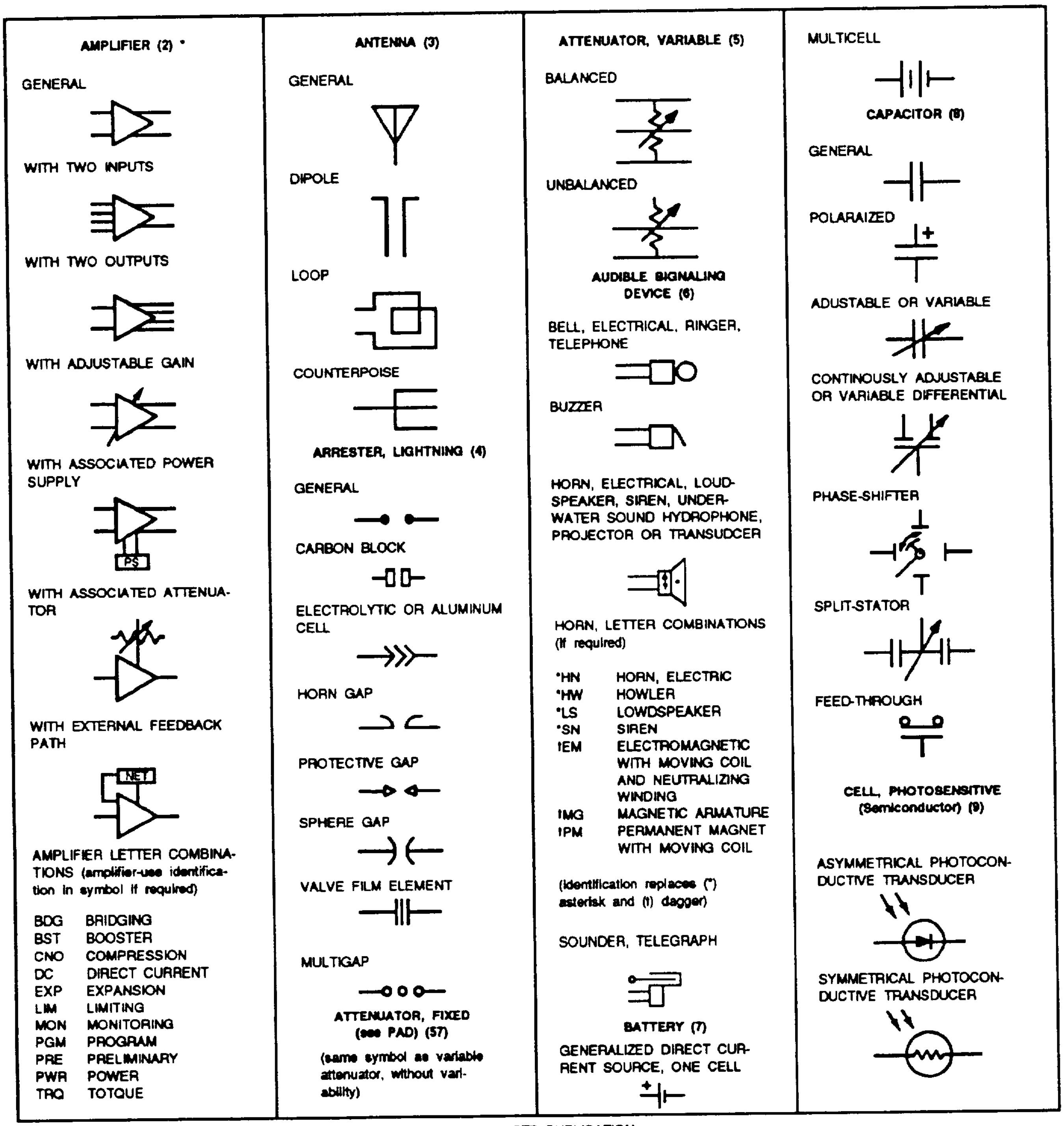
APPENDIX III

ELECTRICAL SYMBOLS



* NUMBER IN PARENTHESES INDICATES LOCATION OF SYMBOL IN MIL-STD PUBLICATION

79NP0343

PHOTOVOLTAIC TRANSDUCER; SOLAR CELL

CIRCUIT BREAKER (11)

GENERAL

WITH MAGNETIC OVERLOAD

OR

DRAWOUT TYPE

CIRCUIT ELEMENT (12)

GENERAL

CIRCUIT ELEMENT LETTER COMBINATIONS (replaces (*) asterisk)

EG	EQUALIZER
FAX	FACIMILE SET
FL	FILTER
FL-BE	FILTER, BAND ELIMINATION
FL-BP	FILTER, BAND PASS
FL-HP	FILTER, HIGH PASS
FL-LP	FILTER, LOW PASS
PS	POWER SUPPLY
RG	RECORDING UNIT
RU	REPRODUCING UNIT
DIAL	TELEPHONE DIAL
TEL	TELEPHONE STATION
TPR	TELEPRINTER
TTY	TELETYPEWRITER

ADDITIONAL LETTER COMBINATIONS (symbols preferred)

AR	AMPLIER
AT	ATTENUATOR
C	CAPACITOR
CB	CIRCUIT BREAKER
HS	HANDSET
I	INDICATING OR SWITCH BOARD LAMP
L	INDUCTOR
J	JACK
LS	LOUDSPEAKER
MIC	MICROPHONE
OSC	OSCILLATOR
PAD	PAD
P	PLUG
HT	RECEIVER, HEADSET
K	RELAY
R	RESISTOR
S	SWITCH OR KEY SWITCH
T	TRANSFORMER
WR	WALL RECEPTACLE

CLUTCH; BRAKE (14)

DISENGAGED WHEN OPERATING MEANS IS DE-ENERGIZED

OR

ENGAGED WHEN OPERATING MEANS IS DE-ENERGIZED

OR

COIL, REPLAY and OPERATING (16)

OR

SEMICIRCULAR DOT INDICATES INNER END OF WIRING

OR

CONNECTOR (18)

ASSEMBLY, MOVABLE OR STATIONARY PORTION; JACK, PLUG, OR RECEPTACLE

OR

JACK OR RECEPTACLE

OR

PLUG

OR

SEPARABLE CONNECTORS

OR

TWO-CONDUCTOR SWITCHBOARD JACK

TWO-CONDUCTOR SWITCHBOARD PLUG

JACKS NORMALLED THROUGH ONE WAY

JACKS NORMALLED THROUGH BOTH WAYS

2-CONDUCTOR NONPOLARIZED, FEMALE CONTACTS

2-CONDUCTOR POLARIZED, MALE CONTACTS

WAVEGUIDE FLANGE

PLAIN, RECTANGULAR

CHOKE, RECTANGULAR

ENGAGED 4-CONDUCTOR; THE PLUG HAS 1 MALE AND 3 FEMALE CONTACTS, INDIVIDUAL CONTACT DESIGNATIONS SHOWN

A B C D OR A B C D

COAXIAL, OUTSIDE CONDUCTOR SHOWN CARRIED THROUGH

COAXIAL, CENTER CONDUCTOR SHOWN CARRIED THROUGH, OUTSIDE CONDUCTOR NOT CARRIED THROUGH

X

MATED CHOCK FLANGES IN RECTANGULAR WAVEGUIDE

COUNTER, ELECTROMAGNETIC; MESSAGE REGISTER (26)

GENERAL

WITH A MAKE CONTACT

COUPLER, DIRECTIONAL (27)

(common coaxial/waveguide usage)

(common coaxial/waveguide usage)

E-PLANE APERTURE-COUPLING, 30-DECIBEL TRANSMISSION LOSS

E 30 DB

COUPLING (28)

BY LOOP FROM COAXIAL TO CIRCULAR WAVEGUIDE, DIRECT-CURRENT GROUNDS CONNECTED

CRYSTAL, PIEZO-ELECTRIC (62)

DELAY LINE (31)

GENERAL

TAPPED DELAY

BIFILAR SLOW-WAGE STRUCTURE (commonly used in traveling-wave tubes)

(length of delay indication replaces (*) asterisk)

DETECTOR, PRIMARY; MEASURING TRANSDUCER (30) (see HALL GENERATOR and THERMAL CONVERTER)

DISCONTINUITY (33)

(common coaxial/waveguide usage)

EQUIVALENT SERIES ELEMENT, GENERAL

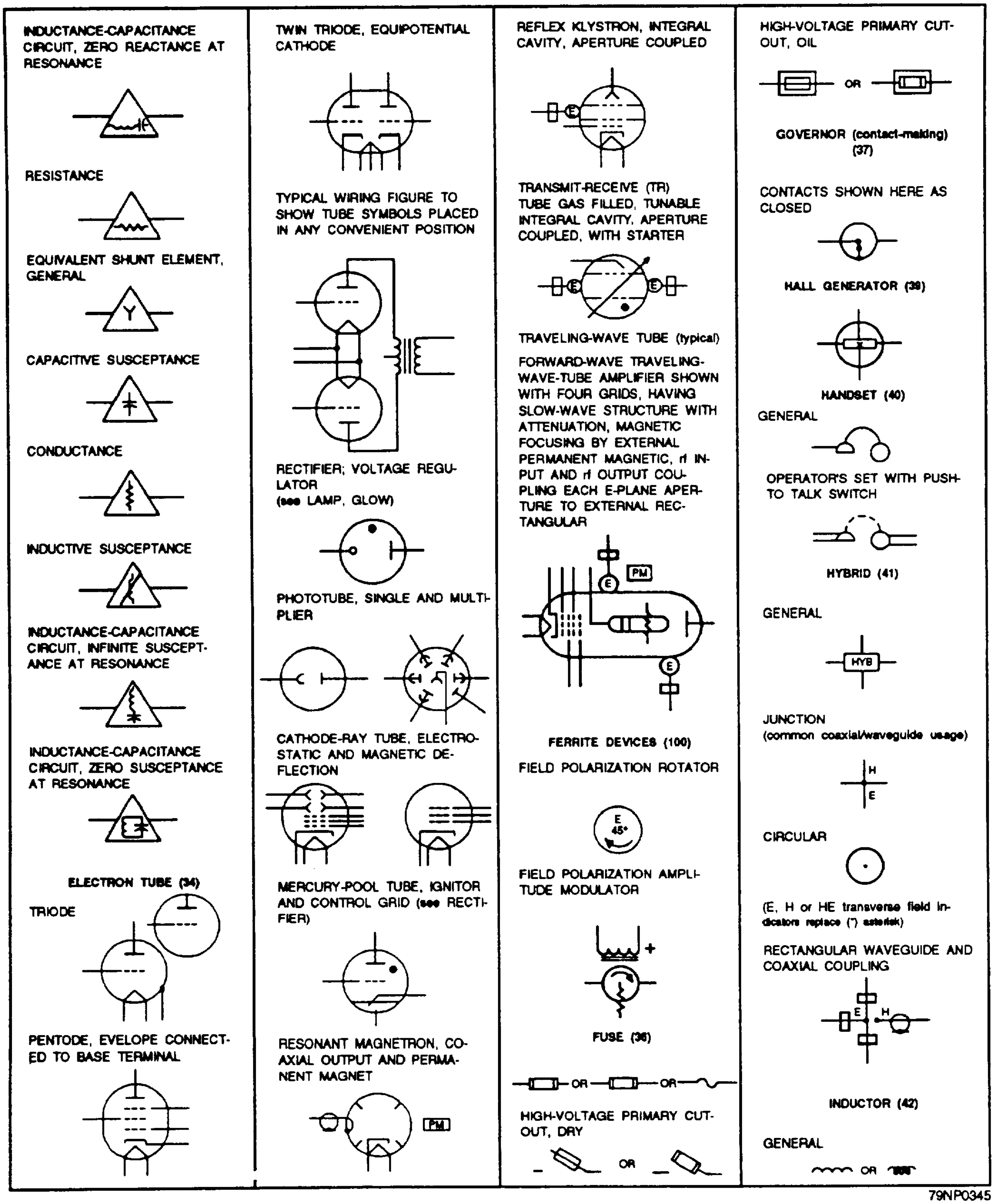
Z

CAPACTIVE REACTANCE

INDUCTIVE REACTANCE

INDUCTANCE-CAPACITANCE CIRCUIT, INFINITE REACTANCE AT RESONANCE

79NP0344


INDUCTANCE-CAPACITANCE CIRCUIT, ZERO REACTANCE AT RESONANCE
RESISTANCE
EQUIVALENT SHUNT ELEMENT, GENERAL
CAPACITIVE SUSCEPTANCE
CONDUCTANCE
INDUCTIVE SUSCEPTANCE
INDUCTANCE-CAPACITANCE CIRCUIT, INFINITE SUSCEPTANCE AT RESONANCE
INDUCTANCE-CAPACITANCE CIRCUIT, ZERO SUSCEPTANCE AT RESONANCE
ELECTRON TUBE (34)
TRIODE
PENTODE, EVELOPE CONNECTED TO BASE TERMINAL
TWIN TRIODE, EQUIPOTENTIAL CATHODE
TYPICAL WIRING FIGURE TO SHOW TUBE SYMBOLS PLACED IN ANY CONVENIENT POSITION
RECTIFIER; VOLTAGE REGULATOR (see LAMP, GLOW)
PHOTOTUBE, SINGLE AND MULTIPLIER
CATHODE-RAY TUBE, ELECTROSTATIC AND MAGNETIC DEFLECTION
MERCURY-POOL TUBE, IGNITOR AND CONTROL GRID (see RECTIFIER)
RESONANT MAGNETRON, COAXIAL OUTPUT AND PERMANENT MAGNET
PM
REFLEX KLYSTRON, INTEGRAL CAVITY, APERTURE COUPLED
E
TRANSMIT-RECEIVE (TR) TUBE GAS FILLED, TUNABLE INTEGRAL CAVITY, APERTURE COUPLED, WITH STARTER
E
E
TRAVELING-WAVE TUBE (typical)
FORWARD-WAVE TRAVELING-WAVE-TUBE AMPLIFIER SHOWN WITH FOUR GRIDS, HAVING SLOW-WAVE STRUCTURE WITH ATTENUATION, MAGNETIC FOCUSING BY EXTERNAL PERMANENT MAGNETIC, rf INPUT AND rf OUTPUT COUPLING EACH E-PLANE APERTURE TO EXTERNAL RECTANGULAR
E
PM
E
FERRITE DEVICES (100)
FIELD POLARIZATION ROTATOR
E
45°
FIELD POLARIZATION AMPLITUDE MODULATOR
+
FUSE (36)
OR
OR
HIGH-VOLTAGE PRIMARY CUTOUT, DRY
OR
HIGH-VOLTAGE PRIMARY CUTOUT, OIL
OR
GOVERNOR (contact-making) (37)
CONTACTS SHOWN HERE AS CLOSED
HALL GENERATOR (39)
HANDSET (40)
GENERAL
OPERATOR'S SET WITH PUSH-TO TALK SWITCH
HYBRID (41)
GENERAL
HYB
JUNCTION (common coaxial/waveguide usage)
H
E
CIRCULAR
(E, H or HE transverse field indicators replace (*) asterisk)
RECTANGULAR WAVEGUIDE AND COAXIAL COUPLING
E
H
INDUCTOR (42)
GENERAL
OR
79NP0345

MAGNETIC CORE

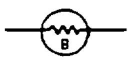
TAPPED

ADJUSTABLE, CONTINUOUSLY ADJUSTABLE

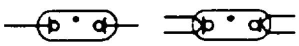
KEY, TELEGRAPH (43)

LAMP (44)

BALLAST LAMP; BALLAST TUBE



LAMP, FLUORESCENT, 2 AND 4 TERMINAL



LAMP, GLOW; NEON LAMP

A-C

D-C

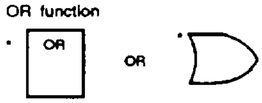
LAMP, INCADESCENT

INDICATING LAMP; SWITCHBOARD LAMP
(see VISUAL SIGNALING DEVICE)

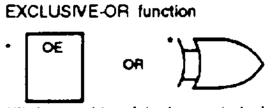
LOGIC
(including some duplicate symbols; left and right-hand symbols are not mixed)

AND function

OR function



EXCLUSIVE-OR function



((*) input side of logic symbols in general)

CONDITION INDICATORS

STATE (logic negation)

A LOGIC NEGATION OUTPUT BECOMES 1-STATE IF AND ONLY IF THE INPUT IS NOT 1-STATE

AN AND FUNC. WHERE OUTPUT IS LOW IF AND ONLY IF ALL INPUTS ARE HIGH

ELECTRIC INVERTER

(elec. invtr. output becomes 1-state if and only if the input is 1-state)
(elec. invtr. output is more pos. if and only if input is less pos.)

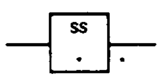
LEVEL (relative)

1-STATE IS LESS + | 1-STATE IS MORE +

(symbol is a rt. triangle pointing direction of flow)

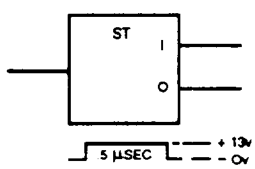
AN AND FUNC. WITH INPUT 1-STATES AT MORE POS. LEVEL AND OUTPUT 1-STATE AT LESS POD. LEVEL

SINGLE SHOT (one output)

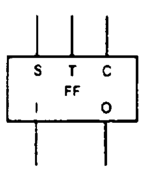


(waveform data replaces inside/outside (*))

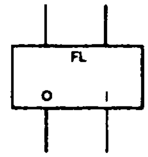
SCHMITT TRIGGER, WAVEFORM AND TWO OUTPUTS



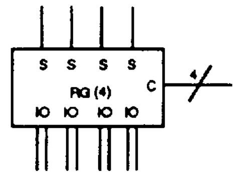
FLIP-FLOP, COMPLEMENTARY



FLIP-FLOP, LATCH



REGISTER



(binary register denoting four flip-flops and bits)

AMPLIFIER (see AMPLIFIER)

CHANNEL PATH(s) (see PATH, TRANSMISSION)

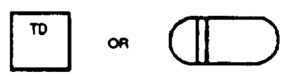
MAGNETIC HEADS (see PICK-UP HEAD)

OSCILLATOR (see OSCILLATOR)

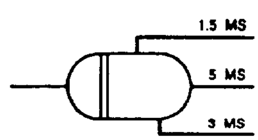
RELAY CONTACTS (see CONTACT, ELECTRICAL) RELAY, ELECTROMAGNETIC (see RELAY COIL RECOGNITION

SIGNAL FLOW (see DIRECTION OF FLOW)

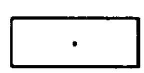
TIME DELAY (see DELAY LINE)



TIME DELAY WITH TYPICAL DELAY TAPS:



FUNCTIONS NOT OTHERWISE SYMBOLIZED



(identification replaces (*))

LOGIC LETTER COMBINATIONS

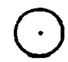
S	SET
C	CLEAR (reset)
T	TOGGLE (trigger)
(N)	NUMBER OF BITS
BO	BLOCKING OSCILLATOR
CF	CATHODE FOLLOWER
EF	EMITTER FOLLOWER
FF	FLIP-FLOP
SS	SINGLE SHOT
ST	SCHMITT REGISTER
RG(N)	REGISTER (N stages)
SR	SHIFT REGISTER

MACHINE, ROTATING (46)

GENERATOR

MOTOR

METER, INSTRUMENT (48)

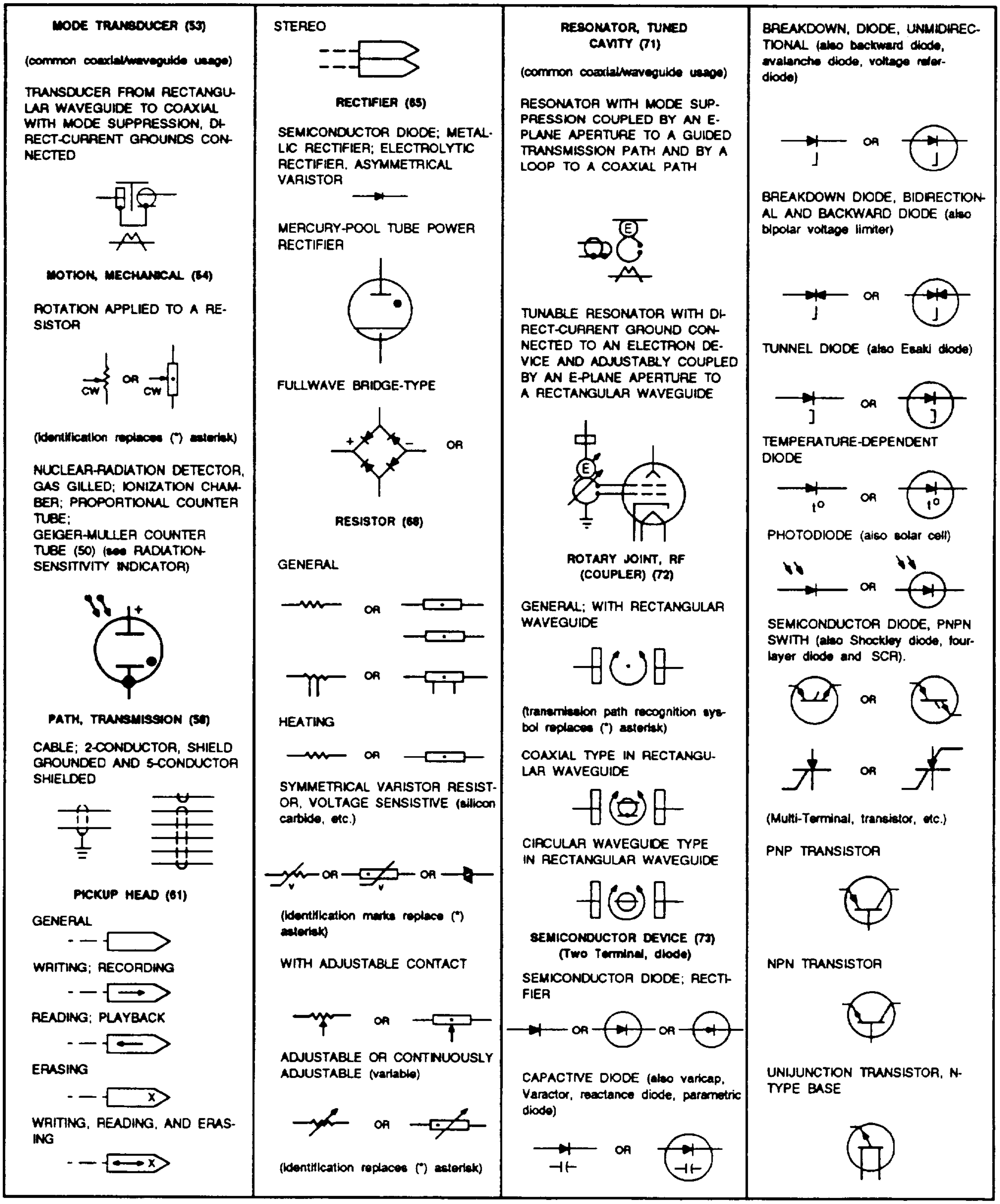


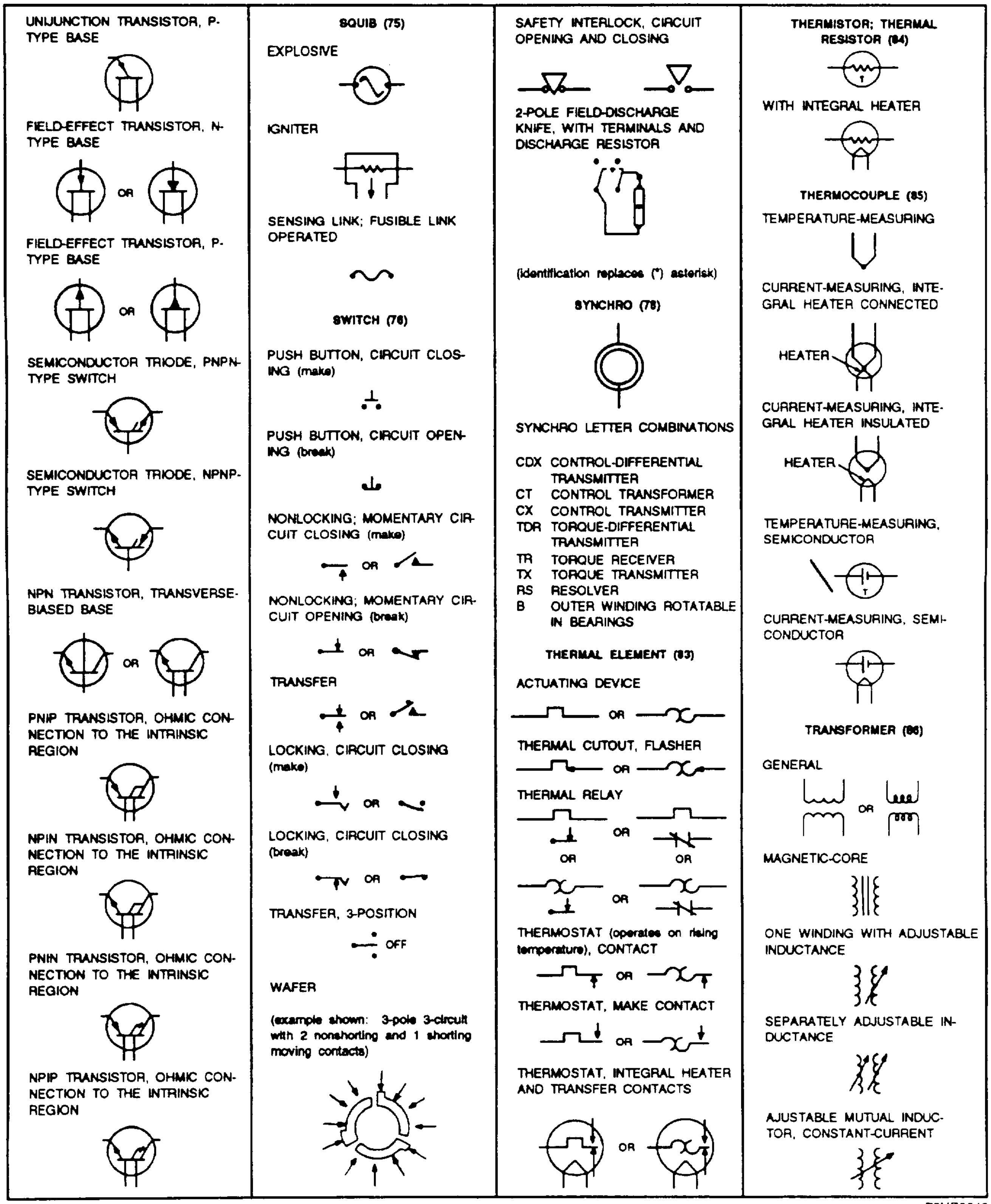
(identification replaces (*) asterisk)

METER LETTER COMBINATIONS

A	AMETER
AH	AMPERE-HOUR
CMA	CONTACT-MAKING (or breaking) AMMETER
CMC	CONTACT-MAKING (or breaking) VOLTMETER
CRO	OSCILLOSCOPE OR CATHODE-RAY OSCILLOGRAPH
DB	DB (decibel) METER
DBM	DBM (decibels referred to 1 milliwatt) METER
DM	DEMAND METER
DTR	DEMAND-TOTALIZING RELAY
F	FREQUENCY METER
G	GALVANOMETER
GD	GROUND DETECTOR
I	INDICATING
INT	INTEGRATING
µA or UA	MICROMMETER
MA	MILLIAMMETER
NM	NOISE METER
OHM	OHMMETER
OP	OIL PRESSURE

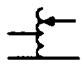
79NP0346


MODE TRANSDUCER (53)
(common coaxial/waveguide usage)
TRANSDUCER FROM RECTANGULAR WAVEGUIDE TO COAXIAL WITH MODE SUPPRESSION, DIRECT-CURRENT GROUNDS CONNECTED
MOTION, MECHANICAL (54)
ROTATION APPLIED TO A RESISTOR
CW OR CW
(identification replaces (*) asterisk)
NUCLEAR-RADIATION DETECTOR, GAS GILLED; IONIZATION CHAMBER; PROPORTIONAL COUNTER TUBE;
GEIGER-MULLER COUNTER TUBE (50) (see RADIATION-SENSITIVITY INDICATOR)
+
PATH, TRANSMISSION (58)
CABLE; 2-CONDUCTOR, SHIELD GROUNDED AND 5-CONDUCTOR SHIELDED
PICKUP HEAD (61)
GENERAL
WRITING; RECORDING
READING; PLAYBACK
ERASING
X
WRITING, READING, AND ERASING
X
STEREO
RECTIFIER (65)
SEMICONDUCTOR DIODE; METALLIC RECTIFIER; ELECTROLYTIC RECTIFIER, ASYMMETRICAL VARISTOR
MERCURY-POOL TUBE POWER RECTIFIER
FULLWAVE BRIDGE-TYPE
+ – OR
RESISTOR (68)
GENERAL
OR
OR
HEATING
OR
SYMMETRICAL VARISTOR RESISTOR, VOLTAGE SENSISTIVE (silicon carbide, etc.)
OR OR
V V
(identification marks replace (*) asterisk)
WITH ADJUSTABLE CONTACT
OR
ADJUSTABLE OR CONTINUOUSLY ADJUSTABLE (variable)
OR
(identification replaces (*) asterisk)
RESONATOR, TUNED CAVITY (71)
(common coaxial/waveguide usage)
RESONATOR WITH MODE SUPPRESSION COUPLED BY AN E-PLANE APERTURE TO A GUIDED TRANSMISSION PATH AND BY A LOOP TO A COAXIAL PATH
E
TUNABLE RESONATOR WITH DIRECT-CURRENT GROUND CONNECTED TO AN ELECTRON DEVICE AND ADJUSTABLY COUPLED BY AN E-PLANE APERTURE TO A RECTANGULAR WAVEGUIDE
E
ROTARY JOINT, RF (COUPLER) (72)
GENERAL; WITH RECTANGULAR WAVEGUIDE
(transmission path recognition symbol replaces (*) asterisk)
COAXIAL TYPE IN RECTANGULAR WAVEGUIDE
CIRCULAR WAVEGUIDE TYPE IN RECTANGULAR WAVEGUIDE
SEMICONDUCTOR DEVICE (73) (Two Terminal, diode)
SEMICONDUCTOR DIODE; RECTIFIER
OR OR
CAPACTIVE DIODE (also varicap, Varactor, reactance diode, parametric diode)
OR
BREAKDOWN, DIODE, UNMIDIRECTIONAL (also backward diode, avalanche diode, voltage referdiode)
OR
BREAKDOWN DIODE, BIDIRECTIONAL AND BACKWARD DIODE (also bipolar voltage limiter)
OR
TUNNEL DIODE (also Esaki diode)
OR
TEMPERATURE-DEPENDENT DIODE
t° OR t°
PHOTODIODE (also solar cell)
OR
SEMICONDUCTOR DIODE, PNPN SWITH (also Shockley diode, four-layer diode and SCR).
OR
OR
(Multi-Terminal, transistor, etc.)
PNP TRANSISTOR
NPN TRANSISTOR
UNIJUNCTION TRANSISTOR, N-TYPE BASE
79NP0347

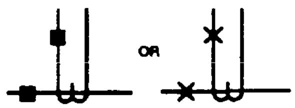

UNIJUNCTION TRANSISTOR, P-TYPE BASE
FIELD-EFFECT TRANSISTOR, N-TYPE BASE
OR
FIELD-EFFECT TRANSISTOR, P-TYPE BASE
OR
SEMICONDUCTOR TRIODE, PNPN-TYPE SWITCH
SEMICONDUCTOR TRIODE, NPNP-TYPE SWITCH
NPN TRANSISTOR, TRANSVERSE-BIASED BASE
OR
PNIP TRANSISTOR, OHMIC CONNECTION TO THE INTRINSIC REGION
NPIN TRANSISTOR, OHMIC CONNECTION TO THE INTRINSIC REGION
PNIN TRANSISTOR, OHMIC CONNECTION TO THE INTRINSIC REGION
NPIP TRANSISTOR, OHMIC CONNECTION TO THE INTRINSIC REGION
SQUIB (75)
EXPLOSIVE
IGNITER
SENSING LINK; FUSIBLE LINK OPERATED
SWITCH (76)
PUSH BUTTON, CIRCUIT CLOSING (make)
PUSH BUTTON, CIRCUIT OPENING (break)
NONLOCKING; MOMENTARY CIRCUIT CLOSING (make)
OR
NONLOCKING; MOMENTARY CIRCUIT OPENING (break)
OR
TRANSFER
OR
LOCKING, CIRCUIT CLOSING (make)
OR
LOCKING, CIRCUIT CLOSING (break)
OR
TRANSFER, 3-POSITION
OFF
WAFER
(example shown: 3-pole 3-circuit with 2 nonshorting and 1 shorting moving contacts)
SAFETY INTERLOCK, CIRCUIT OPENING AND CLOSING
2-POLE FIELD-DISCHARGE KNIFE, WITH TERMINALS AND DISCHARGE RESISTOR
(identification replaces (*) asterisk)
SYNCHRO (78)
SYNCHRO LETTER COMBINATIONS
CDX CONTROL-DIFFERENTIAL TRANSMITTER
CT CONTROL TRANSFORMER
CX CONTROL TRANSMITTER
TDR TORQUE-DIFFERENTIAL TRANSMITTER
TR TORQUE RECEIVER
TX TORQUE TRANSMITTER
RS RESOLVER
B OUTER WINDING ROTATABLE IN BEARINGS
THERMAL ELEMENT (83)
ACTUATING DEVICE
OR
THERMAL CUTOUT, FLASHER
OR
THERMAL RELAY
OR
OR
OR
OR
THERMOSTAT (operates on rising temperature), CONTACT
OR
THERMOSTAT, MAKE CONTACT
OR
THERMOSTAT, INTEGRAL HEATER AND TRANSFER CONTACTS
OR
THERMISTOR; THERMAL RESISTOR (84)
WITH INTEGRAL HEATER
THERMOCOUPLE (85)
TEMPERATURE-MEASURING
CURRENT-MEASURING, INTEGRAL HEATER CONNECTED
HEATER
CURRENT-MEASURING, INTEGRAL HEATER INSULATED
HEATER
TEMPERATURE-MEASURING, SEMICONDUCTOR
CURRENT-MEASURING, SEMICONDUCTOR
TRANSFORMER (86)
GENERAL
OR
MAGNETIC-CORE
ONE WINDING WITH ADJUSTABLE INDUCTANCE
SEPARATELY ADJUSTABLE INDUCTANCE
AJUSTABLE MUTUAL INDUCTOR, CONSTANT-CURRENT

79NP0348

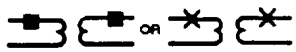
AUTOTRANSFORMER, 1-PHASE ADJUSTABLE



CURRENT, WITH POLARITY MARKING

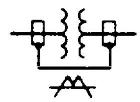


POTENTIAL, WITH POLARITY MARK



WITH DIRECT-CURRENT CONNECTIONS AND MODE SUPPRESSION BETWEEN TWO RECTANGULAR WAVEGUIDES

(common coaxial/waveguide usage)

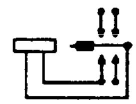


SHIELDED, WITH MAGNETIC CORE

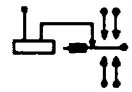
WITH A SHIELD BETWEEN WINDINGS, CONNECTED TO THE FRAME

VIBRATOR; INTERRUPTER (87)

TYPICAL SHUNT DRIVE (terminals shown)



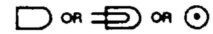
TYPICAL SEPARATE DRIVE (terminals shown)



VISUAL SIGNALING DEVICE (88)

COMMUNICATION SWITCHBOARD-TYPE LAMP

INDICATING, PILOT, SIGNALING, OR SWITCHBOARD LIGHT (see LAMP)



(identification replaces (*) asterisk)

INDICATING LIGHT LETTER COMBINATIONS

A	AMBER
B	BLUE
C	CLEAR
G	GREEN
NE	NEON
O	ORANGE
OP	OPALESCENT
P	PURPLE
R	RED
W	WHITE
Y	YELLOW

JEWELED SIGNAL LIGHT

79NP0349

INDEX

ASSIGNMENT 1

Textbook Assignment: "The Electrician's Mate Rating, General Safety Practices, and Administration," chapter 1, pages 1-1 through 1-36.

> Learning Objective: Recognize the fundamentals of the enlisted rating structure and identify the general requirements for advancement of active duty and inactive duty Electrician's Mates.

1-1. To what rating category do Electrician's Mates (EMs) belong?

1. Apprenticeship
2. Emergency
3. General
4. Service

1-2. When assigned to shore duty, an EM may work outside the rate or rating.

1. True
2. False

1-3. What is the purpose of assigning an NEC to EMs?

1. To identify their specialized skills
2. To show whether they are eligible to draw proficiency pay
3. To identify the types of training for which they qualify
4. To indicate the highest types of training for which they qualify

> Learning Objective: Identify the uses of training publications, technical manuals, and other printed source materials.

1-4. If you want to find advanced information on field changes, you should refer to what publication?

1. *Electronic Information Bulletin*
2. *Bibliography for Advancement Study*
3. *Department of Defense Information Security Program Regulation*
4. *All Hands*

1-5. If you want to find information about new developments in shipboard engineering, you should refer to what publication?

1. *Fathom*
2. *Electronics Information Bulletin*
3. *All Hands*
4. *Deckplate*

1-6. To what publication should you refer for information about the prevention of shipboard accidents?

1. *Military Requirements for Petty Officers 3 & 2*
2. *Deckplate*
3. *Fathom*
4. *All Hands*

1-7. The Navy Electricity and Electronics Training Series (NEETS) modules provide what type of training?

1. NEETS provides beginners with the fundamentals of electrical and electronic concepts
2. NEETS provides military factors needed to perform the duties of your rate
3. NEETS provides techniques for installing electrical equipment
4. NEETS provides the step-by-step procedures for conducting casualty control drills

1-8. Which of the following is a purpose of the Electronics Installation and Maintenance Book (EIMB)?

1. To provide beginners with the fundamentals of electrical and electronic concepts
2. To implement the major policies found in NSTM, chapter 10
3. To provide techniques for installing electrical equipment
4. To provide step-by-step procedures to conduct casualty control drills

1-9. Which of the following publications will help you in determining safe practices when working with electrical and mechanical equipment?

1. *Naval Ship's Technical Manual (NSTM)*
2. *Standard Organization and Regulations of the U.S. Navy*, OPNAVINST 3120.32
3. *Safety of Precautions for Forces Afloat*, OPNAVINST 5100.19
4. Each of the above

1-10. By observing proper safety precautions, you will prevent which of the following situations?

1. Equipment damage
2. Personal injury
3. Both 1 and 2 above
4. Dirty equipment

1-11. Usually, what amount of current is fatal if it passes through a person's body for 1 second or more?

1. 1.0 mA
2. 0.2 mA
3. 0.1 A
4. 1.0 A

1-12. Most shipboard deaths due to electrocution are caused by shock received from what voltage/source?

1. 450 Vac
2. 115 Vac
3. 120 Vdc
4. Ungrounded equipment

1-13. Final approval to work on an energized switchboard is required from which of the following persons?

1. The commanding officer
2. The engineering officer
3. The officer of the deck
4. The operations officer

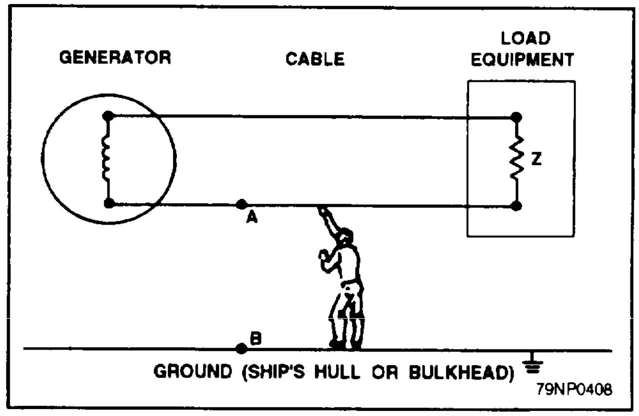


Figure 1A.

IN ANSWERING QUESTION 1-14, REFER TO FIGURE 1A.

1-14. What is the potential from B to A?

1. 0V
2. Full line voltage
3. One-half of the line voltage
4. One-half of the phase voltage

1-15. Shipboard electrical systems are not considered as a perfect ungrounded system. Which of the following factors makes this statement correct?

1. Generator insulation resistance and capacitance to ground
2. RFI filter capacitance to ground
3. Cable resistance and capacitance to ground
4. Each of the above

Learning Objective: Identify requirements for ground connections and recognize precautions regarding the repair of circuits, and the use of rubber matting, ground straps, and shorting probes.

1-16. When equipment grounding is provided, you can make sure that the bonding surfaces will have a positive metal-to-metal contact by taking which of the following actions?

1. Check the mechanical connection to ensure proper contact
2. Securely fasten the connection with the proper mounting hardware
3. Clean the shock mount
4. All of the above

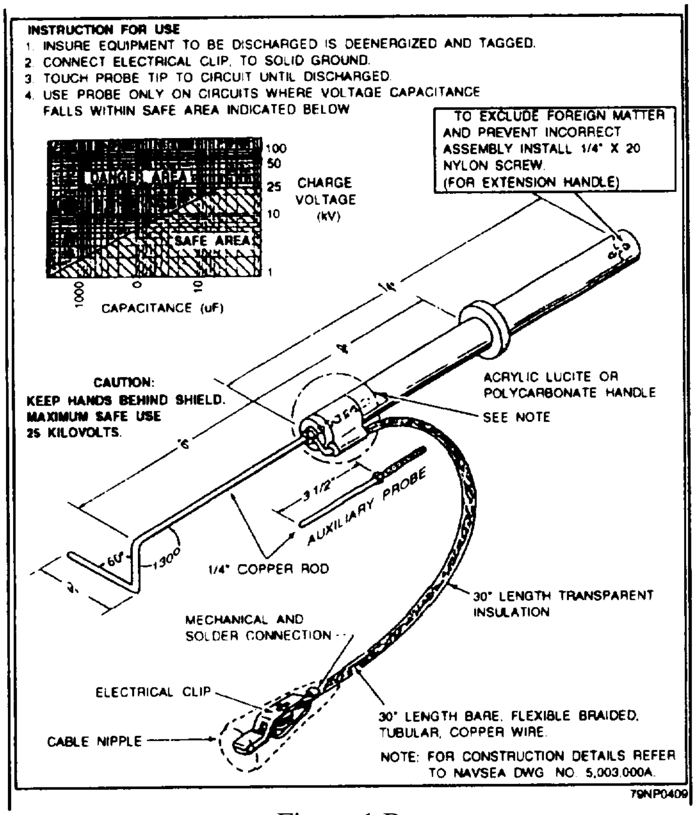


Figure 1 B.

IN ANSWERING QUESTION 1-17, REFER TO FIGURE 1B.

1-17. When using the safety shorting probe to discharge a 30 μF capacitor, what is the maximum safe voltage to discharge?

1. 100 KV
2. 1,000 KV
3. 10,000 V
4. 1,000 V

1-18. Before disconnecting a meter, what should you do to the current transformer?

1. Open the secondary
2. Short circuit the primary
3. Short circuit the secondary
4. Ground the secondary

1-19. Most potential transformer primary windings are protected by what types of devices?

1. Fuses
2. Switches
3. Resistors
4. Capacitors

1-20. To discharge capacitors in de-energized equipment, which of the following devices is used?

1. A screwdriver
2. A ground strap
3. A shorting probe
4. Each of the above

1-21. What is an acceptable resistance reading for the ground connection between the ship's hull and the metal frame of a portable electric drill?

1. 1 ohm or less
2. 2 ohms
3. 1,000 ohms
4. 1 megohm

1-22. You are inspecting a portable electric drill, and you notice the cord has exposed conductors. What action should you take?

1. Replace the plug
2. Replace the cord
3. Patch the cord with tape
4. Cut the damaged section out and splice in a good section of the same type of cord

1-23. Which of the following is NOT an acceptable procedure to follow when using a portable electric drill?

1. Lay out the cord so no one will trip over it
2. Wear safety goggles
3. Use a three-conductor extension cord
4. Remove the third prong when a three-hole receptacle is not available

1-24. What is the most delicate part of a piece of test equipment?

1. The meter
2. The range adjustment
3. The faceplate
4. The power supply

1-25. The top surfaces of electric workbenches must be insulated with what type of material?

1. Rubber matting and adhesive
2. 3/8-inch Benelex 401
3. 1/8-inch Benelex 401
4. 1/8-inch rubber insulation

1-26. A workbench must be secured to the deck.

1. True
2. False

1-27. All electrical workbench receptacles must be supplied from a common or an isolation transformer.

1. True
2. False

1-28. If you need to find information about the approved deck coverings to use in your work area, you should refer to what publication?

1. OPNAVINST 3120.32
2. OPNAVINST 5100.19
3. NEETS
4. *NSTM*, chapter 634

1-29. The dielectric feature of electrical rubber gloves is based on what characteristic, if any, of the glove?

1. The color of the label
2. The wall thickness of the glove
3. The size of the glove
4. None

1-30. When operating a deck buffer rated at 120 volts, what is the lowest class of rubber gloves that you can safely wear?

1. I
2. II
3. III
4. 0

1-31. To ensure maximum protection from floor matting, you should take all EXCEPT which of the following actions?

1. Use general-purpose black floor matting
2. Clean the matting whenever it becomes contaminated
3. Make sure the matting is always in place
4. Use MILSPEC MIL-M-15562 matting

Learning Objective: Recognize various aspects of damage control.

1-32. After reporting on board ship, at what point should naval personnel become acquainted with the types and locations of fire-fighting equipment?

1. After being assigned to a repair party
2. After qualifying in damage control
3. As soon as possible
4. As needed

1-33. What is the safest type of fire-extinguishing agent for you to use on an electrical fire?

1. Potassium bicarbonate (PKP)
2. Soda acid
3. Carbon dioxide (CO_2)
4. Foam

1-34. During a fire, what person determines whether the power should be secured?

1. The repair party leader
2. The on-scene leader
3. The repair party electrician
4. Damage control central

1-35. When it becomes necessary to rig casualty power cables, what person(s) is/are responsible for tying the cables up in the overhead?

1. The repair party electrician
2. The on-scene leader
3. The person assigned by the locker leader
4. All members of the repair party

Learning Objective: Recognize the effects of electric shock on the human body, and identify the procedures for rescuing a person in contact with an energized circuit. Identify the procedures for resuscitating an unconscious person.

1-36. If a person is unconscious because of an electric shock, you should start artificial respiration at what point?

1. As soon as possible
2. After assistance arrives
3. When ordered by senior personnel
4. After transporting the person to sick bay

1-37. A person has just received an electrical shock from an electric drill, and you cannot find the switch or receptacle. What is the quickest and safest method for you to use to free the victim?

1. Turn the drill switch off
2. Cut the portable cable
3. Pull the fuses at the distribution box
4. Pull the flexible cable of the drill until the victim is clear of its contact

1-38. A person has stopped breathing but is still alive. This person is said to be in which of the following states?

1. Cardiac arrest
2. Near-death experience
3. Respiratory failure
4. Suspended animation

1-39. To prepare a victim quickly for administration of mouth-to-mouth artificial respiration, you should take which of the following steps?

1. Place the victim face down on a level area, slide a folded blanket under the stomach, and drain saliva from the mouth
2. Place the victim face upon a level area, slide a folded blanket under the small of the back, lift the lower jaw forward, and depress the tongue
3. Place the victim face up, clear the mouth and throat, tilt the head back, lift the lower jaw, and pinch the nose shut
4. Place the person in comfortable surroundings, loosen the shirt collar and other tight-fitting clothing, turn the head to one side, and drain the saliva from the mouth

1-40. Which of the following actions should NOT be performed during the administration of closed-chest massage?

1. Apply pressure to the breastbone at the rate of 60 to 80 times a minute
2. Apply the least pressure that will secure an effective pulse beat
3. Apply pressure to the chest wall with the fingers at the rate of 2 to 15 times per minute
4. Pause from time to time to see if a spontaneous heartbeat has returned

1-41. When administering CPR to an adult, you should depress the sternum what approximate distance?

1. 1 1/2 to 2 inches
2. 2 to 3 inches
3. 3 inches
4. 1/2 to 1 inch

Learning Objective: Recognize the various types of injuries and identify first aid procedures.

1-42. What type of wound has torn skin and tissue?

1. An abrasion
2. An incision
3. A laceration
4. A contusion

1-43. What measure is the last resort when trying to control bleeding?

1. Applying direct pressure to the wound
2. Using a tourniquet
3. Using pressure points
4. Using back pressure

1-44. What method, if any, should you use to indicate to medical personnel that a victim has had a tourniquet applied?

1. Mark his/her forehead with a capital letter T
2. Have the patient tell them
3. Have the patient tell them to look on his/her medical record
4. None; they will see it when they examine the patient

A. THERMAL BURN
B. ELECTRICAL BURN
C. CHEMICAL BURN

Figure 1C.

IN ANSWERING QUESTIONS 1-45 THROUGH 1-48, REFER TO FIGURE 1C AND SELECT THE BURN DEFINED BY THE QUESTION.

1-45. Caused by chemical action on tissue.

1. A
2. B
3. C

1-46. A direct result of heat caused by the fire.

1. A
2. B
3. C

1-47. Caused by electrical current passing through tissue.

1. A
2. B
3. C

1-48. Caused by exposure of the tissue to steam.

1. A
2. B
3. C

1-49. Burns of what degree are characterized by blistering of the skin?

1. First
2. Second
3. Third
4. Fourth

IN ANSWERING QUESTIONS 1-50 AND 1-51, REFER TO FIGURE 1-15 IN YOUR TEXT.

1-50. What percentage of a person is considered burned when the burned area is confined to the right leg?

1. 1 %
2. 9 %
3. 18 %
4. 30 %

1-51. When steam blisters cover half of a victim's back, (a) what percentage of (b) what class burn exists?

1. (a) 9 % (b) third degree
2. (a) 18 % (b) second degree
3. (a) 9 % (b) second degree
4. (a) 18 % (b) third degree

1-52. When treating a victim with second or third degree burns, you should treat for what symptom first?

1. Shock
2. Burn
3. Pain
4. Fluid loss

Learning Objective: Identify factors that cause environmental harm and recognize precautionary measures.

1-53. Personnel that work in noise-hazardous areas with a noise level of 84 dB and above are required to have a hearing test within what specified period of time after reporting aboard ship?

1. 12 months
2. 6 months
3. 90 days
4. 30 days

1-54. At what minimum decibel level is double hearing protection required?

1. 104 dB
2. 84 dB
3. 64 dB
4. 54 dB

1-55. Heat stress is caused by the body trying to regulate its temperature. Which of the following is/are cause(s) of heat stress?

1. Air temperature
2. Thermal radiation
3. Humidity
4. All of the above

1-56. Which of the following is NOT a cause of heat stress?

1. A ship operating in a hot or humid climate
2. Excessive steam and water leaks
3. Missing or deteriorated pipe lagging
4. Ventilation operating properly

1-57. A heat stress survey is required in any space when the ambient temperature reaches or exceeds what minimum temperature?

1. 90°F
2. 100°F
3. 120°F
4. 140°F

1-58. The reason for conducting a heat survey of a space is to

1. determine the air temperature
2. look for steam leaks
3. identify problems
4. determine the safe stay time for personnel

> Learning Objective: Identify hazardous materials and recognize the precautions to take when handling such materials.

1-59. Of the following items, which one is NOT considered a hazardous item?

1. Acid
2. Enamel paint
3. Coffee grounds
4. Oil

1-60. You can prevent an injury if you regard all aerosols as presenting what hazard?

1. Flammable
2. Foul smelling
3. Water based
4. Full of CFCs

1-61. Electrical equipment should be painted only when the lack of paint will cause what condition?

1. Overheating
2. Corrosion
3. Electric shock
4. Shabby, unimpressive equipment

1-62. Which of the following actions should NOT be taken to prevent corrosion?

1. Apply primer to bare metal
2. Paint identification plates
3. Use approved solvents when treating surfaces
4. Cover moving parts with silicon lubricant

1-63. What are the two types of insulating varnish?

1. Clear-baking and shellac
2. Clear, air-drying and lacquer
3. Shellac and lacquer
4. Clear-baking and air-drying

1-64. When the use of water-based solvent is not practical, what cleaner is recommended?

1. Inhibited methyl chloroform
2. Carbon tetrachloride
3. Benzene
4. Ether

1-65. What action should you take when using cleaning solvents in a confined space?

1. Provide a ventilation source to blow in the space
2. Rig ventilation to blow out of the space
3. Open all portholes
4. Wear a dust mask

1-66. You should NOT use which of the following types of material to clean electrical contacts?

1. Silver polish
2. Steel wool
3. Sandpaper
4. A burnishing tool

1-67. Of the factors listed below, which one(s) cause(s) cathode-ray tubes (CRTs) to be classified as a hazardous material?

1. They are subject to considerable force from atmospheric pressure
2. The chemical coating inside is extremely toxic
3. Both 1 and 2 above
4. They get extremely hot

1-68. Of the following materials, which one is NOT a hazardous material released when the glass envelope of a CRT is broken?

1. Barium getters
2. Barium acetate
3. Thorium oxide
4. Copper oxide

1-69. If you cannot return a CRT to the manufacturer for disposal, what action should you take?

1. Make it harmless by breaking the vacuum glass seal
2. Double bag it, and throw it away
3. Send the CRT to the nearest facility with a burn room for disposal
4. Poke a hole through the face

Learning Objective: Identify the use of caution and danger tags.

1-70. Which of the following phrases is NOT allowed when a caution tag is used?

1. CHECK OIL LEVEL PRIOR TO OPERATION
2. DO NOT OPERATE WITHOUT EOOW PERMISSION
3. DO NOT OPERATE IN HIGH SPEED
4. DO NOT OVERCHARGE

1-71. What publication contains an explanation of the steps required to tag out a piece of equipment?

1. SECNAVINST 5216.5
2. OPNAVINST 3120.32
3. OPNAVINST 4790.4
4. NSTM, chapter 090

1-72. Red tags are used when all EXCEPT which of the following conditions exists?

1. The operation of equipment could jeopardize the safety of watch standers
2. The operation of equipment would damage a component
3. PMS is being performed on a system
4. Special instructions are needed before the equipment can be operated

1-73. When two or more repair groups are performing repairs on a system, the responsibility for posting a red tag rests with

1. each repair group
2. the engineer officer
3. one repair group
4. the officer of the deck

Learning Objective: Identify shipboard organization responsibilities.

1-74. What function is derived from the manner in which the engineering department is organized?

1. It is used to develop a watchbill for enlisted personnel aboard ship
2. It provides for proper assignment of duties and for proper supervision of personnel
3. It identifies personnel qualified for advancement
4. It prevents unqualified personnel from operating equipment

1-75. Which of the following is/are the purpose(s) of the National Apprenticeship Standards of the U. S. Navy?

1. To provide registered certification of the rate training of Navy personnel
2. To achieve recognition of the Navy person equal to his/her civilian counterpart
3. Both 1 and 2 above
4. To ensure personnel are properly trained for their watchstation aboard ship

ASSIGNMENT 2

Textbook Assignment: "Electrical Installations," chapter 2, pages 2-1 through 2-55.

Learning Objective: Identify various types, sizes, and uses of shipboard electrical cables according to their designations, markings, and so forth.

2-1. What was the driving force for developing the low smoke family of cables?

1. Smoke from fires causes standard cables to become grounded
2. The contract for the old style of cables expired
3. The Navy needed a new cable that would give off less toxic fumes and smoke during a fire
4. Standard cables could not handle high current without smoking

2-2. Which of the following are classifications of cable types?

1. Special purpose
2. Nonflexing service
3. Repeated flexing service
4. Each of the above

2-3. What is the purpose of aluminum or steel covering of armored cable?

1. To prevent interference from outside electromagnetic sources
2. To give physical protection to the cable sheath during installation
3. To prevent accidental damage from items carried or moved nearby
4. To provide a magnetic field for degaussing the ship

2-4. Which of the following is a purpose for using nonflexing cables?

1. To use with portable tools
2. To use with permanent installations
3. To use as casualty power only
4. To prevent battle damage

2-5. Flexing service cable designed for use aboard ship is commonly referred to as being portable because

1. it is principally used as leads to portable electric equipment
2. it is principally used as leads to installed electric equipment
3. it is lighter than other types of cable
4. it is easily stripped of insulation

2-6. Repeated flexing, general use-cable is categorized by what means?

1. The ambient temperature rating
2. The voltage rating
3. The current rating
4. The number of conductors in the cable

2-7. If you see the symbol HOF on a cable designation, you know the cable is of what type?

1. Repeated flexing service, experimental
2. Heat and oil resistant, flexible
3. Heat resistant, synthetic rubber, extra flexible
4. Heat and oil resistant, nonflexible

2-8. A cable listed in the *Cable Comparison Guide* has a 7 at the end of the cable designation. Which of the following is the meaning of the 7?

1. The number of conductor pairs and the circular mils of the conductor only
2. The number of conductors, the number of conductor pairs, and the circular mils
3. Either 1 or 2 above, depending on the type of cable
4. It has a resistance of 7Ω per foot

2-9. A radio frequency (RF) cable designated as LSTTRSU-10 in the C*able Comparison Guide* has what total number of conductors?

1. 20
2. 40
3. 60
4. 80

2-10. The designation of a nonflexing service cable is LSDHOF-400. What does (a) the letter D and (b) the number 400 indicate?

1. (a) Degaussing
   (b) approximate cross-sectional area of a single conductor expressed in thousands of circular mills
2. (a) Two conductors
   (b) number of strands per conductor
3. (a) Two conductors
   (b) approximate cross-sectional area of a single conductor expressed in thousands of circular mills
4. (a) Degaussing
   (b) number of strands per conductor

2-11. If you need to find a comprehensive listing of the requirements for installing cables aboard Navy ships, you should refer to what publication?

1. *General Specifications for Ships of the U.S. Navy*, NAVSEA S9AAO-AA-SPN-010
2. *Electrician's Mate*, OPNAVINST 4790.4
3. *3-M Manual*, OPNAVINST 4790.4
4. *Ship's Organization and Regulations Manual*, OPNAVINST 3120.32

2-12. A cable has been constructed so that it provides added protection, allowing it to function for a longer period under fire conditions. What term describes this cable?

1. Armored cable
2. Circuit integrity
3. Watertight integrity
4. Special use cable

2-13. What information is on the thin marker tape present on most cables and cords under the binder or jacket?

1. Name and location of the manufacturer
2. The year the cord or cable was made
3. The MILSPEC number of the cord or cable
4. All of the above

2-14. When selecting a replacement cable for a particular installation, you must know all EXCEPT which of the following factors?

1. The demand factor
2. The allowable voltage drop
3. The total connected load current
4. The number of bends in the cable

2-15. Before choosing the size of cable to use in a circuit installation, what information is necessary for you to know?

1. The demand factor, the total connected load current, and the voltage of the circuit
2. The total connected load current, the power factor, and the allowable voltage drop
3. The ambient temperature, the total connected load current, and the demand factor
4. The total connected load current, the demand factor, and the allowable voltage drop

2-16. Which, if any, of the following is the reason for keeping cable runs as short as possible?

1. To lower construction costs
2. To keep attenuation to a minimum
3. To simplify damage control efforts
4. None of the above

2-17. When determining the total connected load current for a dc power circuit, you should add what number of watts for each installed receptacle?

1. 50
2. 100
3. 150
4. 200

2-18. What letters would be used to designate an emergency lighting circuit on a cable supplying 115 volts ac to a circuit with a load of 120 watts?

1. EL
2. EP
3. L
4. C

Learning Objective: Identify installation, repair, and protection procedures.

2-19. You are installing new cables. You should measure the bend radius at what point on the cable?

1. On the top of the cable
2. On the bottom of the cable
3. On the innermost portion of the cable
4. On the outside of the cable away from the bend

2-20. In what publication will you find the exact method to use when installing cables?

1. *Electronics Installation and Maintenance Handbook* (EIMB)
2. *NSTM*
3. Cable *Comparison Guide*
4. NAVEDTRA 12164

2-21. What action should you take before you clamp a solder-type terminal to a conductor?

1. Untwist and tin the strands
2. Twist the strands tightly only
3. Twist the strands tightly and solder them only
4. Twist the strands tightly, solder them, and tin the terminal board

2-22. A cable has been newly installed. What type of meter should you use to test the insulation resistance?

1. A megger
2. An ammeter
3. A wattmeter
4. A voltmeter

2-23. Neutral polarity in a conductor is identified by what color?

1. Red
2. Black
3. White
4. Blue

2-24. The marking system for power and lighting cables is shown in what sequence?

1. Source, voltage, and service
2. Voltage, source, and service
3. Service, source, and voltage
4. Source, service, and voltage

2-25. A cable marked as (1-120-2)-24-C(2) indicates that the circuit is supplying what maximum voltage?

1. 12 V
2. 24 V
3. 120 V
4. 220 V

2-26. A circuit marking of (4-168-1)-4P-A(1) indicates that the circuit is supplying (a) what voltages of (b) what type power?

1. (a) 450 V (b) casualty
2. (a) 115 V (b) casualty
3. (a) 450 V (b) ship's service
4. (a) 115 V (b) ship's service

2-27. If you want cable to present a neat appearance and to be traced easily in equipment, you should take what action?

1. Wrap them together with tape
2. Secure them to the side of the equipment with small lengths of wire
3. Twist the wires together
4. Lace them together

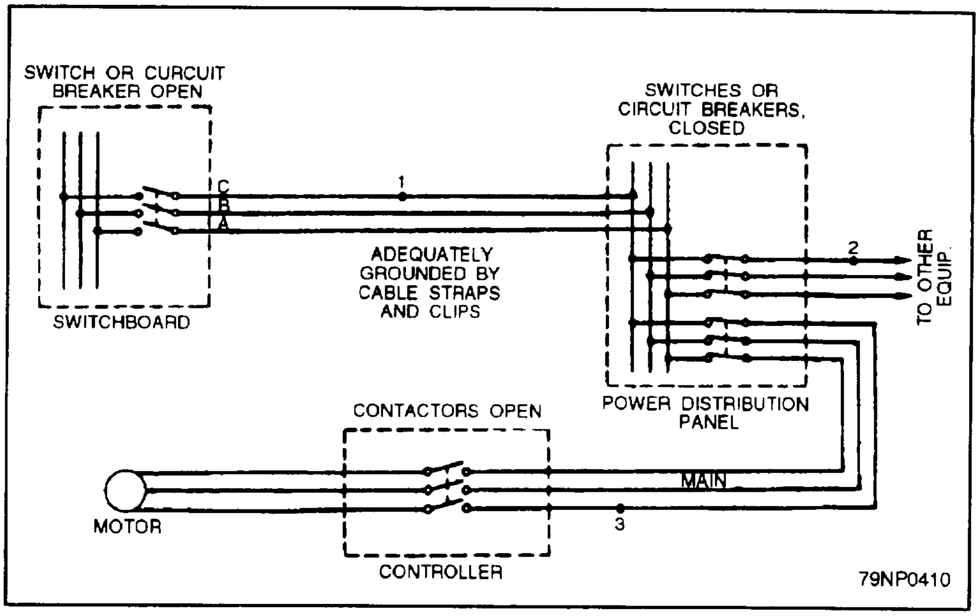


Figure 2A.

IN ANSWERING QUESTIONS 2-28 AND 2-29, REFER TO THE TYPICAL POWER FEEDER SHOWN IN FIGURE 2A.

Learning Objective: Recognize the steps to take when troubleshooting a distribution system.

2-28. To isolate the legs or phase leads of the power circuit, you should take which of the following steps?

1. Open the switches or circuit breakers at the power distribution panel
2. Make sure the motor controller contractors are open
3. Both 1 and 2 above
4. Remove the ground straps and clips

2-29. With the circuit in the condition shown, a ground is detected in the power circuit at point 3. What should be done to isolate the faulty section and locate the ground?

1. Open all breakers shown and use a Megger to test each circuit individually to localize the fault
2. Use a Megger to test the motor leads to find what phase is at fault
3. Operate the switchboard ground detector to find what phase is grounded
4. Stop each piece of equipment fed from the power distribution panel until the ground disappears

Learning Objective: Recognize the purpose for cable maintenance and insulation, and identify the properties of different insulating materials.

2-30. What is the primary purpose of cable maintenance?

1. To keep the wireways clean and free of dust
2. To preserve the insulation resistance
3. To prevent damage to the cables
4. To prevent loose connections

2-31. Which of the following purposes is/are served by insulation on electric cables and equipment?

1. Isolating current-carrying conductors and conductive structural parts of other circuits or equipment
2. Insulating points of unequal potential from one another
3. Both 1 and 2 above
4. Protecting the current-carrying conductors from interference from outside electromagnetic sources

2-32. Electrical insulating materials are classified according to what characteristic?

1. Their material composition
2. Their temperature index
3. Their resistivity coefficient
4. Their thickness

A. CLASS A
B. CLASS B
C. CLASS C
D. CLASS O

Figure 2B.

IN ANSWERING QUESTIONS 2-33 THROUGH 2-36, SELECT THE CLASS OF INSULATION FROM FIGURE 2B THAT IS ASSOCIATED WITH THE MATERIAL USED AS THE QUESTION.

2-33. Impregnated cotton.

1. A
2. B
3. C
4. D

2-34. Quartz.

1. A
2. B
3. C
4. D

2-35. Paper.

1. A
2. B
3. C
4. D

2-36. Asbestos.

1. A
2. B
3. C
4. D

2-37. Shipboard lighting transformers in a 60-hertz circuit are constructed using what class insulation?

1. Class A
2. Class B
3. Class C
4. Class O

2-38. What is the limiting temperature of a piece of equipment with class N insulation?

1. 155°C
2. 180°F
3. 200°F
4. 200°C

Learning Objective: Identify the procedures for measuring circuit insulation resistance.

2-39. If local lighting switches are double pole, leaving them open allows their insulation resistance to be measured when testing the local branch circuit.

1. True
2. False

2-40. When measuring the insulation resistance of an armored power cable with a Megger, what is the maximum desired resistance from the cable armor to ground?

1. 0Ω
2. 100W
3. 1 M Ω
4. Greater than 1 M Ω

2-41. When measuring the insulation resistance of a complete lighting circuit with a Megger, what is the minimum desired resistance to ground?

1. Less than 1 Ω
2. 1 Ω
3. 500,000 Ω
4. More than 1 MΩ

2-42. You would use a nomograph when taking what measurement?

1. The resistance/foot of a cable
2. To correct a resistance reading of a cable
3. To translate a resistance reading to a temperature index
4. To correct a resistance reading of a piece of equipment

2-43. If a cable has been energized for 6 hours, what temperature should the cable be assumed to be for purposes of heating resistance?

1. 40°F
2. 70°F
3. 90°F
4. 104°F

Learning Objective: Identify the procedures you should use to prepare, use, and care for casualty power and shore power cables.

2-44. What is the size and designation for casualty power cables on ac power systems?

1. LSDHOF-93
2. LSMHOF-3
3. LSTHOF-42
4. LSFHOF-48

2-45. Casualty power cable leads are color coded for identification. What are the proper colors for A, B, and C phases, respectively?

1. Red, white, and black
2. Black, white, and red
3. Black, red, and white
4. Red, black, and white

2-46. To provide or install shore power to a ship requires which of the following equipment?

1. Shore power station and receptacle
2. Connecting cable
3. Cable plug
4. All of the above

2-47. The shore-power system is designed to provide enough power for all equipment normally energized while at sea.

1. True
2. False

2-48. You are connecting casualty power cables in a dark compartment. What conductor feature is identified by three separate servings of twine or O-rings?

1. Phase A
2. Phase C
3. The conductor polarity
4. The neutral connection

2-49. What type of cable is used to connect fixed terminals that penetrate decks and bulkheads?

1. LSTSGU-75
2. LSDSGU-75
3. LSTHOF-75
4. LSDHOF-75

Learning Objective: Identify equipment needs, installation methods, and testing procedures that are required when connecting shore power.

2-50. Shore power is supplied to the ship through the use of (a) what specific length of (b) what type of cable?

1. (a) 175 feet (b) THOF-400
2. (a) 175 feet (b) TSGU-400
3. (a) 150 feet (b) THOF-400
4. (a) 150 feet (b) TSGU-400

2-51. You are testing the phase sequence of a shore connection. What is indicated by a clockwise rotation of the phase sequence indicator?

1. Correct phase sequence
2. Incorrect phase at the shore station
3. High voltage at the shore station
4. Three-phase power is not available

2-52. Kickpipes that penetrate wooden decks should be made from what material?

1. Iron
2. Aluminum
3. Steel
4. Neoprene

> Learning Objective: Recognize the operating fundamentals of electrical switches and protection devices.

2-53. Limit switches are installed so they are connected in what configuration with (a) the master switch and (b) the voltage supply circuit?

1. (a) Parallel (b) parallel
2. (a) Parallel (b) series
3. (a) Series (b) parallel
4. (a) Series (b) series

2-54. What is a pilot device?

1. A large device that controls other large devices
2. A small device that controls a large device
3. A large device that controls a small device
4. A small device that controls other small devices

2-55. A thermal overload relay is adjusted to trip at a predetermined value. What action can you take to vary the tripping current?

1. Change the relative position of the contacts
2. Raise and lower the dashpot plunger
3. Rotate the splitter arm
4. Move the relay heater coil

> Learning Objective: Recognize the operating principles and identify the repair procedures for circuit breakers.

2-56. What type of protection is provided by reverse-power relays?

1. They protect the generators from damage by motoring prime movers
2. They prevent the motoring generator from damaging the prime movers
3. They prevent loss of power to the prime movers
4. They limit the amount of circulating current between paralleled generators

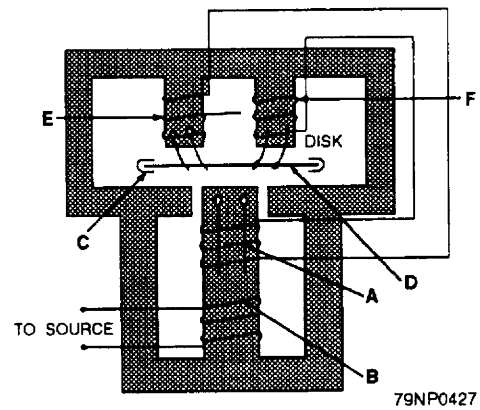


Figure 2C.

IN ANSWERING QUESTIONS 2-57 AND 2-58, REFER TO FIGURE 2C.

2-57. Oscillations in the induction disk of the timer element of the relay are dampened by which component?

1. A
2. B
3. C
4. D

2-58. What condition must take place to cause reverse rotation of the disk?

1. The polarity of power through coil A must be in a direction that will cause a torque on the disk through a reaction with the fluxes of the upper and lower poles
2. The polarity of coil E must reverse with respect to the polarity of coil F
3. The current through coils A and B must reverse with respect to the polarity of coils E and F
4. The current through coils E and F must reverse with respect to the polarity of coil B

2-59. When two or more dc generators are connected in parallel, what device disconnects a generator from the line if the generator starts drawing power from the line?

1. A thermal-type relay
2. A reverse-power relay
3. A magnetic-type relay
4. A reverse-current relay

2-60. The polarity of the voltage applied to the potential coil on a reverse-current relay will remain the same when the generator terminal current is reversed.

1. True
2. False

2-61. To actuate a phase-failure relay, what action must take place?

1. A flux cancellation between the flux produced in the relay coils and the flux produced in the coils in the Rectox unit
2. An imbalance of current through the relay coils
3. A flux cancellation between the flux produced by one relay and one coil in the Rectox unit, and the flux produced by the other relay coil and the other coil in the Rectox unit
4. An imbalance between the flux produced in the relays in the Rectox unit

2-62. What is used to compensate for variations in reactance of the reactors introduced during manufacturing?

1. Two resistors
2. An inductor is placed in each Rectox
3. A bridge rectifier is placed in series with the reactors
4. Two 2-coil reactors

2-63. What is the closing sequence of the contacts in an ACB circuit breaker?

1. Main contacts close only
2. Arcing contacts and the main contacts close together
3. Arcing contacts close; then the main contacts close
4. The main contacts close; then the arcing contacts close

2-64. Which of the following trip elements should NOT be used on the AQB-A250 circuit breaker?

1. 300 A
2. 275 A
3. 150 A
4. 125 A

2-65. The instantaneous trip setting of the AQB-A250 circuit breaker is adjusted by using what components?

1. Thermal studs
2. Shunt trips
3. Trip coils
4. Adjusting wheels

2-66. Which of the following circuit breakers must be manually operated to interrupt current flow?

1. Type NQB
2. Type NLB
3. Both 1 and 2 above
4. Type ACB

2-67. Which of the following conditions is most likely to cause a relay magnet to chatter?

1. Rusty magnet sealing surfaces
2. Shorted coils
3. Open coils
4. Burned contacts

2-68. Selective tripping is useful aboard ship for what reason?

1. It allows overcurrents to flow in the circuits
2. It systematically opens all circuits when damage occurs
3. It maintains overcurrents where fuses will not
4. It isolates faulty circuits without interrupting other associated circuits

Learning Objective: Recognize the proper procedures for installing power cords and testing portable equipment.

2-69. When testing a grounded receptacle, what is the maximum acceptable resistance from the ground connection to the ship's hull?

1. Less than 1 Ω
2. 0.0001 Ω
3. 1.0 Ω
4. 1.05 Ω

2-70. At what interval should the connections of new portable electric wiring be tested?

1. Before being used for the first time
2. Before every use
3. Semiannually
4. Annually

2-71. While testing the power cord of a portable electric drill, you notice a fluctuation in the resistance reading. The fluctuating resistance reading indicates which of the following problems?

1. A short
2. A ground
3. A faulty cable
4. Each of the above

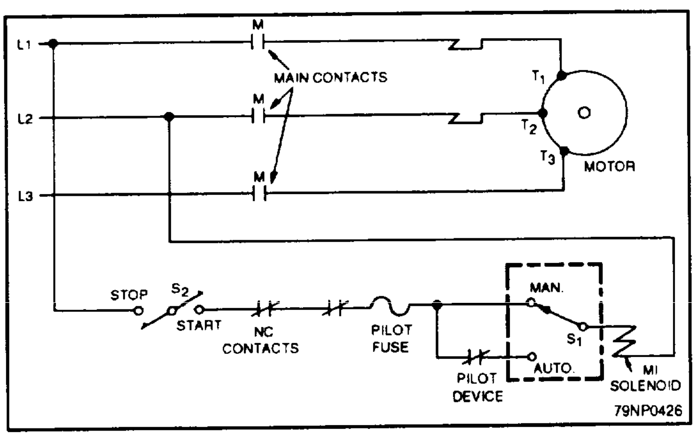


Figure 2D.

IN ANSWERING QUESTION 2-72, REFER TO FIGURE 2D.

2-72. Switch S_2 is closed and switch S_1 is in the automatic position. Under normal load conditions, which component controls starting and stopping of the motor?

1. The fuse
2. The main contact for L2
3. The pilot device
4. The main contact for L1

2-73. A magnetic-type overload dashpot relay tends to trip before the overload current becomes excessive. How can you adjust the relay to trip at a greater current?

1. Lower the plunger by turning the dashpot in a reverse direction
2. Raise the plunger by turning the dashpot in a forward direction
3. Lower the indicating plate
4. Raise the indicating plate

ASSIGNMENT 3

Textbook Assignment: "AC Power Distribution Systems," chapter 3, pages 3-1 through 3-40.

Learning Objective: Identify the purpose and functions of the components of ac power distribution systems.

3-1. Which, if any, of the following systems make(s) up the power distribution system?

1. The casualty power system
2. The emergency power system
3. The ship's service system
4. All of the above

3-2. What is the function of the switchboard bus ties?

1. To permit switchboards to be cross connected and to allow paralleling of generators
2. To allow power distribution direct from the generator to the load
3. To allow the generators to operate in series
4. To feed power to the dc generator

3-3. On small ships, locating distribution panels centrally with respect to the load and feeding them directly from the generators has which of the following advantages?

1. It simplifies the installation
2. It reduces the weight and space requirements
3. It reduces equipment requirements
4. Each of the above

Learning Objective: Identify information found on circuit identification plates and recognize the importance of identifying the phase sequence in power distribution systems.

3-4. What information is contained on circuit information plates located on distribution panels?

1. The circuit number and the name of the circuit controlled only
2. The circuit number, the name of the circuit controlled, and the space served
3. The space served and the circuit number only
4. The space served, the circuit number, and the circuit power used

3-5. You are troubleshooting a circuit and you want to know the maximum allowed current. This information is marked on which, if any, of the following plates?

1. Distribution panel circuit information plate
2. Distribution panel cabinet information plate
3. Cable identification plate
4. None of the above

3-6. For what reason, if any, is the phase sequence important to the distribution system aboard ship?

1. An improper phase sequence will cause voltage fluctuations
2. The phase sequence determines the amount of current available
3. The phase sequence determines the direction of rotation of three-phase motors
4. None; the phase sequence has no effect on the distribution system

3-7. What is the advantage of using an MBT as an alternate power source to a vital load?

1. Circuit conditions can be met before energizing
2. Automatic switching of power supplies
3. The load can be secured faster in an emergency
4. The maintaining of 58% of the lighting circuits if one phase is lost

Learning Objective: Identify the characteristics and uses of critical hardware components of ac power distribution systems.

3-8. What service is provided by bus transfer equipment?

1. Short-circuit protection to the ship's service generators
2. Prevention of overloading the generator circuit breakers
3. Prevent paralleling of two switchboards if the voltage and current relationships are improper
4. Two sources of power to equipment that is vital to the ship

3-9. Aboard ships, switchgear groups are physically separated as much as practical for what reason?

1. To allow easy access for maintenance
2. To prevent accidental loss of power
3. To afford greater protection from damage during battle
4. To prevent unnecessary weight during construction

3-10. Which of the following is NOT a function provided by switchboards aboard ships?

1. Automatic shifting of power to alternate sources if normal power is lost
2. Distribution of three-phase, 450-volt power
3. Circuit protection
4. Control, monitoring, and protection of the ship's service generators

3-11. What is the purpose of the disconnect links?

1. They provide a convenient means of load testing ship's service generators
2. They provide a means of securing power to a switchboard during a fire
3. They enable repairs to be conducted to one switchboard without affecting the operation of the whole system
4. They are used to provide overcurrent protection to the main bus

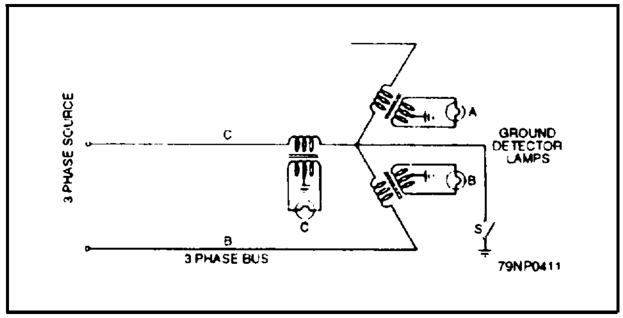


Figure 3A.

IN ANSWERING QUESTIONS 3-12 AND 3-13, REFER TO FIGURE 3A.

3-12. If lamp A is out when switch S is open, what problem is indicated?

1. Phase A is grounded
2. Lamp A is burned out
3. Phases B and C are shorted
4. Phase A is partially grounded

3-13. What indication is given if lamp C is dim when switch S is closed?

1. Phase C has a ground
2. Phase B is shorted
3. Phase A is open
4. Phase C has a partial open

Learning Objective: Recognize the operating principles of ac generators, including related construction features and devices needed to drive them.

3-14. The output of all ac generators is generated in what winding?

1. The field winding
2. The stator winding
3. The rotor winding
4. The armature winding

3-15. Revolving armature generators are seldom used for what reason?

1. Their output power is conducted through fixed terminals
2. They are subject to arc-over at high voltages
3. They are physically larger than other types of generators
4. They are more expensive to operate

3-16. When dealing with the load rating of ac generators, what factor must be accounted for?

1. The internal heat the generator can withstand
2. The speed of the generator
3. The weight of the field windings
4. The type of voltage regulator used

3-17. Which of the following statements defines the term *power factor*?

1. The difference between the voltage and the current
2. It is set at 0.08 lagging
3. The product of the voltage and the current of the system
4. The expression of the losses within the electrical distribution system

3-18. AC generator sets may be divided into what two classes?

1. Low-speed, turbine-driven and high-speed, engine-driven
2. High-speed, turbine-driven and high-speed, engine-driven
3. Low-speed, engine-driven and high-speed, turbine-driven
4. Low-speed, engine-driven and low-speed, turbine-driven

3-19. What function is provided by ac generator exciters?

1. DC to the field windings
2. DC to the load
3. AC to the stationary armature
4. AC to the stationary field windings

3-20. The rotary force used to provide the rotating action in generators may be supplied by which of the following prime movers?

1. An electric motor
2. A turbine
3. An internal combustion engine
4. Each of the above

3-21. The rotary force from the prime mover is transmitted to the ac generator by which of the following components?

1. Stator
2. Exciter field
3. Rotor drive shaft
4. AC generator armature

Learning Objective: Identify the operating principles of single-, two-, and three-phase ac generators, including the wye- and delta-connected types.

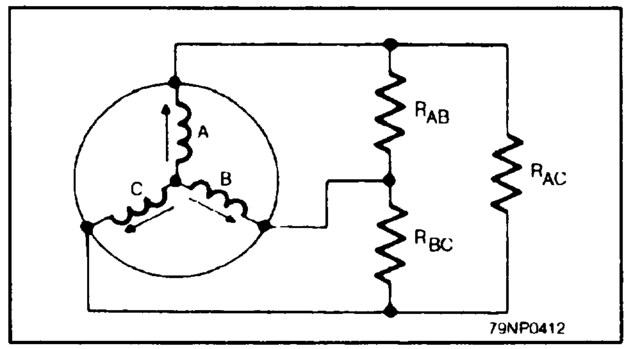


Figure 3B.

IN ANSWERING QUESTION 3-22, REFER TO FIGURE 3B.

3-22. What is the magnitude of the voltage across any two phases?

1. Larger than the voltage across a single phase
2. Equal to the sum of the voltage across all three phases
3. Equal to the voltage across a single phase
4. Smaller than the voltage across a single phase

3-23. When you use vectors to analyze ac circuits, what rotation direction represents (a) positive and (b) negative polarity?

1. (a) Right (b) left
2. (a) Counterclockwise (b) clockwise
3. (a) Right (b) clockwise
4. (a) Counterclockwise (b) left

3-24. In a purely capacitive circuit, what is the relationship between voltage and current?

1. Voltage leads current
2. Voltage and current are in phase
3. Current leads voltage
4. Current lags voltage

3-25. A generator is operating at 450 volts ac, 60 hertz, supplying a load of 1,000 amperes and 306,000 watts. What is the power factor?

1. 1.24
2. 0.80
3. 0.75
4. 0.68

3-26. When the phase voltage is 100 volts in a delta-connected ac generator, what is the line or load voltage?

1. 200.0 V
2. 173.0 V
3. 100.0 V
4. 70.7 V

3-27. When the phase current in a balanced delta-connected generator is 20 amperes, what is the line current?

1. 34.6 A
2. 20.0 A
3. 10.0 A
4. 6.6 A

Learning Objective: Identify the factors that determine the output frequency and voltage of ac generators, and recognize the principles 01 generator synchronization and voltage regulation.

3-28. The output frequency of an ac generator varies directly with which of the following generator characteristics?

1. The number of poles on the rotor
2. The speed of rotation of the rotor
3. Both 1 and 2 above
4. The frequency of the field current

3-29. The line voltage of a wye-connected stator with a balanced load isn't twice the phase voltage for what reason?

1. The loads seen by the generator are usually inductive
2. The load across each line is different
3. The line currents are unequal
4. The phase voltages are out of phase with each other

3-30. At which of the following points will a generator's output voltage increase?

1. When the rotating field strength increases
2. When the load increases
3. Both 1 and 2 above
4. When the rotor speed decreases

3-31. A decrease in general terminal voltage caused by an inductive load is partly the result of which of the following actions?

1. Reduced current through the armature conductors
2. Increased dc field flux caused by the aiding action of the armature mmf
3. Reduced dc field flux caused by the opposing action of the armature mmf
4. Increased armature mmf produced by increased field flux

3-32. The most practical method to control voltage of an ac generator is to regulate the generator's speed.

1. True
2. False

Learning Objective: Identify the operational principles, characteristics, and design features of transformers.

3-33. In transformers, electrical energy is transferred from one circuit to another through which of the following actions?

1. Hysteresis coupling
2. Electrostatic radiation
3. Electromagnetic induction
4. Resistive-capacitive coupling

3-34. When a transformer transfers electrical energy, what elements are either increased or decreased by the transformer?

1. Current and voltage only
2. Frequency and current only
3. Voltage and frequency only
4. Frequency, voltage, and current

3-35. In a transformer, what winding is designated as the primary?

1. The one with the highest voltage
2. The one with the lowest voltage
3. The one that delivers energy to the load
4. The one that receives energy from an ac source

3-36. You can reduce eddy current losses in the core of a transformer by installing which of the following components?

1. Grain-oriented material
2. Heat-treated core material
3. Thin, insulated lamination
4. Subdivided windings

3-37. In a transformer, the low-voltage winding is placed next to the core instead of the high-voltage winding for what reason?

1. To reduce I_r drop
2. To reduce leakage flux
3. To reduce hysteresis loss
4. To reduce insulation requirements

3-38. In each winding of a transformer, the total induced voltage has what relationship to the number of turns in that winding?

1. Proportional
2. Reciprocal
3. Additive
4. Subtractive

3-39. Because of damage caused by heat, you should NOT operate a transformer rated at 400 hertz at which of the following frequencies?

1. 450
2. 420
3. 370
4. 340

3-40. A transformer's efficiency is stated as a ratio of what factor of the transformer's input to output?

1. Power
2. Line loss
3. Phase current
4. Voltage

3-41. Which of the following losses does NOT affect the efficiency of a transformer?

1. Hysteresis losses
2. Eddy current losses
3. Leakage reactance losses
4. Copper losses

Learning Objective: Identify the operational features of various transformer connections.

3-42. To obtain maximum current output from a single-phase transformer, you should connect the sections of the secondary windings in what configuration?

1. Series-opposing
2. Parallel-opposing
3. Series-adding
4. Parallel-adding

3-43. When a large number of single-phase loads are supplied from a three-phase transformer bank, what is the desirable connection of the transformer secondary?

1. Wye
2. Delta
3. High voltage
4. Low power factor

3-44. What letter is used to identify the secondary winding of a power transformer?

1. H
2. L
3. T
4. X

3-45. Which of the following types of equipment are used to supply 400 hertz power to a transformer?

1. Motor generator units
2. Static converters
3. Both 1 and 2 above
4. Steam turbines

3-46. What are the two principal types of transformer construction?

1. Shell and pancake
2. Polyphase and single phase
3. Core and shell
4. Power and current

3-47. By what means are hysteresis losses kept to a minimum in transformers?

1. By using grain-oriented, silicon steel laminations in the core
2. By insulating adjacent lamination sections
3. By regulating the temperature of the transformer
4. By using pancake coils instead of round wire in the secondary

3-48. If a transformer is wound with 100 turns on the primary, 150 turns on the secondary, and has a secondary voltage of 600 volts, what voltage is applied to the primary?

1. 600 V
2. 400 V
3. 250 V
4. 200 V

Learning Objective: Recognize the various principles and procedures used to rig or unrig casualty power.

3-49. What is the main purpose of the casualty power system?

1. To make temporary connections to vital circuits
2. To make permanent connections to vital equipment
3. To make permanent connections to vital circuits
4. To make temporary connections to furnish power to ac generators

3-50. Casualty power bulkhead terminals are permanently installed on opposite sides of the bulkhead for what reason?

1. To provide casualty power to selected equipment
2. To transmit power through compartments without loss of watertight integrity
3. To transmit power through decks without loss of watertight integrity
4. To provide a means of making proper phase polarity checks

3-51. When a generator is used exclusively for casualty power purposes, you must perform which of the following actions?

1. Open the generator circuit breaker
2. Open the generator disconnect links
3. Strip the switchboard that the generator is feeding
4. Transfer all bus transfer switches to emergency power

3-52. A portable cable used to rig ac casualty power systems can carry (a) what maximum current for (b) what maximum number of hours?

1. (a) 92 A (b) 4
2. (a) 92 A (b) 40
3. (a) 200 A (b) 40
4. (a) 200 A (b) 4

3-53. When unrigging casualty power, what procedure should you follow?

1. Remove both ends of the first cable at the power source, remove both ends of the last cable at the load, and then unrig the remaining cables
2. Remove both ends of the last cable at the load, and then proceed step-by-step to the power source
3. Unrig the cable between the power source and the load, and then proceed to the power source and load
4. Remove both ends of the first cable at the power source, and then proceed step-by-step to the load

3-54. Shore power connections aboard ship may be used to supply power to another ship alongside.

1. True
2. False

3-55. It is hazardous for a shore power installation to have one circuit breaker supplying more than one power cable for what reason?

1. A fire hazard is created when more than one cable is energized
2. Phase rotation and orientation can't be verified without energizing all the cables at once
3. The cable may short circuit
4. A requirement for handling live cables will exist when unrigging shore power

3-56. When testing shore power cables, what should be used as the shore ground resistance?

1. The ship's hull
2. A 16 AWG or larger wire with one side dropped over the side of the ship
3. The enclosure that houses the shore power terminals or receptacles
4. Phase A of the shore power cable

3-57. The casualty power system provides a good means of testing repaired equipment without jeopardizing the normal electrical distribution system.

1. True
2. False

3-58. What person is authorized to order the energization of the casualty power system?

1. The damage control assistant
2. The electrical officer
3. The E division officer
4. The E division LCPO

3-59. What is the (a) normal current carrying capacity of portable casualty power cables and (b) the casualty current-carrying capacity?

1. (a) 200 A (b) 93 A
2. (a) 93 A (b) 93 A
3. (a) 200 A (b) 200 A
4. (a) 93 A (b) 200 A

3-60. An exercise in rigging casualty power is not considered completed until damage control central receives the report stating that what action(s) have been completed?

1. The equipment is operating on normal power only
2. All portable cables have been restored only
3. The equipment is operating on normal power and all portable cables have been restored
4. Cables have been restored and PMS has been accomplished

3-61. To what publication should you refer for the insulation resistance requirements for shore power cables?

1. OPNAVINST 4790.4
2. OPNAVINST 5100.19
3. NSTM, chapter 300
4. EIMB

3-62. When using spliced cables, what action should you take?

1. Measure the cables to make sure they aren't too short
2. Use spliced cables only in low-voltage systems
3. Remove all spliced connections from shore power cables
4. Make sure the phases are continuous and have not been altered at the splice

3-63. What is the key component of the phase-sequence indicator?

1. The three-phase induction motor
2. The saturable reactor
3. The three-phase Rectox unit in parallel with a fill-wave rectifier
4. The digital display

3-64. When, if ever, is it permissible to move energized shore power cables?

1. When the ship is being inspected by an admiral and the cable must be arranged neatly
2. While fighting a fire on the pier
3. While troubleshooting the source of smoke coming from the cables
4. Never

3-65. In the formula Eg = $\mathbf{K\theta N}$, what does the K represent?

1. The strength of the magnetic field
2. The synchronous speed of the magnetic field
3. The generated voltage
4. The constant determined by the construction

3-66. By what means is the terminal voltage of an ac generator varied?

1. By varying the dc excitation to the field winding
2. By altering the power factor of the machine
3. By adding or removing the number of active coils in the field
4. By varying the resistance of the field winding

3-67. What is the cause of the terminal voltage of an ac generator dropping?

1. An IR drop only
2. An increased load only
3. An IR drop and increased load
4. Increased dc excitation to the field

3-68. In a generator, what causes the armature reaction to be much larger than the armature resistance?

1. The large resistance of the coils compared to the small inductance
2. The large inductance of the coils compared to the small resistance
3. The higher temperature of the rotor windings compared with the stator windings
4. The induction load on the governor

3-69. Which of the following conditions causes the efficiency of a power transformer to be less than 100%?

1. The size of the resistive load on the secondary
2. The copper losses in the windings and the hysteresis and eddy current losses in the core
3. The IR drop in the windings and voltage crossover from the primary to the secondary windings
4. Loose connections at the primary

ASSIGNMENT 4

Textbook Assignment: “Shipboard Lighting,” chapter 4, pages 4-1 through 4-41.

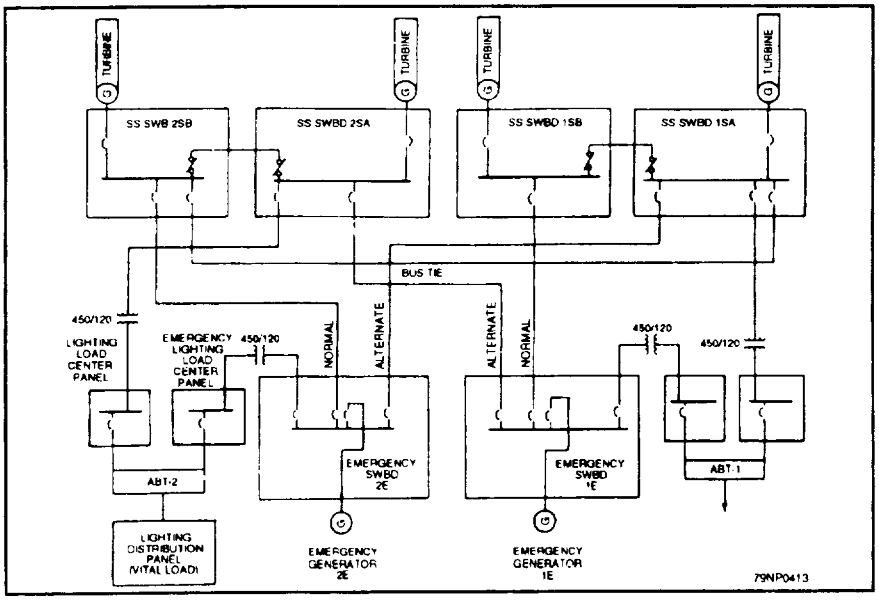


Figure 4A.

IN ANSWERING QUESTIONS 4-1 AND 4-2, REFER TO FIGURE 4A.

Learning Objective: Identify the fundamentals of a shipboard lighting distribution system.

4-1. What are the two sources of power to ABT-2?

1. Emergency switchboards 2E and 1E
2. Ship’s service switchboard 2E and 1E
3. Ship’s service switchboard 2SA and ship service switchboard 2SB
4. Emergency switchboard 2E and ship’s service switchboard 2SA

4-2. What, if anything, prevents both the alternate and the normal power source breakers of the emergency switchboard from being closed at the same time?

1. Vigilant watch standing
2. The circuit breakers are electrically and mechanically interlocked
3. The frequency and voltage monitoring system
4. Nothing

4-3. A vital lighting load receives its power from what total number of sources?

1. One
2. Two
3. Three
4. Four

4-4. It is preferable to connect lighting transformer banks in a delta-delta configuration for what reason?

1. If one of the transformers is damaged or fails, the remaining two transformers will carry about 58% of the initial load capacity
2. It’s more economical to operate them in this configuration than in a series configuration
3. If connections overheat, there is less chance of fire occurring
4. It allows less wiring to be used, saving weight

Learning Objective: Identify various shipboard lighting sources and lamps and recognize their use.

4-5. In incandescent lamps above 50 watts, the inert gas allows the lamp to operate in which of the following ways?

1. Lower efficiency and lower temperature
2. Lower temperature, which causes higher efficiency
3. Higher temperature, which causes lower efficiency
4. Higher temperature and efficiency

4-6. Lamps rated at (a) what approximate power are of the vacuum type because inert gas would have (b) what effect on their luminous output?

1. (a) 50 (b) decrease
2. (a) 60 (b) decrease
3. (a) 50 (b) increase
4. (a) 60 (b) increase

4-7. If you operate a lamp with what (a) respect to its rated voltage, the operation will have (b) what effect on the life of the lamp?

1. (a) Higher (b) unchanged
2. (a) Higher (b) decreased
3. (a) Lower (b) decreased
4. (a) Lower (b) unchanged

4-8. Which of the following is a type of bulb finish available through the Navy supply system?

1. Inside frosted
2. Silvered bowl
3. Clear
4. Each of the above

4-9. Medium-base lamps are commonly used for what type of illumination?

1. For direct 1,000-watt flood lamps
2. For indirect lighting on lamps rated between 300 and 500 watts
3. For general lighting on lamps rated at 300 watts or less
4. For detail lighting on three-way lamps

4-10. What type of base is used for incandescent lamps rated above 300 watts?

1. Mogul
2. Medium
3. Candelabra
4. Intermediate

4-11. When you operate a lamp at a higher than rated voltage, what is the effect on the life of the lamp?

1. It is increased
2. It is decreased
3. It depends on the type of lamp
4. It remains unchanged

4-12. In what way do fluorescent lamps produce light?

1. Current causes the electrodes at each end to glow
2. Heat from the vaporized mercury causes the phosphor coating to give off light
3. Invisible, short-wave radiation is produced by the discharge through the mercury vapor
4. The inductive kick of the ballast causes the electrodes at each end to glow

4-13. You are looking at a lamp symbol and see a black dot inside the symbol. What does this symbol tell you about the lamp?

1. It is gas filled
2. It is vacuum sealed
3. The type of phosphorescence used in the lamp
4. The type of electrode in the lamp

4-14. You have closed the circuit switch to a fluorescent lamp. When does the current start to flow between the lamp's electrodes?

1. Immediately
2. When the glow lamp bimetal strip touches the fixed electrode
3. As soon as the bimetal strip is heated by the glow lamp
4. After the starting circuit opens

4-15. Which of the following is the reason for fluorescent lamps ignition?

1. The voltage developed by the collapse of the ballast magnetic field when the start circuit opens causes an arc across the electrodes
2. The heat of the glow lamp causes the starter to short circuit the start circuit
3. The voltage developed in the ballast causes the starter to open and produce an arc at the electrodes
4. The conduction of the mercury vapor in the lamp short circuits the ballast

4-16. You can operate a fluorescent lamp rated at 120 volts at which of the following voltages without seriously affecting the operation or life of the lamp?

1. 95 V
2. 105 V
3. 130 V
4. 150 V

4-17. What means should you use to minimize the stroboscopic effect of fluorescent lamps that arc operating on three-phase ac circuits?

1. Reduce the number of lamps in the circuit
2. Operate the lamps in different circuits on different phases
3. Increase the number of lamps in the circuit
4. Combine two or three lamps in a fixture and operate them on different phases

4-18. You can tell if a fluorescent lamp is defective by which of the following indications?

1. Worn electrodes
2. Blackened ends
3. It is too bright
4. It is noisy

4-19. The color of the light produced by a glow lamp is determined by the

1. inert gas used in the lamp
2. voltage used to operate the lamp
3. type of electrode used
4. size of the limiting resistor

4-20. If a glow lamp is operated on alternating current, when, if ever, is light produced?

1. During a portion of the negative half cycle
2. During a portion of the positive half cycle
3. During a portion of each half cycle
4. Never

4-21. You need to determine whether a 120-volt lighting fixture is energized by ac or dc. What means should you use to make this determination?

1. A TV lamp
2. A glow lamp
3. A fluorescent lamp
4. An incandescent lamp

4-22. The starting gas used in low-pressure sodium lamps includes which of the following gases?

1. Argon
2. Neon
3. Xenon
4. All of the above

4-23. What color light is produced by low-pressure sodium lamps?

1. Iridescent blue
2. Diffusible green
3. Monochromatic yellow
4. Magenta red

4-24. The low-pressure sodium lamp requires what amount of time to reach full brilliancy?

1. 1 to 5 minutes
2. 7 to 15 minutes
3. 15 to 30 seconds
4. 30 to 60 seconds

4-25. What type of mechanism, if any, is used to dim the light output of a low-pressure sodium lamp?

1. A 0- to 1,000-ohm rheostat is placed in series with the lamp
2. A 0- to 1,000-ohm rheostat is placed in parallel with the lamp
3. The supply voltage to the lamp is adjusted
4. None; the light cannot be dimmed

4-26. You should not allow a low-pressure sodium lamp's internals to come in contact with air for what reason?

1. The phosphor coating of the lamp will oxidize
2. Moisture in the air may combine with the sodium in the lamp to produce heat and hydrogen
3. Ethane gas is produced by mixing the salt-laden air with-the neon gas inside the lamp
4. Phosgene gas is produced if the element is energized in air

4-27. Low-pressure sodium lamps should be stored in which of the following ways?

1. In their original wrapper
2. Horizontally
3. In spaces with sprinkler systems
4. All of the above

4-28. You are disposing of a low-pressure sodium lamp over the side of the ship. Which of the following protective equipment must you wear?

1. Eye protection
2. Protective clothing
3. A face shield
4. All of the above

4-29. Lighting fixtures are designated according to which of the following design features?

1. Size
2. Color
3. Type of enclosure
4. Illumination

4-30. The number and type of regular permanent lighting fixtures installed in a compartment for general illumination is determined by which of the following factors?

1. Current
2. Voltage
3. Both 1 and 2 above
4. Light intensity

4-31. What is the purpose of the phosphor coating in fluorescent lamps?

1. To cause the electrodes at each end to glow
2. To cause the heat from the vaporized mercury to make the phosphor coating give off light
3. To produce invisible, short-wave radiation by the discharge through the mercury vapor
4. To absorb the invisible short-wave radiant energy produced by the lamp and reradiate it over a band of wavelengths visible to the eye

4-32. What undesirable effect results when fluorescent lamps are operated on ac circuits?

1. A capacitive load on the electrical distribution system
2. A flicker that may cause a stroboscopic effect on rotating machinery
3. Excessive heat
4. Excessive current is drawn from the line while starting the lamps

4-33. In time of war, all topside light must be filtered to become red in color.

1. True
2. False

4-34. You should use a few drops of ammonia in the rinse water when cleaning light fixtures for what reason?

1. To sterilize the fixture
2. To remove the soap film
3. To kill insects that may enter the fixture
4. To remove oily fingerprints

Learning Objective: Recognize the principles of operation and identify maintenance performed on navigational lights.

A. 50-WATT, TWO-FILAMENT B. 100-WATT, TWO-FILAMENT C. 15-WATT, ONE-FILAMENT D. 50-WATT, ONE-FILAMENT

Figure 4B.

IN ANSWERING QUESTIONS 4-35 THROUGH 4-39, REFER TO FIGURE 4B AND SELECT THE LAMP SIZE FROM THE FIGURE THAT MUST BE REPLACED IN THE FIXTURE OF THE NAVIGATIONAL LIGHT USED AS THE QUESTION.

4-35. Mast head lights.

1. A
2. B
3. C
4. D

4-36. Port and starboard side lights.

1. A
2. B
3. C
4. D

4-37. White stem light.

1. A
2. B
3. C
4. D

4-38. Man overboard light.

1. A
2. B
3. C
4. D

4-39. Forward and after anchor light.

1. A
2. B
3. C
4. D

4-40. If a ship has the upper and lower red task lights burning steadily, what condition is indicated?

1. Launching aircraft
2. Not under command
3. Man overboard
4. Minesweeping

4-41. When are navigation lights tested at sea?

1. Every Friday, at 0700
2. Every 2 hours during the afternoon
3. Every day, about 1 hour before sunset
4. Once a month, according to PMS requirements

4-42. The Grimes light is used for which of the following ship's functions?

1. Station marking
2. ASW operation signaling
3. Identifying stores
4. Indicating a disabled ship

4-43. What is the purpose of station marking lights?

1. To identify the stores that are to be sent to a replenishment station
2. To identify ships involved in ASW operations
3. To help ships maintain their stations in a convoy
4. To identify lines of departure for amphibious operations

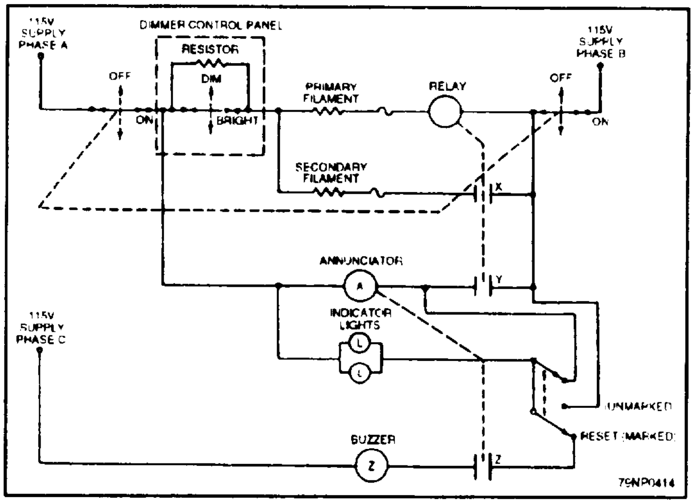


Figure 4C.

IN ANSWERING QUESTIONS 4-44 AND 4-45, REFER TO THE RUNNING LIGHT CONTROL SCHEMATIC DIAGRAM SHOWN IN FIGURE 4C.

4-44. When the relay of the running light is deenergized because the primary filament failed, the relay functions and performs which of the following actions?

1. Sounds the buzzer and moves an annunciator target to read out
2. Energizes the indicator light
3. Transfers power to the secondary filament of the affected light
4. All of the above

4-45. While repairing the affected running light, you can silence the buzzer by what means?

1. Close contacts X and Y
2. Close contacts Y and Z
3. Place the reset switch in the horizontal position
4. Place the reset switch in the vertical position

4-46. What color are the hull contour signal lights?

1. Red
2. Yellow
3. White
4. Blue

Learning Objective: Recognize construction features of searchlights and identify procedures for testing, inspecting, cleaning, lubricating, and repairing them.

4-47. What is the usual location of operating keys for blinker lights?

1. On the signal bridge
2. In radio central
3. In the pilothouse
4. On the mast

4-48. Searchlights are classified by which of the following means?

1. Their shape and power source
2. Their shape and reflector size
3. Their light source arid the size of the reflector
4. Their light source and their voltage

4-49. What is the operating voltage of a transformer-equipped, 8-inch, scaled-beam searchlight?

1. 12 V
2. 28 V
3. 60 V
4. 115 V

4-50. What device holds together the backshell housing and shutter of an 8-inch, sealed-beam searchlight?

1. The springs
2. A swivel-mounted yoke
3. The rail clamp
4. A quick-release clamp ring

4-51. What device is installed to align the backshell housing of the 8-inch, scaled-beam searchlight?

1. A yoke
2. A swivel
3. A clamp ring
4. A hook and key

4-52. Which of the following is the primary use of the 12-inch incandescent searchlight?

1. Signaling
2. Illumination
3. Searching
4. Identification

4-53. To increase the light intensity and range of a 12-inch searchlight, a small amount of what element is added to the lamp by the manufacturer?

1. Neon
2. Mercury
3. Argon
4. Xenon

4-54. The safety switch of the 12-inch, mercury-xenon searchlight has what total number of contacts?

1. One
2. Two
3. Three
4. Four

4-55. When the mercury-xenon arc searchlight is turned on, what amount of voltage is supplied to the spark gap?

1. 25 V
2. 65 V
3. 25,000 V
4. 50,000 V

4-56. The mercury-xenon arc lamp starting current is limited by what component?

1. The RF coil
2. The feed through capacitor
3. The five parallel-connected resistors
4. The five series-connected resistors

4-57. What material should you use to clean the reflector of a searchlight?

1. Standard Navy brightwork polish
2. Inhibited methyl chloroform
3. Hot water with a few drops of ammonia
4. Dry cleaning solvent P-D-680

Learning Objective: Recognize the fundamentals of shipboard-diversified lighting equipment.

4-58. The use of light traps to prevent a light from being shown topside is preferred over door switches when which of the following situations exists?

1. The possibility exists of exposing light from hatches on deck above the compartment
2. The activities in the compartment must be carried on uninterrupted by a lack of light
3. The flow of traffic through the compartment is heavy
4. Each of the above

4-59. When door switches are connected in series or in parallel, in what location are lock-in devices installed?

1. On the outer door only in both series and parallel door switch circuits
2. Anywhere in the circuit in both series and parallel door switch circuits
3. Any accessible location in a series door switch circuit and on the outer door in a parallel door switch circuit
4. Any accessible location in a parallel door switch circuit and on the outer door in a series door switch circuit

4-60. What type of lighting fixtures are provided for illuminating crane and hoist areas?

1. Permanently installed floodlights
2. Portable floodlights
3. Station marker lights
4. Battle lanterns

4-61. The portable, hand-held battle lantern contains what total number of batteries?

1. One
2. Two
3. Three
4. Four

4-62. The portable hand-held, sealed-beam lamp is rated at what voltage?

1. 6 V
2. 5 V
3. 3 V
4. 4 V

4-63. The relay-operated lantern should be installed in what position?

1. With the relay upright
2. With the relay at either side
3. With the relay at the bottom
4. With the relay in any position

4-64. Relay-operated lanterns are required to be installed in all EXCEPT which of the following spaces?

1. Freezer boxes
2. Watch stations
3. Machinery compartments
4. Battle dressing stations

4-65. A compartment aboard ship is furnished electrical power from the 220-volt power circuit, the 117-volt ship's service lighting system, the 117-volt emergency lighting system, and the 117-volt power circuit. What circuit should furnish power for the relay-operated hand lantern?

1. The 220-volt power circuit
2. The 117-volt power circuit
3. The 117-volt emergency lighting system
4. The 117-volt ship's service system

4-66. The portable flood lantern has what total number of viewing windows?

1. Eight
2. Two
3. Six
4. Four

4-67. While checking the condition of the battery of a portable flood lantern, you discover that only the red and white balls are floating at the surface of the electrolyte. What amount of charge does the battery have?

1. 10%
2. Between 50 and 90%
3. 95%
4. 100%

4-68. For what specified period of time can portable flood lanterns be operated before the batteries must be recharged?

1. 1 hour
2. 7 hours
3. 3 hours
4. 5 hours

ASSIGNMENT 5

Textbook Assignment: "Electrical Auxiliaries," chapter 5, pages 5-1 through 5-73.

Learning Objective: Recognize the principles of operation and identify safe working practices for storage batteries, battery chargers, and small craft electrical systems.

5-1. The specific gravity of battery electrolyte is the ratio of what electrolyte components?

1. The weight of a specific volume of water to the weight of the same volume of acid
2. The weight of a specific volume of acid to the weight of the same volume of water
3. The weight of acid to the temperature of water
4. The temperature of water to the temperature of acid

5-2. On a small boat, what is the adjusted specific gravity of a fully charged battery?

1. 1.000 to 1.830
2. 1.150 to 1.460
3. 1.210 to 1.220
4. 1.400 to 1.600

5-3. What is the corrected specific gravity reading for a battery whose electrolyte temperature is 89°F and has an uncorrected reading of 1.212?

1. 1.200
2. 1.210
3. 1.215
4. 1.220

5-4. What is the corrected specific gravity reading for a battery whose electrolyte temperature is 74°F and has an uncorrected reading of 1.220?

1. 1.218
2. 1.216
3. 1.214
4. 1.212

5-5. What method should you use to mix electrolyte?

1. Heat the water before pouring it into the acid
2. Always pour water into the acid
3. Use only aluminum or zinc containers
4. Always pour acid into the water

5-6. If you want to know the rating of a lead-acid storage battery, you would normally use what hourly discharge rate?

1. 25-hour rate
2. 20-hour rate
3. 10-hour rate
4. 6-hour rate

5-7. An equalizing charge on a battery is continued for 4 hours until which of the following conditions is met?

1. The terminal voltage shows no change
2. The charging current shows no change
3. The specific gravity of all cells shows no change
4. The temperature of all cells exceeds 125°F

5-8. Which of the following battery conditions may be caused by a high charging rate?

1. Excessive gassing
2. Sulfated plates
3. Inverse electrolysis
4. Reverse polarization

5-9. You have spilled battery acid on your arm. What is the first step you should take?

1. Sprinkle baking soda on the area
2. Cover the area with boric acid powder
3. Wash the area thoroughly with fresh water
4. Spread a thin coating of petroleum jelly over the area

IN ANSWERING QUESTIONS 5-10 AND 5-11, REFER TO FIGURE 5-4 IN YOUR TEXTBOOK.

5-10. The output of the battery charger is determined by what component(s)?

1. Switch S2
2. Switch S3
3. The SCRs
4. Resistor R4

5-11. What component compensates for temperature changes?

1. Resistor R4
2. Resistor R5
3. Zener diode CR13
4. Control coil L1

5-12. What action should you take to prevent a small boat motor from overheating?

1. Operate the starting motor for 30-second periods at 2-minute intervals
2. Operate the starting motor for a maximum of 2-minute periods at 30-second intervals
3. Continue the operation of the starting motor after the drive pinion engages the flywheel
4. Intermittently operate the starting motor for about 2 minutes, and, if the engine fails to start, allow the motor to cool before trying again

5-13. What is the ratio of the speed of the starting motor to that of the engine?

1. 150 to 1
2. 15 to 1
3. 2 to 1
4. 1 to 1

5-14. On a starting motor, what causes the pull-in coil to de-energize once the solenoid switch is closed?

1. The solenoid plunger opens the coil contacts
2. The holding coil closes auxiliary contacts in the start circuit
3. The start motor terminals are opened, shorting the pull-in coil
4. The pull-in coil is shorted by the plunger disk closing the start contacts

Learning Objective: Identify the way ship's air compressor and air-conditioning and refrigeration systems operate.

5-15. The low pressure air compressor has what total number of modes of operation?

1. One auto and two manual (low and high)
2. Two auto (low and high) and one manual
3. One manual and three auto (low, medium, and high)
4. Two manual (low and high) and two auto (low and high)

5-16. On an air compressor, what condition is indicated by the enable running light?

1. Power is available to the compressor
2. The compressor is in the automatic mode
3. The dew point is at a safe level
4. The compressor is in an operative condition

5-17. What compressor component operates to allow the flow of the injection water?

1. Servo valve SV1
2. Timing relay 6TR
3. Control relay 1CR
4. Pressure switch PS1

5-18. When operating in the automatic 125 setting, the compressor is set to (a) start and (b) stop at what pressure?

1. (a) 105 psig rising (b) 120 falling
2. (a) 110 psig rising (b) 125 psig falling
3. (a) 105 psig falling (b) 120 psig rising
4. (a) 110 psig falling (b) 125 psig rising

5-19. What compressor component operates to drain the dehydrator condensate sump?

1. Solenoid valve SV7
2. Timing relay 3TR
3. Selector switch 1SEL
4. Control relay 16CR

5-20. What component acts to delay compressor shutdown for 10 minutes once a discharge pressure of 125 psig is reached?

1. Pressure switch PS1
2. Timing relay 1TR
3. Selector switch 1SEL
4. Undervoltage relay UV

5-21. Freeze storerooms and chill storerooms are maintained at what temperature, respectively?

1. 32°F and 40°F
2. 0°C and 33°C
3. 33°F and 0°F
4. 0°F and 33°F

5-22. What is the purpose of the elapsed time meter?

1. To keep track of the time a compressor is operated
2. To operate timed contacts at precise set points
3. To prevent equipment from being overused between overhauls
4. To allow operators to set the equipment to start and stop automatically

5-23. On a refrigeration system, timing relays provide what safety feature?

1. Prevent overloading the refrigeration compressor
2. Secure the refrigeration after 10 seconds if no oil pressure develops
3. Prevent the unit from operating if there is no water
4. Secure the controller if there is a loss of voltage

5-24. The oil pressure safety switch is designed to secure the refrigeration compressor if the oil pressure drops to what minimum value?

1. 24 psi
2. 22 psi
3. 18 psi
4. 12 psi

5-25. What type of controller is used on the air-conditioning system?

1. LVP
2. LVR
3. LVRE
4. LVCR

IN ANSWERING QUESTIONS 5-26 THROUGH 5-29, REFER TO FIGURE 5-10 IN YOUR TEXTBOOK.

5-26. What is the purpose of the heater in the control circuit?

1. To keep the ambient temperature above freezing to prevent sluggish operation of the compressor
2. To keep the oil of the compressor warm
3. To prevent condensation from forming in the compressor motor windings
4. To keep the control circuitry from freezing

5-27. The suction pressure switch SP is set to (a) open and (b) close at what pressure?

1. (a) 5 in.Hg (b) 8 psig
2. (a) 5 in.Hg (b) 5 psig
3. (a) 8 in.Hg (b) 8 psig
4. (a) 8 in.Hg (b) 5 psig

5-28. What voltage is used to operate the components of the control circuit?

1. 440 Vac
2. 120 Vac
3. 110 Vac
4. 28 Vac

5-29. What is the purpose of timing relay TR?

1. It closes after a 10-second time delay to de-energize the compressor if water pressure has not caused water pressure switch W to close its contacts
2. It inserts a 10-second time delay between the time the compressor is energized and suction pressure switch SP becomes active
3. It opens after a 10-second time delay to de-energize the compressor if oil pressure has not caused oil pressure switch OP to close its contacts
4. It prevents short circuiting the compressor motor by inserting a time delay on start up

> Learning Objective: Identify the basic operating procedures for pendulum window wipers, portable welders, ultrasonic cleaners, and electrostatic precipitators.

5-30. What voltage is used to operate the wiper motor?

1. 68 to 115 Vdc
2. 115 Vac
3. 220 Vdc
4. 440 Vac

5-31. What are the three major components of a window wiper?

1. Drive unit, load monitor, and wiper arm
2. Control box, rectifier unit, and drive unit
3. Load monitor, drive unit, and wiper arm
4. Control box, drive unit, and wiper arm

5-32. What feature de-ices the window served by the wiper?

1. Heaters placed on the bulkhead next to the window
2. A wire-wound resistor placed in the control box
3. A 36-watt heating element in the wiper arm
4. The friction of the blades on the window

5-33. The tank of the ultrasonic cleaner has what total number of sections?

1. One
2. Two
3. Three
4. Four

5-34. What principle permits the ultrasonic cleaner to operate with very little loss of strength?

1. The relative incompressibility of all liquids
2. The size of sound waves
3. The temperature of the cleaning medium
4. The frequency of the sound waves

5-35. What principle is the basis for the operation of the vent fog precipitator?

1. The inversion square law
2. Kirchoff's law
3. Ohm's law
4. Electrostatic precipitation

5-36. What safety feature is incorporated into a precipitator to prevent electrical shock to the operator?

1. The primary is fused
2. The surge limiting resistor
3. The secondary is grounded
4. The access cover safety switch

> Learning Objective: Identify the basic operation of the propulsion shaft torsionometer.

5-37. What is the purpose of the shaft torsionometer system?

1. To measure the torque on the propulsion shaft
2. To prevent the shaft from being overstressed
3. To allow precise shaft speeds to be maintained
4. To determine the optimum screw blade angle for maximum efficiency

5-38. By what means are shaft hp readings displayed in remote areas of the ship?

1. Torque
2. Repeaters only
3. Remote displays only
4. Repeaters and remote displays

> Learning Objective: Recognize the basic theory of operation of various pieces of deck equipment, including winches, elevators, UNREP systems, and electric forklifts.

5-39. The magnetic brakes of the electric anchor windlass provide what safety feature?

1. A positive engagement/disengagement of the reduction gears
2. Remote operation of the brake
3. Prevent overspeed
4. Hold the load if power fails

5-40. What is the purpose of the controlled torque coupling?

1. To control the speed of the windlass when dropping anchor
2. To ensure constant torque on the gypsy head
3. To prevent excessive stresses when the anchor is being housed
4. To disconnect the windlass motor from power if there is an overload

5-41. If the power fails when the anchor and chain are being lowered, the electric brake is designed to hold what percentage of the rated load?

1. 250 %
2. 225 %
3. 200 %
4. 150 %

5-42. The capstan is designed to heave (a) what line at (b) what speed?

1. (a) 8-inch (b) 50 feet/minute
2. (a) 6-inch (b) 150 feet/minute
3. (a) 8-inch (b) 150 feet/minute
4. (a) 6-inch (b) 50 feet/minute

5-43. What elevator component slows the elevator once it reaches the desired level?

1. The limit switches insert resistance in the motor circuit
2. The photo sensors engage the brake
3. A cam-operated limit switch switches the motor to a lower speed just before the desired level
4. The reduction gear coupling disengages

> A. LOCATED AT EACH LEVEL SERVED; USED TO STOP THE ELEVATOR IN AN EMERGENCY
> B. STOPS THE ELEVATOR IF IT SHOULD FAIL TO STOP AT THE UPPERMOST LEVEL
> C. STOPS THE MOTOR TO PROTECT IT FROM AN OVERCURRENT CONDITION
> D. PREVENTS ELEVATOR OPERATION IF THE CABLES BECOME LOOSE

Figure 5A.

MATCH THE PROTECTIVE FEATURES IN QUESTIONS 5-44 AND 5-45 WITH THEIR PURPOSE IN FIGURE 5A.

5-44. Motor overloads.

1. A
2. B
3. C
4. D

5-45. Slack cable switch.

1. A
2. B
3. C
4. D

5-46. In electrohydraulic elevators, speed changes are accomplished by what means?

1. Using a variable resistor in the control circuit
2. Varying the stroke of the hydraulic pump
3. Altering the hydraulic oil pressure to the pump
4. Altering the reduction gear coupling ratio

5-47. Elevators are prevented from being operated from more than one location by the installation of what component(s)?

1. Interlocked pushbutton stations
2. Limit switches
3. Emergency-run switches
4. Door mechanical interlocks

5-48. If an elevator platform overtravels in the down direction, which of the following devices helps to prevent damage to the platform and the hull?

1. Spring bumpers
2. Electric brakes
3. Safety clamps
4. All of the above

5-49. The functions performed in electric elevators by limit switches, relays, and contractors are performed in electronically controlled elevators by what component(s)?

1. The sensing heads
2. The cam targets
3. The motor controller
4. The static logic panel

5-50. What advantage, if any, is gained by using a dc motor as the pilot motor?

1. The dc pilot motor operation is economical
2. The dc pilot motor is simple to operate and requires little maintenance
3. The dc pilot motor makes an infinite number of platform speeds available, which range from 3 to 90 feet per minute
4. None

5-51. Which of the following is the purpose of the sensing heads mounted up and down the elevator trunk?

1. To slow and stop the elevator
2. To prevent the elevator from overspeeding
3. To prevent overtravel
4. Each of the above

5-52. What arc the two major units of the UNREP system?

1. Sending and control
2. Control and receiving
3. Control and monitoring
4. Sending and receiving

5-53. What is the purpose of the ram tensioner?

1. To keep the wire rope from tangling on the UNREP winches
2. To prevent the highline winches from paying out too much wire
3. To help the highline winch operator keep the highline tight during UNREP operations
4. To return the empty trolley to the delivery ship

5-54. Which of the following are components of the receiving unit of the receiving ship?

1. A chain hoist, worm gear, arm rotation motor, and king post winches
2. A king post, a receiving head, an elevator, a carriage return unit, and a remote control console
3. A king post, a receiving head, an arm rotation motor, and king post winches
4. An elevator, king post winches, a chain hoist, a remote control unit, and an arms rotation motor

5-55. Which of the following are components of the steer motor power circuit in an electric forklift?

1. The drive motor and its series field
2. An electric motor, hoist and tilt cylinders, and a directional control value
3. The steering motor and contacts of the steer relay coil (S)
4. The lift pump motor and contacts of the pump relay coil (P)

5-56. What is the advantage of using solid-state control circuitry integrated with magnetically operated devices to regulate the speed of the series driven motor in an electric forklift?

1. Enables the generator to handle heavy loads at slow speeds with large battery currents
2. Allows longer battery-powered operation before recharging is needed
3. Prevents damage to the control circuitry from power fluctuations
4. Enables the control circuitry to operate under higher current conditions

5-57. In a forklift, thermal switches serve to protect the drive and steer motor circuits by opening if what minimum motor frame temperature is reached?

1. 225°F
2. 230°F
3. 245°F
4. 250°F

Learning Objective: Identify the purpose and basic operating fundamentals of the ship's steering system and its associated equipment.

5-58. Where is the ship's control console located?

1. The after steering room
2. The auxiliary control room
3. The pilothouse
4. The main engineering space

5-59. The rudders have a maximum working angle of what number of degrees (a) left and (b) right from the middle ship's position?

1. (a) 35 (b) 38
2. (a) 35 (b) 35
3. (a) 38 (b) 38
4. (a) 38 (b) 35

5-60. Which of the following means can be used to control the operation of the steering gear?

1. Hand electric
2. Autopilot
3. Emergency control
4. Each of the above

5-61. What is the most common cause of failure in any hydraulic system?

1. Excessive use
2. Low oil pressure
3. Dirty oil
4. Loss of power

A. PROVIDES RUDDER POSITION INFORMATION TO OPERATORS
B. PROVIDES A MECHANICAL INDICATION OF THE RUDDER COMMAND POSITION
C. PROVIDES A NONVERBAL MEANS OF COMMUNICATING RUDDER COMMANDS FROM THE PILOTHOUSE TO THE STEERING GEAR ROOM
D. PROVIDES THE OPTION OF STEERING FROM EITHER THE PORT OR STBD BRIDGE WING

Figure 5B.

IN ANSWERING QUESTIONS 5-62 THROUGH 5-65, MATCH THE TERM USED AS THE QUESTION WITH ITS DEFINITION SHOWN IN FIGURE 5B.

5-62. Rudder angle display system.

1. A
2. B
3. C
4. D

5-63. Portable steering control unit.

1. A
2. B
3. C
4. D

5-64. Helm wheel angle indicator.

1. A
2. B
3. C
4. D

5-65. Rudder angle order system.

1. A
2. B
3. C
4. D

Learning Objective: Identify the operation and maintenance of electric galley and laundry equipment.

5-66. Which of the following electric galley ranges are currently used?

1. Type A, 36 inches
2. Type B, 20 inches
3. Type C, 30 inches
4. Each of the above

5-67. What is the most common type of convection oven used aboard ship?

1. Type 10
2. M-series
3. Series 60
4. Model 250

5-68. What is the heating range of the electric griddle?

1. 380 to 475°F only
2. 375 to 600°F
3. 350 to 450°F only
4. 200 to 450°F

5-69. What is the most frequent trouble with electric cooking equipment in the galley?

1. Burnt contacts
2. Open thermostats
3. Loose connections
4. Improperly set thermostats

5-70. What is the normal dry weight load capacity of the washer extractor?

1. 35 pounds
2. 53 pounds
3. 60 pounds
4. 100 pounds

5-71. What means is used to operate the brake and clutch assemblies?

1. Ship's service compressed air
2. Hydraulic fluid under pressure
3. Friction of the reduction gears
4. Water pressure from the ship's fresh water system

5-72. When is the automatic injection system used?

1. During MANUAL mode
2. During FORMULA mode
3. During COMMAND mode
4. During an imbalance situation

5-73. The washer extractor should always be loaded to capacity before operating for what reason?

1. To save power
2. Lighter loads place undo wear on the machine
3. To prevent possible damage to items being washed
4. Lighter loads may fail to distribute the clothes properly

ASSIGNMENT 6

Textbook Assignment: "Motor Controllers," chapter 6, pages 6-1 through 6-24.

Learning Objective: Recognize the operating characteristics of protective and operative components of controllers. Identify adjustments that can be made on controllers.

6-1. What are the two general methods of starting motors electromagnetically?

1. Manually and automatically
2. Across-the-line and reduced voltage
3. Across-the-line and manually
4. Accelerating and reduced voltage

6-2. By what means are the contactors of a magnetic controller operated?

1. By electromechanical devices
2. By a remote control master switch
3. By a locally controlled master switch
4. Each of the above

6-3. What type of controller is used to start a 1/4-hp dc motor?

1. A dc across the line motor controller
2. A static variable-speed controller
3. An ac primary resistor
4. An autotransformer

6-4. What type of controller is used to insert resistance in the secondary circuit of a wound rotor motor?

1. An ac secondary resistor
2. A dc secondary resistor
3. An ac primary resistor
4. An autotransformer

6-5. What is the major advantage of the closed transition transformer over the open transition transformer?

1. It's smaller in size; therefore, it's cheaper and lighter
2. The motor can't slip out of phase during the transition phase
3. It has fewer moving parts, making it less susceptible to breakdown
4. It has higher transition current; therefore, it allows the motor to maintain speed during the transition phase

6-6. Which of the following is a disadvantage of an open transition compensator?

1. The motor may slip into phase during transition, causing an overload
2. The resistor dissipates too much heat
3. The wound rotor has a tendency to overspeed
4. The motor may slip out of phase during transition, causing an overload

6-7. By what means is the designation of a magnetic controller shown?

1. Alphabetically, according to the minimum horsepower rating of the connected load
2. Numerically, according to the maximum horsepower rating of the connected load
3. By the amount of current at which the controller is capable of operating safely
4. By the maximum horsepower rating of the connected load

6-8. You are installing a new 450-volt, three-phase motor and controller according to a ship alteration. If the motor is rated at 15 hp, you should use what size controller?

1. 1
2. 2
3. 3
4. 0

6-9. What type of controller enclosure provides the least amount of ventilation to the internal components?

1. Open
2. Spraytight
3. Watertight
4. Submersible

6-10. If a master switch is mounted in the controller, it is classified as what type of switch?

1. Local
2. Remote
3. Momentary
4. Maintaining

6-11. What is the purpose of arcing contacts?

1. To allow auxiliary contacts to cool off
2. To reduce the amount of arcing at the main contacts when opening or closing
3. To prevent arcing in the contactor during opening and closing
4. To energize auxiliary loads when the contactor closes

6-12. What method, if any, should you use to keep arcing contacts clean?

1. Wipe them with inhibited methyl chloroform
2. File them with a very fine file, then wipe them with a clean, soft cloth
3. Clean them with standard Navy brightwork polish
4. None; they are self-cleaning

6-13. By what means do magnetic blowout coils quench the arc across contacts?

1. By increasing the contact separation
2. By providing a magnetic flux that blows out the arc
3. By opposing the current flow
4. By pulling the arc toward the contacts

6-14. When the energized contacts in an ac contactor are opened, what method is used to quench the arc that is created?

1. Blowout coils dissipate the arc
2. An air gap dissipates the arc
3. Shading bands cause the arc to scatter and disappear
4. The inductive reactance of the coil dissipates the arc

6-15. What factor allows ac contactor coils to be smaller than dc coils rated for the same voltage?

1. AC doesn't cause as much current as dc
2. AC coils are constructed of different types of wire
3. DC causes more internal heat to be built up
4. Inductive reactance causes counter-emf to limit current flow in an ac coil

Learning Objective: Recognize the operating fundamentals on an ac motor controller.

6-16. A controller protecting a motor is able to disconnect it from the power supply, keep it disconnected, and then restart it automatically when conditions return to normal. Which of the following forms of protection is the controller providing?

1. Overload
2. Low voltage
3. Low-voltage release
4. Each of the above

6-17. Shunt contractors will handle up to what (a) current at what (b) voltage?

1. (a) 700 A (b) 120 V
2. (a) 600 A (b) 230 V
3. (a) 700 A (b) 230 V
4. (a) 600 A (b) 120 V

6-18. What material is used to construct the arcing contacts of a dc controller?

1. Copper manganese
2. Cadmium with a coating of copper
3. Silver oxide
4. Copper with a heavy coating of cadmium

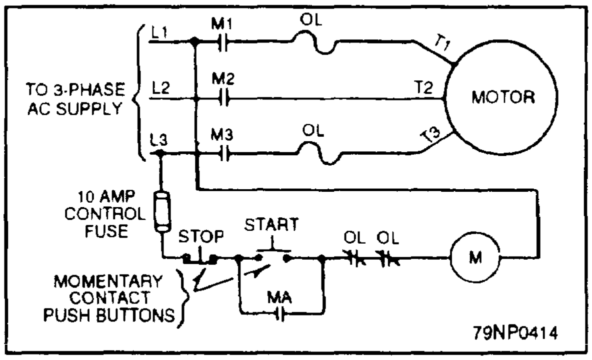


Figure 6A.

IN ANSWERING QUESTIONS 6-19 THROUGH 6-21, REFER TO THE AC CONTROLLER SHOWN IN FIGURE 6A.

6-19. What forms of protection are provided by the magnetic controller?

1. Low-voltage and low-voltage release only
2. Low-voltage and overload only
3. Low-voltage release and overload only
4. Low-voltage release, low-voltage, and overload

6-20. You push the button that starts the motor. After you release the start button, what contact closes to complete a holding circuit for energizing the contactor coil?

1. M1
2. M2
3. M3
4. MA

6-21. To reverse the direction of rotation of the motor, the controller must be capable of performing which of the following functions?

1. Disconnecting L2 from T2
2. Disconnecting L1 from T1 or L3 from T3
3. Connecting L1 to T3 and L3 to T1
4. Closing MA at the same time that M1, M2, and M3 are closed

6-22. What is the major difference between an LVR and an LVRE controller?

1. The LVRE does not use a coil in its circuit to operate the contacts
2. The LVR has no auxiliary contact to maintain the circuit across the start switch
3. The LVRE doesn't use overload contacts in series with the operating coil
4. The LVR doesn't need to be manually reset upon loss of normal line voltage

6-23. What means is used to determine the speed of ac squirrel cage induction motors?

1. The value of voltage supplies
2. The amount of current through the rotor
3. The speed of the rotating magnetic field
4. The resistance of the stator winding

6-24. What means should you use to change the speed of an ac motor through the controller?

1. Change the connections to the motor
2. Change the resistance in the starting circuit
3. Vary the line frequency
4. Step up the supply voltage

6-25. One type of a motor speed controller controls the speed of the ac motor by performing which of the following actions?

1. Increasing and decreasing stator current
2. Switching from one set of stator windings to another
3. Increasing and decreasing the voltage of the power source
4. Shunting different values of resistance across the stator windings

6-26. What means is used to determine the speed of dc motors?

1. The number of poles in the armature
2. The amount of current flowing through the field and armature windings
3. The direction of current flow through the field windings
4. The frequency of the applied voltage

6-27. A reversing type of controller protects a three-phase induction motor against low voltage and overload by causing the motor to stop running due to line voltage failure. After line voltage is restored, what action, if any, should you perform to restart the motor?

1. Press the forward or reverse push buttons
2. Reset the overloads and press the forward and reverse push buttons simultaneously
3. Interchange two of the three leads to the motor
4. None; the motor automatically restarts

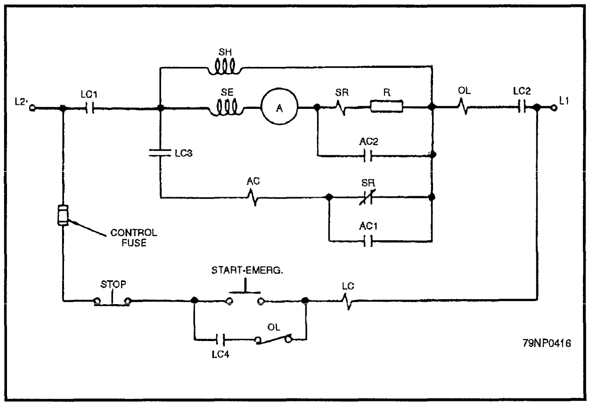


Figure 6B.

IN ANSWERING QUESTIONS 6-28 THROUGH 6-31, REFER TO THE DC CONTROLLER WITH ONE STAGE OF ACCELERATION SHOWN IN FIGURE 6B.

6-28. If the start button is pressed, what action will cause line contacts LC1 and LC2 to close?

1. Closing line contacts LC4
2. Operation of contactor coil LC
3. Operation of overload relay coil OL
4. Current flowing through armature A and contacts LC3

6-29. After closing contacts LC1, LC2, and LC3, the controller accelerates the motor. By what means does the controller connect the motor across the line?

1. By the SR contact completing the circuit to coil AC
2. By contact AC2 shorting out the starting resistor
3. By allowing coil SR to restore, closing the SR contact
4. Each of the above

6-30. After the motor is connected directly across the line, what should you do to interrupt the circuit?

1. Press the stop button
2. Press the start-emergency button
3. Short out the series relay coil
4. Short out the starting resistor

6-31. To vary the speed of the motor, what action should you take to change the controller circuitry?

1. Disconnect SR-relay SR
2. Disconnect the shunt field winding
3. Connect a rheostat in series with the SH winding
4. Connect a rheostat in parallel with the AC coil

6-32. What is the most common method used to reverse the direction of rotation of a dc motor through a controller?

1. Reversing the rotation of the rotating magnetic field
2. Reconnecting the brush leads to place the brushes in series
3. Reversing the connections of the field with respect to the armature
4. Reversing the connection of the armature with respect to the field

6-33. Three-phase autotransformers are used to start three-phase induction motors and synchronous motors because they have the ability to perform what function?

1. Furnish variable voltage
2. Reverse the direction of rotation of the motor rotor
3. Switch motor stator connections from wye to delta
4. Switch motor stator connections from delta to wye

6-34. By tapping an autotransformer, it is possible to obtain a voltage higher than the source voltage.

1. True
2. False

6-35. What is the most common application of logic controllers aboard ship?

1. Fractional horsepower motors
2. Propulsion motor control
3. Elevator control
4. AC governor control system

6-36. Logic devices and controllers have what advantage over standard electrical components?

1. They have a quicker response
2. They don't have any moving parts
3. They consume less power
4. All of the above

6-37. In a magnetic circuit breaker, what circuit is opened by an overload relay?

1. The main contacts
2. The master switch
3. The operating coil of the high-speed contactor
4. The operating coil of the main contactor

6-38. Which of the following is a coarse adjustment to the thermal overload relay?

1. Changing the heater element
2. Changing the magnetic air gap
3. Increasing the distance between the heater and the sensitive unit
4. Decreasing the distance a bimetallic strip has to move to open the circuit

6-39. The tripping current of magnetic overload relays must be set higher than the starting current of the motor they serve.

1. True
2. False

A.	BIMETAL
B.	DASHPOT
C.	INDUCTION
D.	SOLDER POT
E.	SINGLE METAL

Figure 6C.

IN ANSWERING QUESTIONS 6-40 THROUGH 6-42, REFER TO THE TYPES OF OVERLOAD RELAYS SHOWN IN FIGURE 6C.

6-40. Of the relays shown in figure 6C, which one is NOT a type of thermal overload relay?

1. A
2. B
3. C
4. D

6-41. A heat-sensitive element that lengthens when heated to open the contacts is used in what type of thermal overload relay?

1. B
2. C
3. D
4. E

6-42. What type of thermal overload relay is manufactured for exclusive use in ac circuits?

1. A
2. B
3. C
4. D

6-43. In relation to the starting current of the motor they serve, the tripping current of the magnetic overload relay must be set in what way?

1. Higher than the starting current
2. Lower than the starting current
3. The same as the starting current
4. 1/4 the starting current

6-44. In the instantaneous and time-delay magnetic overload relays, you should use what method to adjust the current settings?

1. Replace the heating unit
2. Change the air gap between the tripping armature and the series coil
3. Change the distance between the induction coil and the tube
4. Change the distance between the heater and the heat-sensitive unit

6-45. Which of the following types of overload relays requires a time delay before it is reset?

1. Dashpot
2. Magnetic
3. Solder pot
4. Each of the above

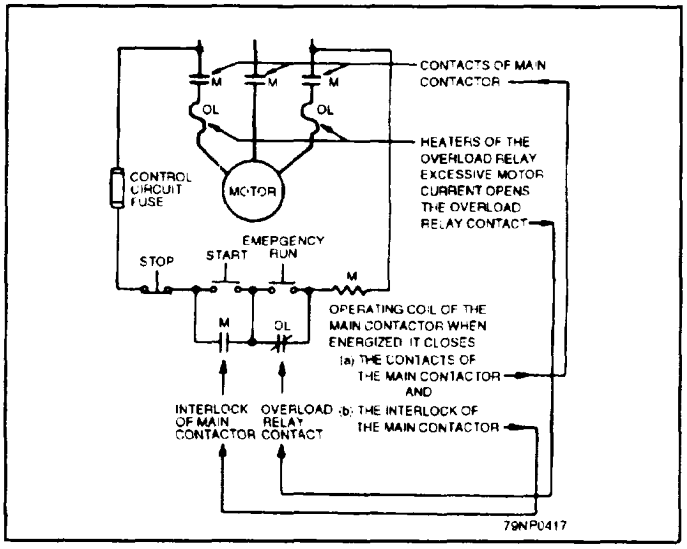


Figure 6D.

IN ANSWERING QUESTIONS 6-46 AND 6-47, REFER TO FIGURE 6D.

6-46. The emergency run switch bypasses or shunts which of the following components?

1. The stop switch
2. The interlock of the main contactor
3. The overload contacts
4. The control circuit fuse

6-47. Short-circuit protection to the motor and controller is provided by which of the following devices?

1. The circuit breaker at the power distribution panels
2. The fuses at the power distribution panels
3. The controller circuit fuses
4. The overload relays

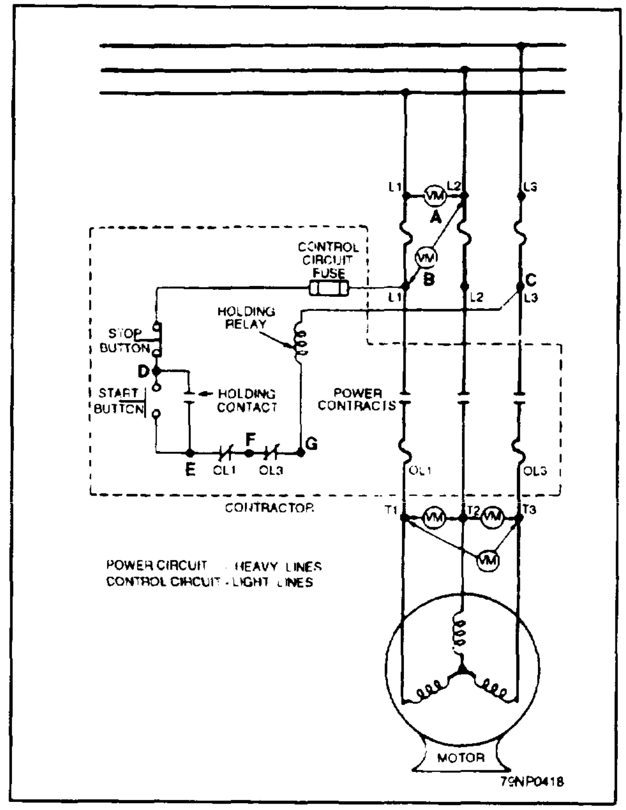


Figure 6E.

IN ANSWERING QUESTIONS 6-48 THROUGH 6-50, REFER TO THE THREE-PHASE MAGNETIC LINE STARTER SHOWN IN FIGURE 6E.

6-48. If a voltage is read at position A and no voltage is present at position B, which of the following statements is true?

1. The voltmeter is defective
2. All fuses are good
3. The L1 fuse is defective
4. The L2 fuse is defective

6-49. After the start button is released, the motor immediately stops. What is the probable cause?

1. The holding relay is open
2. The power contacts on L1 did not close
3. The holding relay contacts MA did not close
4. The OL1 is defective

6-50. With the stop button open and the start button depressed, what voltage will be present between points B and D?

1. 440 V
2. 220 V
3. 110 V
4. 0 V

A.	INSUFFICIENT TIP PRESSURE
B.	BROKEN SHADING COIL
C.	MECHANICALLY DAMAGED
D.	EXCESSIVE JOGGING

Figure 6F.

IN ANSWERING QUESTIONS 6-51 THROUGH 6-53, REFER TO FIGURE 6F, AND SELECT THE DEFINITION FOR THE SYMPTOM USED AS THE QUESTION.

6-51. Overheated contact tips.

1. A
2. B
3. C
4. D

6-52. Short contact life.

1. A
2. B
3. C
4. D

6-53. Coil failure (not overheated).

1. A
2. B
3. C
4. D

ASSIGNMENT 7

Textbook Assignment: "Maintenance and Repair of Rotating Electrical Machinery," chapter 7, pages 7-1 through 7-49.

> Learning Objective: Identify proper cleaning methods for motors and generators.

7-1. The main objectives of shipboard preventative maintenance are to prevent all EXCEPT which of the following situations?

1. Motor controller malfunctions
2. Cable insulation from having a low resistance
3. Generators from being synchronized out of phase
4. Motor bearing failure

7-2. The accumulation of dirt, moisture, and oil in generator and motor ventilation ducts causes local or general overheating for what reason?

1. The resistance to the dissipation of heat is decreased
2. The resistance to the dissipation of heat is increased
3. Moisture and dirt form a nonconducting paste
4. Oil and dirt form a nonconducting paste

7-3. If you need to find the detailed procedures for cleaning electrical machinery, you should refer to what chapter of the NSTM?

1. 090
2. 220
3. 244
4. 300

7-4. You are blowing dust from a 75-KW generator using compressed air. What means should you use to remove the dust-laden air from the generator?

1. A vacuum cleaner
2. Compressed air pressure of less than 30 psi
3. A suction blower placed at the opening opposite the air jet
4. A suction hose placed at the same opening as the air jet

7-5. Which of the following is NOT a cleaning solvent you should use when cleaning electrical equipment?

1. Inhibited methyl chloroform
2. Alcohol
3. Clean fresh water
4. Low-pressure air

> Learning Objective: Identify the types, care of, and insulation methods for motor generator bearings.

7-6. What type of bearing is designed to support loads resulting from forces that are applied perpendicular to the shaft?

1. Thrust
2. Radial
3. Sleeve
4. Angular

7-7. In motor construction, what factor determines whether a thrust or radial bearing is installed?

1. Whether the bearing housing is or is not disassembled to renew bearing grease
2. Whether the drain holes on the bearing housing are accessible
3. Whether the motor is mounted vertically or horizontally
4. Whether the rotor has clockwise or counterclockwise rotation

7-8. In operating machinery, you should suspect malfunctioning ball bearings if which of the following g symptoms occurs?

1. A loss of speed
2. Arcing brushes
3. A high temperature
4. All of the above

7-9. You are starting a motor. You can expect serious bearing problems if high temperatures are reached within what specified amount of operating time?

1. 50 to 60 minutes
2. 30 to 40 minutes
3. 20 to 25 minutes
4. 10 to 15 minutes

7-10. When grease cups for a motor aren't used to grease bearings, where should they be kept?

1. In the custody of the responsible maintenance personnel
2. In the custody of the chief engineer
3. On a wire attached to the motor
4. On a wire attached to a pipe plug

7-11. Of the following motors, which one can you grease without disassembling the bearing housing?

1. A vertically mounted motor
2. A fire pump motor with an accessible drain hole
3. A motor-driven winch without a clutch
4. A fan motor without an accessible drain hole

7-12. In the absence of other instructions, at what specified level should you maintain the oil in an oil-lubricated, ball-bearing motor housing?

1. Level with the center of the bearing
2. Level with the top of the bearing
3. Almost level with the bearing inner ring at the lowest point
4. Almost level with the bearing inner ring at the highest point

7-13. To prevent damage to a bearing that you are pulling, you should place the bearing puller on the shaft and what other assembly?

1. The oiler ring
2. The outer race
3. The inner race
4. The shield

7-14. When cutting a seized bearing from a shaft, you should be careful to cut only 3/4 of the way through the inner ring. What is the reason for this precaution?

1. To prevent loss of bearing internals
2. To prevent damaging the shaft
3. To prevent personal injury from flying parts
4. To prevent overheating the bearing journal

7-15. When bearings are replaced on a shaft, the pressure should be applied to which of the following locations?

1. The bearing inner race
2. The bearing outer race
3. Both 1 and 2 above
4. The bearing oil seal

7-16. You are using the infrared method for mounting a motor bearing. The bearing temperature should NOT exceed which of the following temperatures?

1. 100°F ±10°
2. 150°F ±10°
3. 175°F ±10°
4. 203°F ±10°

7-17. Because of grease deterioration or contamination, which of the following methods of mounting bearings is undesirable?

1. The oven method
2. The hot-oil method
3. The infrared method
4. The arbor-press method

7-18. Which of the following types of bearings are used on large propulsion generators and motors?

1. Rolling
2. Journal
3. Right line
4. Tapered rolling

7-19. The sleeve bearings of a motor overheat. As a watch stander, what action should you take?

1. Stop the motor without securing the load
2. Stop the motor immediately after securing the load
3. Secure the load and let the motor run until the bearing cools
4. Continue to run the motor at the rated load until the bearing cools

A. ANGULAR CONTACT BEARING
B. RADIAL BEARING
C. THRUST BEARING
D. SLEEVE BEARING

Figure 7A.

IN ANSWERING QUESTIONS 7-20 THROUGH 7-23, REFER TO FIGURE 7A.

7-20. What type of bearing is designed to support loads resulting from forces that are applied perpendicular to the shaft?

1. A
2. B
3. C
4. D

7-21. What bearing is used when the load is completely axial?

1. A
2. B
3. C
4. D

7-22. What type of bearing is used in an application where there are radial and thrust loads?

1. A
2. B
3. C
4. D

7-23. What bearing types are examples of antifriction bearings?

1. A and B only
2. A, C, and D only
3. B and C only
4. A, B, and C

Learning Objective: Identify maintenance procedures used for brushes, commutators, and slip rings.

7-24. Which of the following factors determines the grade of brush used in a motor or generator?

1. The time in service
2. The size of the motor or generator
3. The load and speed of the motor or generator
4. All of the above

7-25. At what point should you install new brushes in a generator or motor?

1. When the brushes have enclosed shunts
2. When the brushes have a polished surface
3. When the brushes are worn to within 1/8 inch of the metallic parts
4. When the brushes polarity is reversed

7-26. What method should you use to calculate brush pressure?

1. Subtract the spring pressure from the brush contact area
2. Subtract brush contact area from the spring pressure
3. Divide the brush contact area by the spring pressure
4. Divide the spring pressure by the brush contact area

7-27. When seating a brush, you should use sandpaper and what other equipment?

1. A file
2. A brush seater
3. An oilstone
4. Emery paper

7-28. When seating a brush, you should place the sandpaper between the brush and the commutator with the rough side toward (a) what component and (b) pull in what direction?

1. (a) The brush
   (b) in the direction of rotation
2. (a) The commutator
   (b) opposite the direction of rotation
3. (a) The commutator
   (b) in the direction of rotation
4. (a) The brush
   (b) opposite the direction of rotation

A. USE NO. 0 SANDPAPER
B. USE THE BRUSH SEATER AT THE HEEL OF THE BRUSH
C. USE NO. 1 SANDPAPER
D. VACUUM THE CARBON DUST FROM THE COMMUTATOR
E. VACUUM THE WHITE POWDER FROM THE BRUSH HOLDERS AND WINDINGS

Figure 7B.

IN ANSWERING QUESTION 7-29, REFER TO FIGURE 7B.

7-29. Of the sequences shown below select the proper one for seating brushes.

1. A, C, D, B, and E
2. C, B, A, D, and E
3. A, C, D, E, and B
4. C, A, D, B, and E

7-30. On propulsion and magnetic minesweeping equipment, only one grade of brush is permitted. What means is used to determine the grade?

1. The manufacturer
2. The operating temperature
3. The operating speed
4. The connected load

7-31. If you do not have the applicable technical manual, what tension should be placed on the brushes of integral kilowatt generators?

1. 1 1/2 psi
2. 2 to 2 1/2 psi
3. 3 1/2 to 4 psi
4. 4 1/2 psi

7-32. Brush holders should be no more than what (a) maximum distance nor what (b) minimum distance from the commutator of a motor or generator?

1. (a) 1/8 inch (b) 1/8 inch
2. (a) 1/16 inch (b) 1/8 inch
3. (a) 1/16 inch (b) 1/16 inch
4. (a) 1/8 inch (b) 1/16 inch

7-33. To complete the job of seating the motor brushes, you should perform which of the following steps?

1. Pull a fine strip of sandpaper between the brush and commutators once or twice, vacuum the dust that results, and clean the commutator
2. Turn the sandpaper over, sandpaper again, and touch the seater to the heel of the brush for 1 or 2 seconds
3. Touch the seater to the commutator for 1 or 2 seconds, vacuum the dust that results, and clean the commutator
4. Lift the brush, insert the seater between the brush and commutator for 1 or 2 seconds, and clean the commutator

7-34. You are trying to locate the best position for commutation using the reverse rotation method. Which of the following is the correct procedure for you to follow?

1. Center one coil of the armature over the adjacent pole pieces
2. Use full load, measure the speed, reverse the direction of rotation, and adjust the reversing the rotation and adjusting the brushes until the rated speed is achieved
3. Use a full load, adjust the field strength and terminal voltage, reverse the direction of rotation, and adjust the field strength and terminal voltage again. Keep reversing the rotation and adjusting the field strength until the rated speed and voltage are attained
4. Each of the above

7-35. After 2 weeks of operation, a commutator develops a bluish-colored surface. What is the cause?

1. Impurities in the brush material
2. Oxidation of the commutator bars
3. Normal commutation
4. Improper commutation

7-36. What is the maximum distance an armature commutator may be out of round?

1. 0.002 inch
2. 0.005 inch
3. 0.010 inch
4. 0.015 inch

7-37. Which of the following methods should you use to correct an out-of-round commutator?

1. Grinding
2. Hand sanding
3. Lathe turning
4. Machine stoning

7-38. To true a commutator in place, you should use which of the following methods?

1. Sandpapering
2. Turning on a lathe
3. Grinding on a lathe
4. Hand- or machine-stoning

IN ANSWERING QUESTION 7-39, REFER TO FIGURE 7-20 IN YOUR TEXTBOOK.

7-39. The good undercutting shown is best described by which of the following statements?

1. The mica is cut low and square between the copper segments
2. The mica is cut low and square between the commutator risers
3. The mica and copper segments are cut high and square
4. The mica is cut at a taper between segments

7-40. A commutator is being hand stoned. At what recommended speed should the armature be rotated?

1. At or slightly over the rated speed
2. At or slightly under the rated speed
3. 50% of the rated speed
4. 25% of the rated speed

7-41. You need to season commutators in minimum time. To do this, you should start with 25% of full load operating for (a) what specified number of hours and then increasing the load to operate at (b) what percentage per hour until full load is reached?

1. (a) 4 (b) 15%/3
2. (a) 4 (b) 10%/1
3. (a) 3 (b) 15%/1
4. (a) 3 (b) 10%/3

7-42. When a large rotor is lifted by rope slings, which of the following components should be protected from the slings?

1. The ac rotor
2. The dc armature
3. The bearing journals
4. Each of the above

7-43. In a wound-ac rotor, reduced torque, excessive vibration, sparking at the brushes, and an uneven collector ring are indications of what electrical malfunction?

1. An opened rotor coil
2. An opened field coil
3. A shorted rotor coil
4. A shorted field coil

Learning Objective: Identify test, maintenance, and rewind procedures for motors and generators.

A. TEST FOR CONTINUITY WITH AN OHMMETER
B. TEST FOR MECHANICAL DIFFICULTIES
C. TEST FOR GROUNDS
D. VISUALLY INSPECT THE STATOR

Figure 7C.

IN ANSWERING QUESTION 7-44, REFER TO THE TESTING PROCEDURES SHOWN IN FIGURE 7C.

7-44. Of the sequences shown below, select the one for testing a damaged stator.

1. C, A, B, and D
2. C, D, B, and A
3. B, A, C, and D
4. C, B, A, and D

7-45. When testing a three-phase, wye-connected winding for shorted pole-phase groups, what method should you use?

1. Connect the external leads of all phases to one test lead
2. Apply low-voltage dc between each phase lead and the midpoint of the connected phases
3. Open each connected phase and apply low-voltage dc to an open winding
4. Open each connected phase and apply low-voltage ac to an open winding

7-46. What is the indication for a shorted pole-phase group?

1. A north-seeking compass needle
2. A south-seeking compass needle
3. No deflection of the compass needle
4. A clockwise rotation of the compass needle

7-47. The balanced current test is performed on three-phase ac windings to locate what type of motor malfunction?

1. Open coils
2. Shorted phases
3. Grounded coils
4. Reversed phases

7-48. You are testing a three-phase, delta-connected winding for a shorted phase. What procedure should you follow?

1. Open one delta connection and send low-voltage ac through all phases connected in series
2. Open one delta connection and send low-voltage dc through the other two phases connected in series
3. Open one delta connection and send low-voltage ac through the other phases connected in parallel
4. Open each delta connection and send low-voltage ac through each phase separately

7-49. You are using an ohmmeter to test a three-phase, wye-connected winding for an open circuit. You get a low reading when the ohmmeter leads are on terminals A and B, a high reading when the leads are on B and C, and another high reading when the leads are on A and C. These readings indicate that there is an open in what phase?

1. A
2. B
3. C

7-50. When testing a three-phase, ac, delta-connected winding, you open each of the connected phases and pass low-voltage dc through all phases in series.

1. True
2. False

7-51. Blue sparks that pass around the armature of a running machine indicate an open armature coil. The sparking occurs because, as the segment to which the open coil is attached passes under a brush, the brush is performing which of the following actions?

1. Closing and opening a circuit
2. Burning the coil insulation
3. Shorting out the coil
4. Grounding the coil

7-52. After you have rewound and baked an armature rated at 500 volts, what is the lowest megohm reading allowed? (NOTE: This reading is taken before a high-potential test.)

1. 1.0 megohm
2. 2.0 megohms
3. 200.0 megohms
4. 400.0 megohms

7-53. A pole pitch is best described by which of the following phrases?

1. The span of a coil
2. The width of a coil
3. The distance between the centers of two adjacent poles
4. The distance between the coil connections

7-54. What is meant by the term *progressive lap winding*?

1. The winding is connected to segments two pole pitches apart, and the connections progress in a counterclockwise direction
2. The winding is connected to adjacent segments, and the connections progress in a counterclockwise direction
3. The winding is connected to segments two pole pitches apart, and the connections progress in a clockwise direction
4. The winding is connected to adjacent segments, and the connections progress in a clockwise direction

7-55. What is the purpose of the bar-to-bar test in an armature stripping procedure?

1. To determine the type of winding
2. To identify the commutator pitch
3. To determine the coil throw
4. To identify the coil pitch

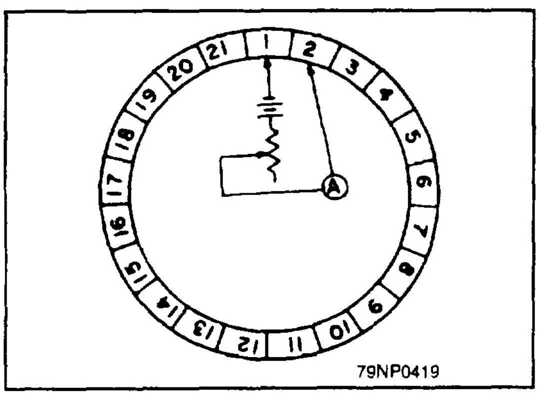


Figure 7D.

IN ANSWERING QUESTIONS 7-56 AND 7-57, REFER TO THE ARMATURE WINDING IDENTIFICATION SHOWN IN FIGURE 7D.

7-56. The milliammeter reading decreases when the probe at segment 2 is moved successively from segments 2 through 11 and then increases from 11 through 21. What type of winding is indicated?

1. Simplex wave
2. Duplex wave
3. Simplex lap
4. Duplex lap

7-57. The milliammeter decreases and then increases two times when the probe at segment 2 is moved successively to each segment around the commutator. What type of winding is indicated?

1. Four-pole wave
2. Four-pole lap
3. Six-pole wave
4. Six-pole lap

7-58. You are testing a commutator using the bar-to-bar method. What equipment should you use?

1. A voltmeter
2. A frequency meter
3. A 6-volt battery and milliammeter
4. A Megger

IN ANSWERING QUESTION 7-59, REFER TO FIGURE 7-44 IN YOUR TEXTBOOK.

7-59. The tool identified as number 5 is used for which of the following functions?

1. To shape coil ends
2. To lift coil leads
3. To remove fiber wedges
4. To undercut the commutator

7-60. What means are used to classify electrical insulating materials?

1. Their thickness
2. The materials they are made from
3. Their size
4. Their temperature indexes

7-61. What is the upper temperature rating of class A insulation that has been immersed in dielectric?

1. 105°C
2. 130°C
3. 155°F
4. 80°F

7-62. To prevent the pocketing of varnish when varnishing a stator, you should rotate the armature during which of the following steps?

1. Wiping
2. Baking
3. Dipping
4. Draining

7-63. What method should you use to conduct an ac high-potential test on a newly rewound armature?

1. Apply the test voltage across the grounded shaft and each of the commutator segments individually
2. Short-circuit the commutator segments with several turns of bare wire and apply the test voltage across the common connection and the grounded armature shaft
3. Disconnect the leads of each of the coils and apply the test voltage across each coil individually
4. Apply the test voltage across the grounded shaft and the bearings of the shaft

7-64. Before assembling the coils in an armature, what type of insulation should you place in the coil slots?

1. Class A
2. Glass tape
3. Polyamide paper
4. Rigid, laminated-type GME-MIL-P-15037

7-65. To prevent centrifugal force from throwing the coils outward, when should you place the banding wire on the armature?

1. Before baking
2. After baking
3. Before prebaking
4. While the coils are hot

7-66. What, if anything, is the difference between shunt and series field coils?

1. Shunt coils are made of a few turns of heavy wire, and series field coils are made of many turns of fine wire
2. Shunt field coils are made of many turns of fine wire, and series field coils are made of fewer turns of heavy wire
3. Shunt field coils are wound clockwise, and series field coils are wound counter-clockwise
4. Nothing; both are identical

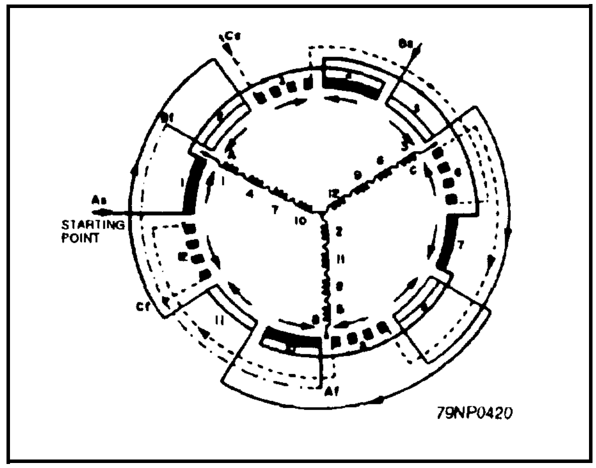


Figure 7E.

IN ANSWERING QUESTION 7-67, REFER TO THE THREE-PHASE, FOUR-POLE, SERIES WYE WINDING SHOWN IN FIGURE 7E.

7-67. In what direction does current flow in group 10 of phase A?

1. In the opposite direction of group 3
2. In the opposite direction of group 4
3. In the same direction as group 1
4. In the same direction as groups 1, 4, and 7

7-68. When you have completed winding a coil, which of the following devices should you use to make a polarity check?

1. A compass
2. An ammeter
3. A voltmeter
4. A megohmmeter

7-69. DC motors are usually reversed by a change in the direction of current flow through the armature for which of the following reasons?

1. The series field is hard to reach
2. The armature leads are longer
3. Only one element is involved
4. All of the above

7-70. What means should you use to reverse the direction of rotation of a three-phase motor?

1. Shift the neutral plane
2. Reverse the shunt field leads
3. Reverse two motor leads only
4. Reverse all three motor leads

7-71. Usually, what is the cause of single-phase motor failure?

1. A loss of line voltage
2. Bearing failure
3. Running winding failure
4. Starting winding failure

IN ANSWERING QUESTION 7-72, REFER TO FIGURE 7-70 IN YOUR TEXTBOOK.

7-72. If the motor is running on 110 volts, and you want to run it on 220 volts, you should connect the windings in what way?

1. Connect the run windings in series
2. Connect the start windings in parallel
3. Connect both the run and start windings in parallel with each other
4. Connect the start and run windings in series with each other

7-73. The running and starting windings are placed in the stator of a single-phase motor in which of the following ways?

1. The starting winding is placed in the bottom of the slots, and the running winding is placed on top of the running winding
2. The running winding is placed in the bottom of the slots, and the starting winding is placed on top of the running winding
3. The running and starting windings are placed in series with one another
4. The running and starting windings are placed in opposite slots within the stator

ASSIGNMENT 8

Textbook Assignment: "Voltage and Frequency Regulation," chapter 8, pages 8-1 through 8-44.

Learning Objective: Recognize the characteristics of type I, II, and III ac power systems.

8-1. Refer to table 8-1 in your textbook. What type of electrical power has the most stringent voltage and frequency requirements?

1. Type I
2. Type II
3. Type III
4. Type IV

8-2. Type III power is normally produced by what means?

1. Ship's service turbine generators
2. Diesel emergency generators
3. Steam-driven dc generators
4. Motor generator sets

8-3. The automatic voltage regulator maintains the generator's output voltage by regulating the dc through what part of the static exciter?

1. The control winding
2. The primary winding
3. The linear conductor
4. The secondary winding

8-4. What factor determines the magnitude of the generated voltage of an ac generator?

1. Resistance of the field windings
2. Strength of the field flux
3. Size of the armature windings
4. Type of prime mover used

8-5. Which of the following methods is normally used to provide voltage control in a dc generator?

1. A rheostat is placed in series with the load
2. The speed of the generator is varied
3. The strength of the generator shunt field is varied
4. All of the above

Learning Objective: Recognize the operating principles of direct-acting voltage regulators and identify the operating procedures of ship's service installations using direct-acting voltage regulators.

8-6. Spare voltage-sensitive control elements are NOT installed for voltage regulators on which of the following equipment?

1. Motor generator sets
2. Ship's service switchboards
3. Emergency switchboards
4. Static frequency changers

8-7. In the direct-acting rheostatic voltage regulator, what part exerts a mechanical force directly on a special type of regulating resistance?

1. Interlocking springs
2. Electric solenoid
3. Regulator coil
4. Leaf springs

8-8. In what configuration, if any, is the voltage regulator connected to the shunt field of the exciter?

1. In series
2. In parallel
3. In series-parallel
4. None

8-9. The silver buttons in a Silverstat voltage regulator are connected to taps on what component(s)?

1. Regulator coil
2. Voltage-adjusting rheostat
3. Regulating resistance plates
4. Range-setting resistors

8-10. The range covered by each voltage-adjusting rheostat of the regulator can be set so the rheostat's midposition is in the normal operating position to obtain the rated generator voltage. What component should you adjust to set the range?

1. The damping transformer
2. Resistors connected in series with the regulator coil
3. The resistance plate connected in series with the rheostat
4. The resistance plate connected in parallel with the rheostat

8-11. In what configuration is the primary of the damping transformer connected in a regulator that controls a large ac generator?

1. Across the output of the exciter
2. In series with the voltage-adjusting rheostat
3. In series with the regulator coil
4. Across the output of the cross-current compensator

8-12. In what way does a direct-acting voltage regulator respond to a decrease in generator load?

1. The regulator armature is pulled toward the regulator coil, more silver buttons are pushed together, and the regulating resistance increases
2. The regulator armature is pulled toward the regulator coil, more silver buttons are spread apart, and the regulating resistance increases
3. The regulator armature is pulled away from the regulator coil, more silver buttons are pushed together, and the regulating resistance decreases
4. The regulator armature is pulled away from the regulator coil, more silver buttons are spread apart, and the regulating resistance decreases

8-13. You are switching a direct-acting voltage regulator system from manual to automatic control. It is necessary for you to leave the control switch in the TEST position momentarily to allow which of the following actions to occur?

1. The exciter field current to stabilize
2. The generator field current to stabilize
3. The damping transformer transient current to die down
4. The silver buttons to readjust

8-14. The moving arm of a direct-acting regulator will behave in what way if the damping transformer connections are reversed?

1. It will swing continuously from one end of its travel to the other
2. It will move very sluggishly in response to a generator voltage change
3. It will be pulled toward the regulator coil and remain in that position
4. It will be pulled away from the regulator coil and remain in that position

Learning Objective: Recognize the operating principles of the rotary amplifier (amplidyne) type of voltage regulator and identify the procedures used to operate ship's service installations with this type of regulator.

8-15. The voltage regulator transfer switch for two generators (A and B) is in the GEN B position. The voltages of the generators are controlled in what way?

1. Both generator A and B are controlled by generator B's regulator
2. Only generator B is regulated, since generator A is out of the circuit
3. Generator A is controlled by the standby regulator, and generator BA is controlled by its own regulator
4. Generator A is controlled by its own regulator, and generator B is controlled by the standby generator

8-16. The stabilizer functions to prevent hunting in the voltage regulator circuit. It does this by what means?

1. It aids any change in the amplidyne control field current
2. It decreases the inductance of the saturated reactor
3. It increases the inductance of the saturated reactor
4. It opposes any change in amplidyne control field current

8-17. When the number of saturated reactor coil turns in the voltage adjusting unit is decreased, the inductance of the saturated reactor reacts in what way?

1. It decreases, and the voltage held by the regulator is lowered
2. It increases, and the voltage held by the regulator is lowered
3. It decreases, and the voltage held by the regulator is raised
4. It increases, and the voltage held by the regulator is raised

8-18. What unit provides the regulator with a signal proportional to the ac generator voltage?

1. The pilot alternator
2. The amplidyne unit
3. The potential unit
4. The stabilizer

IN ANSWERING QUESTION 8-19, REFER TO FIGURE 8-8 IN YOUR TEXTBOOK.

8-19. If the generator voltage is near normal in the automatic control circuit, buck circuit current from F2 to F1 in the amplidyne control field has what magnitude?

1. Nearly equal to the boost circuit current
2. Maximum to overcome the boost circuit current
3. Minimum to enable the boost circuit current to keep the amplidyne control field steady
4. Negligible

8-20. By what means does the automatic control circuit oppose an increase in ac generator voltage?

1. The saturated reactor current increases, causing an increase in the amplidyne control field current
2. The pilot alternator voltage decreases, causing a decrease in the amplidyne control field current
3. The pilot alternator voltage increases, causing an increase in the amplidyne control field current
4. The saturated reactor current decreases, causing a decrease in the amplidyne control field current

8-21. A decrease in generator frequency affects the reactance of the saturated reactor and the frequency compensation circuit in what way?

1. The reactance of the saturated reactor increases, and the frequency compensation network behaves like an inductance
2. The reactance of the saturated reactor increases, and the frequency compensation network behaves like a capacitance
3. The reactance of the saturated reactor decreases, and the frequency compensation network behaves like an inductance
4. The reactance of the saturated reactor decreases, and the frequency compensation network behaves like a capacitance

8-22. At unity power factor, the compensating voltage across the compensating potentiometer rheostat is in phase with what voltage?

1. Voltage across the teaser leg of the T-connected potential transformer secondary
2. Resultant output voltage of the three-phase response network
3. Phase B line-to-neutral voltage
4. Voltage across the resistor-inductor series circuit in the three-phase response network

8-23. Two generators are placed in parallel operation in a rotary voltage regulator system. By what means are the load distribution and power factor adjusted?

1. The manual control handwheels and prime mover governors
2. The manual control handwheels and the voltage-adjusting unit
3. The voltage-adjusting unit and prime mover governors
4. The voltage-adjusting unit and the saturated reactor tap switch

8-24. You should check the amplidynes' short-circuiting brushes periodically for what reason?

1. Improper brush contact may result in an excessively high amplidyne voltage output
2. They tend to arc and spark more than other brushes
3. Heat developed tends to loosen electrical connections
4. Short-circuiting causes them to wear faster, shortening their life

Learning Objective: Recognize the operating principles of the static excitation voltage regulator system and identify the procedures for operating the ship's service installation using this system.

IN ANSWERING QUESTIONS 8-25 THROUGH 8-27, REFER TO FIGURE 8-12 IN YOUR TEXTBOOK.

8-25. Switches S1 and S2 contain a large number of series-connected contacts for what reason?

1. To eliminate arcing when turned to the OFF position
2. To minimize arcing effects when power is removed
3. To provide multiple circuit path connections
4. To prevent the contacts from becoming hot

8-26. The output of the static exciter is controlled by the current through what circuit component(s)?

1. Transformer primaries
2. Transformer secondaries
3. Transformer control windings
4. Output rectifier CR1

8-27. The automatic voltage regulator maintains the generator's output voltage by regulating the dc through what part of the static exciter?

1. The control winding
2. The primary winding
3. The linear inductor
4. The secondary winding

IN ANSWERING QUESTIONS 8-28 THROUGH 8-31, REFER TO FIGURE 8-16 IN YOUR TEXTBOOK.

8-28. The reactance value of L6 in the voltage regular depends on what other value?

1. The average of the line voltages
2. The output of CR
3. The value of the secondary of T5
4. The output of CW1

8-29. Each magnetic amplifier is operated in the center portion of its magnetic core saturation curve by adjusting what components?

1. L7 and R13
2. R11 and R12
3. L6 and L1
4. R14 and R15

8-30. The initial field current for starting the ac generator is provided by which of the following components?

1. The static exciter
2. The output rectifiers
3. A 50 kW, dc generator
4. Each of the above

8-31. The steady state and transient frequency requirements for type II power can be met with electro-hydraulic governors. However, a motor generator or static converter will still be required for what type of voltage control?

1. I
2. V
3. III
4. IV

Learning Objective: Recognize the operating principles of the SPR-400 voltage regulator and identify maintenance requirements.

8-32. The purpose of the SPR-400 line voltage regulator is to ensure precision control of variations in which of the following factors?

1. Line voltage
2. Load changes
3. Power factor
4. All of the above

8-33. If there is a decrease of the dc in the control winding, what is the effect of the (a) voltage of the opposing winding and (b) output of the autotransformer?

1. (a) Decreases (b) decreases
2. (a) Decreases (b) increases
3. (a) Increases (b) decreases
4. (a) Increases (b) increases

8-34. Refer to figure 8-20 in your textbook. The purpose of potentiometer R21 is to compensate for what factor?

1. The resistance in the cables from the regulator to the load
2. The internal resistance of the regulator
3. The resistance of the regulator load
4. The resistance of the input voltage

8-35. You should frequently inspect the SPR-400 line voltage regulator for which of the following possible causes of improper operation?

1. Dust
2. Dirt
3. Moisture
4. All of the above

Learning Objective: Identify the operating fundamentals of the 30 kW motor-generator set.

8-36. What means is used to control the output of the static exciter?

1. A preamp and trigger circuit
2. The output of the power section of the regulator acts on windings within the static exciter
3. An ac error signal is produced by a three-phase bridge rectifier
4. The signal produced by chokes in series with the generator output

8-37. What means are used to control the SCRs in the power circuit?

1. By using an amplified error signal that is developed in the reference bridge and fed through a unijunction transistor circuit
2. By varying the excitation to the Zener diodes
3. By varying the firing time of the main SCR in each inverter
4. By providing a signal proportional to the converter input voltage

8-38. What means is used to provide the no-load field excitation to the motor-generator set?

1. Current flowing through the SCPT primaries
2. The rectified output of the secondary windings of the SCPT
3. The output of the voltage divider network
4. The field-flashing circuit

8-39. Variations in generator output frequency is compensated for the

1. drive motor current being increased or decreased
2. drive motor voltage being increased or decreased
3. resistance being placed in parallel with the stator windings
4. excitation to the stator being increased or decreased

Learning Objective: Identify the operating characteristics of static converters.

8-40. By what means does the voltage act to regulate converter output voltage?

1. By varying the excitation to the Zener diodes
2. By providing a constant voltage to the main SCR in each inverter
3. By controlling the firing time of the main SCR in each inverter
4. By controlling the main SCR with a signal proportional to the converter input voltage

8-41. In mode 1 operation, what drives the ac end of the motor generator?

1. The ship's service power supply
2. The standby batteries
3. The emergency diesel generator
4. The attached turbine

Learning Objective: Recognize the operating fundamentals of the synchronizing monitor.

IN ANSWERING QUESTIONS 8-42 AND 8-43, REFER TO FIGURES 8-26 AND 8-27 OF YOUR TEXTBOOK.

8-42. The K1 relay is energized for which of the following examples of phase angle (θ), voltage difference (ΔV), and frequency difference (ΔF)?

1. θ = -45°, ΔV = 1%, ΔF = 0.1 Hz
2. θ = -22°, ΔV = 3%, ΔF = 0.1 Hz
3. θ = 0°, ΔV = 5%, ΔF = 0.5 Hz
4. θ = + 5°, ΔV = 5%, ΔF = 2.0 Hz

8-43. The synchronizing monitor is connected to a circuit consisting of two generators and the K1 relay is energized. In what way does this configuration affect the parallel operation of the generators?

1. They are automatically paralleled
2. They are not automatically paralleled but may be manually paralleled
3. They may not be paralleled while the K1 relay is energized but are automatically paralleled when it is de-energized
4. They may not be paralleled while the K1 relay is energized but may be manually paralleled when the relay is de-energized

IN ANSWERING QUESTIONS 8-44 THROUGH 8-46, REFER TO FIGURE 8-28 IN YOUR TEXTBOOK.

8-44. The reference bias voltage for Q1 in the synchronizing monitor appears across what component?

1. Capacitor C1
2. Resistor R2
3. Resistor R6
4. Zener diode CR8

8-45. The phase difference circuit turns Q1 off as a result of what action?

1. Reverse bias voltage across CR10
2. Reverse bias voltage across R6
3. Base-to-emitter short caused by the conduction of CR9
4. Base-to-emitter short caused by the conduction of CR10

8-46. The voltage difference circuit turns off as a result of what action?

1. Reverse bias voltage across Q5
2. Reverse bias voltage across R19
3. Base-to-emitter short caused by the conduction of CR18
4. Base-to-emitter short caused by the conduction of Q5

8-47. Refer to figure 8-34 in your textbook. Which of the following components in the frequency difference monitoring circuit are connected so that a beat frequency voltage is produced between the oncoming generator and the bus?

1. Primaries of T2 and T3
2. Secondaries of T2 and T3
3. Secondaries of T2 and CR11
4. Transistors Q3 and Q4

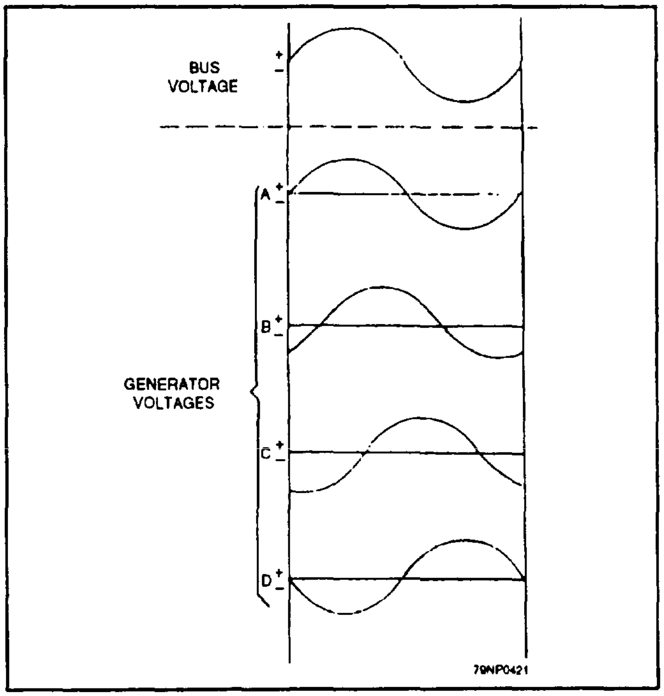


Figure 8A.

IN ANSWERING QUESTION 8-48, REFER TO FIGURE 8A.

8-48. When occurring simultaneously with the indicated bus voltage, what generator voltage will produce the maximum current flow in CR10 in the phase difference monitoring circuit of the synchronizing monitor?

1. A
2. B
3. C
4. D

8-49. Refer to figure 8-35 in your textbook. This figure shows the results of various steps in the generation of a signal that is used to fire SCR1 in the frequency difference monitoring circuit. What is the purpose of the step that produces the waveform shown in diagram E?

1. To produce a beat frequency voltage between the oncoming generator and the bus
2. To rectify and filter the beat frequency voltage
3. To assure that the clipped signal goes to zero when the original beat frequency voltage goes to zero
4. To assure that the clipped beat frequency signal maintains a constant dc level

8-50. A unijunction transistor has 0 volts on base 1 and 12 volts on base 2. If the transistor fires when the base 1-to-emitter voltage reaches 8 volts, the transistor has what *eta* value (intrinsic standoff ratio)?

1. 1 to 3
2. 1 to 2
3. 2 to 3
4. 4 to 3

IN ANSWERING QUESTIONS 8-51 THROUGH 8-53, REFER TO FIGURES 8-34, 8-36, AND 8-37 IN YOUR TEXTBOOK.

- Study Hint: Assume that the difference in frequency between the oncoming generator voltage and the bus voltage is 0.2 Hz.

8-51. What is/are the time constant period(s) for one cycle of the beat frequency voltage?

1. 0.5
2. 2.0
3. 2.5
4. 5.0

8-52. What is the function of the frequency differential circuit?

1. To energize relay K1 through the control of transistor Q2
2. To match the impedance of the static exciter of the generators being paralleled
3. To prevent excessive frequency variations in the generators being monitored
4. To take the monitored generator off line if the frequency output varies by more than 4 Hz

8-53. By which of the following means is Q2 controlled?

1. Simultaneous action of the voltage difference circuit and the frequency difference circuit
2. The frequency difference circuit only
3. The phase difference circuit only
4. Either 1 or 2 above, depending on the voltage difference circuit or the phase difference circuit

IN ANSWERING QUESTIONS 8-54 THROUGH 8-56, REFER TO FIGURE 8-40 IN YOUR TEXTBOOK.

8-54. In the voltage difference monitoring circuit, the K1 relay will not close if the voltage difference in the generators is more than what specified percentage?

1. 5 %
2. 2 %
3. 3 %
4. 4 %

8-55. The difference in the magnitude of the sensing signals from the oncoming generator and the bus is detected in what bridge circuit component?

1. CR15
2. CR16
3. CR17 (points A and B)
4. CR18 (points A and B)

8-56. What is the purpose of R19?

1. To prevent large voltage variations
2. To de-energize relay K1
3. To ensure that Q5 will remain off when relay K1 is de-energized
4. To ensure that Q5 will remain off when K1 is energized

Learning Objective: Identify the techniques used to service transistorized circuits.

8-57. High-power transistors that are noticeably hot while operating have been damaged beyond use.

1. True
2. False

8-58. When using a signal generator as a transistor tester, what is the first connection you should make?

1. Connect the power line to an isolation transformer
2. Connect the chassis of the signal generator to ground
3. Connect the chassis of the signal generator to the chassis of the equipment to be tested
4. Connect the line voltage to the signal generator

8-59. What action should you take to prevent damage to a transistor?

1. Always ground the base of the transistor before conducting any resistance tests
2. Use isolation transformers to protect transistors from test equipment
3. When using an ohmmeter, use only those ranges that pass 2 mA or less
4. Use only signal tracers with a transformerless power supply

8-60. Multimeters that are used for voltage measurements in transistor circuits should have what minimum high ohms/volt sensitivity?

1. 5,000 ohms/volt
2. 10,000 ohms/volt
3. 15,000 ohms/volt
4. 20,000 ohms/volt

8-61. Ohmmeters will damage transistors if the meters have a range that is greater than what maximum amperage?

1. 1.00 mA
2. 0.25 mA
3. 0.50 mA
4. 0.75 mA

ASSIGNMENT 9

Textbook Assignment: "Electrohydraulic Load-Sensing Governors" and "Degaussing," chapters 9 and 10, pages 9-1 through 10-21.

Learning Objective: Recognize various governor controls and operations.

9-1. What is the advantage of using electrohydraulic governors instead of mechanical governors?

1. Electrohydraulic governors are more powerful for a given size
2. Mechanical governors are more expensive to maintain
3. Electrohydraulic governors provide closer frequency regulation
4. Mechanical governors are more prone to misadjustment because of shock

9-2. Which of the following is a disadvantage of obtaining the speed signal of a governor by sensing the output frequency of the generator?

1. A short circuit on the generator could result in a loss of signal
2. The governor responds slower to speed changes
3. Frequent load changes will cause the governor to hunt
4. The governor must be manually controlled when paralleling with another generator

9-3. What means is used to obtain stability in the prime mover?

1. Electrical feedback circuits
2. Speed signals are filtered to remove ripples
3. Backup circuits automatically replace signals lost by open switches
4. Sensitivity adjustments on the governor provide precise speed control

9-4. What does the speed droop do for the operation of a generator?

1. It allows you to parallel generators that have dissimilar governors
2. It prevents overspeeding of the prime mover
3. It slows down the generator when an overload condition exists
4. It prevents you from paralleling generators unless the frequency of both generators is the same

9-5. Which of the following means should be used to give the governor a signal that corresponds to the speed of the equipment under control?

1. The dc signal developed in the reference circuit
2. The output voltage of the generator being controlled
3. A permanent magnet generator or alternator mounted on the shaft of the equipment
4. Both 2 and 3 above

9-6. What means is used to connect the load-measuring circuits of governors on all generators operating in parallel?

1. A bus tie cable
2. An isolation transformer
3. Common ground connections
4. Feedback circuits

9-7. What is the purpose of the load signal box in EG-R governors?

1. To allow the governor to be paralleled with dissimilar generators
2. To prevent the governor from hunting by producing negative feedback signals
3. To detect changes in the load before they appear as speed changes
4. To provide the backup signal to the governor if the speed signal is lost

9-8. What device is used to couple the EG-R hydraulic actuator to the remote servo piston?

1. Electrical cables
2. High-pressure lines
3. A mechanical linkage
4. A buffer piston

9-9. What type of governor system offers the highest work capacity?

1. EG-R
2. EG-4 with a hydraulic actuator
3. EG-3C
4. EGB-2P

9-10. If a negative dc voltage is sent to the actuator from the electronic control box, what will happen to the pilot valve plunger?

1. It will travel in an upward direction
2. It will travel in a downward motion
3. It will maintain its steady state position
4. It will hunt in an upward and downward motion

9-11. If the power piston is forced down, the fuel flow to the prime mover will react in what way?

1. It will decrease
2. It will increase
3. It will stop
4. It will remain the same

9-12. Control oil pressure is approximately (a) what amount of (b) what oil pressure?

1. (a) 1/4 (b) compensation
2. (a) 1/2 (b) residual
3. (a) 1/4 (b) residual
4. (a) 1/2 (b) compensation

A. Acts to produce the temporary negative feedback (in the form of a pressure differential) applied to the compensation land of the pilot valve plunger during speed changes

B. Reacts to the position of the control land to increase or decrease the speed of the prime mover through a linkage to the fuel or steam valve

C. Prevents overtravel of the throttle by reacting to a temporary negative feedback signal in the form of a pressure differential across it during changes in position of the power piston

D. Used to control the rate at which the pilot valve plunger returns to the centered position after a change in load condition on the prime mover

Figure 9A.

IN ANSWERING QUESTIONS 9-13 THROUGH 9-16, REFER TO FIGURE 9A AND SELECT THE DESCRIPTION OF THE COMPONENT OF THE ELECTROHYDRAULIC GOVERNOR USED AS THE QUESTION.

9-13. Compensation land.

1. A
2. B
3. C
4. D

9-14. Buffer system.

1. A
2. B
3. C
4. D

9-15. Needle valve.

1. A
2. B
3. C
4. D

9-16. Power piston.

1. A
2. B
3. C
4. D

9-17. By what means does the EG-R actuator control the position of the prime mover fuel or steam supply?

1. By using the centrifugal force of a ballhead device to cause the pilot valve to move up or down
2. By controlling the flow of oil to and from the upper side of the power piston in the remote servo
3. By developing a signal proportional to the output speed and applying it to the ballhead governor section
4. By controlling the excitation to the external three-phase potential transformers

9-18. With the pilot valve of the EG-R actuator centered, in what direction, if any, is oil directed by the power piston?

1. To the right side of the buffer piston
2. To the bottom of the power piston
3. To the top of the power piston
4. None; no oil flows

9-19. An increase in prime mover speed will cause the EG-R control box to send a signal to complete what action?

1. Slow the oil pump gears
2. Lower the power piston
3. Raise the pilot valve plunger
4. Lower the pilot valve plunger

9-20. The pilot valve plunger of the EG-R actuator is moved by the pressure on top of the compensation land. What component controls the rate at which the plunger moves?

1. The needle valve setting
2. The strength of the buffer piston spring
3. The relief valve spring pressure stations
4. The strength of the signal acting on the armature magnet

9-21. Which of the following is an application of a hydraulic amplifier?

1. Operating a power control mechanism when little force is required
2. Operating a power control mechanism when a relatively large force is required
3. Diesel engines
4. On the output of generators, developing a signal proportional to the frequency

9-22. When used, the three-way valve of the EG-R hydraulic actuator must be turned to drain after starting for what reason?

1. Oil caught in the line would cause false signals in the amplifier
2. Oil would be trapped under the pilot valve plunger, making the amplifier inoperative
3. Sediment from the oil would collect and cause the governor to fail
4. Oil pressure would rise and cause the relief valve to lift

9-23. Which of the following is NOT a use of the EG-M control box?

1. To convert the input from the pMG into a negative speed signal
2. To provide the control signal to the electronic amplifier in ;the load signal control box
3. To convert a three-phase input signal from the generator into a +dc signal
4. To develop an error voltage using the outputs of the speed section and the speed reference section

9-24. It is desirable to detect load changes and respond to them before they appear as turbine speed changes for what reason?

1. To increase efficiency
2. To decrease line losses
3. To minimize speed change transients
4. To minimize line voltage transients

9-25. What is the primary source of most problems in the hydraulic actuator or valve operator?

1. Dirty oil
2. Incorrect needle valve setting
3. Incorrect speed reference setting
4. Wrong type of oil used

Learning Objective: Recognize the principles of the earth's magnetic fields as they relate to the degaussing systems.

9-26. A ship's magnetic field moves with the ship through the water. Because of this magnetic field, the ship can trigger magnetic-sensitive ordnance. Degaussing systems are used aboard ship for which of the following reasons?

1. To trigger sensitive devices
2. To protect the hull from rust
3. To help reduce the ship's distortion of the earth's magnetic field
4. To make the ship's hull a large magnet

9-27. The lines of magnetic force at the earth's surface don't run in straight lines. They appear more like isobar lines on a weather map. The lines of force interact with ferrous materials in what way?

1. They align the lines of force around longitude
2. They distort the background field into areas of increased or decreased magnetic strength
3. They create an induced magnetic field
4. They distort to avoid passing near the ferrous material

9-28. On earth, where is the south magnetic pole located?

1. In the southern hemisphere
2. In the northern hemisphere
3. At the equator
4. Half way between the north and south geographic poles

9-29. The earth's magnetic field is made up of what components?

1. The H and Z zones
2. The H and X zones
3. The Z and Y zones
4. The X and Y zones

9-30. What instrument is used to determine the angle of the horizontal field?

1. A pivotal voltmeter
2. A strength ammeter
3. A navigational compass
4. A dip needle

9-31. At the equator, what is the vertical intensity of the earth's magnetic field?

1. Maximum, upward, and positive
2. Minimum, downward, and negative
3. Perpendicular and zero
4. Horizontal and zero

9-32. The magnitude of a ship's permanent magnetism depends on which of the following conditions?

1. The earth's magnetic field where the ship was built
2. The material from which the ship is constructed
3. The orientation of the ship at the time the ship was built with respect to the earth's magnetic field
4. All of the above

9-33. Navy ships are depermed for which of the following reasons?

1. To increase the number of the ship's effective degaussing coils
2. To decrease the permanent magnetization of the ship
3. To decrease the induced magnetization of the ship
4. All of the above

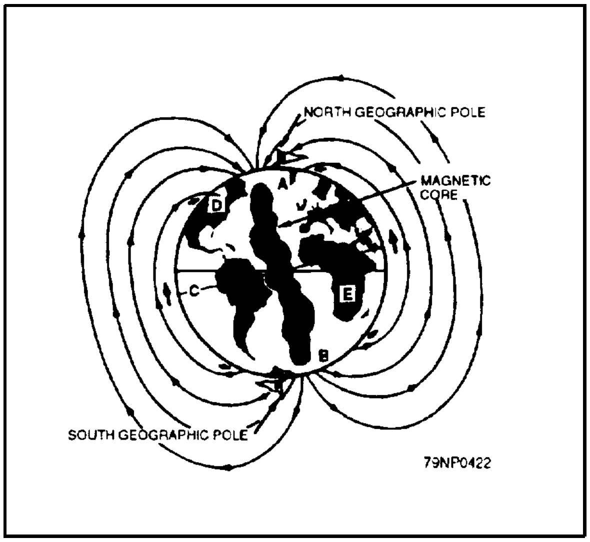


Figure 9B.

IN ANSWERING QUESTIONS 9-34 AND 9-35, REFER TO THE EARTH'S MAGNETIC FIELD SHOWN IN FIGURE 9B.

9-34. The earth's magnetic field lines of force enter the surface at what location?

1. The north magnetic pole
2. The south magnetic pole
3. The magnetic equator
4. A point midway between the magnetic equator and the South Pole

9-35. At what location on the earth's surface do the magnetic lines of force point away with the strongest flux?

1. A
2. B
3. C
4. D

9-36. The horizontal component of the earth's magnetic field is maximum at which of the following locations?

1. The magnetic equator
2. The north pole of the magnetic core
3. The south pole of the magnetic core
4. Both 2 and 3 above

9-37. A ship's induced magnetism depends on which of the following components?

1. The strength of the earth's magnetic field
2. The heading of the ship with respect to the inducing earth's magnetic field
3. Both 1 and 2 above
4. The vertical induced component of magnetism

9-38. What two field components make up the horizontal field of a ship's induced magnetism?

1. The longitudinal and athwartship
2. The vertical induced and athwartship
3. The longitudinal and the vertical
4. The athwartship and the vertical

9-39. The magnitude of the vertical field component of a ship's induced magnetization depends on what factor?

1. The ship's heading
2. The magnetic latitude
3. The magnetic longitude
4. The horizontal induced field component

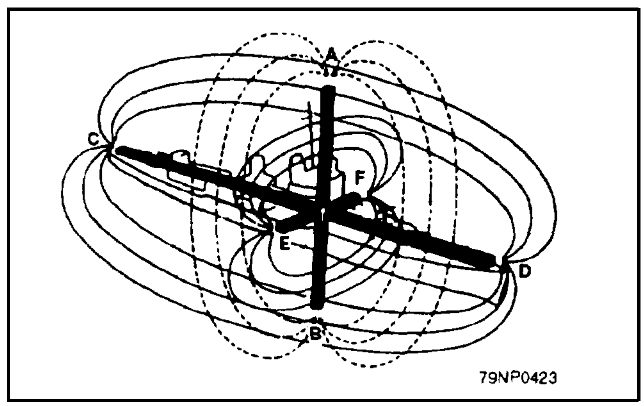


Figure 9C.

IN ANSWERING QUESTIONS 9-40 AND 9-41, REFER TO THE THREE COMPONENTS OF THE SHIP'S INDUCED MAGNETISM SHOWN IN FIGURE 9C.

9-40. When the ship is on a southerly heading at the magnetic equator, the induced magnetisms of AB, CD, and EF have what relationship?

1. AB and CD are maximum, and EF is minimum
2. AB is maximum, and CD and EF are minimum
3. CD is maximum, and AB and EF are minimum
4. EF and CD are maximum, and AB is minimum

9-41. A ship steaming on a north heading changes course to the east. What effect does this have on the ship's induced magnetic field?

1. CD changes from zero to maximum
2. CD changes from maximum to zero
3. EF changes from maximum to minimum
4. AB changes from maximum to minimum

9-42. The equipment that measures the magnetic field of a ship at a degaussing range has which of the following physical locations?

1. At or near the bottom of the channel
2. On the ship
3. Ashore
4. Both 2 and 3 above

9-43. A ship is check ranged for which of the following reasons?

1. To ensure that the degaussing coil settings match those given in the degaussing folder
2. To determine if the ship requires the installation of additional degaussing coils
3. To ensure that the current settings are adequate
4. To ensure that the degaussing charts are accurate

9-44. At what specified interval must minesweepers be checked at a degaussing range?

1. Semiannually
2. Quarterly
3. Monthly
4. Weekly

9-45. What is the minimum number of coils in a degaussing system?

1. One
2. Two
3. Three
4. Four

9-46. Degaussing coils are energized from what type of power sources?

1. The 120-volt lighting circuit
2. The 48-volt gyro batteries
3. Direct current
4. Alternating current

9-47. The magnetic fields produced by the permanent and induced vertical components of a ship's magnetization are counteracted by which of the following degaussing coils?

1. A
2. L
3. M
4. F

9-48. The ship's vertical induced magnetization varies with which of the following factors?

1. The ship's latitude
2. The ship's pitch
3. The ship's roll
4. All of the above

9-49. The forward one-fourth to one-third of a ship is encircled by which of the following coils?

1. Q
2. M
3. L
4. F

9-50. The strength of the FI-QI and FP-QP coils depends on which of the following factors?

1. The ship's heading and draft
2. The ship's draft and latitude
3. The ship's latitude and heading
4. The ship's heading and speed

9-51. The FI-QI degaussing coils counteract which of the following fields?

1. Longitudinal permanent
2. Longitudinal induced
3. Athwartship induced
4. Vertical induced

9-52. The L coil is installed aboard what type of ship?

1. An aircraft carrier
2. A replenishment ship
3. A submarine
4. A minesweeper

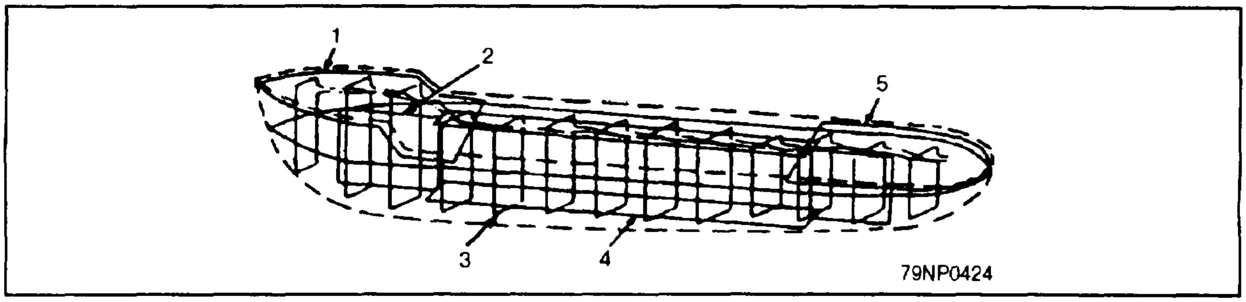


Figure 9D.

IN ANSWERING QUESTION 9-53, REFER TO FIGURE 9C AND THE DEGAUSSING COIL LOCATIONS SHOWN IN FIGURE 9D.

9-53. The magnetism of the fore-aft component is counteracted by which of the following coils?

1. 3 and 4 only
2. 4 and 5 only
3. 1, 3, and 5
4. 2, 4, and 5

9-54. A degaussing coil for correcting athwartships permanent and athwartships induced magnetization has what designation?

1. A
2. AX
3. API
4. AP-AI

9-55. Magnetic fields produced by the permanent and induced longitudinal components of a ships magnetization are counteracted by which of the following coils?

1. F
2. L
3. Q
4. Each of the above

9-56. Which of the following conditions can change a ship's attitude?

1. Roll
2. Trim
3. Heading
4. Each of the above

9-57. What equipment is used to automatically control the current of degaussing systems?

1. A gyrocompass and magnetometer
2. A magnetometer and reversing switch
3. A magnetometer and gyrocompass control
4. A polarity switch and gyrocompass

9-58. A magnetometer that controls the induced field currents receives a signal from what total number of axes?

1. One
2. Two
3. Three
4. Four

9-59. The AUTODEG equipment must be secured if the automatic controls become inoperative.

1. True
2. False

9-60. Magnetometer-controlled AUTODEG equipment has what total number of modes of operation?

1. One
2. Two
3. Three
4. Four

9-61. The degaussing system coil turns, current magnitude, and polarities for a ship are established during calibration. Calibration is accomplished at what location?

1. A degaussing range
2. A deperming crib
3. A dry dock
4. A pier

9-62. Degaussing coil currents should be monitored and compared to which of the following values?

1. Those previously recorded on the degaussing log
2. Those recorded in the degaussing folder
3. Those listed in the quartermaster's log
4. Those listed in the degaussing technical manual

9-63. When the EMS degaussing system is in the manual mode, the M-coil switch is set to what polarity?

1. Positive for northern latitudes
2. Positive for southern latitudes
3. Negative for northern latitudes
4. Neutral for all latitudes

9-64. When the ship's heading changes and the geographical location does not, the magnitude and polarity of what components will vary?

1. FP-QP and L
2. FI-QI and A
3. FP-QP and M
4. L, A, and FI-QI

9-65. In the SSM degaussing system, which of the following components is/are installed to warn personnel of faulty operations?

1. Ground detectors
2. Temperature alarm
3. Blown fuse indicators
4. Each of the above

9-66. What method is used to mark the insulating sleeving of degaussing conductors?

1. Painting
2. Branding
3. Notching
4. Stenciling

9-67. In the degaussing system, adjustments for ampere-turn ratios are made in what component(s)?

1. The degaussing switchboard
2. The remote control panel
3. The connection boxes
4. The through boxes

9-68. What is the required length for all conductors inside a connection box?

1. 1 1/2 times the length to the farthest terminal
2. 1 1/2 times the length to the nearest terminal
3. 2 times the length to the nearest terminal
4. 2 times the length to the farthest terminal

9-69. The degaussing folder is an official ship's log.

1. True
2. False

9-70. The degaussing folder is prepared by what person?

1. The navigator
2. The engineer
3. The electrical officer
4. The degaussing range personnel

9-71. At what point is the degaussing folder prepared?

1. After each yard period
2. Once each year
3. Once each 5 years
4. During initial calibration

9-72. You should NOT use which of the following equipment to remove dust and dirt from automatic degaussing control equipment?

1. LP air
2. A bellows
3. A lint-free rag
4. A vacuum cleaner

9-73. What is the fastest and easiest way for you to check connection boxes or through boxes for moisture?

1. Remove the box cover
2. Remove the drain plug
3. Loosen the cable packing gland
4. Check the ground meter at the switchboard

ASSIGNMENT 10

Textbook Assignment: "Cathodic Protection," "Visual Landing Aids," "Engineering Plant Maintenance, Operations, and Inspections," and "Engineering Casualty Control," chapters 11 through 14, pages 11-1 through 14-27.

Learning Objective: Identify the characteristics of the cathodic protection system.

10-1. What protection system is installed to reduce corrosion or deterioration of a ship's hull in seawater?

1. Armament
2. Cathodic
3. Resistive
4. Degaussing

10-2. What is the electrolyte in a cathodic protection system?

1. Tricarboxylic acid
2. Sulfuric acid
3. Salammoniac
4. Seawater

10-3. Which of the following factors is used to determine the amount of corrosion on a hull?

1. The temperature of the seawater
2. The resistivity of the seawater
3. Stray electrical currents
4. Each of the above

10-4. What is the specified replacement period for the sacrificial type of anode?

1. 1 year
2. 2 years
3. 3 years
4. 4 years

10-5. What components are installed to protect valves and the sea chest?

1. Iron anodes
2. Aluminum anodes
3. Steel waster pieces
4. Magnesium pieces

10-6. Which of the following is NOT an advantage of sacrificial anodes?

1. Hull protection
2. Ease of installment
3. Little maintenance required
4. Reduced noise level around the hull

10-7. What material is used to make the impressed current cathodic protection system anodes?

1. A carbon-coated rod
2. A silver-chloride coated rod
3. A platinum-coated rod
4. A zinc-coated rod

10-8. What is the current rating of a 4-foot anode?

1. 75 A
2. 100 A
3. 125 A
4. 150 A

10-9. As used with cathodic protection systems, the shaft grounding assembly grounds which of the following components?

1. The electrical motor shafts
2. The propeller shafts
3. The generator shafts
4. The air compressor shafts

10-10. What is the purpose of the large loop placed in a rudder grounding strap?

1. To reduce stray currents
2. To ground the rudder crosshead
3. To permit full rotation of the rudder stock
4. To ensure the strap doesn't get fouled on the deck

10-11. What is the voltage range developed between a disconnected platinum anode and the hull?

1. 1.0 to 2.0 Vdc
2. 1.0 to 2.5 Vac
3. 2.5 to 3.5 Vac
4. 3.0 to 5.0 Vdc

10-12. What is the optimum polarization range of the ships hull-to-reference electrode potential?

1. +1.0 to +2.0 Vdc
2. +0.80 to +0.90 Vdc
3. -0.80 to -0.90 Vdc
4. -1.0 to -2.0 Vdc

Learning Objective: Identify the components of the visual landing aids and recognize their function.

10-13. Which of the following components make(s) up the visual landing aids (VLAs) aboard air-capable ships?

1. Lighting
2. Approach aid
3. Deck markings
4. All of the above

10-14. Which of the following phrases describes the stabilized glide slope indicator (GSI) system?

1. A mechanical light
2. A hand-held landing instrument
3. An electrohydraulic optical landing aid
4. A group of pulsating lights

10-15. The GSI functions in which of the following ways?

1. The reference light mounted inside the GSI is kept steady as the ship moves, allowing the pilot to land safely
2. The helicopter is kept from pitching as it leaves the deck
3. The error signal developed is fed to the gyro to allow it to remain steady
4. The GSI gives the pilot better depth perception when landing at night

10-16. The stabilized GSI platform receives its reference signal to remain level from

1. the ship's navigation gyro
2. a gyro mounted on the platform
3. the main IC switchboard
4. a 400-Hz static converter mounted in the helicopter control station

10-17. The GSI hydraulic pump supplies oil to the hydraulic actuator at what specific pressure?

1. 1,000 psi
2. 1,200 psi
3. 1,400 psi
4. 1,600 psi

10-18. Which of the following components are contained in the GSI lamp house assembly?

1. Three source lights
2. A vent fan
3. An optical lens
4. All of the above

10-19. The homing beacon is (a) what color lamp mounted on (b) what component?

1. (a) White (b) the mainmast
2. (a) Red (b) the superstructure
3. (a) Red (b) the mainmast
4. (a) Blue (b) the superstructure

10-20. Of the lists shown below, which one indicates the three colors of the GSI light bars?

1. Red, green, and white
2. Red, green, and amber
3. Blue, green, and white
4. Blue, green, and amber

10-21. Edge lights are red omnidirectional lamps that can be seen in any direction above deck level.

1. True
2. False

10-22. What color are the line-up lights?

1. Red
2. Blue
3. White
4. Green

Learning Objective: Identify procedures for filling out, handling, and using various engineering logs and records.

10-23. Which of the following documents is/are considered legal records?

1. Engineering Log
2. Engineer's Bell Book
3. Both 1 and 2 above
4. Watch, Quarter, and Station Bill

10-24. Which of the following is information that should be entered in the Engineering Log?

1. Injuries to personnel within the department
2. Mileage steamed for the day and fuel expended
3. Major speed changes and average hourly rpm
4. Each of the above

10-25. The responsibility for the daily verification of the accuracy and completeness of the Engineering Log rests with the

1. engineering officer of the watch (EOOW)
2. engineering officer
3. executive officer
4. commanding officer

10-26. The responsibility for making entries in the Bell Book rest with the

1. throttleman
2. helmsman
3. chief engineer
4. officer of the deck

A.	AHEAD FLANK SPEED
B.	AHEAD FULL SPEED
C.	STOP
D.	AHEAD STANDARD SPEED

Figure 10A.

IN ANSWERING QUESTIONS 10-27 THROUGH 10-29, MATCH THE FOLLOWING BELL BOOK ENTRIES WITH THEIR MEANING SHOWN IN FIGURE 10A.

10-27. II.

1. A
2. B
3. C
4. D

10-28. Z.

1. A
2. B
3. C
4. D

10-29. III.

1. A
2. B
3. C
4. D

10-30. Neat corrections and erasures are permitted in the Engineer's Bell Book if they are made only by the person required to sign the record for the watch and if the change is neatly initialed in the margin of the page.

1. True
2. False

10-31. For a list of the engineering records that must be kept permanently, you would refer to what publication?

1. NSTMs
2. SECNAVINST P5212.5
3. NAVSHIPS 5083
4. NAVSHIPS 3648

10-32. What person enters remarks and signs the record on the AC/DC Electric Propulsion Operating Record?

1. The leading EM
2. The electrical officer
3. The EM of the Watch
4. The engineering officer

10-33. On small ships, the Gyrocompass Operating Record and the I. C. Room Operating Record may be maintained on the same form.

1. True
2. False

10-34. Which of the following is a purpose of maintaining and retaining engineering operating records and reports?

1. To inform responsible personnel of coming events
2. To supply data for the analysis of equipment
3. To warn of impending casualties
4. Each of the above

10-35. Which of the following information is contained in the engineer officer's Night Order Book?

1. Special instructions for the night engineering officer
2. Standing instructions for the night engineering officer
3. Both 1 and 2 above
4. Procedures for lighting off equipment

10-36. Of the following personnel, which one is required to know the content of the Night Orders?

1. The leading duty petty officer of each engineering division, when in port
2. The oil king
3. The principal watch supervisor of engineering departments for both at-sea and inport watches
4. Each of the above

10-37. Unless they are requested by a Naval Court or board or by the Navy Department, the Engineering Log and Engineer's Bell Book are kept on board ship for what minimum number of years?

1. 1
2. 2
3. 3
4. 4

Learning Objective: Recognize the purpose of the Planned Maintenance System (PMS) and identify PMS forms and their uses.

10-38. Which of the following is NOT a use of the PMS?

1. To provide a description of the methods and tools to be used for maintenance
2. To provide for the detection and prevention of impending casualties
3. To estimate and evaluate material readiness
4. To forecast and plan for personnel and material losses

10-39. Which of the following lists are categories of the PMS?

1. Cycle, quarterly, and monthly
2. Quarterly, monthly, and weekly
3. Cycle, monthly, and weekly
4. Cycle, quarterly, and weekly

10-40. The Quarterly PMS Schedule is updated by (a) what person at (b) what interval?

1. (a) Work center supervisor (b) daily
2. (a) Work center supervisor (b) weekly
3. (a) Division officer (b) daily
4. (a) Division officer (b) weekly

10-41. Completed Quarterly PMS schedules are kept on file for what minimum period of time?

1. 1 year
2. 2 years
3. 3 years
4. 6 months

10-42. The Weekly PMS Schedule is updated by (a) what person at (b) what interval?

1. (a) Daily (b) workcenter supervisor
2. (a) Weekly (b) workcenter supervisor
3. (a) Daily (b) division officer
4. (a) Weekly (b) division officer

10-43. The Weekly PMS Schedule contains blank space for the signature of what official?

1. Engineer officer
2. Division officer
3. 3-M assistant
4. Work center supervisor

A.	OPNAV 4790/2L
B.	OPNAV 4790/CK
C.	OPNAV 4790/2K
D.	OPNAV 4790/2Q

Figure 10B.

IN ANSWERING QUESTIONS 10-44 THROUGH 10-46, REFER TO FIGURE 10B AND SELECT THE MDS OPNAV FORM THAT IDENTIFIES THE TITLE USED AS THE QUESTION.

10-44. Ship's Maintenance Action Form.

1. A
2. B
3. C
4. D

10-45. Supplemental Form.

1. A
2. B
3. C
4. D

10-46. Automated Ship's Maintenance Action Form.

1. A
2. B
3. C
4. D

Learning Objective: Recognize the factors involved in planning, estimating, and inspecting work performed by others.

10-47. The amount of information required to be given to personnel doing a particular repair job depends on which of the following considerations?

1. The safety precautions you expect them to ignore
2. The man-hours estimated to complete the job
3. The experience of the personnel assigned to the job
4. The degree of care with which you expect to inspect the job upon completion

10-48. A careful inspection should be conducted after a job has been completed to ensure that the work was properly performed and that necessary records or reports have been prepared.

1. True
2. False

10-49. Which of the following estimates is often the most difficult for a supervisor to make in arriving at a job completion time?

1. Tools required
2. Materials required
3. Personnel required
4. Time and labor required

Learning Objective: Identify the procedures and responsibilities for the various inspections conducted aboard ship.

10-50. What type of inspection is concerned mainly with a ship's ability to carry out its wartime missions?

1. Administrative inspection of the ship as a whole
2. Administrative inspection of the ship's departments
3. Operational readiness inspection
4. Material inspection

10-51. Which of the following types of inspections include battle problems?

1. Operational readiness inspections only
2. Material inspections only
3. Material inspections and operational readiness inspections
4. Formal inspections

10-52. What is the primary purpose of a shipboard battle problem?

1. To provide an opportunity for all hands to participate, if they with to do so
2. To allow machinery testing
3. To provide a medium for testing and evaluating the ability of all divisions to function together as a team
4. To allow senior personnel a chance to pass along their knowledge

10-53. The value of a battle problem to a ship's company is directly proportional to which of the following factors?

1. The amount of preparation time allowed the ship's company before zero problem time
2. The amount of realism provided in the problem
3. The skill of the observing party evaluating the problem procedures
4. The number of trained observers conducting the problem

10-54. Under what circumstances are engineering telephone circuits used during the battle problem?

1. For the observing party to announce the start and end of the problem
2. When the observing party spots an actual casualty
3. When ship's personnel spot an actual casualty
4. When the ship's engineering personnel need to cope with the battle problem assigned to the ship

10-55. In a shipboard battle problem, observers should use equal effort to note excellence as well as weakness.

1. True
2. False

10-56. Unless they have a direct bearing on the material condition, administrative methods and cleanliness should not be considered as part of a material inspection.

1. True
2. False

10-57. Which of the following is a main inspection item for a material inspection of engineering spaces?

1. Procedures used for the replacement of repair parts
2. Installation and maintenance of required fire-fighting equipment in the engineering spaces is done according to up-to-date procedures
3. Maintenance of equipment custody cards
4. Knowledge by responsible engineering personnel of current instructions regarding routine testing and inspections

10-58. Which of the following trials are considered routine ship's trials?

1. Laying up, final acceptance, and recommissioning
2. Tactical, standardization, and post repair
3. Economy, post repair, and full power
4. Preliminary acceptance, economy, and builder's

10-59. What kind of trouble can be expected if a full power trial is held in shallow water?

1. Excessive speed
2. Multiple pump failures
3. Overloading of the propulsion plant
4. Foaming of lube oil in reduction gears

10-60. At what interval should readings be taken and recorded during an economy trial?

1. Every half hour
2. Every hour
3. At the start and end of the trial
4. At the start, middle, and end of the trial

Learning Objective: Recognize the importance of the Hearing Conservation Program and identify hazards that may lead to hearing loss.

10-61. Exposure to what type of sounds can cause a hearing loss?

1. Continued sounds only
2. Intermittent sounds only
3. Continued and intermittent sounds
4. Sounds above 104 dB

10-62. What is the purpose of the Hearing Conservation Program?

1. To identify noise sources
2. To reduce exposure of personnel to potentially hazardous noises
3. To test the hearing of personnel exposed to noise
4. To provide hearing conservation devices

10-63. All personnel who are exposed to potentially hazardous noises may wear hearing devices at their own discretion.

1. True
2. False

10-64. What instruction sets the guidelines for the Secretary of the Navy's policy on occupational safety and health?

1. OPNAVINST 4790.4
2. SECNAVINST 5100.1
3. SECNAWNST 6460.4
4. OPNAVINST 3120.32G

10-65. What is the maximum allowable time between noise level surveys taken aboard ship?

1. 1 year
2. 2 years
3. 6 months
4. After each major yard period

10-66. On board ship, what person is responsible for issuing aural protective devices?

1. The duty corpsman
2. The main propulsion assistant
3. The engineering officer
4. The division officer

10-67. Which of the following actions is the engineering officer required to perform?

1. Have newly reporting personnel receive a hearing test
2. Advise the medical department of personnel who are working in noise areas
3. Arrange for a noise survey to be taken
4. Each of the above

10-68. Which of the following responsibilities would be yours as a work center supervisor?

1. Posting safety signs in your work area
2. Training and counseling your personnel on the effects of noise pollution
3. Ensuring work center personnel have hearing protection
4. Each of the above

Learning Objective: Identify aspects of engineering casualty control.

10-69. Which of the following is the primary objective of engineering casualty control?

1. The prevention, minimization, and battle casualties
2. To minimize personnel casualties
3. To maintain the efficiency of the engineering department
4. To operate engineering equipment at minimum efficiency

10-70. What is the most effective phase of casualty control?

1. Restoration
2. Training
3. Prevention
4. Communications

10-71. Which of the following is/are the cause of most engineering plant casualties?

1. Lack of effective communications
2. Lack of systems knowledge
3. Improper procedures by watch standers
4. Both 2 and 3 above

10-72. Which of the following examples is a reason for an unsatisfactory grade on a casualty control drill?

1. Loss of plant control by the space supervisor or the EOOW
2. Safety violations
3. Lack of knowledge of proper procedures
4. Each of the above

10-73. EOSS is designed to improve the operational readiness of the ship's engineering plant by increasing its operational efficiency and providing better engineering plant control.

1. True
2. False

10-74. Continuous operation of equipment under casualty conditions can be authorized by which of the following ship's officers?

1. Operations officer
2. Engineering officer
3. Officer of the watch
4. Commanding officer

10-75. One of the most important features of the casualty power system is to provide a means for temporary repairs.

1. True
2. False