NONRESIDENT
TRAINING
COURSE

Machinist's Mate 3 & 2 (Surface)

NAVEDTRA 14151

NOTICE

Pages 9-20, 9-21, 9-22, 9-23, 9-24, 9-25, 11-4, 11-6, and 12-11 must be printed on a **COLOR** printer.

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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 references to useful information to be found in other publications. The well-prepared Sailor will take the time to look up the additional information.

Any errata for this course can be found at https://www.advancement.cnet.navy.mil under Products.

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CHAPTER 1

INTRODUCTION TO THE MACHINIST'S MATE (SURFACE) RATING

The fleet needs capable men and women in all ratings. A modern naval force is only as good as the people who man the ships, and the most modern ships are almost powerless without competent operators and technicians. We always have a lot of good people, but they are only as effective as their training. Well-trained people mean a combat-ready Navy, which can guarantee victory at sea.

This nonresident training course (NRTC) is designed to help you increase your knowledge in the various aspects of the Machinist's Mate (MM) rating and to help you advance in rating to MM3 and MM2. Your contribution to the Navy depends on your willingness and ability to accept increasing responsibilities as you advance in rate. When you assume the duties of a Machinist's Mate, you begin to accept certain responsibilities for the work of others. As you advancein your career, you acquire responsibilities in military matters as well as in the occupational requirements of the Machinist's Mate rating.

This NRTC contains basic training information. It helps you to build the platform on which you can stand while you reach out for additional knowledge through other publications and training systems, and through daily contact with your more knowledgeable seniors who will work with you and help you along.

The Navy wants you to advance because your advancement is the badge of confidence that ensures the best seagoing defense force that we can have.

THE MACHINIST'S MATE RATING

The Machinist's Mate rating is a general rating. This means it covers a broad occupational field of related duties and functions.

Machinist's Mates are assigned to all types of ships. Most of you will be assigned to M division, where you operate and maintain ship propulsion machinery and associated equipment such as pumps, distilling plants, compressors, valves, oil purifiers, heat exchangers, governors, reduction gears, shafts, and shaft bearings, marine boilers and their associated equipment, transfer, test, and inventory fuel oil, lube oil and water. You also will maintain records and reports.

If you are assigned duties other than in the enginerooms, you will maintain and repair machinery such as steering engines, anchor windlasses, cranes, winches, elevators, laundry equipment, galley equipment, and air conditioning and refrigeration equipment.

Your duties depend largely on the type of ship or station to which you are assigned. As an example, repair ships and tenders furnish other ships with spare parts, repairs, and other services that are beyond the capabilities of the ship's crew. Your duties on a repair ship or tender may consist mainly of repairs and other services to ships assigned to the tender or repair ships. As a Machinist's Mate, you may choose an area of specialization.

This NRTC will give you a systematic understanding of your job. The occupational standards used in preparing the text are found in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068F, found online at https://buperscd.technology.navy.mil/bup_updt/upd_CD/BUPERS/enlistedManOpen.htm. Study the Machinist's Mate section of NAVPERS 18068F to gain an understanding of the skills you must have. Then, study the subject matter carefully. You will become a better operator and the Navy will profit from your skills.

As you advance to MM3 and then to MM2, your responsibilities for military leadership will be about the same as those of petty officers in other ratings, since every petty officer has military as well as technical duties. Your responsibilities for technical leadership will be special to your rating and directly related to your work as a Machinist's Mate. Your job requires teamwork, along with a special kind of leadership ability that can be developed only if you have a high degree of technical competence and a deep sense of personal responsibility. Work to improve your leadership ability and technical knowledge through study, observation, and practical application.

Technical leadership means more than just giving orders. You can demonstrate some of the most important aspects of technical leadership even if you are not required to tell anyone else what to do. As an MM3 and MM2, you demonstrate technical leadership when you follow orders exactly, when you observe safety precautions, when you accept responsibility, when you continue to increase your knowledge of your job, and when you perform every detail of your work with integrity and reliability.

Integrity of work is really a key factor in technical leadership, and all other factors relate to it in some way. Integrity of work is demonstrated in big ways and little ways-the way you stand a messenger watch, the way you perform PMS, the way you deal with machinery failures and casualties, and the way you wipe up deckplates. When you perform every job just as well as you can, and when you constantly work to increase your knowledge, you demonstrate integrity of work in a concrete, practical, every day sort of way. When your work has integrity, you are demonstrating technical leadership. That leadership will be recognized.

NAVY ENLISTED CLASSIFICATION CODES

The Machinist's Mate rating is a source of a number of Navy enlisted classification (NEC) codes. NECs reflect special knowledge and skill in certain ratings. The NEC coding system is a form of management control over enlisted skills. It identifies skills and training required for specific types of operations or equipment. The Chief of Naval Personnel details skilled personnel to those ships that require these skills. There are a number of NECs that you may earn at certain grade levels by satisfactorily completing an applicable course of instruction at a Navy school. Your personnel office will have complete information on NECs and qualification procedures. NECs and occupational standards are online at https://buperscd.technology.navy.mil/bup_updt/upd_CD/BUPERS/enlistedManOpen.htm.

STANDARDS

The Navy has established certain standards to help you obtain the best results from your training program. These standards provide a step-by-step procedure for you to follow in order to gain the maximum knowledge available as you progress in your rate.

NAVAL STANDARDS

Naval standards are requirements that apply to all ratings rather than to any one particular rating. Naval requirements for advancement to third class and second class petty officer deal with military conduct, naval organization, military justice, security, watchstanding, and other subjects which are required of petty officers in all ratings.

OCCUPATIONAL STANDARDS

Occupational standards are requirements that are directly related to the work of each rating.

Both the naval standards and the occupational standards are divided into subject matter groups.

The *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068F, has replaced the "quals manual" and the NEC manual. Section I contains the occupational and naval standards for advancement to each paygrade in each enlisted rating. Section II contains the NECs.

Your educational services officer should have a current edition of the occupational standards which apply to your rating at this time.

PERSONNEL QUALIFICATION STANDARDS (PQS)

The Personnel Qualification Standards (PQS) program is the result of an increasing need for greater technical know-how within the Navy, and the PQS documents are the guides to the qualification of personnel for this purpose. The PQS program is found at https://wwwcfs.cnet.navy.mil/pqs.

The PQS exist to "Let every man know his job, his place in the ship, his responsibilities to his shipmates and his purpose in fighting." The system places most of the responsibility for learning on the individual and encourages self-achievement. The PQS describe the knowledge and skills that you must have to correctly perform your duties. They provide a convenient record of accomplishment, and provide a means whereby your progress can be monitored regularly by your seniors.

The qualification standard for a specific piece of equipment or an organized group of watch-standing requirements is in booklet form. Each PQS is designed to guide trainees toward qualification by telling them exactly what they must learn to achieve that goal.

The PQS are separated into four main subdivisions:

100 Series—THEORY

200 Series—SYSTEMS

300 Series—WATCHSTATIONS

400 Series—QUALIFICATION CARDS

Theory

The 100 series describes the basic knowledge needed to understand your specific equipment or duties as a Machinist's Mate. It is a list of questions about all of the various engineering fundamentals, including safety. Figure 1-1 is a portion of a turbine theory section from a PQS guide.

Each portion of the theory section has a list of references which contain the answers to the individual items listed.

Systems

In the 200 series, the machinery is broken down into functional sections as the basic building blocks in the learning process. For a complete understanding of a system, you must study all of its functional parts.

This series uses a pattern in the numbers to the right of the decimal. A typical system qualification standard is shown in figure 1-2.

The system section will include:

.1 Explain SYSTEM FUNCTION.

.11 Draw a simplified version of the system from memory.

.2 SYSTEM COMPONENTS-GENERAL. Notice that a series of items about components is given, followed by a list of components with a matrix to identify the items that you are to apply to each component. For example, look at component .21 (metering orifice). In the matrix, you notice Xs below A, B, and C, indicating that items A, B, and C, listed under System Components-General, apply to the metering orifice.

.3 COMPONENT PARTS. This section breaks down the system components into their component parts, and shows you what you must learn about each part.

.4 PRINCIPLES OF OPERATION. Up to this point, you have considered the system from a purely "static" point of view (what the system is and does). In this section, you will analyze the system on a "dynamic" basis (how the components and component parts work together to perform the function of the system).

.5 MAJOR PARAMETERS. In this section you will learn the meanings of measurements such as temperatures, pressures, flow rates, etc., and how these parameters or limits are monitored.

.6 SYSTEM INTERRELATIONS. Now you are required to fit the system into the "big picture." That is, how this system affects and is affected by other systems in the engineering plant.

.7 SAFETY PRECAUTIONS. Do NOT neglect safety precautions; they are written in bitter experience to protect you and your equipment. Here you will find the safety precautions that are unique to this system

Watchstations

The 300 series describes the procedures that you must know to properly operate and maintain the machinery. Figure 1-3 is the first portion of a watchstation standard. You should not think that you stand watch only if your name is on a watch bill. In the qualification standards usage, you are considered to be at your watchstation any time you face the machinery and use your intelligence to cause it to perform correctly or try to analyze malfunctions. All possible procedures may not be detailed in this section, but those that you can reasonably be expected to complete are covered by the OPERATOR and TECHNICIAN watchstations described below.

OPERATOR WATCHSTATION.—Your study of the 200 series showed you what the systems do, how they do it, and many other aspects of their operation. That knowledge is of little value to you and the Navy unless you are able to use it to perform in an efficient manner. In this section, you will be directed to perform and discuss various aspects of procedures and to demonstrate your ability to cope with the machinery at your watchstation.

7103 TURBINE THEORY

This section identifies the terms, principles, and laws that will give you a foundation of understanding of Turbine Theory upon which a working knowledge can be built. The following references were used:

a. *Fireman* (NAVEDTRA 14104)
b. *Machinist's Mate 3 & 2* (NAVEDTRA 14151)
c. *Machinist's Mate 1 & C* (NAVEDTRA 14150)
d. *NAVSHIPS Technical Manual*
e. Manufacturer's instruction books

7103.1 DRAWINGS, SYMBOLS, PUBLICATIONS

.11 Describe the following type of drawings:
a. Isometric
b. Exploded view
c. Perspective

.12 List the manuals and instructions books used most often by your unit.

7103.2 EQUIPMENT, DEVICES

.21 Explain the application and service use of the following:
a. Nozzles
b. Reversing chambers
c. Shrouding
d. Blading
e. Rotor
f. Diaphragm
g. Labyrinth shrouding
h. Carbon packing
i. Bearing
j. Casing
k. Foundations

.22 Explain the protective functions of the following:
a. Speed regulating governor
b. Overspeed trip
c. Relief valve
d. Back pressure trip
e. Emergency hand trip

7103.3 TERMS, DEFINITIONS

.31 Define the following terms as used in engineering:
a. Impulse and reaction
b. Nozzle
c. Staging
d. Pressure compounding
e. Velocity compounding
f. Rateau

Figure 1-1.—Personnel qualification standard—Theory section.

7232 MAIN FEED PUMP RECIRCULATION CONTROL SYSTEM

7232.1 Explain the functions(s) of the MAIN FEED PUMP RECIRCULATION CONTROL SYSTEM as stated in Manufacturer's Instruction Manual.

.11 Draw one line schematic diagram of this system from memory using appropriate symbols and showing all components listed in 7232.2.

.12 Refer to a standard print of this system during the rest of this discussion.

7232.2 SYSTEM COMPONENTS—GENERAL

Discuss the designated items for each component listed below:

A. Explain the function(s) of the component in terms of what it does for the system.
B. Describe the functional location of the component with respect to its position in the system and the reasons(s) for its location in this position.
C. Show or describe the actual physical location of this component.
D. List or describe the source(s) of control signal(s).
E. Describe the modes of control.
F. Discuss the protection provided by this component.
G. List the positions and functions(s) of each position of this component.
H. Describe the "fail" position of the component on loss of control signal and the reason(s) it fails in this position.
I. Describe the physical location of the sensing points for the component.
J. List the ratings of this component.

	A	B	C	D	E	F	G	H	I	J
.21 Metering orifice	X	X	X							
.22 Flow transmitter	X	X	X	X					X	
.23 Toggle relay	X	X	X	X			X			
.24 Transfer valve	X	X	X	X	X					
.25 Recirculation control valve	X	X	X	X	X	X	X	X		X
.26 Multiple orifice	X	X	X							

7232.3 COMPONENT PARTS

A. There are no component parts in this system to be discussed.

1232.4 PRINCIPLES OF OPERATION

Demonstrate an understanding of the internal operation of this system by describing:

.41 Feedwater from the discharge side of feed pump to deaerating feed tank during recirculation.

.42 How Recirculation Control System functions to maintain adequate flow of feed water through the main feed pump.

7232.5 MAJOR PARAMETERS

A. Show or describe the physical location of the sensing point.
B. Show or describe the physical location at which the parameter is displayed for monitoring.
C. State the setpoint(s).
D. State the reason(s) for the setpoint(s) in terms of the effect of operating above or below them.

	A	B	C	D
.51 Recirculation valve position	X	X	X	X
.52 Feed pump flow	X	X	X	X

7232.6 SYSTEM INTERRELATIONS

A. Describe the effect on this system due to the following:
1. Variation in boiler load
2. Loss of control air

B. Describe the effect(s) on the following system(s) due to the operation of this system:
1. Main Feed Pump System
2. Deaerating Feed Tank System

7232.7 SAFETY PRECAUTIONS

A. There are no safety precautions unique to this system.

Figure 1-2.—Personnel qualification standard—System section.

7312 WATCHSTATION—DISTILLING PLANT WATCH

7312.1 OPERATING INSTRUCTIONS

For the operating instructions listed below:

A. Explain the reasons for each step of this procedure.
B. Discuss the control/coordination required while performing this procedure.
C. Discuss the communications that must be established and/or utilized.
D. Discuss the parameter indications(s) that must be monitored.
E. Discuss the safety precautions that must be observed.
F. Perform the steps of this procedure.
G. Perform the steps of this procedure when practicable.

		A	B	C	D	E	F	G
.11	Line up, warm up, operate and secure the distilling plant	X	X	X	X	X	X	
.12	Line up distilling plant distillate for distribution	X	X	X	X	X	X	X
.13	Perform chemical test on distillate	X	X			X	X	X
.14	Operate salinity indicating panel	X	X		X	X	X	X
.15	Observe and record temperatures, pressures and levels on distilling plant and associated machinery							X
.16	Turn all pumps by hand or power (PMS)						X	

Figure 1-3.—Personnel qualification standard—Watchstation section.

.1 NORMAL OPERATIONS. In this section, you are directed to describe existing conditions that indicate the system is functioning properly.

.2 ABNORMAL CONDITIONS that could lead to EMERGENCIES and/or CASUALTIES. An abnormal condition is the first stage of a sequence of events that will lead to an emergency and/or casualty. You must recognize the symptoms of these conditions, and you must know what immediate corrective action to take. In this section, you will be required to discuss the most pertinent of the abnormal conditions.

.3 EMERGENCIES and/or CASUALTIES. In this section, you will discuss and/or perform, when practicable, the procedures used to limit the damage from the emergencies and casualties most pertinent to the watchstation.

.4 INFREQUENT and/or ABNORMAL OPERATIONS. In this section, you will discuss and/or perform, when practicable, those procedures that are too time-consuming or that occur too infrequently to be made mandatory performance items.

TECHNICIAN WATCHSTATION.—When studying to be a technician, your qualifications as an operator will be expanded to include the routine maintenance of your equipment. In this section, you are directed to discuss and perform the routine maintenance checks, tests, alignments, repairs, and replacements that keep the equipment and machinery assigned to you in a combat-ready condition.

INFREQUENT and/or ABNORMAL MAINTENANCE OPERATIONS. As in the operator watchstation, there are infrequent and/or abnormal maintenance operations that are too time-consuming to make them mandatory performance items. In this section, you are asked to discuss and perform those procedures when practicable.

Qualification Cards

The recommended steps to be performed by a ship's service turbogenerator operator at a designated watchstation are found in the 400 series.

When you complete all sections of the qualification standards, you will be able to both operate and maintain the machinery at your watchstation(s). In practice, however, where you start in the standard will be determined by your command, depending upon the immediate need for your services. You will be given a qualification card that will tell you which section you must complete first.

The qualification cards list the items you must complete in the 100, 200, and 300 series of the standard. These cards are your guide, reference, and record of achievement. The qualification cards are packaged separately from the standard and should be retained by you at all times to permit you to take advantage of every opportunity to complete the requirements.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the naval requirements for advancement and the occupational standards of your rating.

In this section, we will discuss most of the publications you will use for detailed information, for advancement, and for everyday work. Some are changed or revised from time to time, some at regular intervals, others as the need arises. Be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Canceled or obsolete information will not help you to do your work or to advance in rate. At best, it is a waste of time; at worst, it is likely to be dangerously misleading.

NETPDTC PUBLICATIONS

The Naval Education andTraining Professional Development and Technology Center (NETPDTC) comes directly under the command of the commander, Naval Education and Training command (NETC) instead of the Chief of Naval Personnel. Training materials published by NETPDTC are designated as NAVEDTRA.

The naval training publications described here include some that are absolutely essential for anyone seeking advancement and some not essential, but extremely helpful.

Nonresident Training Courses (NRTCs)

There are two general types of NRTCs. RATING manuals (such as this one) are prepared for most enlisted ratings. A rating manual gives information that is directly related to the occupational standards on one rating. SUBJECT MATTER manuals or BASIC manuals give information that applies to more than one rating. (Example: *Use and Care of Hand Tools and Measuring Tools*, NAVEDTRA 14256).

NRTCs are revised from time to time to keep them up to date technically. The revision of an NRTC is identified by a letter following the NAVEDTRA number. You can tell whether any particular copy of an NRTC is the latest edition by checking the NAVEDTRA number and the letter following this number in the *List of Training Manuals and Correspondence Courses*, NAVEDTRA 12061 found online at https://www.advancement.cnet.navy.mil. (NAVEDTRA 12061 is actually a catalog that lists all current training manuals and courses; you will find this catalog usefulin planning your study program).

Each time an NRTC is revised, it is brought into conformance with the official publications and directives on which it is based. However, during the life of any edition of an NRTC, changes will be made to the official sources, and discrepancies will arise. You should always refer to the appropriate official publication or directive. If the official source is listed in the Bib, NETPDTC uses it as a source of questions in preparing the fleetwide examinations for advancement.

NRTCs are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you prepare for advancement.

1. Study the occupational standards for your rating before you study the NRTC, and refer to the standards frequently as you study. Remember, you are studying the NRTC primarily to meet these standards.
2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. Try to schedule your studying for a time of day when you will not have too many interruptions or distractions.
3. Before you study any part of the NRTC intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Thumb through the book without any particular

plan. Look at the illustrations and read bits here and there as you see things that interest you. Review the glossary, which provides definitions that apply to words or terms as they are used within the engineering field and within the text. There are many words with more than one meaning. Do not assume that you know the meaning of a word. Look it up in the glossary.

4. Look at the NRTC in more detail to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book. As you look through the book, ask yourself some questions:

What do I need to learn about this?

What do I already know about this?

How is this information related to information given in other chapters?

How is this information related to the occupational standards?

5. When you have a general idea of what is in the NRTC and how it is organized, fill in the details by intensive study. Try to cover a complete unit in each study period—it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will depend on how well you know the subject.

6. In studying any one unit—chapter, section, or subsection—write down questions as they occur to you. Most of you will find it helpful to make a written outline of the unit, or, at least, to write down the most important ideas.

7. As you study, relate the information in the NRTC to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the NRTC, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

9. Think of your future as you study NRTCs. You are working for advancement to third class or second class right now, but you will soon be working toward higher rates. Anything extra that you can learn now will also help you later.

Other NAVEDTRA Publications

There are additional and useful NAVEDTRA publications, and you may want to consult the training manuals for other ratings in occupational fields 3 and 4 (Engineering and Hull). These manuals will add to your knowledge of the duties of others in the engineering department and help you prepare for your next promotion.

NAVSEA PUBLICATIONS

The publications issued by the Naval Sea Systems Command are of particular importance to engineering department personnel. Although you do not need to know everything in these publications, you should have a general idea of where to find the information in them.

Naval Ships' Technical Manual

The Naval Ships' Technical Manual is the basic engineering doctrine publication of the Naval Sea Systems Command. The manual is kept up-to-date by means of quarterly changes. As new chapters are issued they are being designated by a new chapter numbering system.

The following chapters of the *Naval Ships' Technical Manual* are of particular importance to Machinist's Mates; both the new and old numbers for each chapter are listed.

NEW	OLD	CHAPTER
075		Threaded Fasteners
079(3)	(9880.III)	Engineering Casualty Control
231	(9411)	Propulsion Turbines (Steam)
254	(9460)	Condensers and Air Ejectors
262	(9450)	Lubricating Oils, Greases, and Hydraulic Fluids and Lubricating Systems
502	(9500)	Auxiliary Steam Turbines
503	(9470)	Pumps
505	(9480)	Piping Systems
516	(9590)	Refrigeration Systems
531	(9580)	Distilling Plants
550	(9230)	Industrial Gases
551	(9490)	Compressed Air Plants
556	(9210)	Hydraulic Equipment
588	(9830)	Elevators

Deckplate

The *Deckplate* is a monthly publication that contains interesting and useful articles on all aspects of shipboard engineering. This magazine is particularly useful because it presents information that supplements and clarifies information contained in the *Naval Ships' Technical Manual.* It also presents information on new developments in naval engineering.

Manufacturers' Technical Manuals

The manufacturers' technical manuals furnished with most machinery units and many items of equipment are valuable sources of information on construction, operation, maintenance, and repair. The manufacturers' technical manuals that are furnished with most shipboard engineering equipment are given NAVSEA numbers.

Drawings

As a Machinist's Mate, you will read and work from mechanical drawings. You will find information on how to read and interpret drawings in *Blueprint Reading and Sketching,* NAVEDTRA 14040.

You must also know how to locate applicable drawings. For some purposes, the drawings included in the manufacturers' technical manuals for the machinery or equipment may give you the information you need. In many cases, however, you will find it necessary to consult the onboard drawings. These are sometimes referred to as ship's plans or ship's blueprints, and they are listed in an index called the ship drawing index (SDI). The SDI lists all working drawings that have a NAVSHIPS drawing number, all manufacturers' drawings designated as certification data sheets, equipment drawing lists, and assembly drawings that list detail drawings. The onboard drawings are identified in the SDI by an asterisk (*).

Drawings are listed in numerical order in the SDI. Onboard drawings are filed according to numerical sequence. There are two types of numbering systems in use for drawings that have NAVSHIPS numbers. The older system is an S-group numbering system. The newer system, used on all NAVSHIPS drawings since 1 January 1967, is a consolidated index numbering system. A cross-reference list of S-group numbers and consolidated index numbers is given in *NAVSHIPS' Consolidated Index of Materials and Services Related to Construction and Conversion.*

You should know about some manuals and instructions in addition to those we have already covered. Here are those that will probably be most important to *you: The Engineering Maintenance Manual, The Engineering Department Organization Manual, Propulsion Examining Board Guidelines, and Plan of Action and Milestones.* Become familiar with these publications so that you will have a better understanding of your department and the role you should play in an efficient and combat-ready organization. You can usually find these publications and instructions in your engineering logroom.

SAFETY PRECAUTIONS

Many of the *Naval Ships' Technical Manuals (NSTMs),* manufacturer's technical manuals, and every Planned Maintenance System (PMS) maintenance requirement card (MRC) include safety precautions. Additionally, OPNAVINST 5100.19, Naval Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat, and OPNAVINST 5100.23, NAVOSH Program Manual, provide safety and occupational health information. The safety precautions are for your protection and to protect equipment.

During prevention and corrective maintenance, the procedures may call for personal protection equipment (PPE) such as goggles, gloves, hearing protection, and respirators. When specified, your use of PPE is mandatory. You must select PPE appropriate for the job since the equipment is manufactured and approved for different levels of protection. If the procedure does not specify the PPE, and your aren't sure, ask your safety officer.

Most machinery, spaces, and tools requiring you to wear hearing protection are posted with hazardous noise signs or labels. Eye hazardous areas requiring you to wear goggles or safety glasses are also posted. In areas where corrosive chemicals are mixed or used, an emergency eye wash station must be installed.

All lubricating agents, oils, cleaning materials, and chemicals used in maintenance and repair are hazardous materials. Hazardous materials require careful handling, storage, and disposal. PMS documentation provides hazard warnings or refers the maintenance personnel to *the Hazardous Materials User's Guide (HMUG).* Material Safety Data Sheets (MSDSs) also provide safety precautions for hazardous materials. All commands are required to have an MSDS for each hazardous material they have in their inventory. You must be familiar with the dangers associated with the hazardous materials you use in your work. Additional information is available from your command's Hazardous Material/Hazardous Waste Coordinator.

Workers must always consider electrical safety when working around any electrical or electronic machinery or equipment. Procedures normally include special precautions and tag-out requirements for electrical safety. You should review your command's electrical safety program instruction and procedures before beginning any work on electrical or electronic equipment or before working with portable electrical tools.

CHAPTER 2

STEAM TURBINES

Steam turbines convert the thermal energy of steam into mechanical energy to perform useful work. Steam turbines produce power for ship propulsion. They are also prime movers of some auxiliary machinery associated with the propulsion plant, such as forced draft blowers, ship's service generators, and certain large pumps.

As a Machinist's Mate, you will need a thorough understanding of the engineering plant. This chapter will provide general background information. It will give you a foundation upon which to build as you learn more about the specific propulsion machinery aboard your ship and work toward your PQS qualification.

This chapter covers turbine theory; types and classifications of turbines; turbine construction; support systems and controls; and general turbine operation, maintenance, and care. You will find some basic information on propulsion units and their principles of operation in *Fireman,* NAVEDTRA 14104.

Before we discuss the operating principles of the steam turbine, let us briefly describe energy and its relationship to work, power, and horsepower.

ENERGY

Energy is the ability to do work. In the physical sense, work is done when a force acts on matter and moves it. We use heat energy to turn a steam turbine and electric energy to drive motors. The mechanical energy of the pistons in an automobile engine is transmitted to the wheels by the crankshaft, transmission, drive shaft, differential gears, and rear axles. Nuclear energy is used to generate electric power and to drive naval ships.

The most important characteristic of energy is that it can neither be created nor destroyed; it can only change its form.

For example, look at figure 2-1. Chemical energy (stored in the fuel oil) is converted to thermal energy in the boiler. This thermal energy is then transferred to the feedwater and steam within the boiler. The steam is used to carry this thermal energy to the ship's turbines, where the thermal energy is converted to mechanical energy. (You will learn how this is done in the turbine theory section of this chapter.) The mechanical energy of the turbines is used to turn the propeller, which pushes the ship through the water.

STORED ENERGY

Stored energy is energy that is actually contained in, or stored in, an object. There are two kinds of stored energy: potential and kinetic.

Potential Energy

Potential energy is energy within an object waiting to be released, while kinetic energy is energy that has been released. For example, potential energy exists in a rock resting on the edge of a cliff, in water behind a dam, and in steam behind a closed turbine throttle valve. Stored energy in steam is called ENTHALPY and is usually expressed in British thermal units (Btu). Specific enthalpy is the stored energy of a given amount of steam expressed in units of Btu per pound.

Kinetic Energy

Kinetic energy exists because of the relative velocities of two or more objects. If you push the

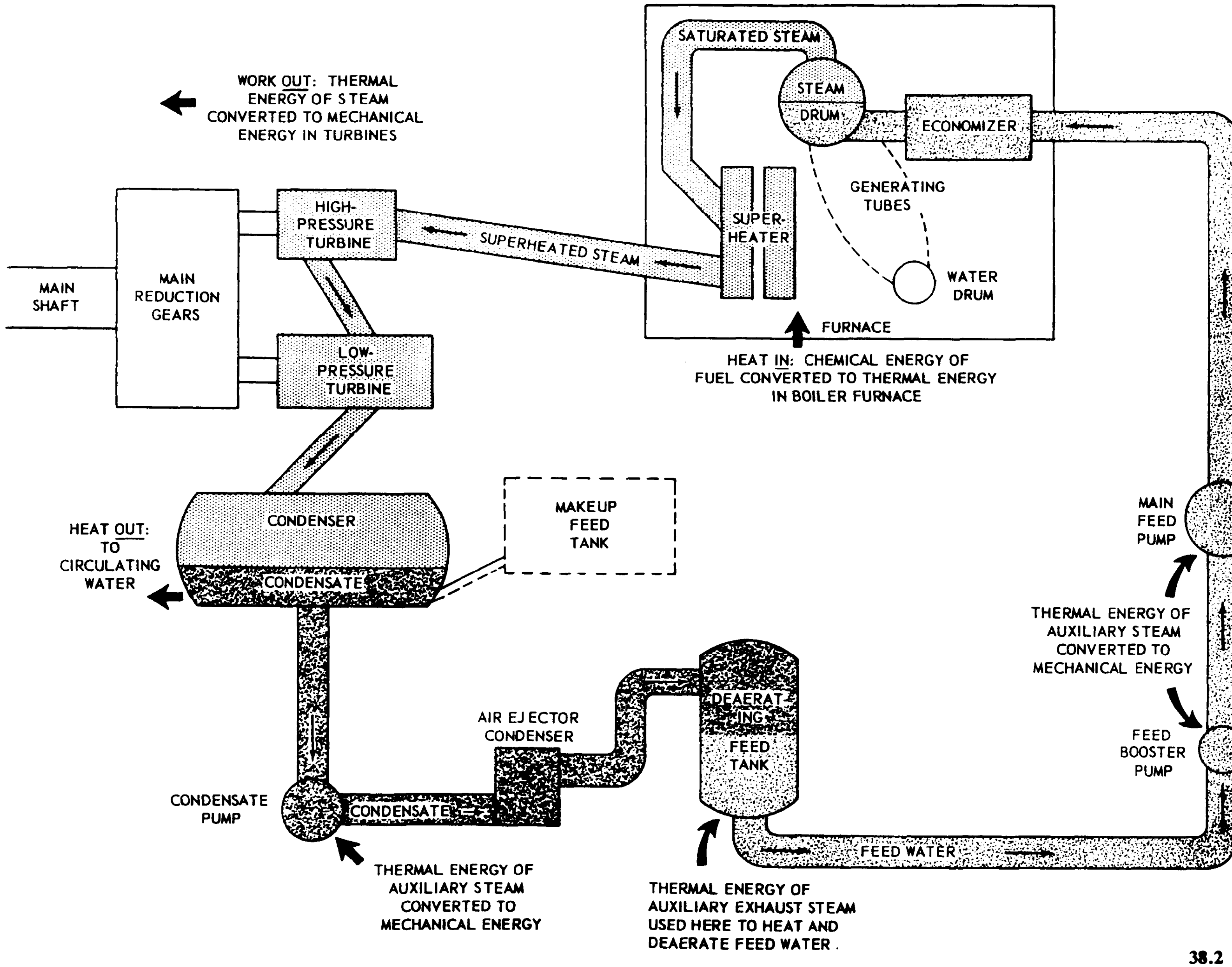

Figure 2-1.—Energy relationships in the basic propulsion cycle.

rock, open the gate of the dam, or open the turbine throttle valve in the examples above, something will move. The rock will fall, the water will flow, and the steam will jet through the turbine's nozzle valves. Thus, the potential energy of the rock, the water, and the steam is converted into kinetic energy.

WORK AND POWER

Work is simply moving an object through a resisting force. The unit of measure for work is the foot-pound (ft-lb).

Power is an amount of work done over a period of time. The most common unit of power is the HORSEPOWER. One horsepower is equivalent to 550 ft-lb per second, or 33,000 ft-lb per minute.

One important factor involving ship propulsion is the relationship between the speed of the ship and the power that the plant must produce to attain that speed.

To understand this relationship, look at figure 2-2. Look at the percentage of horsepower required to run at 40 percent speed; about 7 percent power is required. Now, double the speed to 80 percent and look at the percentage of horsepower required; it has increased to 50 percent. You can see that doubling the speed causes the required power to increase a lot more than double.

This relationship is due to the inherent characteristic of a propeller pushing a ship through the water, and it holds true for all propeller-driven ships.

TURBINE THEORY

Generally, two methods are used in turbine design and construction to get the desired results from a turbine. These are the impulse principle and the reaction principle. Both methods convert the thermal energy stored in the steam into useful work, but they differ somewhat in the way they do it.

IMPULSE PRINCIPLE

Let's use a simple experiment to explain the impulse principle. Imagine that you are running a stream of water through a regular garden hose and you direct the stream of water onto the blades of a toy windmill. The windmill wheel begins to spin due to the impulse of the water stream on the blades. If you put your thumb over the end of the hose to get a farther (faster) shooting stream, the wheel will spin faster. You are creating a greater pressure differential between the hose pressure and the atmosphere through which the water must expand as it exits the hose past your thumb. The expansion through the greater pressure differential gives the water stream a greater velocity, which results in the windmill's spinning faster. To state the principle simply: The pressure of the water stream drops from hose pressure to atmospheric pressure, and the resulting increase in velocity of the stream is equal to the decrease in pressure. A greater pressure differential, therefore, will cause a greater velocity increase.

The same principle applies to the operation of an impulse turbine. The thermal energy of steam will be converted into mechanical energy in essentially four steps. The steam in an impulse turbine (1) passes through stationary nozzles,

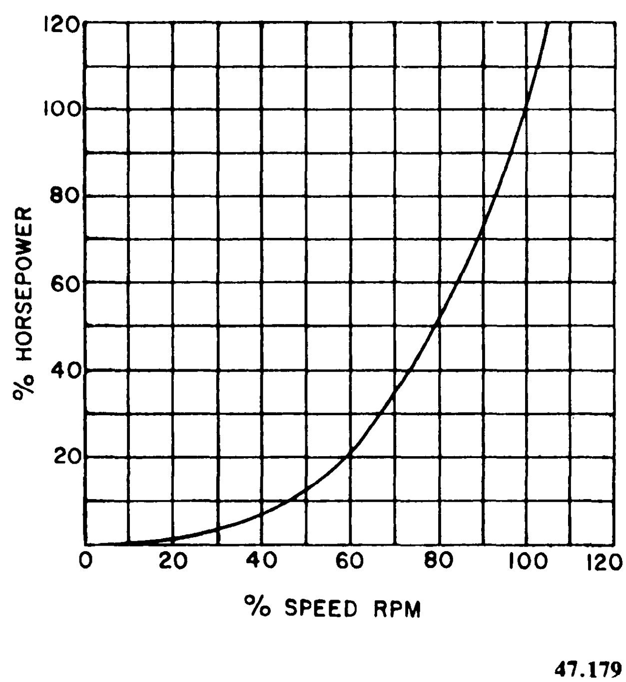

Figure 2-2.—Horsepower-speed cube relationship.

which (2) converts some of the thermal energy contained in the steam (indicated by its pressure and temperature) into kinetic energy (velocity), and (3) directs the steam flow into the blades of the turbine wheel (fig. 2-3). The blades and moving wheel (4) then convert the kinetic energy of the steam into mechanical energy in the form of the actual movement of the turbine wheel and shaft or rotor.

Later in the chapter, we will show how sets of nozzles and wheels can be used in series to utilize the energy of the steam as efficiently as possible. For now, let us see why an impulse turbine uses a certain amount of reactive force as opposed to operating purely on the principle of impulse.

REACTION PRINCIPLE

Newton's third law of motion states that for every action there is an equal but opposite reaction. The recoil of a fired gun is a simple example of this law. If you let loose a pressurized firehose with the nozzle wide open, the velocity of the water leaving the end of the nozzle will cause the nozzle and hose to kick back and fly all over the place.

In a reaction turbine, steam passes through a row of FIXED BLADES which act as nozzles and EXPAND the steam (decrease pressure). This increases the steam's VELOCITY and directs it into the MOVING BLADES, which are almost identical in shape to the fixed blades (fig. 2-4). You can see that until the steam flows into the moving blades, we have only an impulse turbine. However, the moving blades act as nozzles. More thermal energy of the steam will be converted into kinetic energy, and the steam will counteract or kick back onto the moving blades, giving them and the wheel to which they are attached more energy. This is the reason you see a drop (fig. 2-4) in both pressure and velocity across the

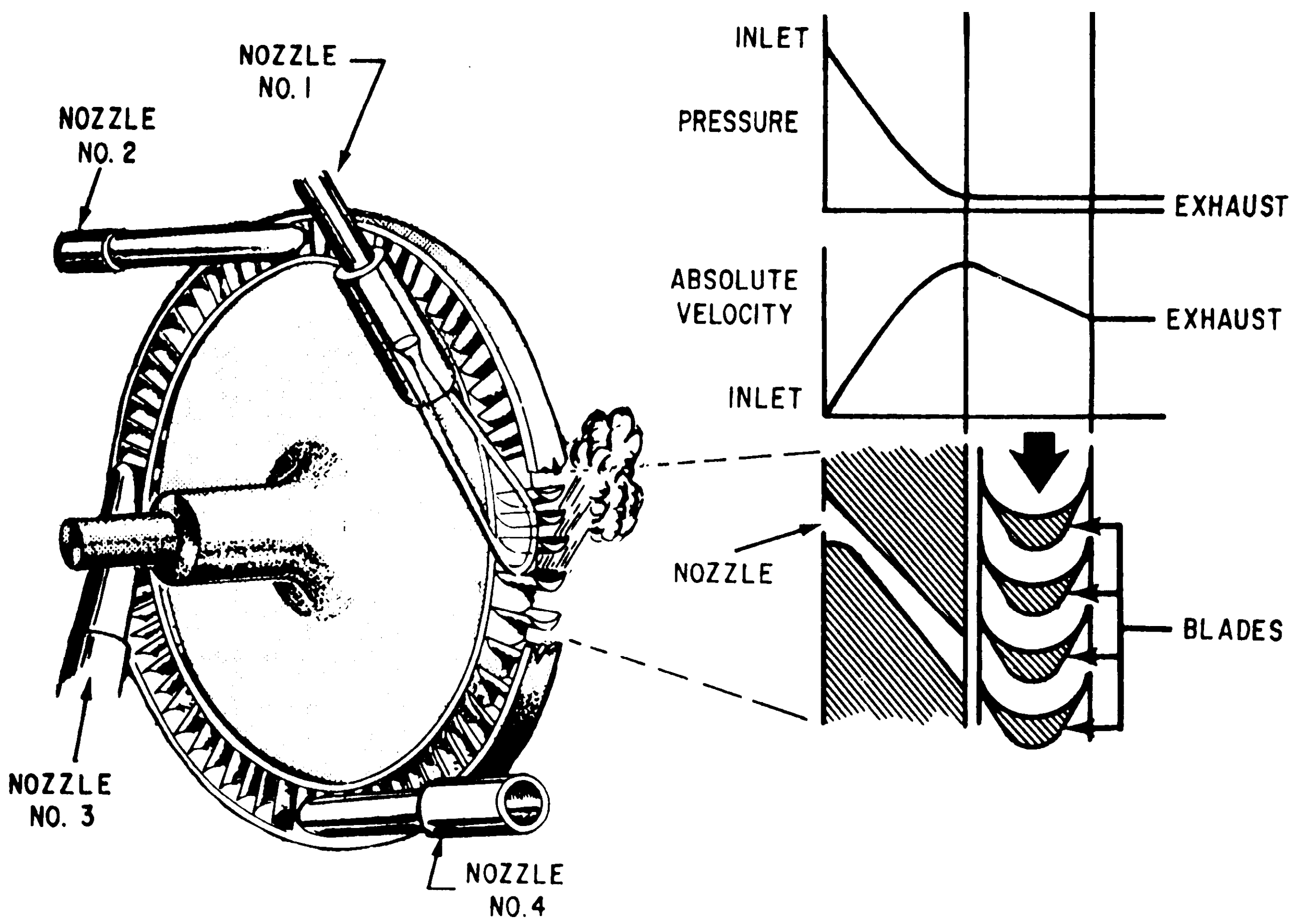

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Figure 2-3.—Pressure-velocity relationship across the nozzles and moving blades of an impulse type turbine.

moving blades of the reaction turbine as opposed to a drop in velocity alone in the impulse turbine. The additional pressure drop across the moving blades provides additional energy (reaction principle) that can be put to work. Consider the principles of both the impulse turbine and the reaction turbine we have described. You can see that by changing the direction of the steam flow in the impulse turbine blades, an additional amount of energy is gained (reaction principle).

Hero's engine, described in *Fireman,* NAVEDTRA 14104 is an absolute reaction turbine. All the thermal energy of the steam that is used is converted into kinetic energy and then into mechanical energy in the moving nozzles. In actual application, however, a pure reaction turbine stage (a row of fixed blades and a row of moving blades) is one in which approximately one-half the thermal energy of the steam is converted into kinetic energy in the fixed blades and approximately one-half is converted in the moving blades.

NOZZLES

Both the impulse and the reaction principles require some device to convert the stored thermal energy of the steam into kinetic energy or velocity. In the reaction turbine you learned that both the fixed and moving blades serve as that device by producing a nozzle effect to create velocity. In the impulse turbine, energy conversion takes place only when the steam passes through the nozzles. The steam passes through the nozzles from a high-pressure area to a lower pressure area, thereby giving high velocity to the steam.

Nozzles come in many different shapes. They are designed for various applications although they are all similar in principle. Figure 2-5 shows a simple convergent nozzle. A convergent nozzle works fine in principle, but it is not very practical in most high-pressure applications because the steam exiting the nozzle into the low-pressure area tends to expand in all directions and is very turbulent. It is difficult to direct the flow of the steam efficiently. To control this turbulence, a section is added to the nozzle to allow the steam to emerge from the nozzle in a smooth stream. The area of the nozzle is gradually increased past the throat to form a DIVERGENT SECTION OF THE NOZZLE. Figure 2-6 shows a convergent-divergent nozzle.

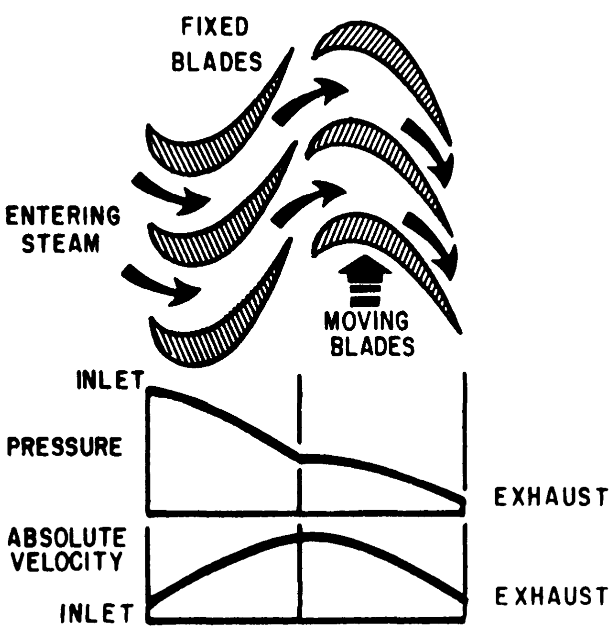

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Figure 2-4.—Pressure-velocity relationship across reaction blading.

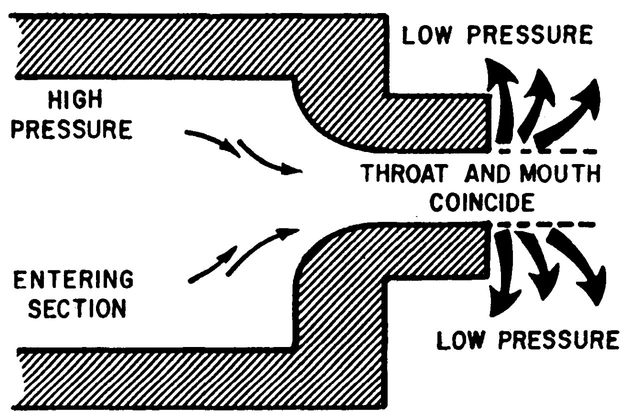

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Figure 2-5.—Convergent nozzle.

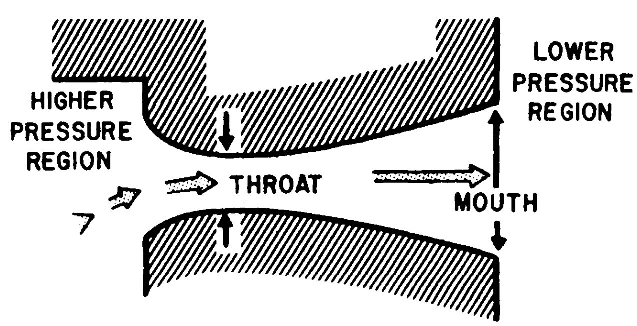

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Figure 2-6.—Convergent-divergent nozzle.

TURBINE CLASSIFICATION

Thus far we have classified turbines into two general groups-impulse turbines and reaction turbines-depending on the method used to cause the steam to do useful work. Turbines may be further classified according to the following:

1. Type and arrangement of staging
2. Direction of steam flow
3. Repetition of steam flow
4. Division of steam flow

A turbine may also be classified as to whether it is a condensing unit (exhausts to a condenser at a pressure below atmospheric pressure) or a noncondensing unit (exhausts to another system such as the auxiliary exhaust steam system at a pressure above atmospheric pressure).

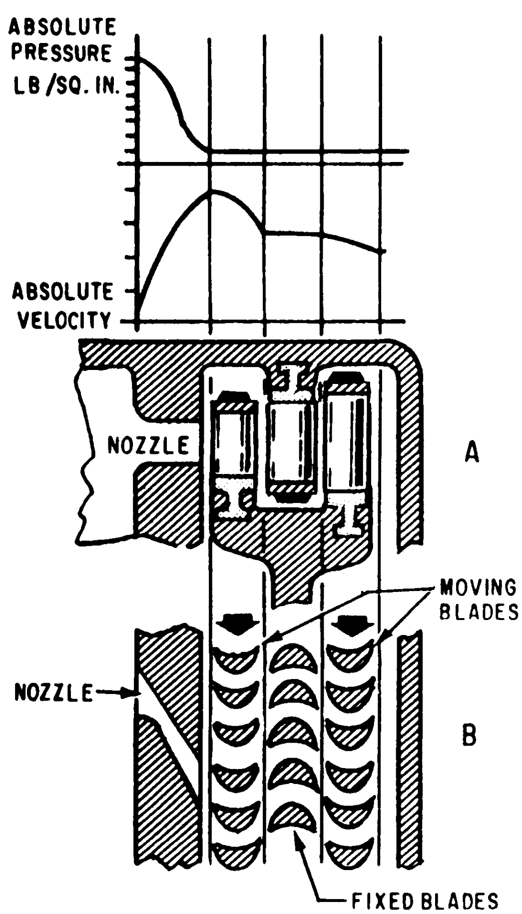

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Figure 2-7.—Pressure-velocity relationships in a velocity-compounded impulse turbine.

STAGING ARRANGEMENTS

An IMPULSE turbine STAGE is one set of nozzles and the succeeding row or rows of either fixed or moving blades. Fixed blades in an impulse turbine do nothing more than redirect the steam flow from one row of moving blades to the next. A simple impulse stage (one set of nozzles and one row of moving blades) is commonly referred to as a RATEAU stage.

A REACTION turbine STAGE is one row of fixed blades and a succeeding row of moving blades. From these descriptions you can see one important difference between an impulse and a reaction stage: An impulse stage has only one pressure drop, since a pressure drop will occur only in a nozzle; whereas, a reaction stage has two pressure drops.

To efficiently utilize the energy of the steam, a turbine must normally have blading and nozzles that will cause more than one pressure drop and/or more than one velocity drop as the steam

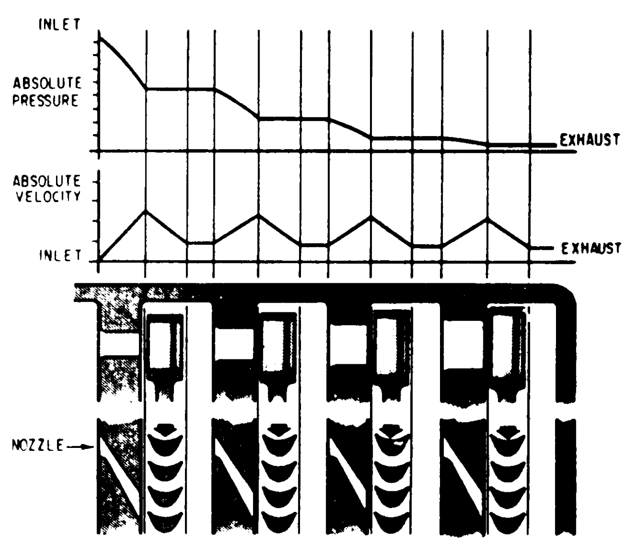

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Figure 2-8.—Pressure-velocity relationships in a pressure-compounded impulse turbine.

passes through it. This is called COMPOUNDING. A turbine that has more than one velocity drop is classified as velocity compounded, and a turbine that has more than one pressure drop is classified as pressure compounded. A combination of pressure and velocity drops is called pressure-velocity compounding.

From our definitions of stages, we can see that an impulse stage may be velocity compounded but is never pressure compounded; and a reaction stage is always pressure compounded but is never velocity compounded. This applies only to stages and NOT to the turbines. Turbines may be designed and constructed to incorporate practically any combination of stages. Let's look at some of the combinations.

Velocity-Compounded Impulse Turbine

A velocity drop in an impulse turbine occurs only in the moving blades; therefore, to obtain more than one velocity drop across an impulse turbine, there must be more than one row of moving blades. (Velocity compounding can also be achieved when only one row of moving blades is used if the steam is directed in such a way that it passes through the blades more than once. This point will be taken up in greater detail in the discussion on the direction of steam flow.) Figure 2-7 shows a velocity-compounded impulse turbine with two rows of moving blades. (NOTE: Two sectional views of the same blading are shown.) This type of arrangement is called a Curtis stage, and, of course, two velocity drops occur across it.

Pressure-Compounded Impulse Turbine

Another method of increasing the efficiency of an impulse turbine is to put two or more Rateau (simple impulse) stages in a row. This combination produces a pressure-compounded impulse turbine which has as many pressure drops as it has stages. Figure 2-8 shows a pressure-compounded impulse turbine.

Pressure-Velocity-Compounded Impulse Turbine

A turbine which has one velocity-compounded (Curtis) stage followed by a series of simple-impulse (Rateau) stages is a pressure-velocity-compounded turbine. This type of turbine (fig. 2-9) is commonly used for ship propulsion.

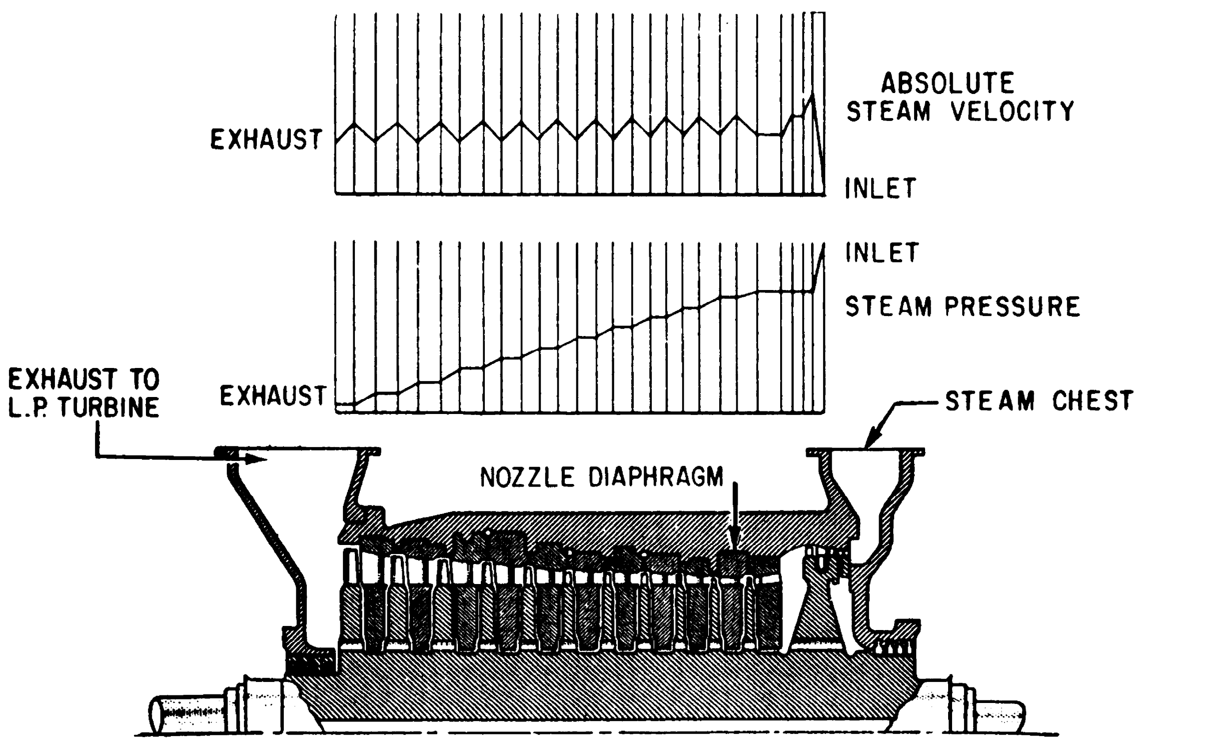

Figure 2-9.—Pressure-velocity-compounded impulse turbine showing velocity and pressure relationships.

(**NOTE:** Only the upper half of the rotor and blading is shown.)

Pressure-Compounded Reaction Turbine

All reaction turbines are pressure compounded. This means they are arranged so the pressure drop across the turbine from inlet to exhaust is divided into many steps by means of alternate rows of fixed and moving blades (figure 2-10). (Note the small curved arrows between the blades and casing and the stator blades and rotor. The arrows indicate that a small amount of steam leaks around these areas and does no work.)

Impulse and Reaction Combination Turbine

Another type of turbine is a combination impulse and reaction type (figure 2-11). This turbine design uses a velocity-compounded impulse (Curtis) stage at the high-pressure end of the turbine followed by reaction blading. The impulse blading causes a large pressure and temperature drop at the beginning, using a large amount of thermal energy. The reaction part of the turbine is more efficient at the lower steam pressure existing at the low-pressure end of the turbine. Therefore, you can see that for certain applications this would be a highly efficient machine with the advantages of both impulse and

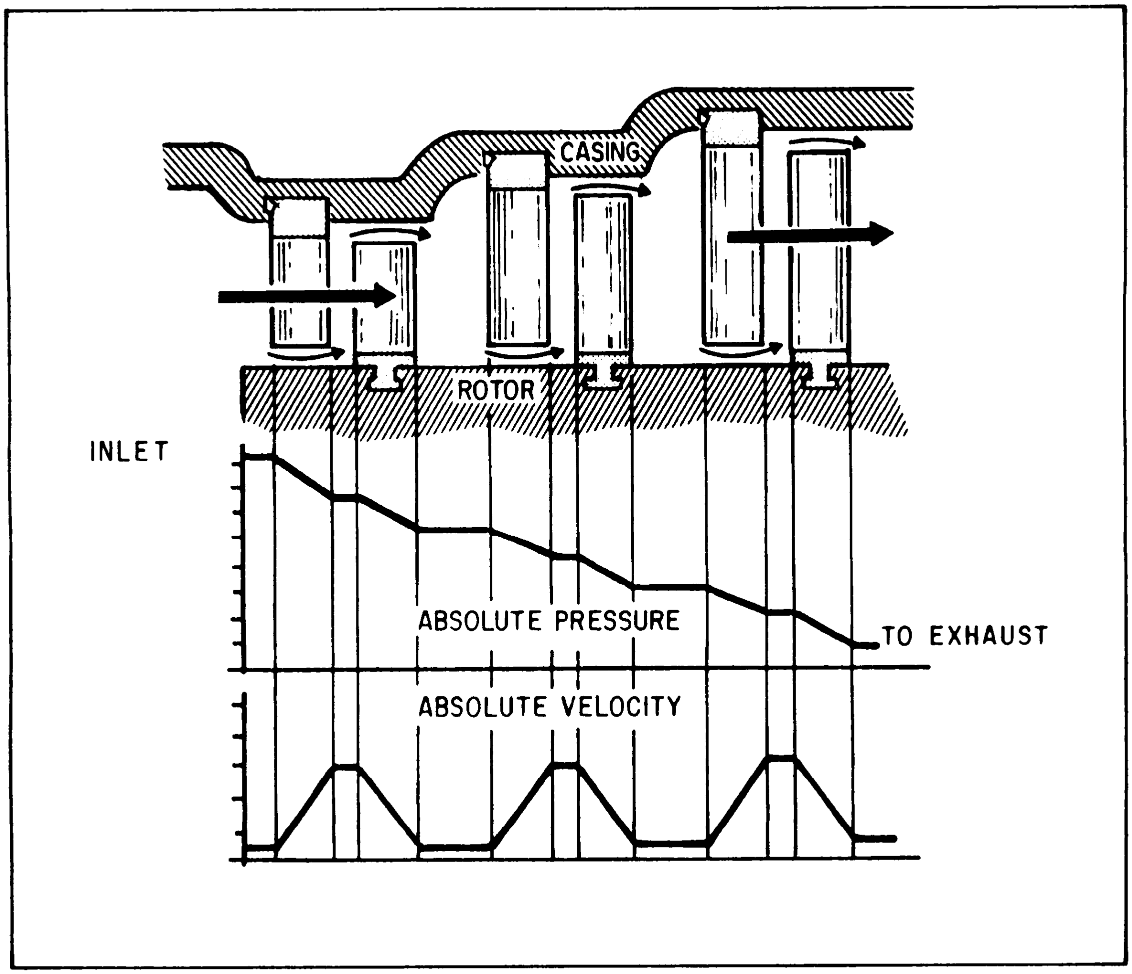

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Figure 2-10.—Diagrammatic arrangement of reaction blading showing velocity and pressure relationships.

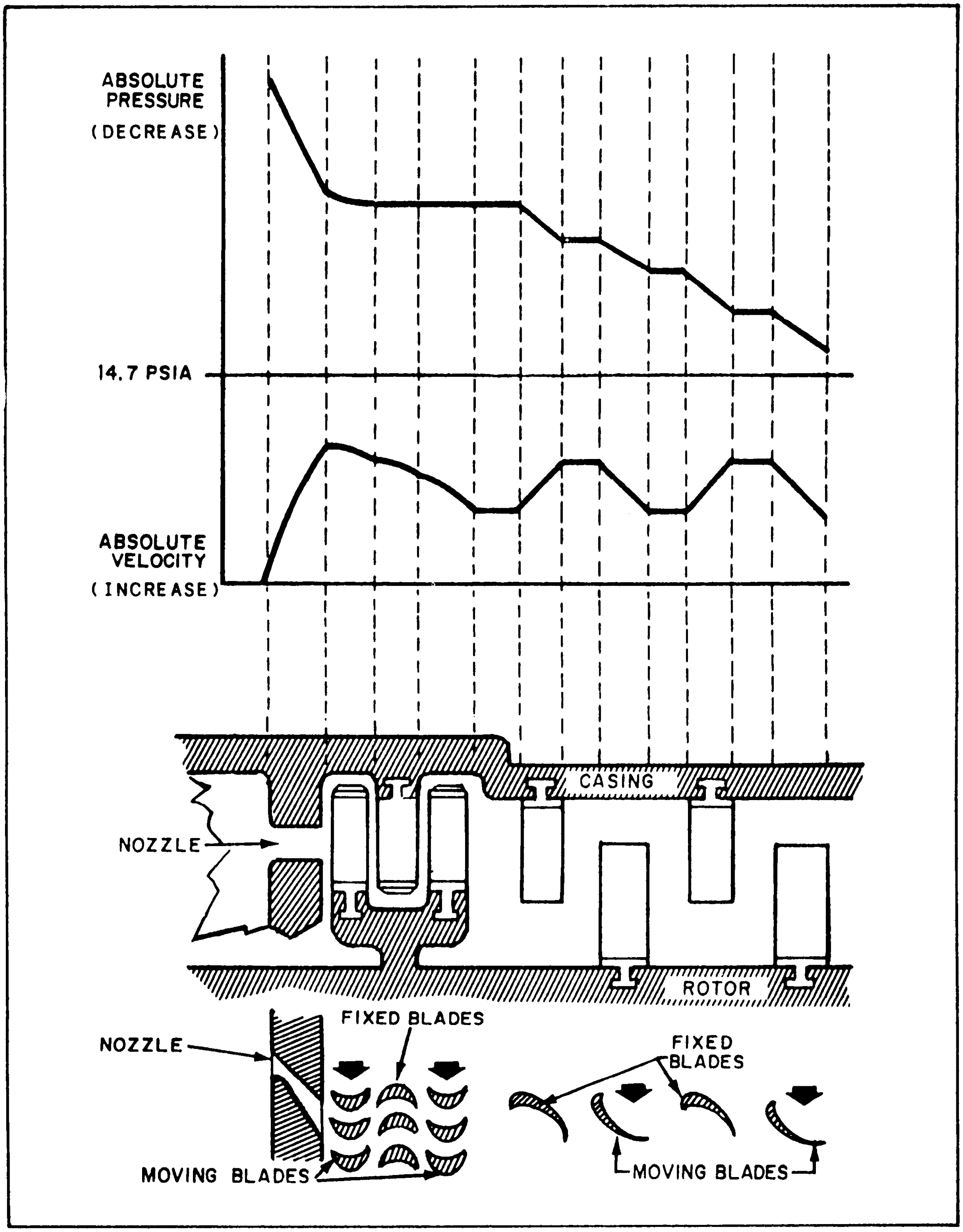

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Figure 2-11.—Diagrammatic arrangement of combination impulse and reaction turbine showing pressure velocity relationships.

reaction blading. Figure 2-12 illustrates a type of the combination turbine commonly called a modified Parson's turbine.

DIRECTION OF STEAM FLOW

There are three different ways in which steam can flow through a turbine: axial flow, helical flow, and radial flow.

Axial Flow

Most turbines are the axial-flow type. This means the flow of steam is in a direction that is almost parallel to the axis of the turbine shaft. Figure 2-12 illustrates an axial-flow turbine.

Helical Flow

The steam in a helical-flow turbine flows at a tangent (angle) to the rotor. This tangential flow is directed into buckets fixed onto the turbine wheel and then back out of the buckets into stationary reversing chambers to be directed back into the buckets. The process is repeated several times. Figure 2-13 illustrates a helical-flow turbine. This turbine may be used to drive main and auxiliary equipment such as pumps and forced draft blowers. This turbine is efficient where a wide speed range is required.

Radial Flow

In the radial-flow turbine, the flow of steam is directed either toward or away from the rotor. This turbine may be used for driving some small auxiliary equipment.

REPETITION OF STEAM FLOW

Most turbines are of the single-entry type, since the steam only passes once through the blades. All multistage turbines are of the single-entry type. However, some turbines, such as the

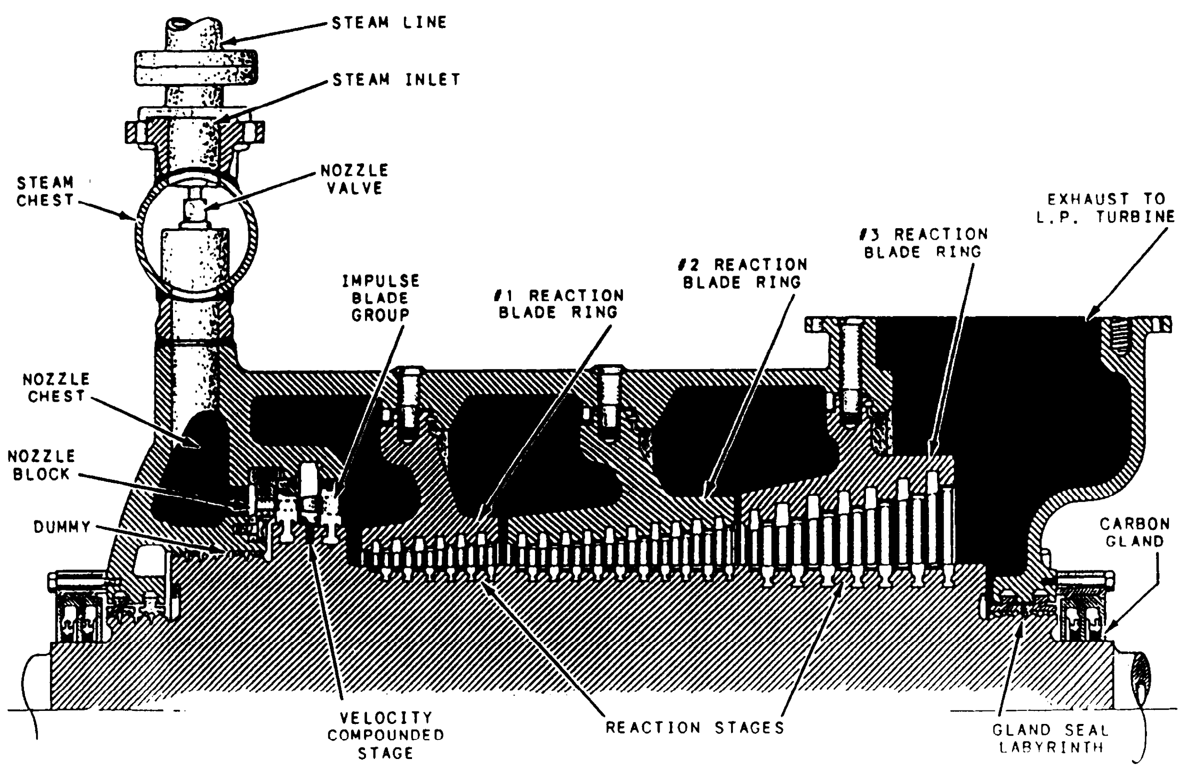

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Figure 2-12.—Combination impulse and reaction turbine.

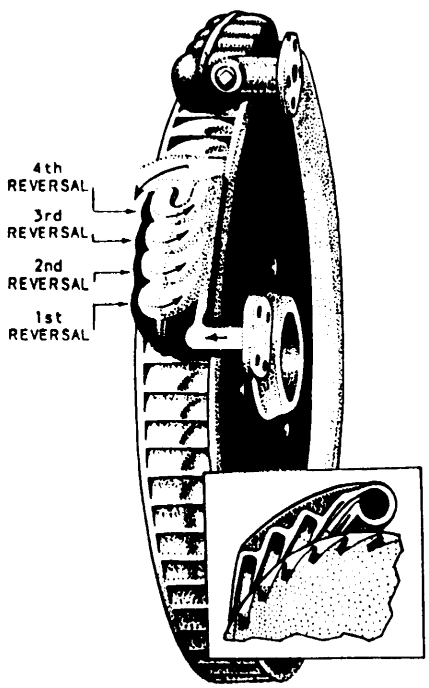

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Figure 2-13.—Cutaway view of steam path in a helical flow turbine.

helical-flow, are the reentry type. In a reentry turbine, the steam is passed more than once through the blades.

DIVISION OF STEAM FLOW

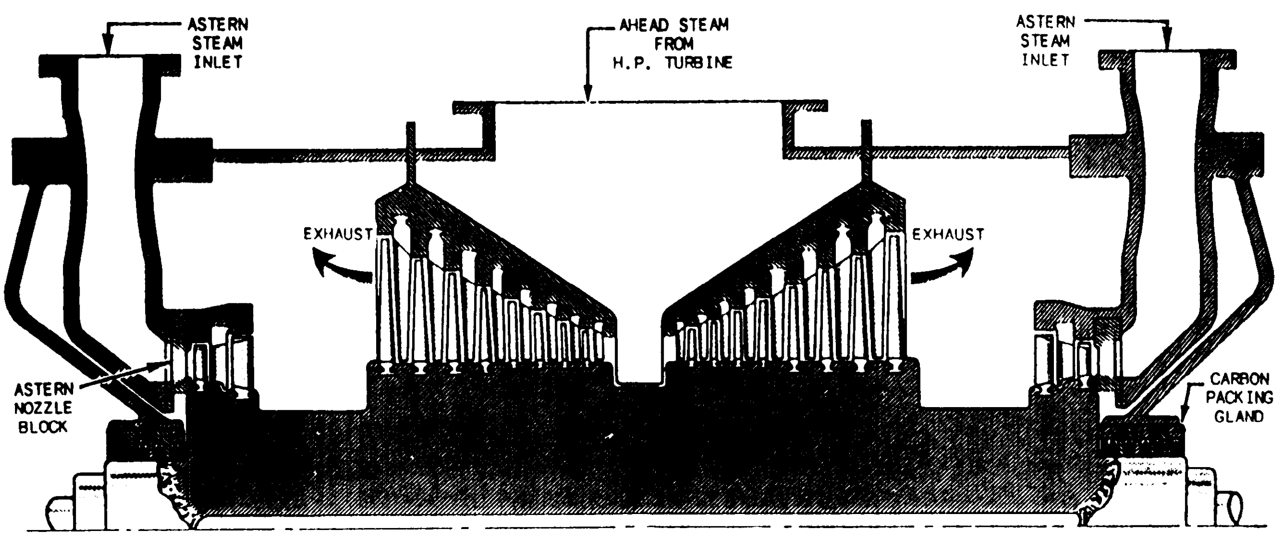
If the steam in a turbine flows in only one direction, it is classified as a single-flow unit. Most turbines are of this type.

Another commonly used method is the double-flow design. Steam from the high-pressure (HP) turbine enters at the center of the low-pressure (LP) turbine and flows outward in both directions through two identical sets of turbine staging. Figure 2-14 shows the steam flow through a double-axial flow, low-pressure turbine.

The double-flow turbine has very little, if any, axial thrust and is quite a bit smaller than a single-flow turbine designed for the same capacity and low-exhaust pressure. The double-flow turbine is generally of the reaction type, because the single-flow reaction-type turbine develops considerable axial thrust from the pressure drop(s) across the moving blades.

TURBINE COMPONENTS AND CONSTRUCTION

Now that you are familiar with basic turbine theory, we will briefly discuss turbine



47.8
Figure 2-14.—Low-pressure double-axial flow reaction turbine.

components, parts, and construction. This information is supplementary to information in *Fireman,* NAVEDTRA 14104.

TURBINE SUPPORT

A turbine must be securely attached to the ship. However, it must also be free to expand and contract as necessary to prevent severe damage due to distortion caused by the large temperature and torsional changes that occur in the turbine. Usually, it is undesirable to allow a turbine to expand in the aft direction, because of turbine-reduction gear alignments, so the aft end of a turbine is secured rigidly to the structure.

There are two basic methods and designs that meet both the rigidity and expansion requirements of turbine foundations.

1. The forward end of the turbine may be mounted with a flexible I-beam, as shown in figure 2-15. The I-beam will flex either fore or aft as the turbine expands or contracts.
2. Elongated bolt holes or grooved sliding seats may be used instead of the I-beam arrangement to do the same job. Steam lines connected to the turbine will normally be curved or looped in some way to allow for expansion of the steam line and prevent excessive strain between the steam line connection and the turbine. The strain could have serious consequences.

There are modifications to these two basic methods. In many ships, the main condenser is supported by the low-pressure turbine, which is rigidly mounted on beams that form integral part of the hull structure. In other ships, the low-pressure turbine may be mounted on the condenser, which, in turn, forms an integral part of the hull. In general, the expansion arrangement of the low-pressure turbine is similar to that of the high-pressure turbine except that the flexible forward support is seldom used. Instead, some arrangements use keys at the center of the low-pressure casing as the fixed point, with expansions occurring equally in the forward and aft directions from the keys. Some arrangements fix the after end of the casing by fitted bolts, while the forward end uses clearance bolts to allow for

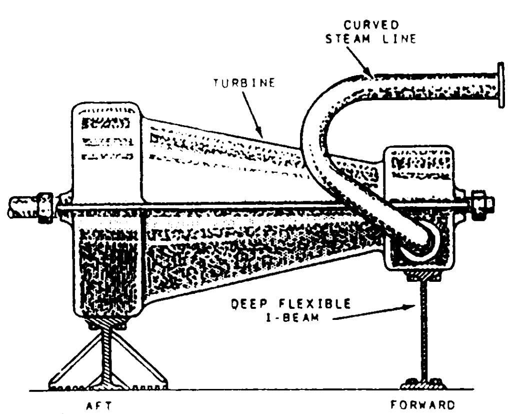


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Figure 2-15.—Turbine foundation, showing flexible I-beam.

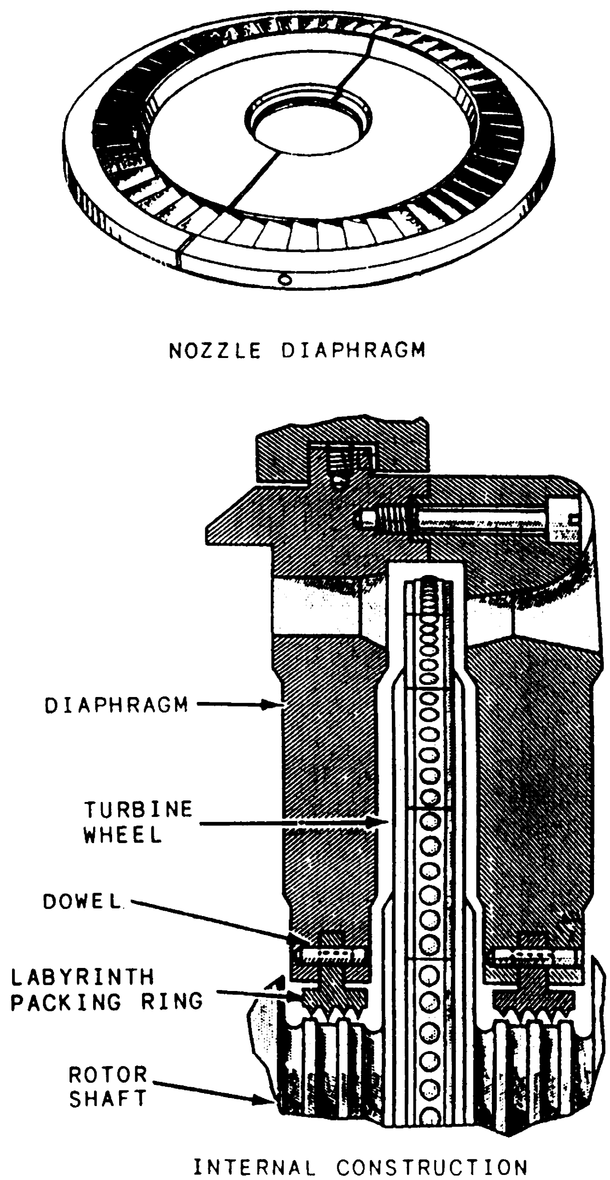

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Figure 2-16.—Turbine nozzle diaphragms. A. Impulse nozzles and nozzle diaphragms. B. Internal construction.

the expansion motion. Another arrangement uses fitted bolts at each end; these bolts fix the ends to flexible twin inlet necks on the condenser.

NOZZLE DIAPHRAGMS

Nozzle diaphragms, illustrated in figure 2-16, are installed in front of the rotating blades of each stage of a pressure-compounded impulse turbine. The diaphragms contain the nozzles which admit steam to the rotating blades of each stage in much the same way as the nozzle groups of the first stage. Some nozzle diaphragms admit steam in an arc of a circle and are called PARTIAL ADMISSION DIAPHRAGMS; other nozzle diaphragms have nozzles extending around the entire circle of blades and are called FULL ADMISSION DIAPHRAGMS. Because of the pressure drop that exists across each diaphragm, a labyrinth packing ring, similar to the shaft gland packing, is placed in a groove in the inner periphery of the diaphragm to minimize the leakage of steam across the diaphragm and along the rotor. Any leakage through the inner periphery of the diaphragm will reduce the amount of the steam thermal energy being converted to mechanical energy and, therefore, reduce the work developed by the stage. Figure 2-16 shows the placement of these rings, which are installed in sections and are spring-backed to hold them together and in place.

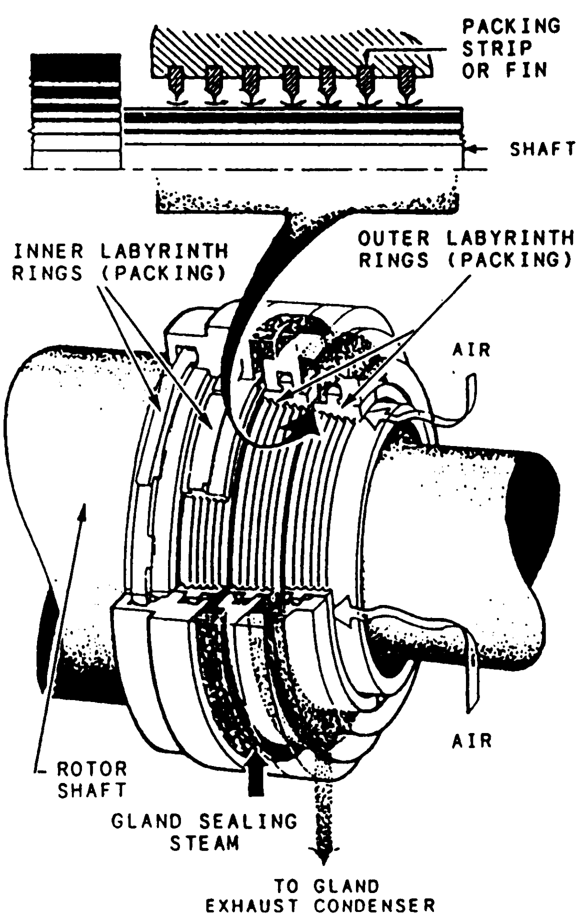

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Figure 2-17.—Turbine gland.

SHAFT PACKING GLANDS

When the pressure inside the turbine casing is greater than atmospheric pressure, shaft packing glands are used to prevent the escape of steam from the casing. The packing glands also help to prevent air from entering the turbine when pressure within the casing is below atmospheric pressure.

In general, three types of shaft glands are used on naval turbines: labyrinth packing glands, carbon packing glands, or a combination of both labyrinth and carbon packing glands. The labyrinth packing gland is the most widely used method of sealing a turbine shaft in naval turbines; therefore, this is the method discussed here.

LABYRINTH PACKING is used in the glands and interstages of modern steam turbines. Labyrinth packing consists of machined packing strips of fins mounted on the casing surrounding the shaft to make a very small clearance between the shaft and the strip. Figure 2-17 shows a labyrinth packing gland. The principle of labyrinth packing seals is that as steam leaks through the very narrow spaces between the packing strips and the shaft, the steam pressure drops. As the steam passes from one packing strip to the next, its pressure is gradually reduced and any velocity that it might gain through the nozzling effect is lost by the action of the steam as it ricochets

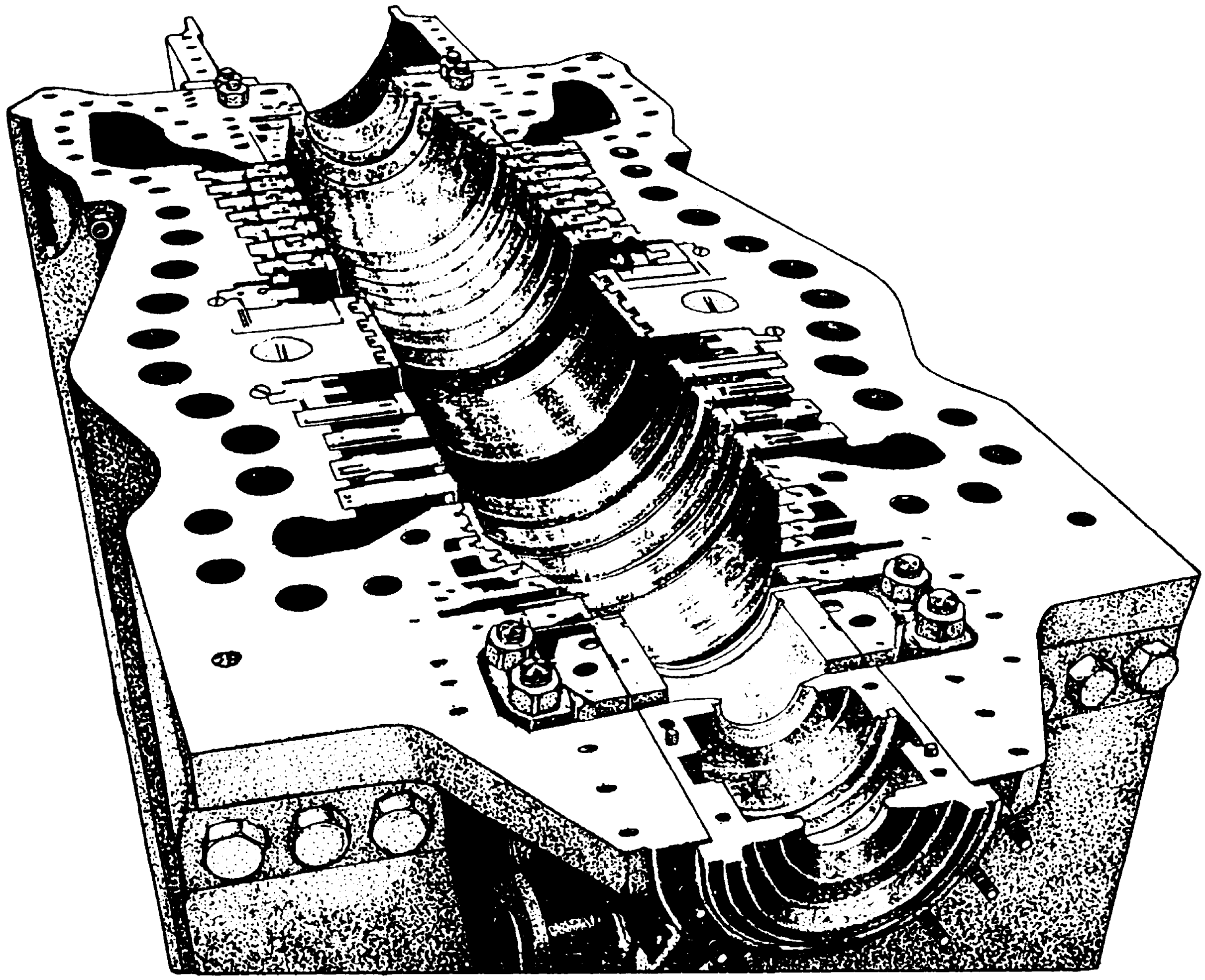

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Figure 2-18.—HP-IP turbine cylinder base with lower sections of seals and diaphragms installed, viewed from thrust end.

back and forth in the gland. Figure 2-18 is the lower half casing of a high-pressure, intermediate pressure (HP-IP) turbine showing the interstage and gland packing installed.

Gland Seal

Packing alone will neither stop the flow of steam from the turbine nor prevent the flow of air into the turbine. Gland sealing steam is used to prevent the entrance of outside air into the turbine, which would reduce or destroy the vacuum in the main condenser. Figure 2-17 shows how gland sealing steam of approximately 2 psig (17 psi absolute) is led into a space between two sets of gland packing. (In older ships, steam is supplied from the auxiliary exhaust steam line through a stop valve.) Two weight-loaded valves operate automatically to maintain a pressure of 1/2 to 2 psig on the glands.

During periods of warming-up, low-speed operation, backdown, and securing, these weight-loaded valves are open. When the turbine is speeded up and the steam flowing from the labyrinth gland of the high-pressure turbine reaches 2 psig, the valve supplying the high-pressure turbine closes automatically, admitting no more gland steam from the auxiliary exhaust line. The high-pressure turbine gland is then supplying enough steam leakage to seal the low-pressure glands. As the turbine speed is increased still further and the pressure in the sealing system rises to approximately 2 1/2 psig, the excess steam is led, by a manually operated or an automatically operated valve, either to the main condenser or to the low-pressure turbine (depending on the ship).

The leak-off connections are linked to the GLAND LEAK-OFF PIPING, which collects and condenses the steam that leaks from the gland, thus preventing the escape and loss of steam to the atmosphere.

A fan-type GLAND SEAL EXHAUSTER puts a slight vacuum on the leak-off piping. The vacuum draws the leak-off steam through a GLAND EXHAUST CONDENSER where the steam is condensed and returned to the feed system.

Most ships use two different methods to supply gland seal to the propulsion and generator turbines. Both methods are basically the same as previously described in that steam is supplied to the glands when the pressure drops to a point that it is needed, and excess steam is relieved from the system when the pressure increases too high.

Steam from the 150 psig steam system is admitted to the gland sealing system through an air-operated supply valve. If the pressure in the system becomes excessive, as in high-power operation, excess steam is "dumped" to the condenser through the LP turbine. This is done by means of another air-operated valve called the excess valve or excess steam unloading valve. The supply and excess valves both have pilot actuators which sense the pressure in the gland seal steam piping. Figure 2-19 shows the valves in greater detail. This system may be used on main propulsion units or steam turbine generators. You will find more detailed information on the actual operation of air-operated valves in chapter 10 of this manual.

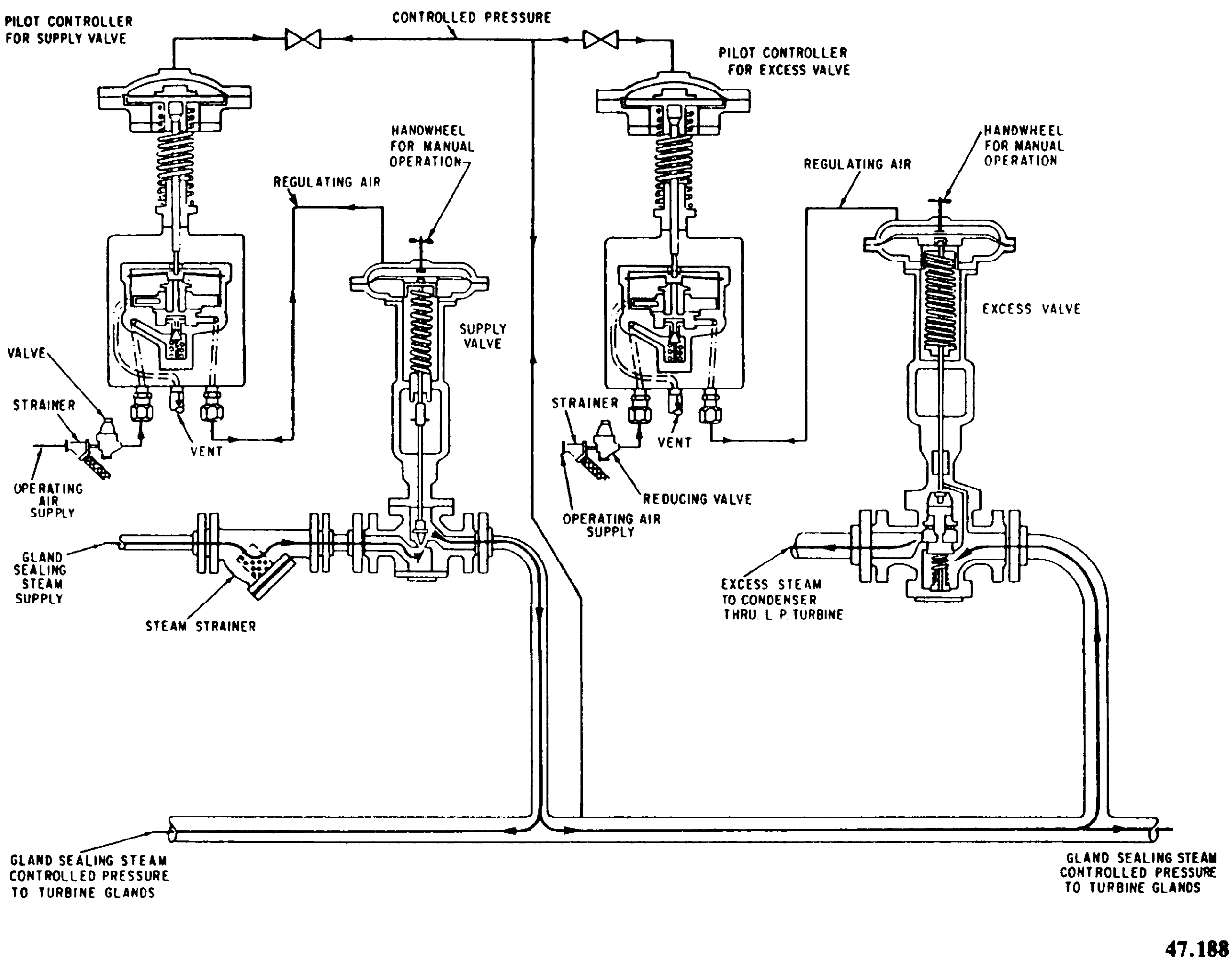

Figure 2-19.—Gland seal regulator mechanism.

Another type of gland seal supply and unloading regulator, the hydraulic type (fig. 2-20), senses the gland seal steam pressure in a bellows assembly and uses lube oil pressure and spring pressure to control the opening and closing of the supply and exhaust (unloading) valves. Both valves are located in a single manifold and are mechanically operated through a lever. The lever is operated by a piston which uses spring pressure to travel downward (which shuts the exhaust and opens the supply). The piston uses lube oil pressure (through a pilot valve) to travel upward (which shuts the supply and opens the exhaust). A detailed explanation of the internal working of the valve is in chapter 10 of this manual. This type of regulator may be found in either main propulsion units or steam turbine generators.

Gland exhaust from main propulsion units is directed to a gland exhaust condenser or the air ejector condenser, and from steam turbine generators to the gland exhaust section of the auxiliary air ejector condenser. In both cases, the steam is condensed and returned to the feed system. Air and other noncondensable gases are discharged to the atmosphere.

TURBINE MATERIALS

The materials used to construct turbines will vary somewhat depending on the steam and power conditons for which the turbine is designed.

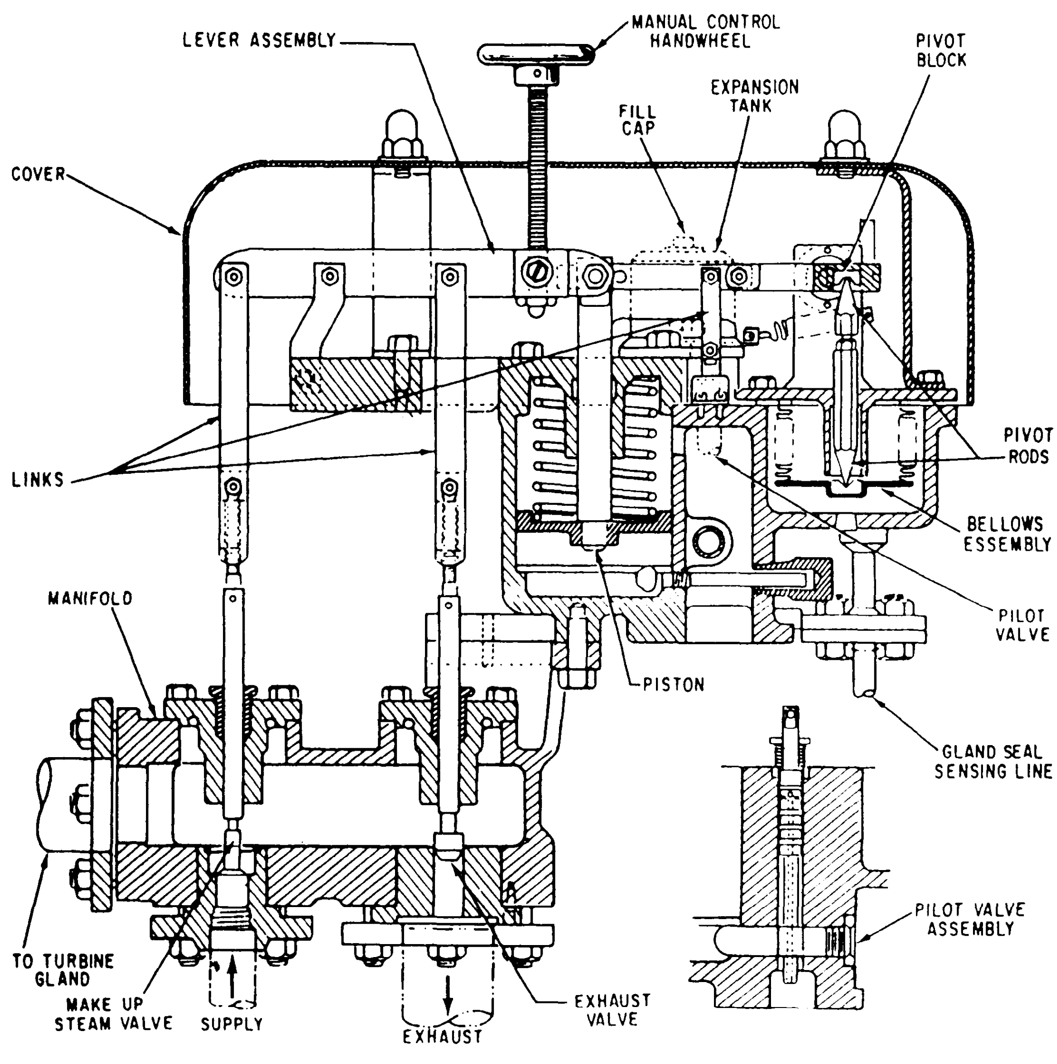

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Figure 2-20.—Hydraulic type turbine gland seal regulator.

Turbine casings are generally made of cast carbon steel for nonsuperheated steam applications. Superheated applications use casings made of carbon molybdenum steel.

Turbine rotors (forged wheels and shaft) are made of carbon steel for low-temperature steam (less than 650°F). High-temperature steam designs use carbon molybdenum or some other creep-resistant alloy.

The turbine blades are generally constructed of a corrosion-resistant alloy for a hard, erosion and corrossion-resistant blade. The blades are attached to the wheels and casings of a turbine by several methods. Some of these methods are shown in figure 2-21. The straight circumferential dovetail (view A) is used primarily to secure rotor blades. The inverted circumferential dovetail (view B) is used to secure blading in most impulse turbines. The side-locking key piece method (view C) is used only on casing blades and consists of driving a locking key piece between the blade root and a groove in the casing. The sawtooth serration method (view D) is used for both rotor and casing

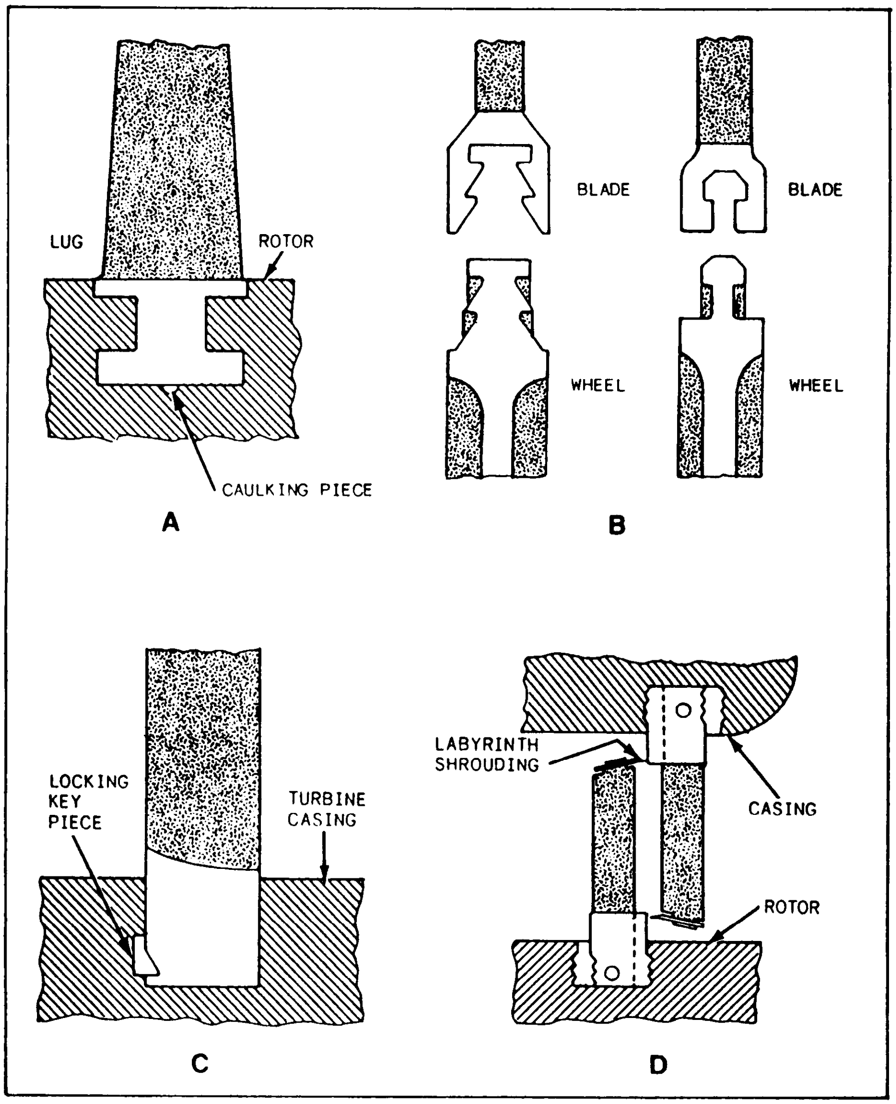

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Figure 2-21.—Methods of securing turbine blades: A. Straight circumferential dovetail. B. Inverted circumferential dovetail. C. Side-locking key piece. D. Sawtooth serration.

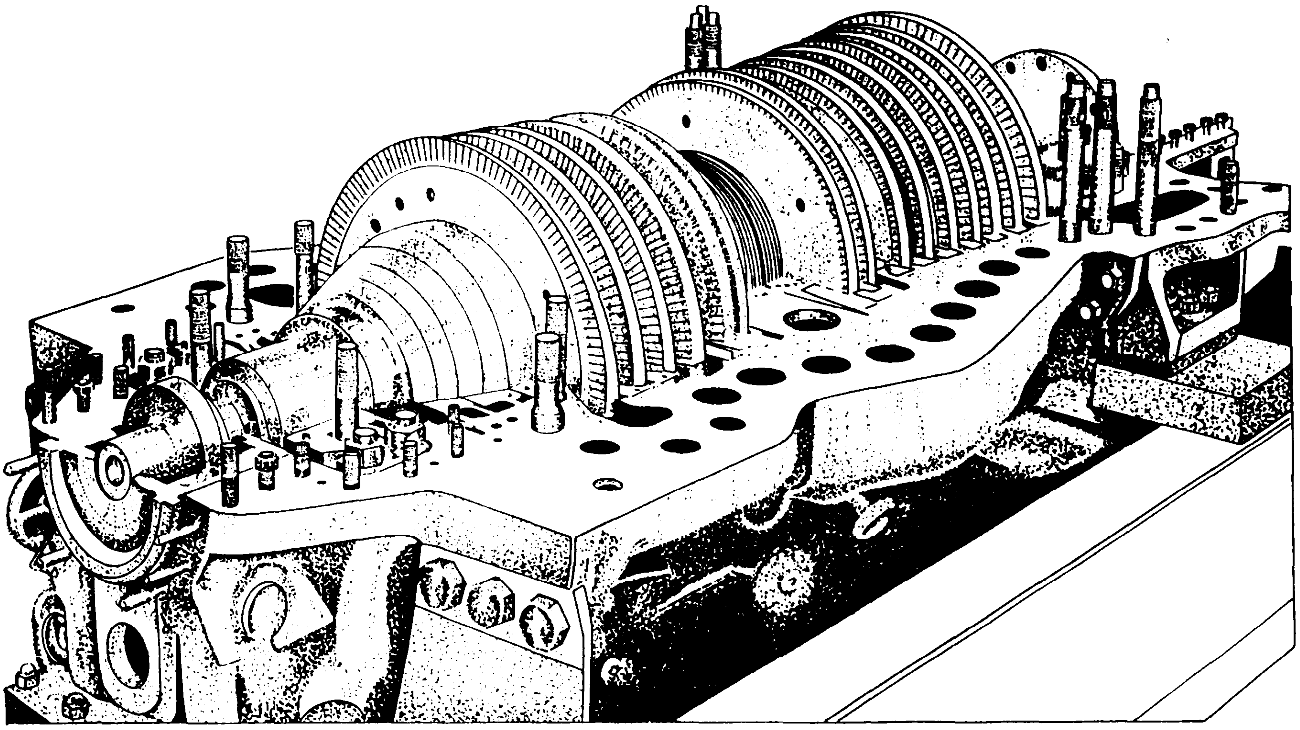

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Figure 2-22.—Turbine cylinder base with rotor installed, viewed from thrust end.

blades. Figures 2-22 and 2-23 show the lower halves of an HP-IP and low-pressure turbine casing with the rotor installed.

Shrouding

Shrouding is a thin metal strip covering the ends of the turbine blades (shown in fig. 2-23). It is installed to reduce vibration stress, which will cause turbine damage. The shrouding is installed by fitting it over tenons located on the end of each blade; it is then riveted in place.

TURBINE CONTROL

Turbines operate at different speeds. Therefore, they must have a method of steam inlet control to allow fairly small changes of turbine speed. A system of nozzle control valves performs this function. Although the turbine speed control system aboard your ship may differ from those described here, you should understand the basic principles by studying the following discussion.

NOZZLE CONTROL VALVES

One type of nozzle control valve system is shown in figure 2-24. It controls speed by varying the number of nozzle valves that are opened. A lifting beam mechanism, drilled with holes, fits over the nozzle valve stems. These stems are of varying lengths and are fitted with shoulders or "buttons" at the upper ends. The nozzle valves are commonly referred to as POPPETS. (A poppet valve has a disc that moves axially, or parallel, with the flow of fluid through the valve.) When the beam is lowered, all valves rest upon their seats. The individual poppets are held tightly shut against their seats by steam pressure. The mushroom shape of the poppets gives the steam pressure adequate surface area to "hold down" the valves. When the beam is raised, the valves open in succession; the shorter ones open first, then the longer ones. Several types of valve linkage arrangements are used to change throttle valve handwheel rotary motion into lifting motion to raise and lower the beam.

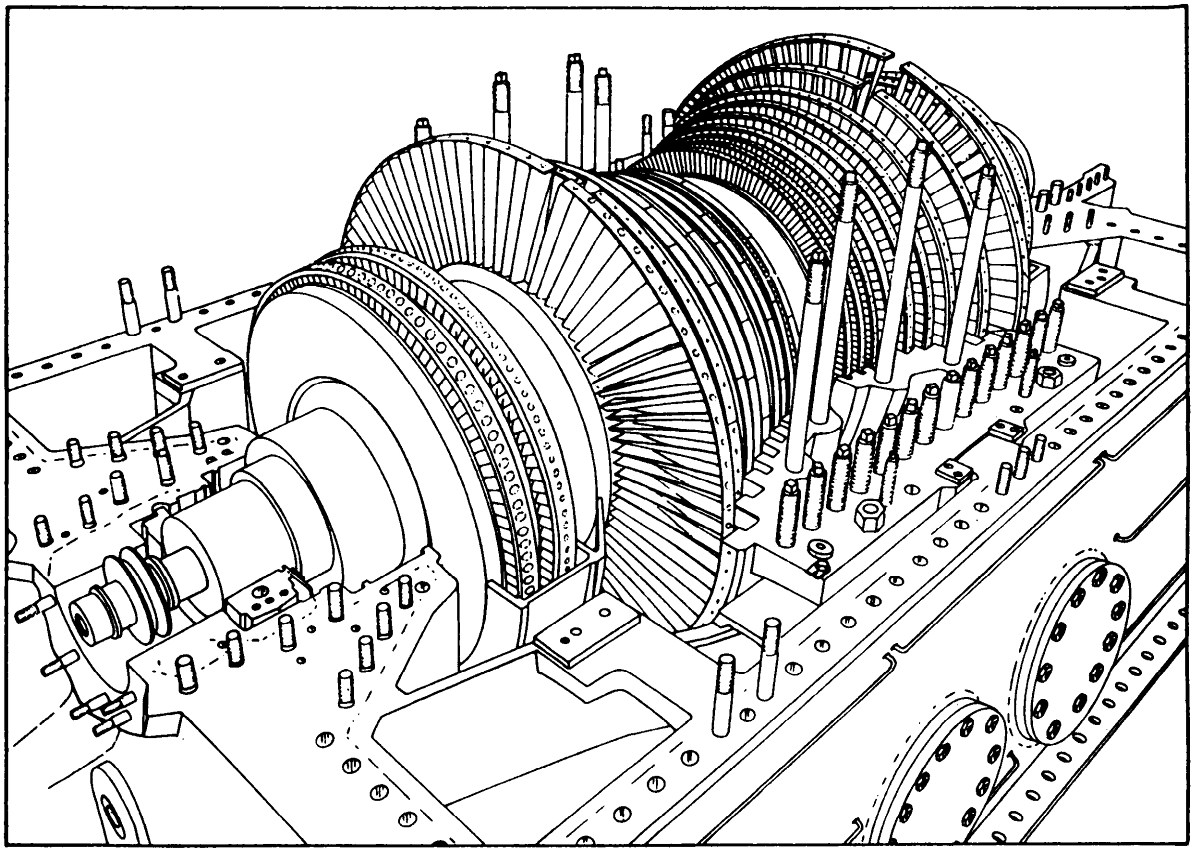

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Figure 2-23.—L. P. turbine cylinder base with rotor installed, viewed from thrust end.

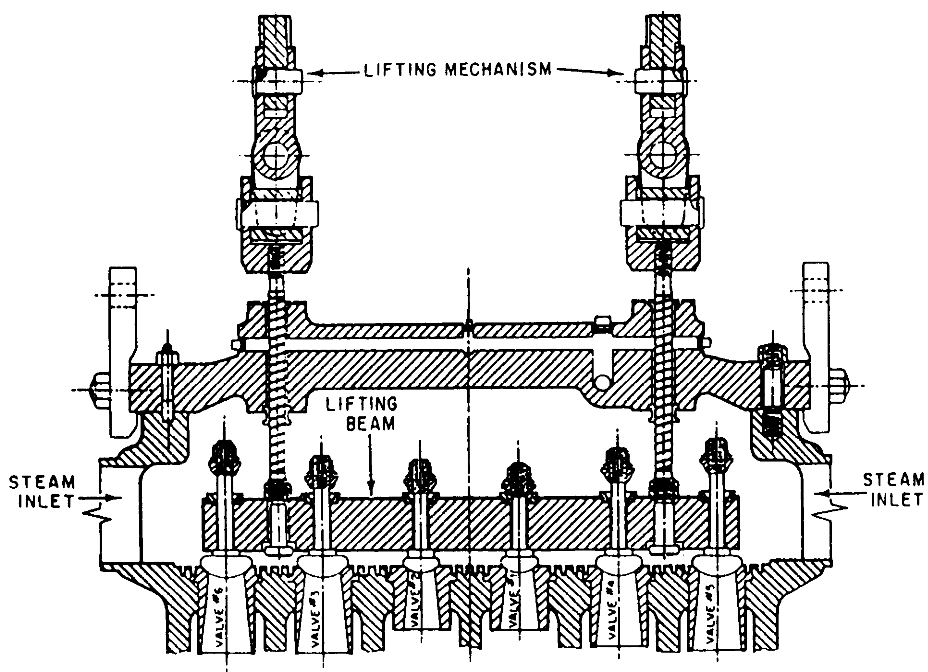

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Figure 2-24.—Arrangement of nozzle control valves.

Another nozzle control valve arrangement is shown in figure 2-25. Five valves are used to admit steam to the high-pressure turbine. The valves are controlled by a camshaft rotated by a throttle handwheel. The camshaft is arranged to open the valves in succession. Valves No. 1 and No. 2 admit steam to the first-stage chest of the turbine. With valves No. 1 and No. 2 fully open, the pressure in the steam chest is approximately equal to line pressure. The first-stage nozzles are passing steam to the first stage at the limit of their capacity. To further increase the power and speed of the turbine, you must increase the amount of steam flowing through the turbine. Valve No. 3 is then opened, admitting steam from the chest through a bypass to the second-stage nozzles. With valve No. 3 fully open, it is necessary to open valve No. 4, which admits steam from the chest through a bypass into the fourth-stage nozzles. With valve No. 4 wide open, the turbine should operate at almost its full power rpm. To get maximum speed and power, valve No. 5 must be opened to admit steam to the sixth-stage nozzles.

In some ships, as the handwheel is rotated, an indicator on the throttle control valve mounting shows which valves are open. Valve No. 1 begins to open as soon as the indicator moves away from the SHUT position. The other valves open at the points indicated as the handwheel is turned counterclockwise. When the indicator reaches the OPEN position, all valves are fully open. Turning the handwheel in the clockwise direction closes the valves in the reverse order.

The cam-operated nozzle valve system may also be used when the bypassing of turbine stages does not occur.

CRUISING ARRANGEMENTS

Every ship has a speed at which the fuel consumption per mile is at a minimum. The most economical speed is based upon the combined fuel consumption per shaft horsepower (shp) per hour of the propulsion engines and the auxiliary machinery. However, a considerable quantity of fuel is required to generate steam used by the auxiliary machinery, even when the ship is stopped. As the speed is increased, there is only a very gradual increase in the amount of fuel consumed (per hour) by the auxiliary machinery. Therefore, as the ship's speed is increased, the percentage of the total fuel consumed by the auxiliary machinery actually decreases. For turbine-driven ships, these varying rates of fuel consumption for the auxiliary machinery result in a most economical speed of between 12 and 20 knots, depending on the type of ship.

To conserve fuel and thereby increase the ship's cruising radius, a major part of all steaming is done close to the most economical speed. Therefore, the most economical speed is generally designated as cruising speed. It is desirable to have the economical speed as high as possible. But there is a practical limit for this

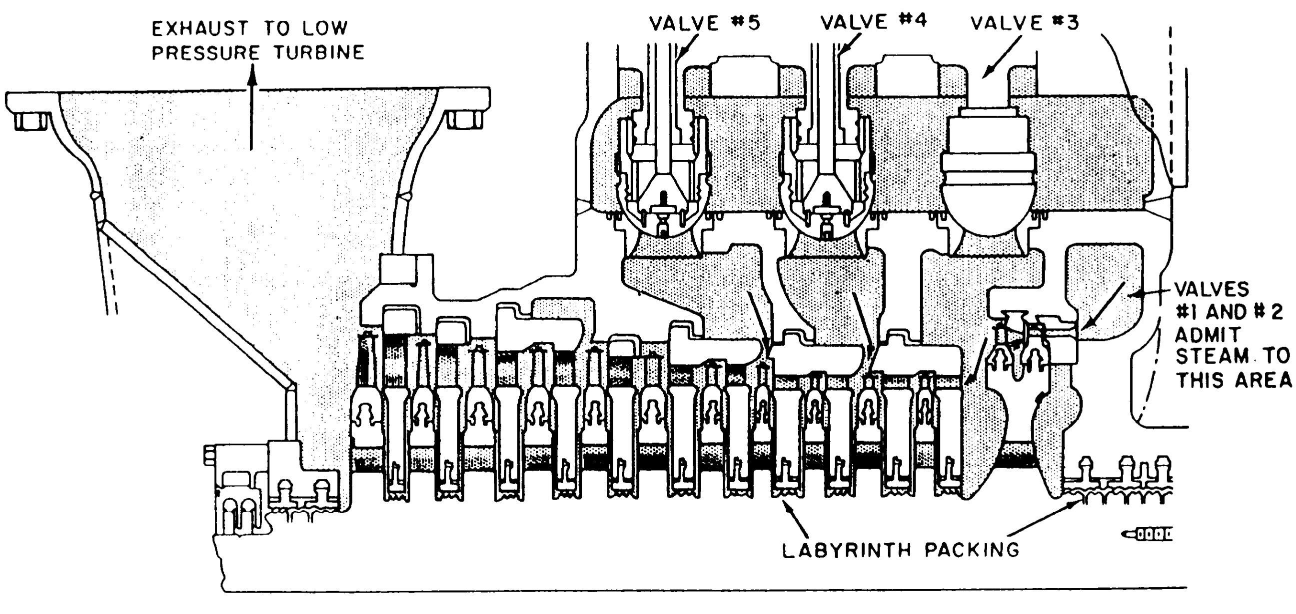

Figure 2-25.—High-pressure turbine showing valve arrangement.

speed because of the progressively increasing resistance of water to the ship's hull as the speed of the ship is increased. Increasing the efficiency of the main engines will tend to raise the most economical speed. The propulsion turbines are designed to have their best steam rate at the cruising speed.

Combatant ships should be able to steam at or near full power for long periods of time. This means that propulsion plants must be designed with a relatively high turbine efficiency at high speeds.

A turbine gets maximum efficiency at the optimum ratio of blade speed to steam speed. Therefore, to obtain the lowest possible fuel consumption per shaft horsepower per hour at cruising speed AND at full power, propulsion turbines must be designed so the optimum ratio of blade speed to steam speed will be approached at both these speeds. This may be accomplished by using cruising stages: high-pressure, intermediate-pressure, low-pressure (HP-IP-LP) turbine combinations.

ASTERN (REVERSING)

Except for electric-drive propulsion units, astern elements are provided with steam propulsion turbine units for emergency stopping, backing, and maneuvering. In units using low-pressure turbine (all except type I), there is an astern element in each exhaust end of the double-flow, low-pressure turbine. The single-casing turbine units have an astern element in the exhaust end of each turbine. Astern elements are usually Curtis stages (velocity-compounded impulse), which develop high torque but have low efficiency. An astern turbine normally is designed to produce from one-fifth to one-half of the ahead turbine full power.

AUXILIARY STEAM TURBINES

In this chapter, we have described the general principles and construction features of the various types of turbines in use by the Navy. We emphasized the larger types of turbines used for main propulsion. There are, of course, a considerable number of small turbines employed in all naval engineering plants for driving auxiliary machinery.

Most auxiliary machinery units outside the engineering spaces on modern naval ships, and many units within these spaces, are driven by electric motors.

EFFICIENCY OF AUXILIARY TURBINES

There are two major advantages in using turbines to drive auxiliary machinery:

1. Turbines ensure greater reliability than motor-driven units. The possibility of interruption or loss of electric power supply is greater than the possibility of loss of steam supply—especially during general quarters and special details.

2. Turbines improve the overall efficiency of the plant by supplying exhaust steam for such auxiliary machinery units as deaerating feed tanks and evaporators, where low pressure is required.

The efficiency of most auxiliary turbines is increased with the use of reduction gears. Those turbines are designed to have comparatively few stages (sometimes only one) to conserve space. This results in a large pressure drop in each stage, and a high steam velocity. To obtain maximum efficiency, the blade speed must also be high. Hence, the reduction gears reconcile the two conflicting speed requirements and increase the general efficiency.

AUXILIARY TURBINE CLASSIFICATION

In general, auxiliary turbines in naval use may be classified (in a manner similar to the general turbine-type classifications) according to the following characteristics:

1. Speed (constant or variable)
2. Exhaust conditions (condensing or non-condensing)
3. Shaft position (horizontal or vertical)
4. Type (impulse or reaction)
5. Steam flow direction (axial, radial, or helical)
6. Stages (single or multiple)
7. Drive (direct or geared)
8. Service (based upon driven auxiliary)
9. Power output capacity, limiting speeds, and so forth

Except for turbine-driven electric generators, the auxiliary turbines are usually impulse turbines of either the helical-flow or axial-flow type. They operate against a back pressure of approximately

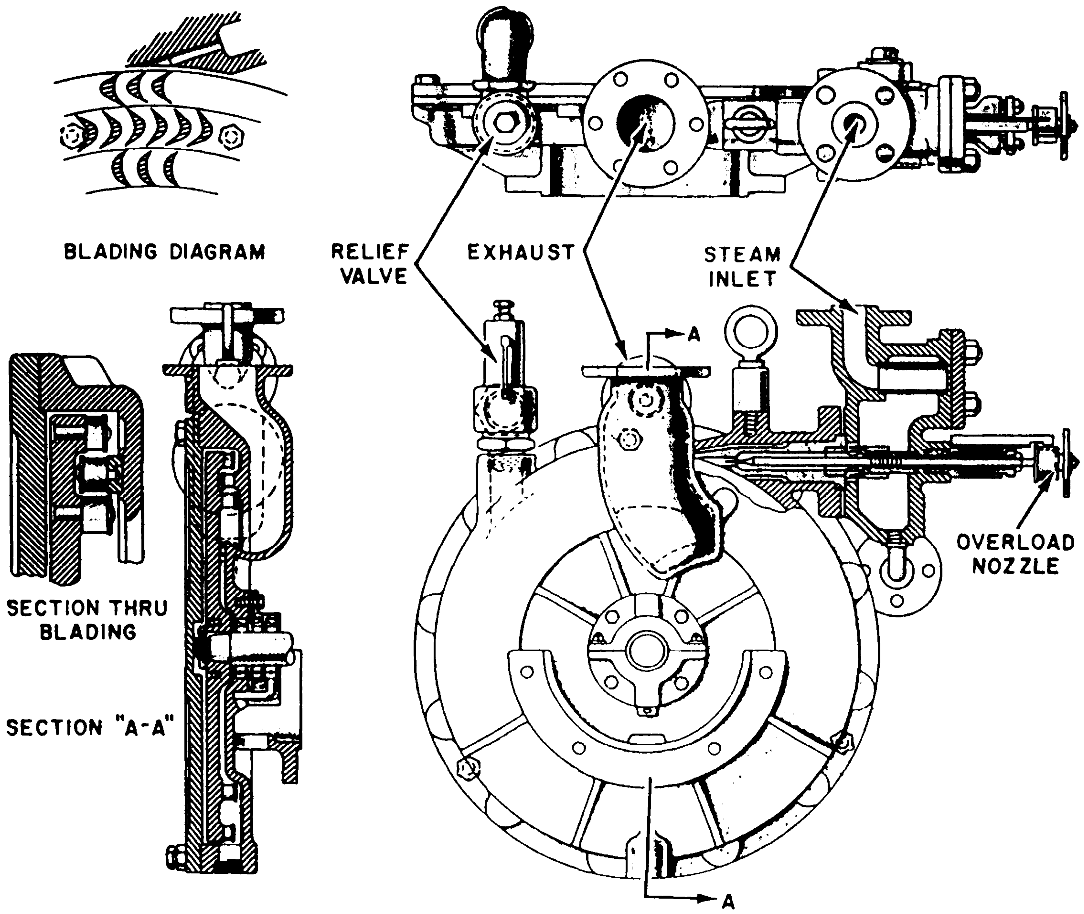

Figure 2-26.—Main lube oil pump turbine.

15 psig, depending upon the auxiliary exhaust line operating pressure of the ship in which they are installed. In later ships, this back pressure is 15-17 psi. Turbines for driving the ship's service generators are ordinarily of the impulse, axial-flow, multistage, geared type.

USES OF AUXILIARY TURBINES

The principle pumps driven by auxiliary turbines include the main condensate pumps, main condenser circulating pumps, main feed pumps, main feed booster pumps, main fuel oil service pumps, forced draft blowers, and main lube or service pumps.

Main Condensate Pump Turbines

On some ships, identical turbines are used to drive main condensate, main feed booster, and the lube oil service pumps. The bucket wheels (turbine wheels) and many other parts, such as governors, bearings, and turbine and gear casings, are interchangeable. Figure 2-26 shows the wheel and blading diagram of a turbine used to drive the main condensate, main feed booster, and lube oil service pumps. These turbines are single-pressure stage, radial-flow, single-entry turbines. Although destroyers and other ships have changed radically since World War II, the basic design of these turbines has changed little. Improved metals are used, however, to withstand the higher pressures and temperatures of steam on modern warships.

Main Condenser Circulating Pump Turbine

Figure 2-27 shows a vertically mounted, single-stage, axial-flow, velocity-compounded, impulse unit. The turbine shaft is coupled to the vertical shaft of the pump. A thrust bearing, mounted integrally with the upper main bearing, carries the weight of the rotating element and absorbs any unbalanced downward thrust. A throttle valve and a double-seated balanced inlet valve (normally held wide open by a governor mechanism) lets the steam into the turbine.

Turbine Generators and Their Operation

The turbine used on a turbogenerator is an axial-flow, pressure-compounded, impulse type. It exhausts to an auxiliary condenser having its own circulating pump, condensate pump, and air ejectors.

Electrical power provided by steam-driven turbogenerators is a vital part of a ship's operation. Many factors are involved in the determination of how many turbogenerators a particular type of ship will have. Most ships which use steam-driven turbogenerators for normal electrical power also have diesel-driven generators for emergency use. Figure 2-28 shows a 750 kW ac turbine generator unit.

Steam enters the turbine through a steam strainer, passes through the throttle valve, through the controlling valves, and then to the first-stage nozzles. The steam then passes from initial pressure to final or condensing pressure.

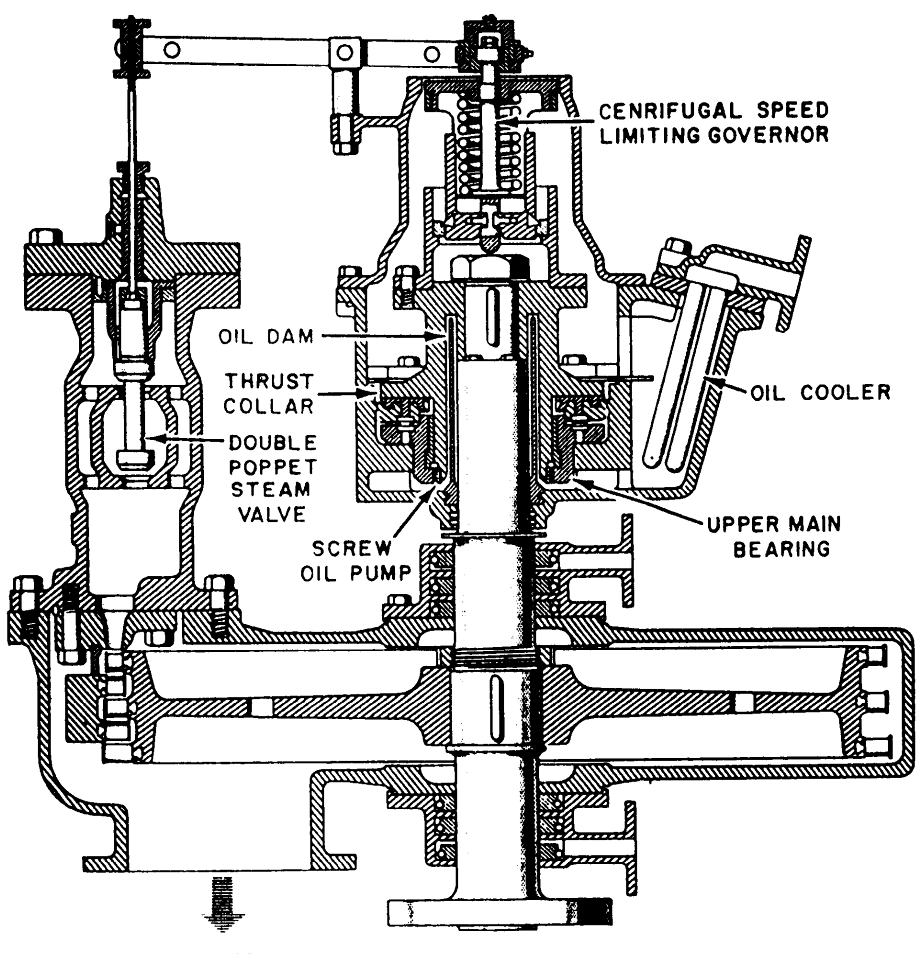

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Figure 2-27.—Main condenser circulating pump turbine.

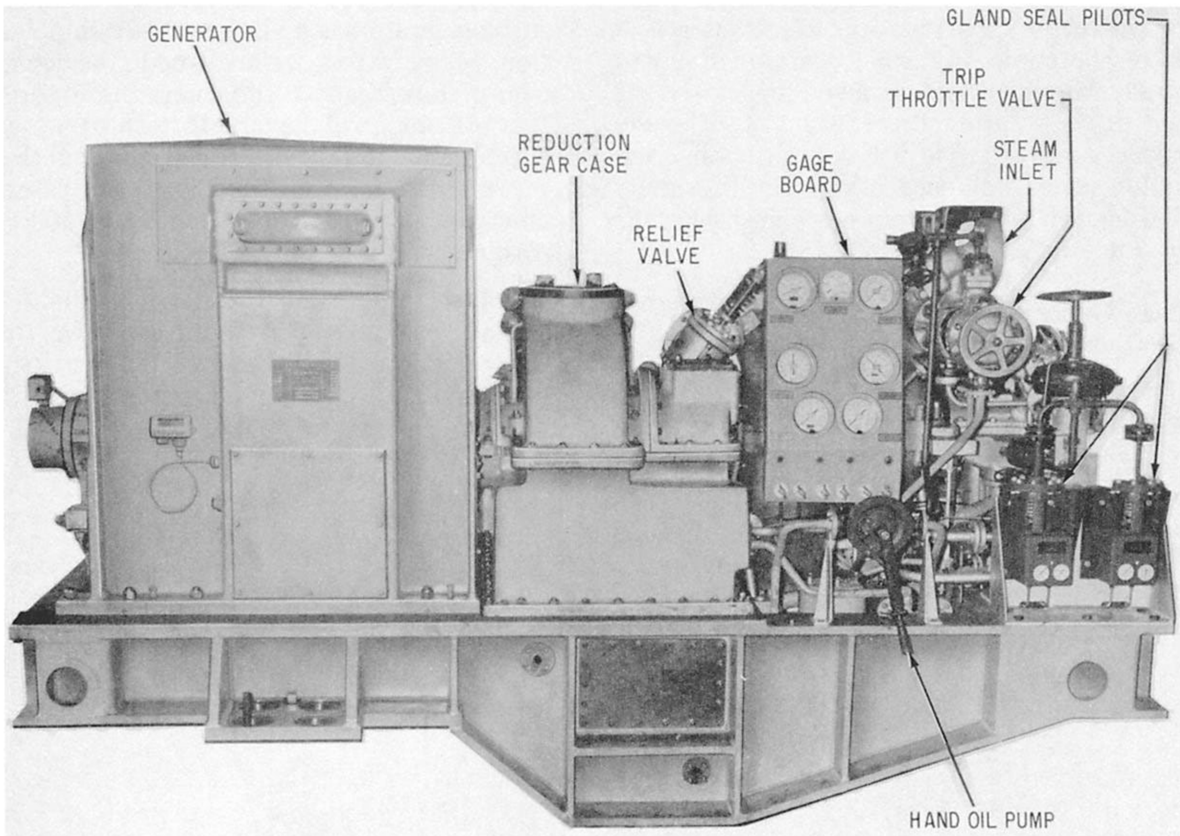

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Figure 2-28.—750 KW a.c. turbine generator set.

The speed of the unit is controlled by a constant-speed governor.

The throttle valve is provided with a hand-wheel for manual control and for resetting the valve after it has been tripped. The throttle valve closes when the overspeed trip or back-pressure trip functions, or when the manual trip lever is pushed.

Operation of turbogenerators should be in accordance with the Engineering Operational Sequencing System (EOSS).

General Precautions on Turbogenerator Operation

The following precautions should be followed carefully when you operate turbogenerators:

1. Test the manual trip to ensure that it is functioning properly.

2. Under no circumstances should you admit steam to the turbine rotor for any appreciable length of time without rolling it. Uneven heating will distort the rotor and cause vibration when the turbine is started.

3. After the turbine is started, test the manual trip for proper operation.

4. When bringing a generator turbine up to speed, you should always accelerate rapidly through the critical speed of the unit; the slight vibration which may occur when going through the critical speed will disappear when the turbine is up to speed.

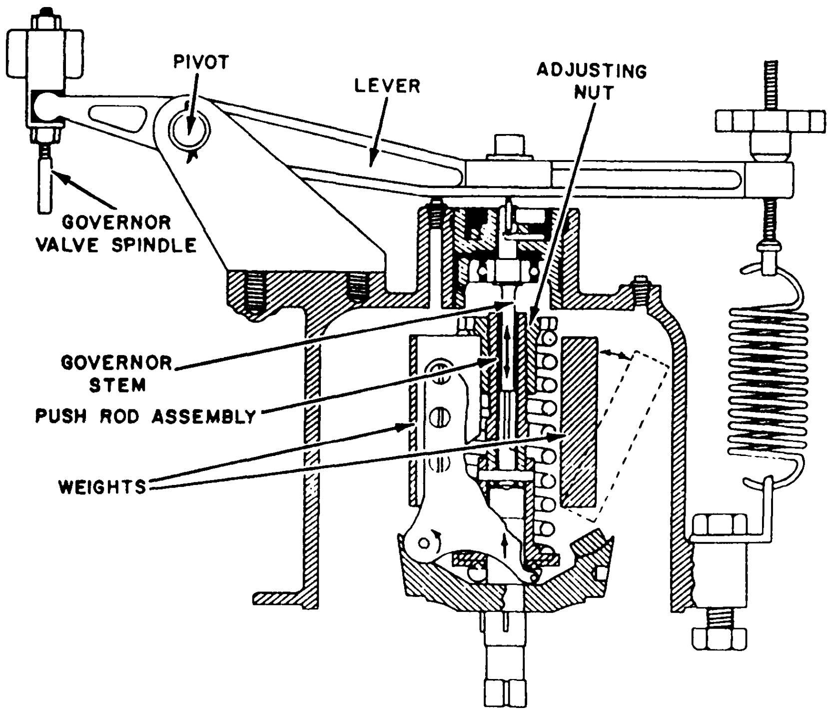

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Figure 2-29.—Speed limiting governor, main condensate pump.

5. The maximum temperature of oil leaving any bearing should NOT exceed 180°F (82 °C).

6. The temperature rise of oil passing through any bearing should NOT exceed 50°F (28 °C).

7. Be sure that all control and safety devices are in proper operating condition. If they are not, the unit should be stopped and the trouble should be located and corrected before the unit is started again.

AUXILIARY TURBINE CONTROL

Auxiliary turbine control differs from that of propulsion turbines in that auxiliary turbines must have some type of automatic speed-control governor or device. There are two types of governors in general use: speed-limiting governors and constant-speed governors.

Speed-Limiting Governor

A speed-limiting governor is a device that limits the maximum speed at which a turbine will operate. This type of governor does not control steam flow to the turbine until it approaches the maximum designed speed. Figure 2-29 shows one of the more common types used on main condensate, main feed booster, and lube oil service pump turbines.

The governor shaft is driven directly by an auxiliary shaft in the reduction gear and rotates at the same speed as the pump shaft. Two flyweights are pivoted to a yoke on the governor shaft and carry arms which bear on a push rod assembly. The push rod assembly is held down by a strong spring and nut. Centrifugal force on the flyweights causes them to move outward. This lifts the arms, which pivot on rollers, against the spring tension on the governor stem whenever the preset speed of the governor is reached. If the turbine speed begins to exceed that for which the governor is set, increased centrifugal force acting on the rotating flyweights will cause them to move farther out. This causes the governor valve to throttle down on the steam. On the other hand, when the turbine slows down, as from an increase in load, the centrifugal force on the flyweights is reduced, and the governor push rod spring acts to pull the flyweights inward. This rotates the lever about its pivot and opens the governor valve, thus admitting more steam. The turbine then speeds up until normal operating speed is reached.

The speed of the pump may vary somewhat with a change in the pump load, but the variation will not be great enough to cause unsatisfactory operation of the unit.

The speed to which the turbine will be limited can be set by removing the cover from the governer assembly and changing the tension of the spring that works against the weights. The total travel of the governor valve, from FULLY OPEN to FULLY CLOSED, should be adjusted to one-fourth inch. This travel should be checked after each readjustment of the spring. The pump is normally operated with the throttle fully open, passing full steam pressure to the governor valve, thereby allowing the valve to control the speed of the unit.

Figure 2-30 shows a CENTRIFUGAL WEIGHT-TYPE SPEED-LIMITING GOVERNOR for a main feed pump. Centrifugal weights are mounted on a hub which rotates with the turbine shaft. The weights pivot on knife edges instead of rollers. As the speed of the turbine increases, centrifugal force causes the free ends of the weights to move outward, compressing the governor spring. This action causes the sleeve to move out against one end of the governor lever. The other end of the governor lever is attached to the operating stem of the double-poppet steam governor valve via a pivot point. The outward movement of the sleeve end of the governor lever will cause inward movement at the valve end. This will close down on the valve and reduce turbine speed. Tension on the spring at the outer end of the double-poppet valve stem tends to open the valve again as soon as the turbine shaft has slowed down and allowed the centrifugal weights to move inward.

Constant-Speed Governor

The constant-speed governor is used on constant-speed machines to maintain a constant speed up to design limits regardless of the load on the turbine. Constant-speed governors are usually set so that the turbine cannot even momentarily exceed 100 percent of normal operating speed. They are used primarily on turbine-generator units.

Ship's service generators supply electricity for lighting and power throughout a ship. Since a constant voltage and frequency must be maintained in the ship's electrical system, the generator turbine operates at a constant speed even under greatly varying loads. This speed is maintained by a constant-speed governor.

One type of ship's service generator turbine control mechanism (fig. 2-31) consists of a

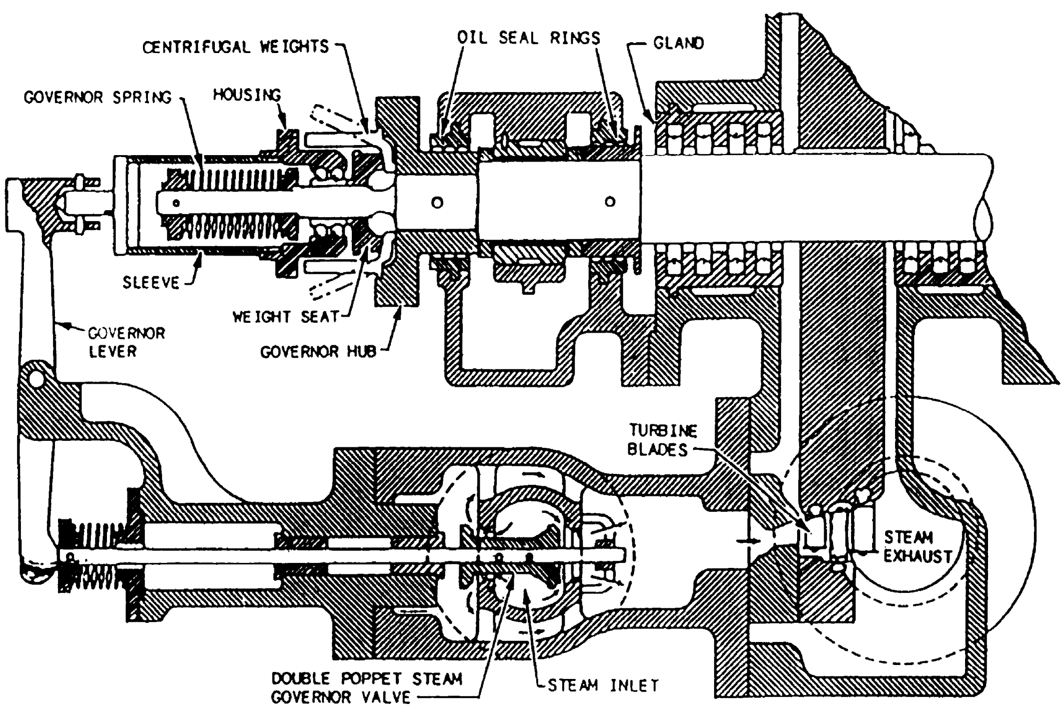

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Figure 2-30.—Speed-limiting governor, main feed pump.

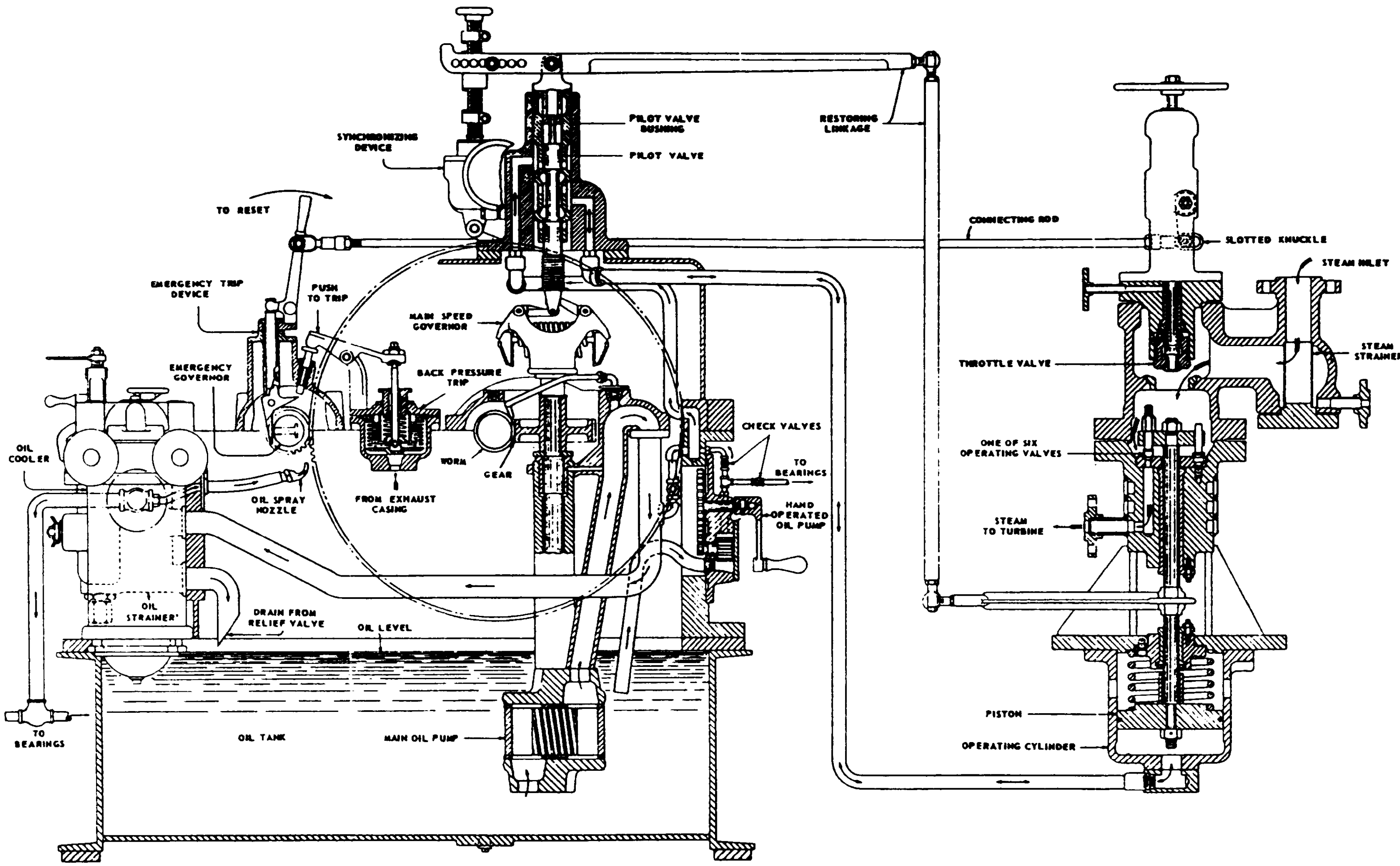

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Figure 2-31.—Ship's service turbine-driven generator-governor system.

centrifugal governor which operates a pilot valve. This valve controls the flow of oil to an operating cylinder, which, in turn, controls the amount of opening or closing of the turbine nozzle valves.

A gear-type oil pump and the main governor, mounted on the same shaft, are driven through a worm and gear (fig. 2-31). The worm is directly connected to the low-speed gear shaft of the turbine reduction gear. It drives the governor at a speed directly proportional to the turbine speed

When the governor tends to slow because of an increased load on the generator, the governor weights move inward and cause the pilot valve to move upward, permitting oil to enter the operating cylinder. The operating piston rises and, through the controlling-valve lever, the lifting beam is raised. The nozzle valves open and admit additional steam to the turbine. The upward motion of the controlling-valve lever causes the governor lever to rise, thus raising the bushing. Upward motion of the bushing tends to close the upper port. This shuts off the oil flow to the operating cylinder and stops the upward motion of the operating piston. This followup motion of the bushing regulates the governing action of the pilot valve. Without this feature the pilot valve would operate, with each slight variation in turbine speed, to alternately fully open and fully close the nozzle valves.

When the turbine tends to speed up because of a decreased load on the generator, the governor weights move outward. This moves the pilot valve downward, opens the lower ports, and allows oil to flow out of the operating cylinder. This action causes the controlling-valve lever to lower the lifting beam, thereby reducing the amount of steam delivered to the turbine. The downward motion of the controlling-valve lever causes the governor lever to lower, thereby lowering the bushing. The downward motion of the bushing tends to close the lower port, preventing oil from flowing out of the operating cylinder.

Another type of constant-speed governor is the ELECTROHYDRAULIC LOAD-SENSING SPEED GOVERNOR. This governor produces the same end result as the flyweight type; that is, it maintains constant turbine speed with varying loads on the generator. Basically, the governor uses an attached gear-type oil pump to provide actuating oil pressure to a hydraulic actuator. The hydraulic actuator is controlled by an electrical signal from the system control box. The control box sends a signal (increased electrical load on the generator) to the actuator to admit more steam to the turbine. The actuator then allows control oil to pass to a remote servo piston in the hydraulic valve actuator (fig. 2-32).

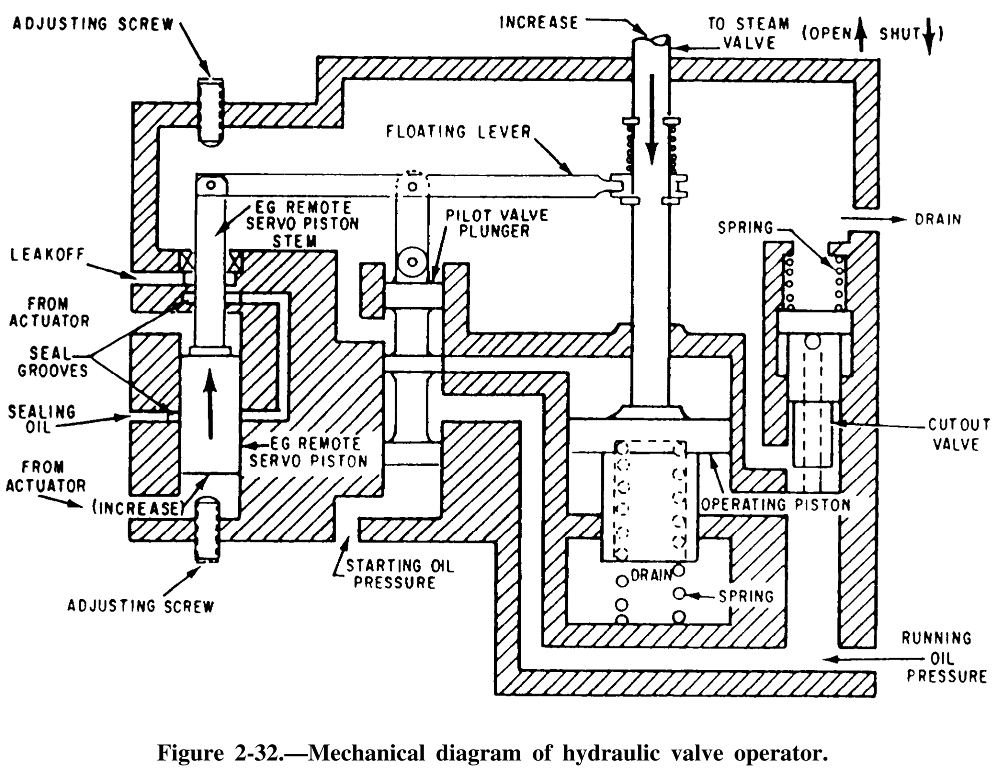

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Figure 2-32.—Mechanical diagram of hydraulic valve operator.

The remote servo piston moves a pilot valve plunger. This allows operating oil to move an operating piston which mechanically opens the steam valve. The whole system is designed so that a failure will close the steam valve to the turbine. A cutout valve minimizes the manual pumping of oil required when starting the turbine. It shuts off the path for the running oil pressure to the bottom of the operating piston, which will tend to counteract the starting oil pressure on the top of the piston. More detailed information about electrohydraulic load-sensing speed governors is contained in *Electrician's Mate* NAVEDTRA 14344.

SAFETY DEVICES

Safety devices differ from control devices in that they have no control over the turbine under normal operating conditions. They come into use only during some abnormal condition to either stop the unit or control its speed.

All turbogenerators have four safety devices: an overspeed trip, a back-pressure trip, a low-oil pressure trip or alarm, and an emergency hand trip.

The OVERSPEED TRIP shuts off the steam supply to the turbine after a predetermined speed has been reached, thus stopping the unit. Overspeed trips are set to trip out at approximately 110 percent of normal operating speed.

The BACK-PRESSURE TRIP closes the throttle automatically whenever the back or exhaust pressure reaches a set pressure.

The LOW-OIL PRESSURE TRIP closes the throttle if the lubricating oil pressure drops below a specified pressure. Some turbogenerators only have low-oil pressure alarms.

The EMERGENCY HAND TRIP provides for manually closing the throttle quickly in case of damage to either the turbines or generators. The emergency hand trip may also be used to close the throttle valve when the turbogenerator is secured.

Some MAIN turbines that use a hydraulic system of throttle control have control features which include a speed-limiting function, an over-speed trip, and a hand trip. This system is found on propulsion turbines which can be inadvertently unloaded (1) by unclutching from the propeller shaft in geared-turbine drives, (2) by electrical load loss in turbine-electric drives, or (3) if the turbine is remotely located from the controlling station (bridge control of automated ships).

TURBINE MAINTENANCE

The maintenance of turbine installations is as important as their proper operation. If proper maintenance procedures are followed, abnormal conditions may be prevented. You will be concerned with major adjustments, as well as measurements, of turbines. In addition, you must know how to fit carbon packing rings to turbines. For more information about the maintenance and repair of auxiliary turbines, you should refer to *NSTM,* chapter 502, and the manual furnished with the unit.

MAJOR ADJUSTMENTS OF A TURBINE

All propulsion turbines installed on ships in the Navy have two major adjustments: the fixing of the proper radial and axial positions of the rotor. The radial position of the rotor is maintained by the journal bearings and the axial position by the thrust bearings.

The clearances in all shaft and diaphragm packings are small, and they will be altered if the position of the rotor changes as a result of wear, either of the journal or of the thrust bearings. This change results in reduced efficiency of the turbine because of the steam leakage from the glands, and repairs will eventually be necessary.

The major reason for maintaining a turbine rotor in its proper position is to prevent damage to the turbine. If the rotor touches the casing at any time because of failure of the thrust or journal bearings while the turbine is in operation, damage will result, and it will be necessary to lift the turbine casing for repairs. Some turbine parts are particularly subject to damage because of close clearances involved. They are the rotor blading, diaphragm packing rings, shaft packing rings, and oil deflector or oil seal rings.

Radial Position of the Rotor

The depth gauge micrometer is the quickest means of detecting any change in the radial position of the rotor resulting from bearing wear. When the turbines were installed, depth gage readings were taken and recorded. Any difference between the original and the new readings will be the amount of bearing wear in the lower half. For additional information on the use of micrometers refer to *Tools and Their Uses*, NAVEDTRA 14256.

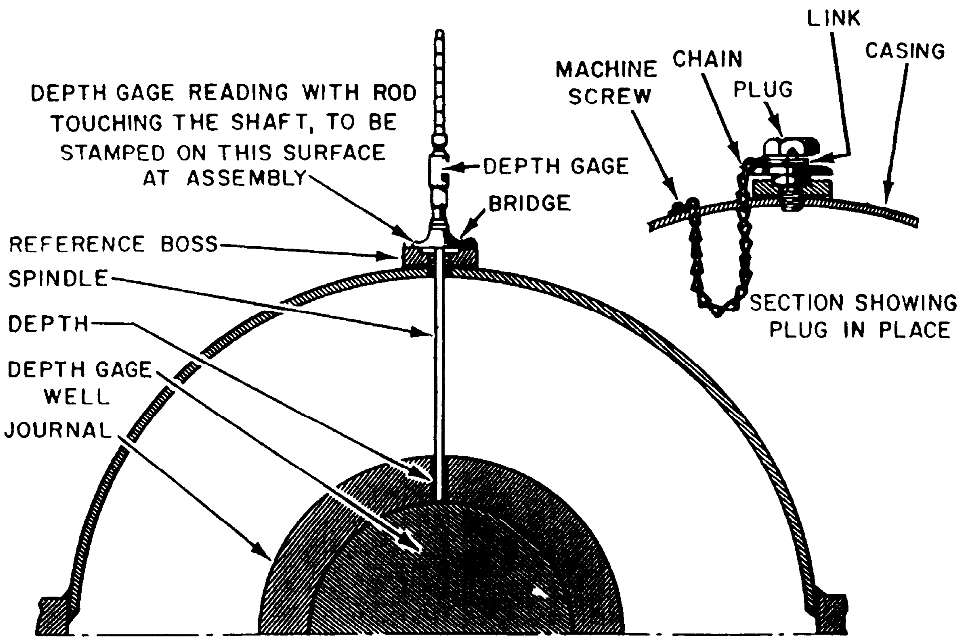

Figure 2-33.—Beariug wear micrometer depth gauge.

To take new readings (fig. 2-33), a depth gauge spindle is inserted into the depth gauge well until the bridge of the gage rests evenly on the reference boss; the knurled handle of the micrometer is then turned until the spindle touches the journal. Read the micrometer and compare the new and the original readings.

Another means of checking bearing wear is by measuring the crown thickness with a ball-attached outside micrometer. When the turbine bearings were installed originally, the radial position of the turbine rotor was set. By using a micrometer, the combined thickness of the bearing shells and liners (at designated places) was measured and stamped on the bearing shell. To take new readings, the bearing cap must be removed, the top half of the bearing lifted off, and the lower half of the bearing rolled out. Radial lines are scribed on one end of each bearing to indicate the measurement points, which are always 1 1/4 inches from the end of the bearing. Any difference between the shipboard and the factory measurements will be the amount of bearing wear.

Another way of measuring bearing wear is by using an inside micrometer to measure the inside diameter of the bearing and an outside micrometer to measure the outside diameter of the journal. The difference between the readings will be the oil clearance. The difference between the old and the new oil clearances will be the amount of bearing wear.

Axial Position of the Rotor

The axial position of a turbine rotor is maintained by means of a thrust bearing, usually

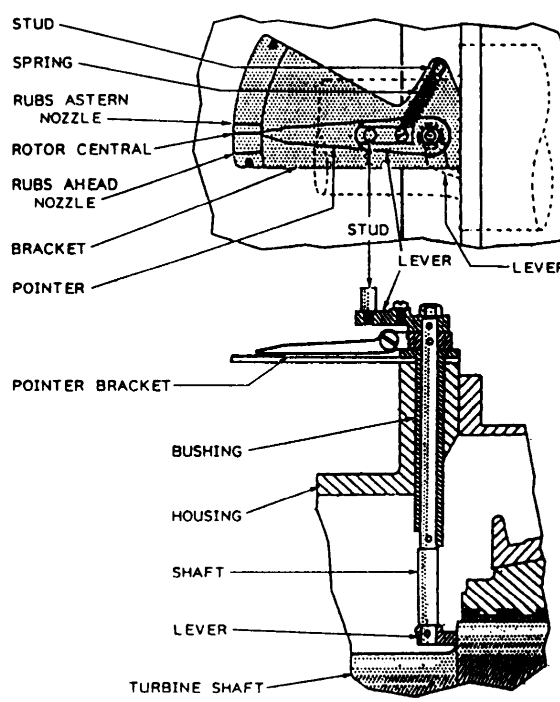

Figure 2-34.—Axial clearance indicator.

of the Kingsbury type. With this type of bearing, the axial position of the rotor is adjusted by machining from the filler piece or by installing a thicker filler piece.

Rotor position indicators are installed on most main turbines, allowing a quick and constant means of checking rotor position. Figure 2-34 shows one type of indicator used.

The most accurate means of determining whether the rotor is operating within safe limits is to check the total oil clearance of the thrust bearing. This clearance can be obtained by measuring the end play of the rotor. Methods of taking this measurement for various installations may differ, but the basic principle is the same. With the thrust bearing completely assembled and the unit not in operation, the rotor is moved (jacked) as far as it will go, first in one direction and then in the opposite direction. The length of travel is measured with a precision instrument, such as a dial indicator.

One method of moving the rotor is as follows: Remove the upper half of the coupling guard and attach the dial indicator to the flanged surface of the bearing cap. To move the rotor forward, apply a bar between the after face of the coupling flange and the face of the adjacent cover. To move the rotor aft, the bar is applied between the forward face of the coupling flange and the face of the bearing cap. In each case, a wooden block is used to prevent marring the metal surfaces. The end play (thrust bearing clearance) is obtained from the two readings of the dial indicator. If the end play is within designed limits, the rotor is operating within its allowable limits.

You can get additional information on journal and bearing clearances from the manufacturer's technical manual for the specific installation, or from *Naval Ships' Technical Manual,* chapter 231.

MAINTENANCE OF LABYRINTH AND CARBON PACKING RINGS

Worn labyrinth packing may be repaired with a chisel bar and a hand chisel. The chisel is struck with a hammer, and then advanced around the periphery of the packing a trifle less than the tool's width. Care must be taken that each new position of the chisel overlaps the preceding position. This procedure expands the LAND (surface area of the packing) in height and draws it out to its original featheredge. The drawing out of the LANDS must be continued to give the packing clearance specified on manufacturer's drawings, instruction books, or maintenance requirements cards. If the clearance is not available from plans, instruction books, or maintenance requirements cards, the drawing of LANDS should be continued until they come within 0.005 of an inch of touching the casing.

CAUTION: This procedure should only be used by experienced individuals. When possible, damaged or worn labyrinth packing should be replaced with new.

When overhauling carbon packing, it is recommended that the removed segments be immediately placed in a box in such a manner that adjacent segments of a ring will be next to each other, as shown by the marks on each end of each segment. Each segment is marked with the number of the ring of which it is a part:

1. Examine all sections of the carbon packing for scores, grooves, and wear in general. If necessary, renew or refit rings in accordance with manufacturer's plans, instruction books, or maintenance requirements cards.
2. The springs must be carefully examined and tested. If they are found to be weak or corroded, they must be renewed.

PLANT MAINTENANCE

Maximum operational reliability and efficiency of steam propulsion plants require a carefully planned and executed program of inspections and planned (preventive) maintenance in addition to strict adherence to prescribed operating instructions and safety precautions. When proper maintenance procedures are followed, abnormal conditions should be prevented.

Continuous and detailed inspection procedures are necessary not only to discover partly damaged parts which may fail at a critical time, but also to eliminate the underlying conditions which lead to early failure (maladjustment, improper lubrication, corrosion, erosion, and other enemies of machinery reliability). Particular and continuous attention must be paid to the following symptoms of malfunctioning:

1. Unusual noises
2. Vibrations
3. Abnormal temperatures
4. Abnormal pressures
5. Abnormal operating speeds

You should familiarize yourself with the specific temperatures, pressures, and operating speeds of equipment required for normal operation, so that departures from normal operation will be more readily apparent.

If a gauge or other instrument gives an abnormal reading, the cause must be fully investigated. You can install a spare instrument or do a calibration test to learn whether the abnormal reading is due to instrument error. However, you must believe the indications and take action accordingly until the indication is proven wrong. Any other cause must be traced to its source.

Because of the safety factor commonly incorporated in pumps and similar equipment, considerable loss of capacity can occur before you see any external evidence. In case of pressure-governor-controlled equipment, changes in the operating speeds from normal for the existing load should be viewed with suspicion. Variations from normal pressures, lubricating oil temperatures, and system pressures indicate either inefficient operation or poor condition of machinery.

When a material failure occurs in any unit, promptly inspect all similar units to determine whether there is any danger of a similar failure. Prompt inspection may eliminate a wave of repeated casualties.

Abnormal wear, fatigue, erosion, or corrosion of a particular part may indicate a failure to operate the equipment within its designed limits or loading, velocity, and lubrication. It also may indicate a design or material deficiency. Unless corrective action can be taken which will ensure that such failures will not occur, special inspections to detect damage should be undertaken as a routine matter.

Pay strict attention to the proper lubrication of all equipment. This includes frequent inspection and sampling to determine that the correct quantity of the proper lubricant is in the unit.

Salt water in the oil can be detected by drawing off the settled water by means of a pipette and by running a standard chloride test. A sample large enough for test purposes can be obtained by adding distilled water to the oil sample, shaking vigorously, and then allowing the water to settle before draining off the test sample. Because of its corrosive effects, salt water in the lubricating oil is far more dangerous to a unit than is an equal quantity of freshwater. Salt water is particularly harmful to units containing oil-lubricated ball bearings.

You will find more information on routine turbine checks and operations in chapter 7 of this manual and more in-depth information on turbines in the *Naval Ships' Technical Manual,* chapter 231 (9411) for propulsion turbines and chapter 502 (9500) for auxiliary turbines.

CHAPTER 3

REDUCTION GEARS AND RELATED EQUIPMENT

This chapter deals primarily with reduction gears used in geared turbine-driven propulsion systems and related equipment such as bearings and shafting. We will discuss the construction, operation, and precautionary care of main reduction gears and reduction gears used on auxiliary turbines. Unless otherwise noted, the information deals with steam turbine drives.

High-speed propellers are less efficient than low-speed propellers. They waste much of their horsepower just churning up water instead of using it to move the ship. Therefore, turbines use reduction gears to gear down to the appropriate speed for the size propeller the ship can carry.

REDUCTION GEARS

Reduction gears are coupled to the turbine shaft through various arrangements of gearing. These gears reduce the speed of the turbine to the low speed required by the propulsion shaft and propeller. Reduction gears may be driven by one or more turbines. A combination of gears is known as a *train,* and that term will be used in this chapter.

Reduction gears are classified according to the number of steps used to reduce speed and the arrangement of the gearing. When two gears are meshed and the driving gear (called a pinion) is larger than the mating gear, the driving gear is called a speed increaser. A driving gear that is smaller than the mating gear is called a speed decreaser. The ratio of the speeds is proportional to the diameters of the pinion and gear. When there are just two gears, the train is known as a single-reduction gear (single-speed increaser or decreaser). Double-reduction gears have more than two gears working together. They keep the size of the bull gear (large gear attached to the propeller shaft) from becoming too large.

PROPULSION REDUCTION GEARS

Turbine drives normally use double-reduction gears. The articulated locked train, double-reduction gear (fig. 3-1) is the most common. All propulsion reduction gears in combatant ships use double-helical gears, which are shown in figure 3-1. These gears produce smoother action of the reduction gearing and avoid tooth shock. A double-helical gear has two sets of teeth at complementary angles to each other; therefore, axial thrust is eliminated. Each member of a double-helical gear set should be capable of axial float to prevent excessive tooth loads caused by a mismatch of the meshing elements. (Axial float means "capable of free motion, neither supporting nor supported by other gears axially.") There is a groove around the center of the gear where the teeth sets come together. This groove provides a path for oil flow, so that a hydraulic pressure is not created between the gears where they mesh.

When the first-reduction gear and the second-reduction pinion each have two bearings and are connected by a quill shaft and flexible coupling(s), the design is called ARTICULATED. A quill shaft is essentially a gear coupling. It has two shaft rings with internal teeth and a shaft with external teeth around each end. The shaft rings are bolted on the far ends of each of the two gears to be connected. The floating member, now called

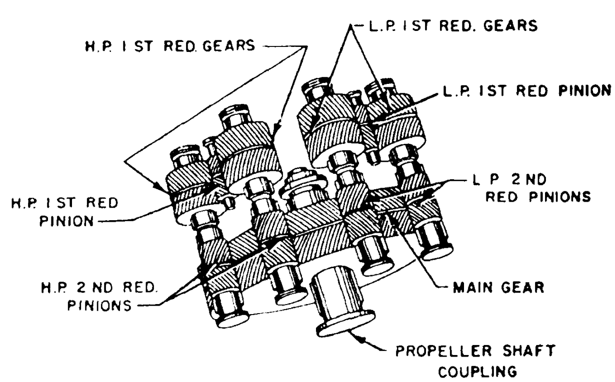

Figure 3-1.—Articulated locked train, double-reduction gear.

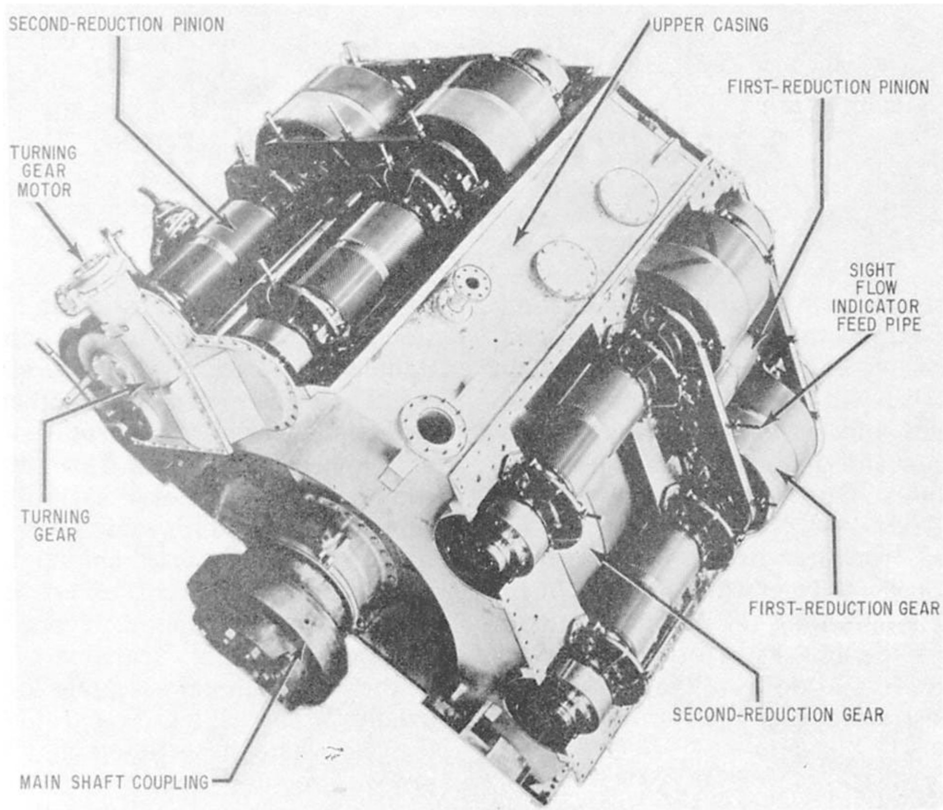

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Figure 3-2.—Typical destroyer-type propulsion gear.

a quill shaft, passes through the hollow centers of both gears. It is supported only at the ends where its teeth mesh with the shaft ends. The quill shaft can be seen in figures 3-4 and 3-8, later in this chapter.

An articulated LOCKED TRAIN GEAR has two high-speed pinions. Each pinion drives two first-reduction gears connected by quill shafts to two separate second-reduction pinions. Each gear and pinion is mounted in its own two bearings. Figure 3-2 shows the major parts of a main reduction gear unit.

The term *locked train* means that the two first-reduction pinions are locked between the two first-reduction gears and transmit the power from the turbines equally to the two gears. This method reduces the load on each gear tooth by 50 percent.

Construction of Main Reduction Gears

The main rotating elements in a propulsion gear unit (main gears and pinions) operate at high rotational speeds. They transmit tremendous power loads. Very slight unevenness of tooth contour and tooth spacing will cause the gears to operate noisily or even to fail. Therefore, these gears are manufactured to very close tolerances. They are cut in rooms in which the temperatures and humidity are closely controlled. Expansion and contraction of the gear-blank, during machining, are negligible. Oxidation, due to moisture in the air, is nearly eliminated. In addition, all gears are carefully checked for errors.

CASINGS.—Except for some small units, gear casings are of welded construction. Most gears have an upper and a lower casing and gear case covers. These casings are of box-girder construction with integral-bearing blocks. The low-speed bull-gear bearing housing is an integral part of the lower casing. Gear case covers are bolted and securely locked to the upper casing. They are arranged so that they can be removed for access to gearing and bearing caps. Inspection plates are usually provided in covers and gear cases so that the rotating parts may be inspected.

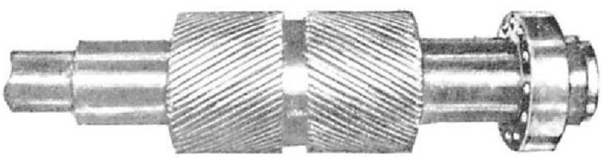

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Figure 3-3.—Single forged-steel pinion.

Casings are arranged for access to oil spray fittings so that the fittings may be cleaned. Turning gears, tachometer drives, lube oil pump drives, sight-flow and thermometer fittings, thermocouples or resistance temperature element (RTE) junction boxes, and electrostatic precipitator vent connections are attached to gear casings.

GEARS.—In general, gears are forged-steel, one-piece constructions, as shown in figure 3-3.

The gear wheel construction and materials depend on the size of the gear. For small gears, the entire gear wheel may be made from a single steel forging. Figure 3-3 shows an example of a single forged-steel pinion. Large gears are generally built up by welding. These gear sections usually are the shaft, the hub or center (which may be omitted when the webs are welded to the shaft), the webs, and the rim in which teeth are cut. The shaft is always of forged steel. When propeller-thrust bearings are located within the propulsion gear casing, a collar is located at the forward end of the low-speed gear shaft. Or, an integral flange for attachment of thrust bearing facing collars is located on the other end of the shaft, forward of the line shaft flange. Other types of construction consist of a close-grained cast-steel body. The body is welded to a shaft, with teeth cut directly in the casting, or a cast-steel body is pressed on a shaft and secured by fore- and aft-shrink rings and a locknut. Figure 3-4 illustrates a typical first-reduction gear. Figure 3-5 shows a bull gear with a flange for an after-thrust bearing.

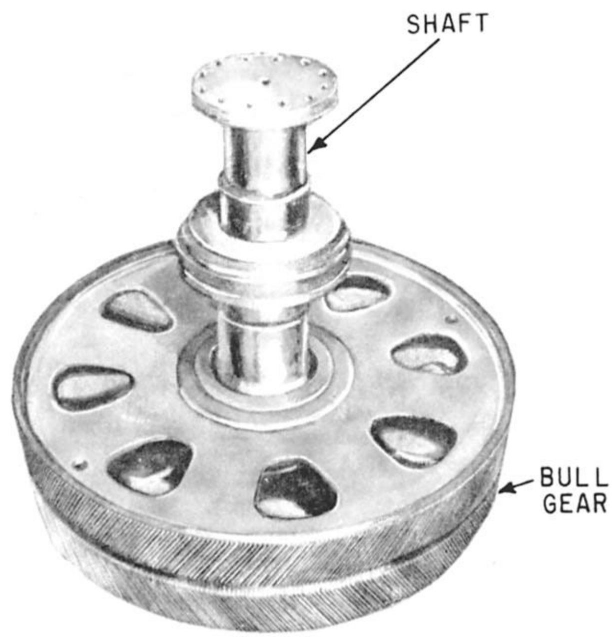

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Figure 3-5.—Bull gear assembly with shaft.

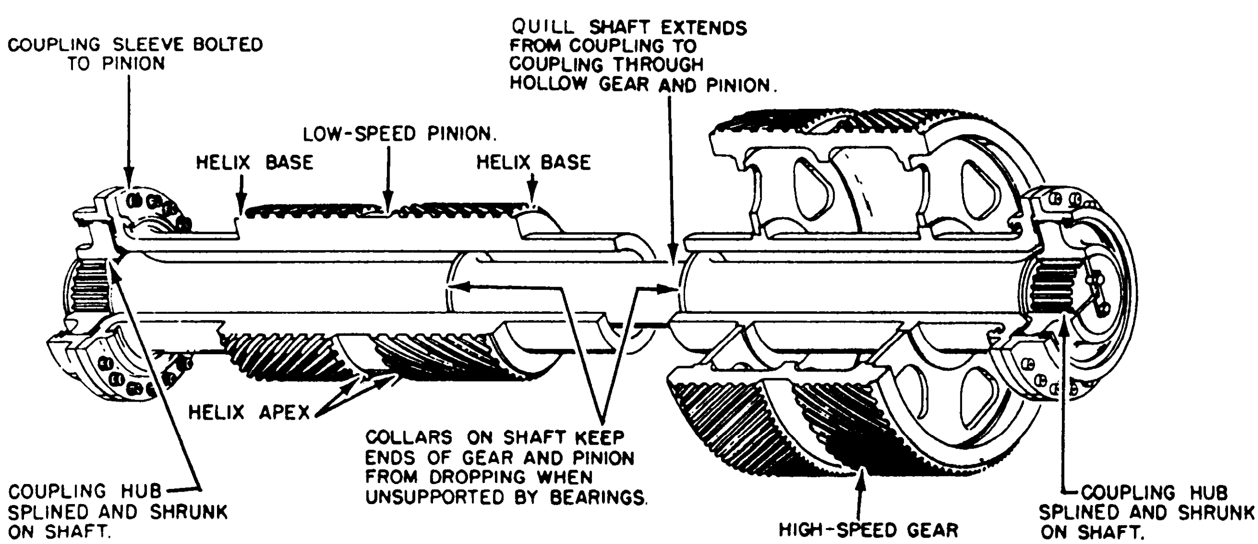

Figure 3-4.—Cutaway view of intermediate rotor assembly articulated gear.

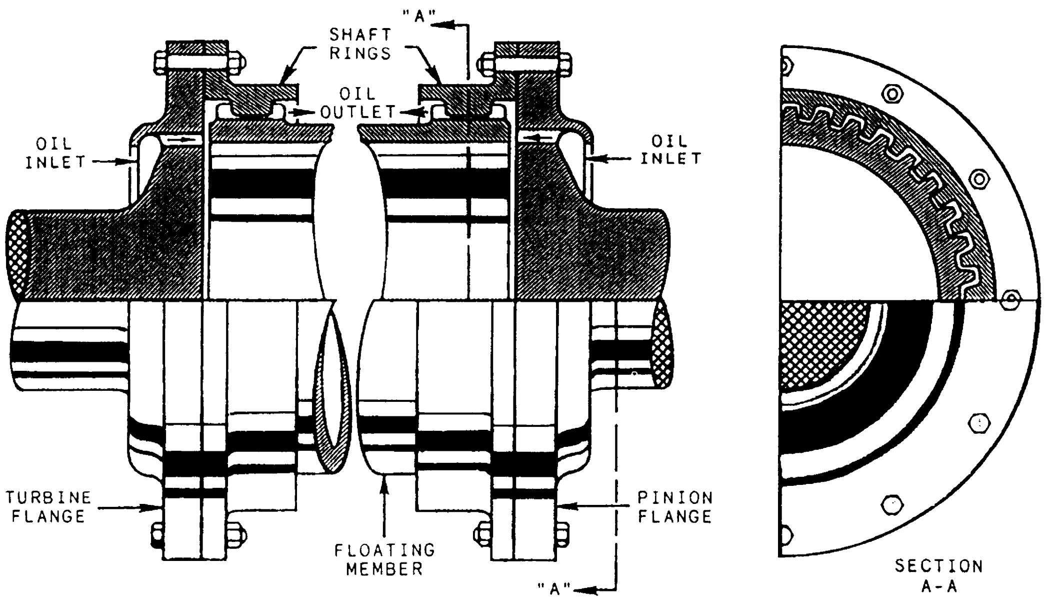

Figure 3-6.—Gear-type flexible coupling.

In a double-reduction, articulated, divided-power path gear set, the high-speed and second-reduction pinions are usually machined from forgings. The first- and second-reduction gears are usually fabricated. The gear shaft and rim are made of steel forgings. The rim and the shaft are assembled with steel webs, welded to the shaft and rim. In wide-faced gears, the position of the steel webs, with respect to the gear teeth, is important in that it may affect gear tooth wear patterns. This assembly is stress relieved and heat treated for desired hardness.

Some gears are rough cut before heat treatmen;, and the final finish operation brings them to the proper size. The journals are then cut slightly oversize to permit a final finishing operation. The teeth are cut in a temperature-controlled room. The cutting operation is continuous. This prevents heat that is generated in cutting from affecting the roundness of the finished gear. The air temperature control prevents changes in the ambient temperature from affecting the roundness of the gear. When the tooth cutting and the finishing operations are completed, the journals are finished so that they are concentric with the shaft axis. The assembly is then balanced. The bull gear is made in a similar fashion. Some first-reduction gears and bull gears in naval use are keyed and locked to the shaft with a locking device. This is done before the teeth are cut and before balancing. When the gears are all completed, the contact between pinion and gear is usually checked in a gear rolling machine before they are assembled in the gear case.

FLEXIBLE COUPLINGS.—Flexible couplings provide longitudinal and angular flexibility between the turbine shafts and the pinion shafts. This permits each shaft to be adjusted axially to its proper position to obtain total axial float.

Most installations have gear-tooth type of flexible couplings. Power is transmitted through a floating intermediate member with external teeth. These teeth mesh with the internal teeth of the shaft rings (sleeves) mounted on the driving and driven shafts.

Figure 3-6 illustrates a design of the gear-type flexible couplings that connect the main turbines to the high-speed pinions of the main reduction gear. The couplings also allow for expansion of the turbine shafts. This takes care of any slight misalignment between the main turbines and the reduction gears, such as thermal expansion and hull movements. Another type of flexible coupling is shown in figure 3-7. In this coupling the floating member is the two sleeves that are bolted together. The internal teeth of the sleeve mesh with the external teeth of the hubs mounted on the shaft. This type of coupling is used most often in diesel engine gears and where self-contained lubrication is advantageous.

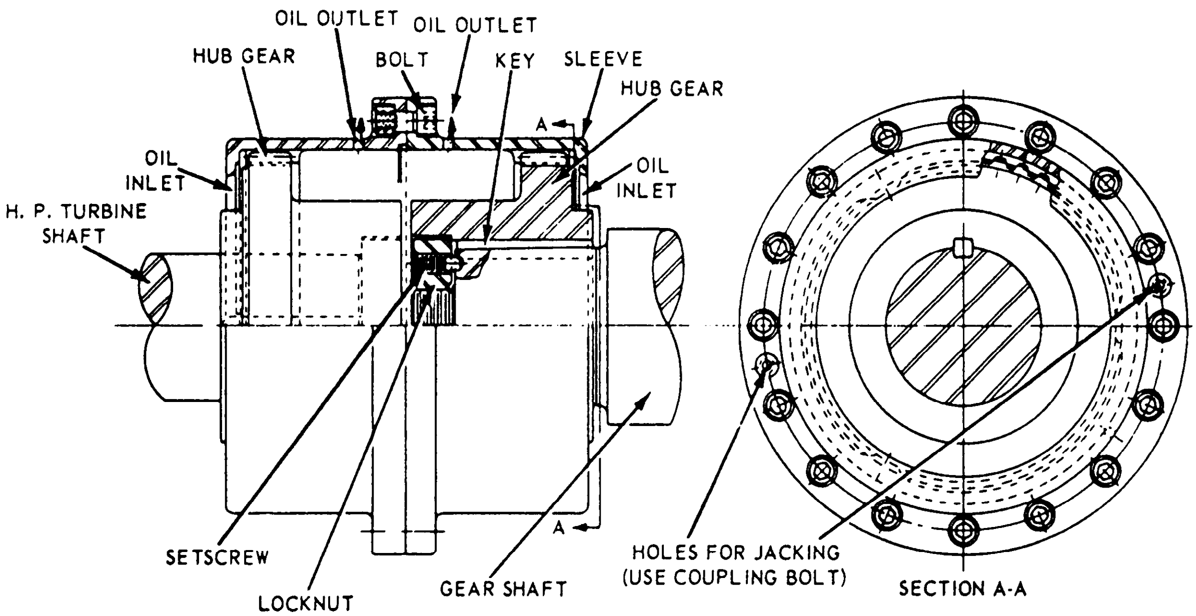

Figure 3-7.—Another gear-type flexible coupling.

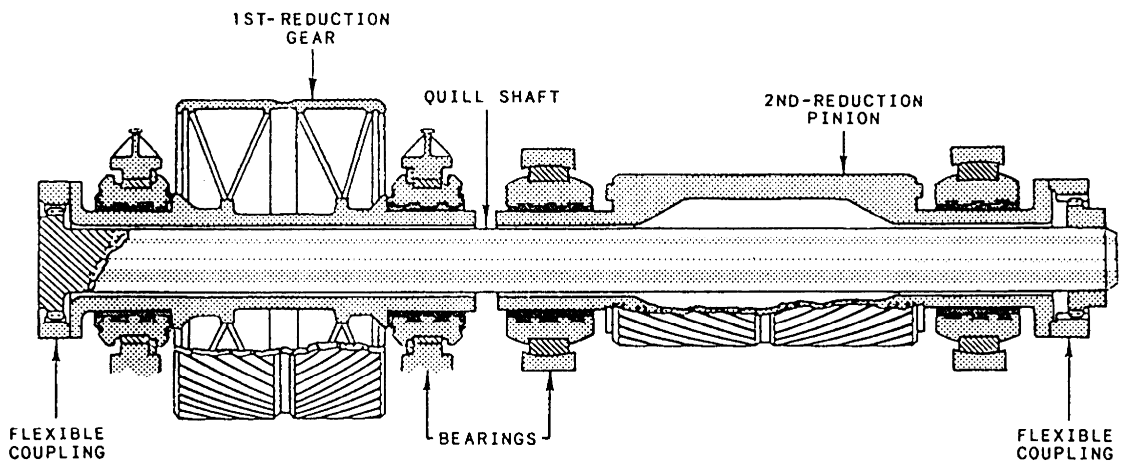

Figure 3-8.—Quill shaft assembly.

The design of the flexible couplings, which connect the first-reduction gears and the second-reduction pinions, is shown in figures 3-8 and 3-4. In this case, a quill shaft of high torsional flexibility is used as the floating member. This shaft provides equal distribution of the load among the several elements of the gear train. The quill shaft runs inside the hollow bore of the high-speed gear and the slow-speed pinion. Figure 3-8 shows how flexibility is obtained between the first-reduction gear and the second-reduction pinion.

A steady flow of oil from the supply passages of adjacent bearings is directed into the flexible couplings when the reduction gears are turning. The oil is caught by projecting lips of the turbine and pinion flanges (fig. 3-6) or sleeves. Centrifugal action forces oil through the horizontal holes in the flanges to the coupling teeth. Oil is discharged from the teeth into coupling guards and then flows into the oil drain system.

TURNING GEARS.—All geared-turbine installations are equipped with an electric motor-driven

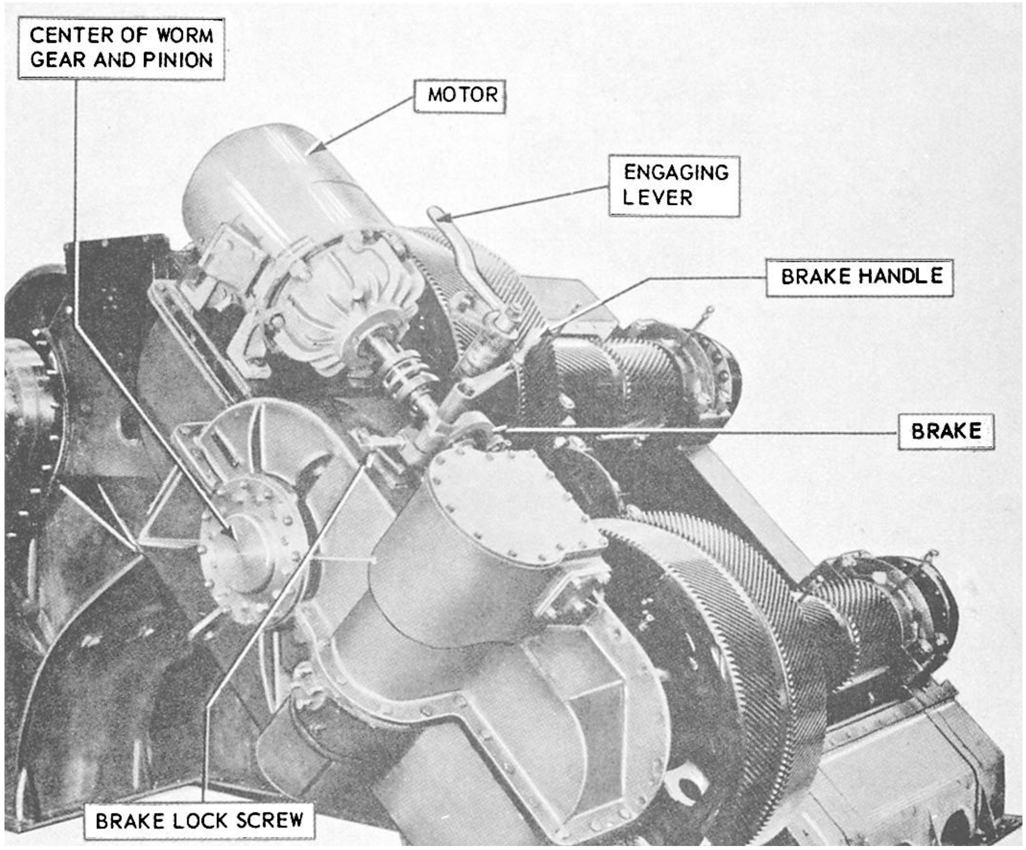

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Figure 3-9.—Propulsion gear after end, high-pressure side, showing turning gear and propeller-locking mechanism.

jacking or turning gear (fig. 3-9). The unit is used to turn the main engine during warming up and securing periods so that the turbine rotor can heat or cool evenly. (The rotor of a hot turbine, or of one that is in the process of being warmed up with gland-sealing steam cut in, will become bowed or distorted if left stationary even for a few minutes.) The turning gear is used for other routine purposes. One example is turning the reduction gear to bring the reduction gear teeth into view during routine inspection. Another is the required periodic rotation of the main engines when they are secured.

The turning gear is mounted on top and at the after end of the reduction gear casing. A shaft extends from the end of the high-pressure, first-reduction pinion to the after end of the reduction gear casing. It connects to the turning gear by a manually operated jaw clutch.

Engaging this clutch connects the pinion to an electric motor through a train of gears. These gears usually consist of one or more sets of worm gears and one or more sets of spur or helical gears. Engaging the clutch and operating the motor will turn one first-reduction pinion. This turns the reduction gears, the main turbines, and the main propeller shaft.

On some installations, the reduction ratio between the main shaft and the electric motor may be as high as 17,000 to 1. With the motor turning and the turning gear engaged, the main shaft will make 1 1/4 turns in approximately 15 minutes. Because of the gearing arrangement, the turbines should never be turned with steam while the turning gear is engaged. It will cause serious damage to the turning mechanism.

The turning gear is equipped with a shaft-locking device (fig. 3-9). This device is used to lock the shaft against rotation while the ship is underway. (On multiscrew ships, if one shaft is stopped with the other(s) operating, the stopped shaft must be locked or it will rotate due to propeller drag through the water.) For this purpose, a friction brake is usually installed on

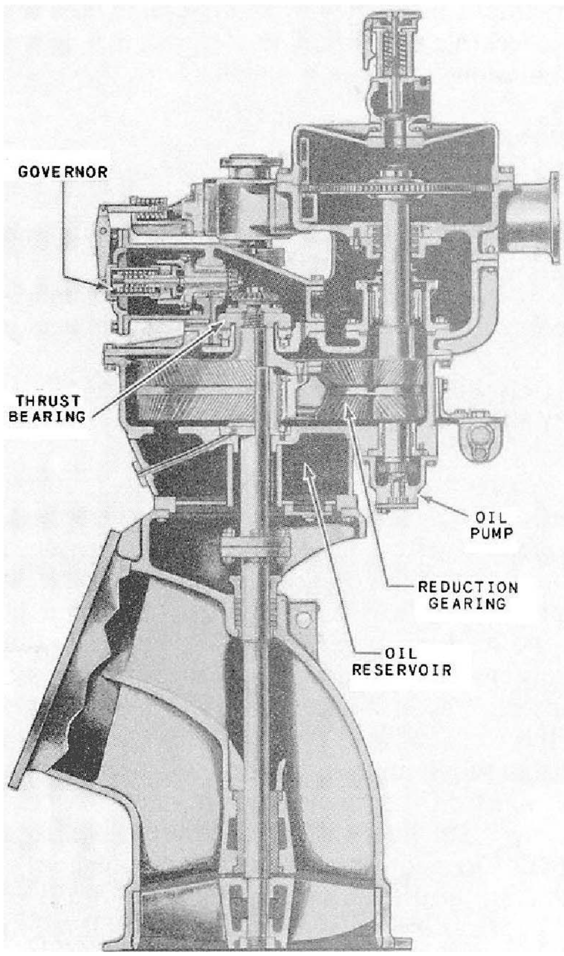

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Figure 3-10.—Vertical propeller type of main condenser circulating pump.

the first-reduction worm shaft. Either a brake drum is mounted on the worm shaft or the shaft coupling serves as a drum. When the turning gear is engaged and the brake is set, a ship can go ahead on its other engines and the idle shaft will be held stationary.

Some turning gears have positive locking devices which use internal and external gear teeth in engagement. Turning gears operated by air motors or by hand are generally used where continuous turning is not required.

To engage the jacking gear clutch, first stop the shaft. This can be done either by stopping the ship or by using the astern turbine to stop and then hold the shaft stationary. NEVER, UNDER ANY CIRCUMSTANCES, ATTEMPT TO ENGAGE THE JACKING GEAR WITH THE SHAFT TURNING. Regardless of how slow the propeller shaft movement may be, damage to the motor or gears, or both, will occur.

REDUCTION GEARS FOR AUXILIARY MACHINERY

Earlier in this chapter, we discussed the double-helix, double-reduction type of propulsion gears. Smaller engine-room machinery, such as turbogenerators and turbine-driven pumps, uses different types of reduction gears.

Most pumps are electrically driven and require no reduction gears. Or, the ship may use a design where one pump of a type is electrically driven and the other is turbine driven. If four pumps of a type are used, the design may be a two and two arrangement. Because of the many different designs of auxiliary reduction gears, selected examples are used in these explanations.

Turbogenerators

A ship's service turbogenerator may use a single-reduction, single-helical gear unit, or a single-reduction, double-helical unit. On the single-reduction, single-helical unit the pinion shaft is flanged and bolted rigidly to the turbine shaft. On the other end, a high-speed thrust bearing is mounted to maintain the axial position of the pinion and turbine rotor. The gear wheel is a steel forging, pressed and keyed on the shaft. One end of the shaft is coupled solidly to the generator shaft. The turbine end is extended to carry the gear that drives the oil pump and governor.

Main Circulating Pumps

Some turbine-driven main circulating pumps use single-reduction, double-helical gears with a ratio of about 8 to 1. These gears (fig. 3-10) reduce the turbine speed of about 5000 rpm to the pump speed of 600 rpm. A gear-type pump mounted on the lower end of the pinion shaft lubricates the reduction gear.

REDUCTION GEAR CARE AND OPERATION

Reduction gears require very little care when compared with other units of engine-room machinery. They need clean pure oil at the designed pressure and temperature, and they need proper alignment. If these requirements are met, reduction gears should give reliable service for the lifetime of the ship.

Lubrication

Proper lubrication of reduction gears is extremely important. Oil at the designated working pressure and temperature must be supplied to the gears at all times while they are being turned over, with or without load. Navy symbol 2190 TEP lubricating oil is used for the propulsion gears as well as for the turbines.

Clean, pure oil is essential for long life and successful operation of the gear. Oil must be free from all impurities—especially water, dirt, grit, and metallic particles. Metal flakes, dirt, lint, and fine chips must be removed when new gears are being worn into a working fit or after work on the gearing or lubrication system. Lint or dirt will clog the spray nozzles and damage the gear teeth. Fine metallic particles may not be picked up by the magnets in the lube oil strainers. Dirt may get through the strainers. These may become embedded in the babbitted bearings and eventually score the journals. In addition, the mixture of dirt and metallic particles may erode metal from the gear tooth surfaces.

The solution is clean, purified oil. For this reason, a lube oil purifier is installed in the engine room. It is used to remove water and other impurities from the oil that lubricates the bearings of the main engine turbines and the bearing and teeth of the main reduction gears. Lube oil purifiers and lube oil purification are discussed in more detail in chapter 4 of this manual.

Sump Oil Level

Some reduction gears are located directly above the lubricating oil sump tank or in a casing which also serves as the sump. You must be sure that the bull gear wheel will not rotate in the oil. If it does, the churning action will aerate the oil and cause the oil temperature to rise. Oil churning can also prevent full-speed operation of the shaft. This condition can be identified by high bearing temperatures and too much air (bubbles) in the sight-flow glasses. If this occurs, the engines must be slowed or stopped until the excess oil can be removed and normal conditions restored. Many bull gears have an oil exclusion pan. It is fitted at the time of manufacture to ensure against rotation of the gears in the oil. Other reduction gear constructions separate the reduction gears from the main sump completely and have oil return lines from the reduction gear casing to the sump. Ensure the proper oil level in the sump by checking the liquid level indicator. (Some installations may use a dipstick.)

Unusual Sounds

A properly operating reduction gear has a certain definite sound. You should be familiar with that sound, and investigate any unusual noises. When you hear one, operate the gears with caution until the cause is discovered and remedied.

REDUCTION GEAR CASING OPENING AND ACCESS

Access into reduction gear casings is strictly controlled. In most cases the engineer officer must be present before any inspection or work on or around the reduction gears is done where access is possible. Access is not limited to an opening of the inspection covers. Work on oil bubble repair or flexible couplings or gear vents on some ships allow access to the gears. Chapter 241 (9420) of the *Naval Ships' Technical Manual (NSTM)* lists the requirements, suggested procedures, and precautions for access control to main reduction gearing. The maintenance requirements cards (MRCs) are another reference for maintenance on reduction gearing where access is required.

The following procedures are examples of the rules which may be in force when reduction gear access is required. Actual approved procedures will differ somewhat, but the basic rules and concepts will apply.

Usually, a controlled area will be set up around the work area. This area may also require the use of some type of tent to surround and cover the access being opened. This tent will protect against material dropped from above or thrown into the area. Flashlights, wrenches, inspection mirrors, and other tools should be securely tied with a lanyard to either a person or a fixed object. Items with potentially loose parts, such as a flashlight, should be taped so that the parts will not fall free if it comes apart. Personnel entering the controlled area should not have items such as watches, rings, necklaces, arm bracelets, or unsecured eyeglasses on their persons. Pockets should be empty and taped. T-shirts or plain, pocketless undershirts should be worn in the area, or all buttons and pockets on the shirts should be securely taped. A watch should be posted at the entrance to the controlled area at all times that the reduction gear access is in progress. This is to ensure that procedures are followed and to limit access to the area to those persons designated by the engineer officer. These procedures (and those similar) are necessary. Reduction gear casualties can be caused when even a small piece of foreign material gets into the wrong place. You learned some of these reasons in the discussion of reduction gear construction.

BEARINGS

Bearings in main propulsion units vary greatly in size, composition, and lubrication requirements, but their purposes are the same. Bearings guide and support rotating elements and prevent free axial or radial movement of these elements. Radial or journal bearings carry loads applied in a plane perpendicular to the axis of the shaft. Thrust bearings carry loads applied in the same direction as the axis of the shaft and restrict axial movement.

The rotor of every turbine must be positioned radially and axially by bearings. Radial bearings carry the weight of the rotor and maintain the correct radial clearance between the rotor and the casing. Thrust bearings limit the axial movement of the rotor.

Some small auxiliary turbines use antifriction bearings, including ball and roller bearings. Our discussion, however, will be limited to friction-type bearings, whose dissmililar metallic surfaces are separated by, and depend upon, an intervening fluid oil film for lubrication and cooling.

Fluid oil-film lubrication is illustrated and explained in chapter 4 of this manual. Its effectiveness depends on a number of factors: the lubricant's properties of cohesion, adhesion, and viscosity; its temperature; its cleanliness; the clearance, alignment, and surface condition of the bearing and journal; the load; and the speed.

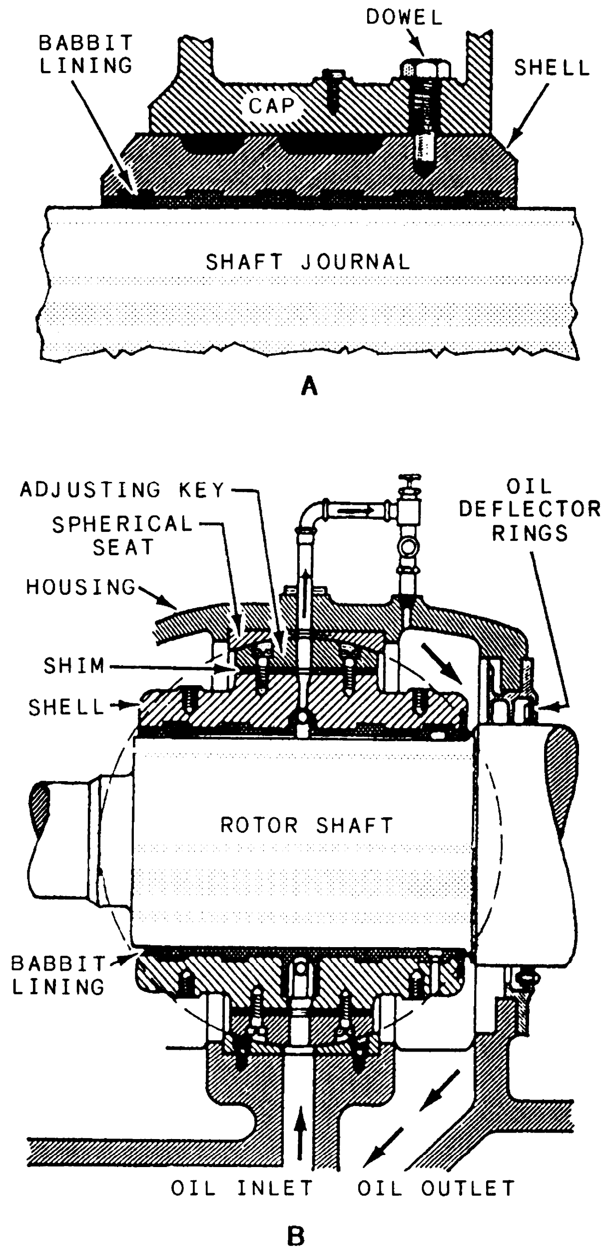


Figure 3-11.—Turbine rotor bearings. A. Cylindrical-seated bearing. B. Adjustable spherical-seated bearing.

RADIAL BEARINGS

Most turbines, including all main turbines, have a radial bearing at each end of the rotor. These bearings are generally known as JOURNAL BEARINGS and may be either the sleeve type or the tilting-pad type. Each type may be either cylindrical seated or spherical seated. Except for the momentary metal-to-metal contact at the time the turbine is started, the two metal surfaces of the journal and bearing are constantly separated by a film of oil.

A typical cylindrical-seated bearing is illustrated in figure 3-11, view A. The shell is lined with BABBIT METAL (a compostion of tin, lead, and antimony), which quickly disposes of the friction heat by transferring it to the lubricating oil passing through the bearing. The bearing cap, or upper half of the bearing housing, is bolted securely to the lower half of the bearing housing. The bolts are not shown in the figure.

The adjustable, spherical-seated, self-aligning bearing figure 3-11, view B, is used in most main turbines. The shell assembly consists of upper and lower cylindrical shells, around which are fitted adjusting keys, or bushings, with spherical-shaped outer surfaces or seats. The male spherical seat fits into a similarly shaped female seat in the bearing housing; the spherical shape permits a small amount of shell movement to compensate for minor misalignment of the shaft.

In some designs of the self-aligning bearing, radial adjustment of the bearing is accomplished either by varying the thickness of the adjusting seats or by placing shims between the adjusting seats and the shells. In other designs, adjustment is initially set by the manufacturer and cannot be changed. This eliminates misadjustments in service. Since the bearings are located close to the shaft glands, oil deflector rings (fig. 3-11) are fitted to the housing. These rings serve two purposes. First, they prevent the oil from moving along the rotor and entering the steam side of the turbine, which would result in contamination of the condensate. Second, they prevent gland-sealing steam from leaking into the journal bearing and contaminating the lubrication oil.

THRUST BEARINGS

You have learned about radial bearings that support and hold the rotor in correct radial position relative to the casing. A turbine also has an axial, or thrust, bearing, which limits the fore-and-aft travel of the rotor. This maintains the necessary clearance between the moving and stationary parts within the turbine.

In some auxiliary turbines, thrust bearings of the ball and roller type are used. In others, the radial bearing is designed with a small thrust bearing surface, along with the radial bearing surface. This type of bearing is actually a combination radial and thrust bearing.

In a small thrust bearing, the babbit-faced thrust plate is rigidly attached to the bearing housing, To provide a path for lubricating oil to the running surface, the babbit-faced surface usually has radial grooves. This type of bearing works satisfactorily for light loads and slow shaft speeds. However, in a thrust bearing of a large, high-speed turbine or propeller shaft, a rigidly mounted thrust plate, even though grooved, will not maintain an adequate oil film between the thrust face of the bearing and the thrust face of the collar. To overcome this difficulty, main

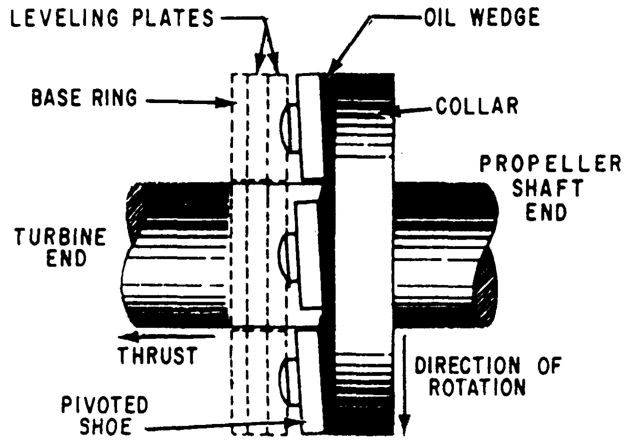


Figure 3-12.—Diagrammatic arrangement of a pivoted-shoe thrust bearing showing oil film.

turbine and propeller shafts are equipped with pivoted shoe-type thrust bearings. In this type of bearing, the thrust plate, instead of being a single rigidly mounted babbit-faced piece, consists of a number of babbit-faced segments, or shoes, that are free to assume a slight tilt. This freedom to assume a tilt helps maintain an adequate oil film between the shoe faces and the thrust collar.

The thrust bearing shoes pivot on the upper leveling plates in such a way that they may tilt very slightly (approximately 0.001 to 0.002 inch or 0.025 to 0.050 millimeter). Because the entire assembly is submerged in oil, the pivoting arrangment allows a continuous wedge-shaped oil film to form between the shoes and thrust collar (fig. 3-12). Whenever the shaft rotates, oil is dragged in (between the shoes and collar and each shoe) at the leading edge of the shoe, which is beveled 30 degrees to allow the oil to enter. The thrust on the shaft or collar has a tendency to squeeze the oil out again. Since the oil streams in at the edge and goes out at the sides and at the trailing edge, the oil film under the leading edge of the shoe is thicker than at the leading edge. In other words, as long as the shaft is rotating, each of the shoes is riding on the oil wedge.

Turbine thrust is usually in one direction only. However, most pivoted-shoe thrust bearings have shoes on both sides of the collar to take care of axial thrust in either direction. In some turbines, where the rotor thrust is always in one direction, or only slightly in the other direction, pivoted shoes may be used on the thrust-absorbing side only. The nonthrust side may have fewer shoes or a smaller diameter thrust bearing.

A thrust bearing may be installed in a separate housing, or it may be enclosed within the radial bearing housing.

Lubrication of bearings differs according to type. Babbitt-lined bearings are lubricated by an approved lubricating oil. Stern tube and strut bearings, which are lined with hardwood, phenolic, or a rubber composition, are lubricated by salt water. Bearings operate with a small lubricant clearance, which is the difference between the outside diameter of the journal and the inside diameter of the bearing. This clearance must always be maintained within specified limits. With proper clearances and proper lubrication, bearings will last for many years.

The information in this training manual is of a general nature. You can find additional information in chapters 241 (9420), 243 (9430), and 244 of *NSTM*. For details concerning a particular unit, consult the manufacturer's technical manual and current MRCs.

MAIN REDUCTION GEAR AND PROPULSION TURBINE BEARINGS

Reduction gear bearings must support the weight of the gears and their shafts. They must also hold the shafts in place against tremendous forces. These forces are exerted by the shafts and gears when they are transmitting power from the turbine shaft to the propeller shaft. Like other radial bearings in main engine installations, these bearings are of the babbitt-lined split type. However, the bearings are not spherically seated and self-aligning. Instead, they are rigidly mounted into the bearing housings by dowels or by locking screws and washers. The angular direction of the forces acting upon a main reduction gear bearing changes with the amount of propulsion power being transmitted by the gear. In some designs, thermocouples or RTEs are installed in bearings. Or, they may be installed in sight-flow fittings.

To avoid wiping, reduction gear bearings must be positioned so that the heavy shaft load is not brought against the area where the bearing halves meet (the split). For this reason, most bearings in reduction gears are placed so that the split is at an angle to the horizontal plane.

Turbine bearings, unlike reduction gear bearings, are self-aligning by a spherical seat for the bearing shells. Turbine bearings are pressure lubricated by the same forced-feed system that lubricates the reduction gear bearings.

MAIN THRUST BEARINGS

The main thrust bearing is usually located in the reduction gear casing. It absorbs the axial thrust transmitted through the shaft from the propeller.

Segmental pivoted-shoe thrust bearings (fig. 3-13), are commonly used for main thrust bearings. This bearing consists of pivoted segments or shoes (usually six or eight) against which the thrust collar revolves. The action of the thrust shoes against the thrust collar restrains the ahead or astern axial motion of the shaft to which the thrust collar is secured. These bearings operate on the principle that a wedge-shaped film of oil is more readily formed and maintained than a flat film, and that it can, therefore, carry a heavier load for any given size.

The upper leveling plates, upon which the shoes rest, and the lower leveling plates equalize

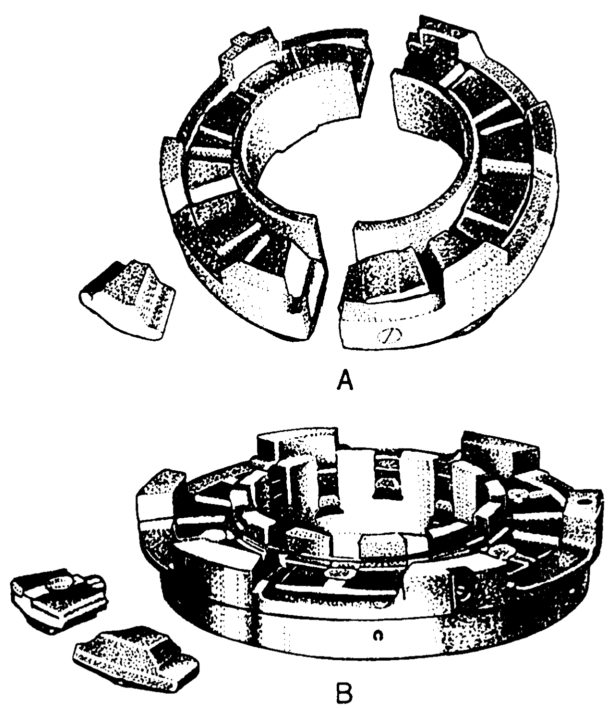


Figure 3-13.—Pivoted-shoe thrust bearing.

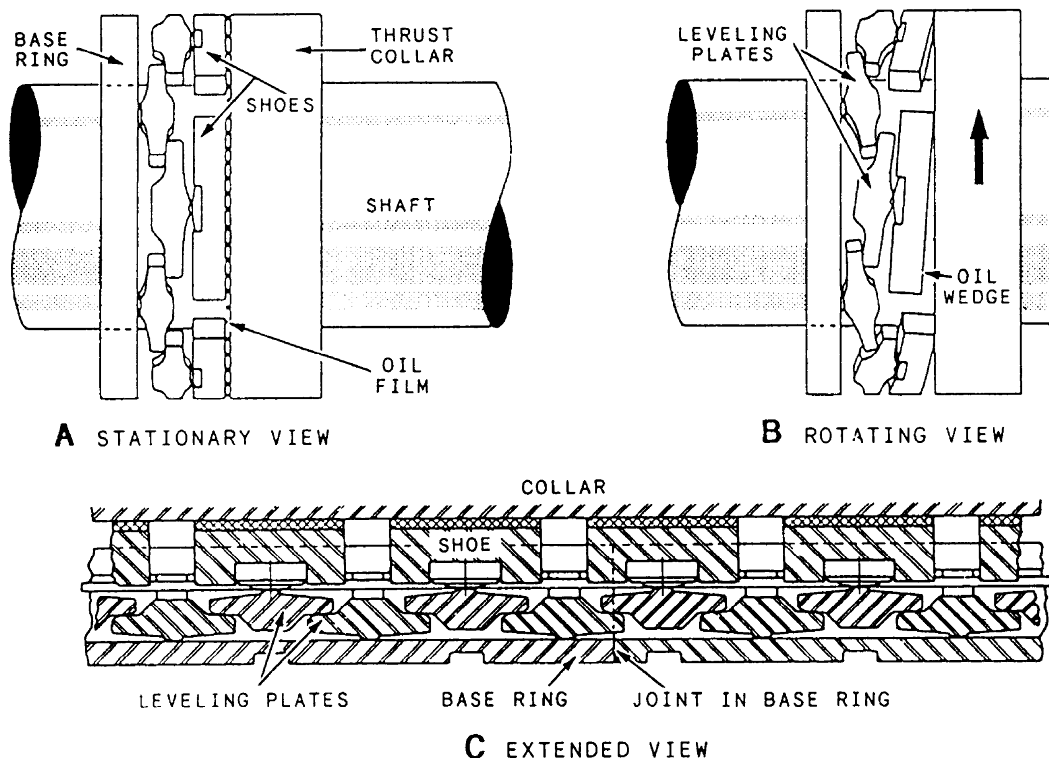


Figure 3-14.—Diagrammatic arrangement of a typical thrust bearing.

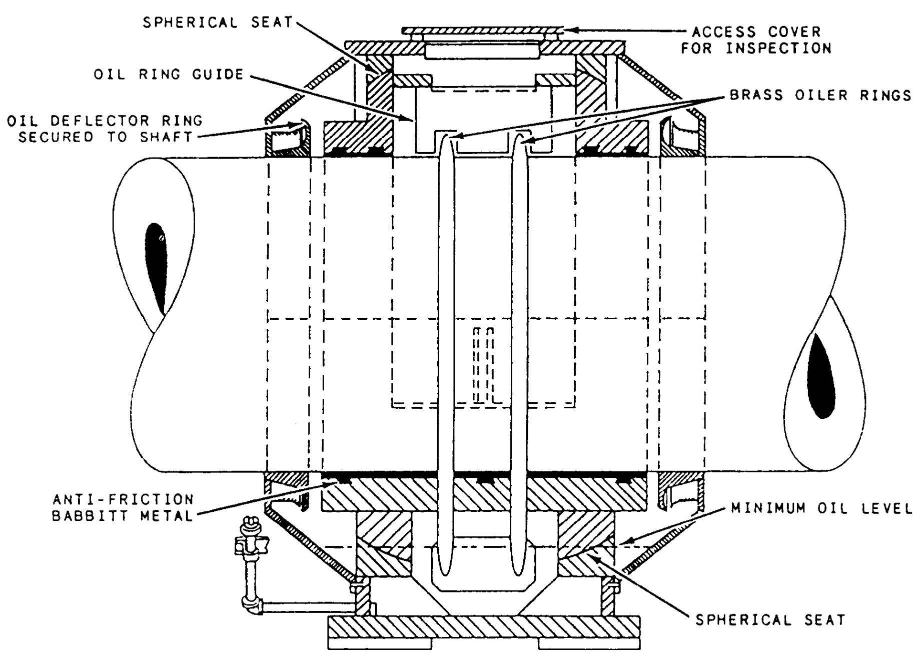
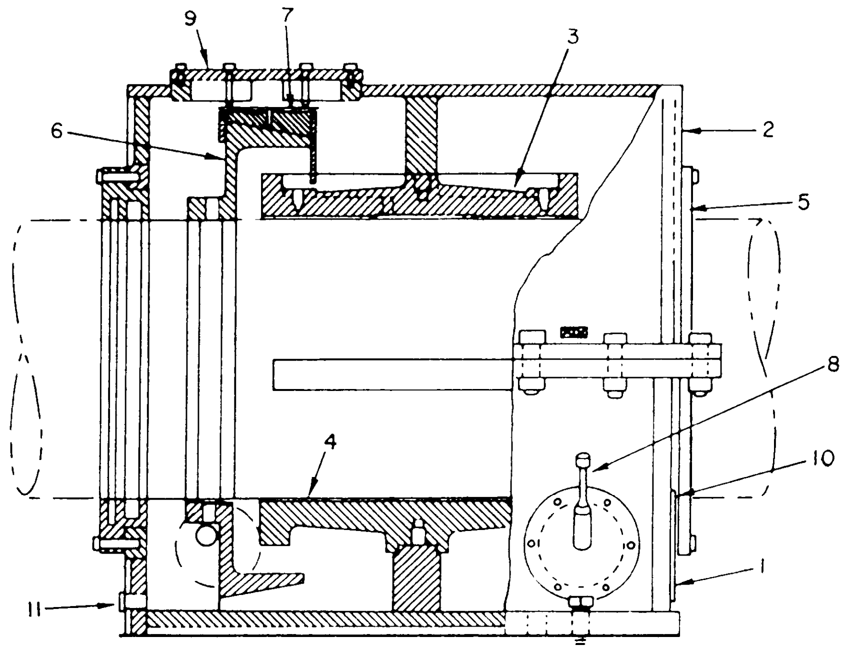


Figure 3-15.—Main line shaft bearing (ring oiled).



1. Bearing Pedestal	**5. Oil Retaining End Cover**	**9. Sight Hole**
2. Bearing Cap	**6. Oil Disc**	**10. Hand Hole**
3. Upper Bearing Shell	**7. Oil Scraper**	**11. Pipe Plug**
4. Lower Bearing Shell	**8. Oil Gauge**	

Figure 3-16.—Line shaft bearing (disc oiled).

the thrust load among the shoes (fig. 3-14). The base ring, which supports the lower leveling plates, holds the plates in place. This ring transmits the thrust on the plates to the ship's structure via housing members, which are bolted to the foundation. Shoe supports (hardened steel buttons or pivots), located in the shoes, separate the shoes and the upper leveling plates. This separation enables the shoe segments to assume the angle required to pivot the shoes against the upper leveling plates. Pins and dowels hold the upper and lower leveling plates in position. This allows ample play between the base ring and the plates to ensure freedom of movement (oscillation only) of the leveling plates. The base ring is kept from turning by its keyed construction, which secures the ring to its housing.

MAIN PROPULSION SHAFT BEARINGS

You will be required to watch and maintain the main propeller shaft bearings. These bearings support and hold the propulsion shafting in alignment. They are divided into two general groups. One group is made up of the main line shaft bearings, or spring bearings. The other is the stern tube bearings and the strut bearings.

Main Line Shaft Bearings or Spring Bearings

Most of these bearings are of the ring- or disc-oiled, babbitt-faced, spherical seat, or shell type. This bearing (fig. 3-15) is designed primarily to align itself to support the weight of the shafting.

The brass oiler rings, shown in figure 3-15, are a loose fit. The rings are retained in an axial position by guides or grooves in the outer bearing shell. As the shaft rotates, the friction between the rings and the shaft is enough to cause the rings to rotate with the shaft. The rings dip into the oil in the sump. Oil is retained on the inside diameter of the rings and is carried to the upper bearings by the rings. The action of the oil ring guides and contact of the rings on the upper shaft causes the oil to be removed from the rings and to lubricate the bearings.

The disc-oiled spring bearing (fig. 3-16) is basically the same as the ring-oiled type except that it uses an oil disc to lubricate the bearing. The oil disc is attached to, and rotates with, the

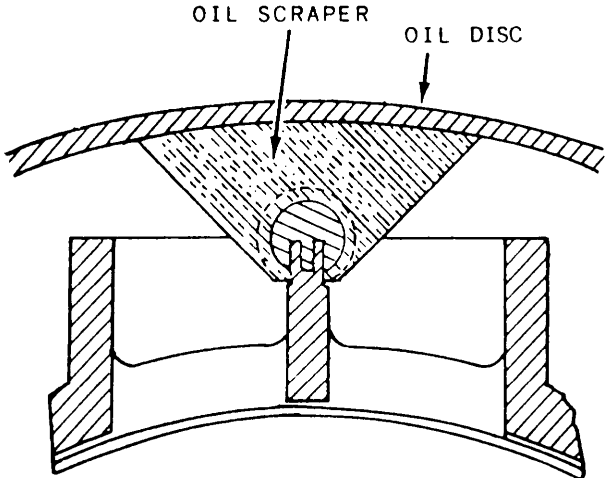


Figure 3-17.—Disc-oiled line shaft bearing scraper arrangement.

shaft. Oil is removed from the disc by a scraper, located at the top of the bearing. The oil then runs into a pocket at the top of the upper bearing shell. (Fig. 3-17 shows the scraper arrangement.) From here it enters the bearing through drilled holes.

Tests have shown that the disc delivers more oil at all speeds than the ring discussed earlier, especially at turning gear speeds. The disc is also more reliable than the ring. Other ships have main line shaft bearings that are force lubricated by a pump.

You should check the spring bearing temperatures and oil levels at least once an hour. Inspection and maintenance should be done according to PMS requirements.

Stern Tubes and Stern Tube Bearings

The stern tube is the position where the shaft passes through the hull of the ship. The shaft is supported in the stern tube by two stern tube bearings. There is one bearing on the inner side and one on the outer side of the hull. The construction of the stern tube bearing is basically the same as that of the strut bearing, which is described later in this chapter.

The position where the shaft passes through the hull must be sealed to prevent seawater from entering the ship. This is accomplished primarily by using either packing or an inflatable shaft seal. Stern tube packing (fig. 3-18) is used only on older ships as a primary sealer.

The packing method uses a stuffing box that is flanged and bolted to the stern tube. Its casting is divided into two annular (ring-shaped) compartments. The forward space is the stuffing

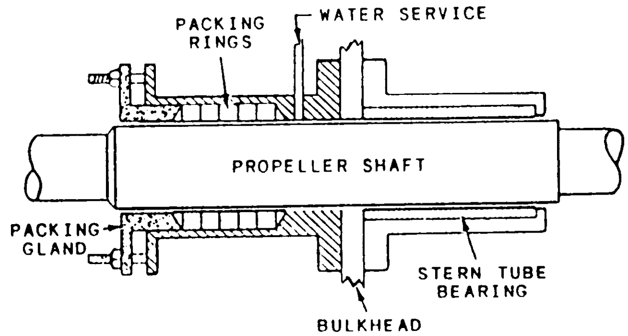


Figure 3-18.—Stern tube stuffing box and gland.

box. proper. The after space contains a flushing connection to provide a positive flow of water through the stern tube for lubricating, cooling, and flushing. This flushing connection is supplied by the firemain. A drain connection is provided both to test the presence of cooling water in the bearing and to allow seawater to flow through the stern tube to cool the bearing when underway. This is done where natural seawater circulation is used.

The gland for the stuffing box is divided longitudinally into two parts. The packing material is according to MIL-P-24377, and it has replaced all previously used packing material. This packing is Teflon impregnated asbestos (PTE).

Usually, the gland is tightened and the flushing connection is closed to eliminate leakage when the ship is in port. It is loosened just enough to permit a slight trickle of water for cooling purposes when the ship is underway. Whenever packing is added to a stern tube, be sure that the gland is drawn up evenly by using a rule to measure the distance between the gland and the stuffing box.

The split inflatable rubber seal ring (fig. 3-19) is installed aft of the prime seal assembly ring. It is used when it is necessary to repair or replace the prime sealing elements when the ship is waterborne.

When the seal is needed, it is blown up with nitrogen and expands against the shaft, making a seal. Nitrogen is used because it is dry and will not deteriorate the seal as rapidly as air.

The operation and testing of the split inflatable ring seal should be done according to ship's instructions and the PMS MRCs. Never exceed the maximum pressure designated for inflating the seal (given in *NSTM,* chapter 243 [9430]). Over-pressurization can rupture the seal.

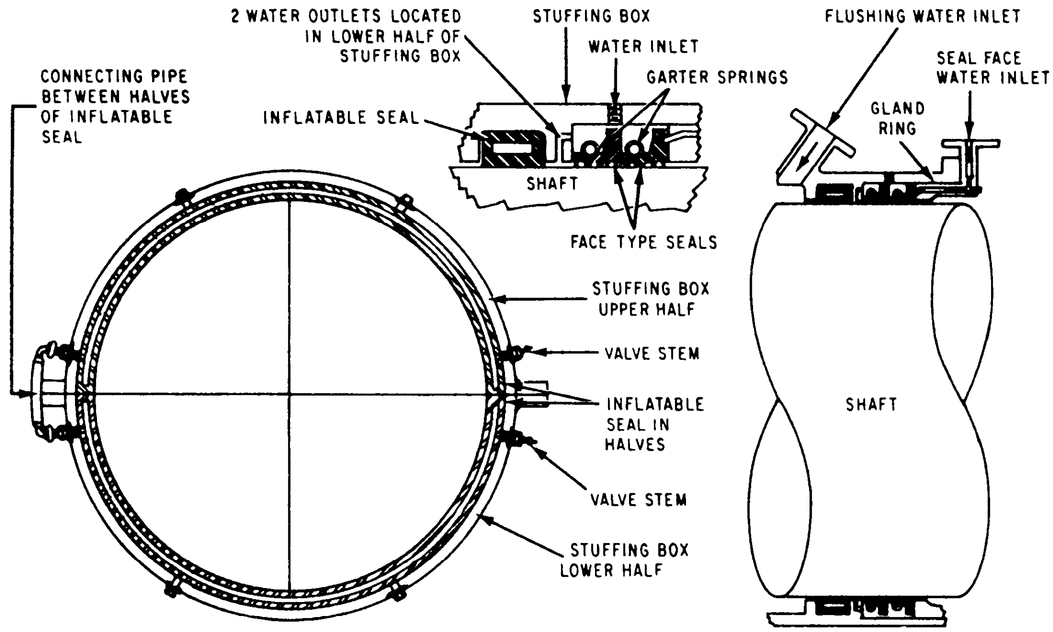


Figure 3-19.—Shaft seal and inflatable sealing ring.

In some installations, mechanical seals are used to seal the stem tube. Two of the major advantages of these seals are (1) they will operate maintenance free for extended periods; (2) they accommodate gross misalignment and allow for excessive bearing wear, high vibration, and large radial and axial movement of the shaft. Figure 3-20 shows a typical shaft seal that has received SHIPALT acceptance for approved use on FFG-7 ships and for retrofit aboard the DD-963 class ships. Refer to the manufacturer's technical manual for further information.

Strut Bearings

Strut bearings, as well as the stem tube bearings, are equipped with composition bushings which are split longitudinally into two halves. The outer surface of the bushing is machined with steps to bear on matching landings in the bore of the strut. One end is bolted to the strut.

Since it is usually not practical to-use oil or grease as a lubricant for underwater bearings, some other frictionless material must be used. There are certain materials that become slippery when wet. They include synthetic rubber; lignum vitae, a hard tropical wood with excellent wearing qualities; or laminated phenolic material, consisting of layers of cotton fabric impregnated and bonded with phenolic resin. Strips made from any of these materials are fitted inside the bearing. Most Navy installations use rubber composition strips (fig. 3-21).

CARE OF BEARINGS AND JOURNALS

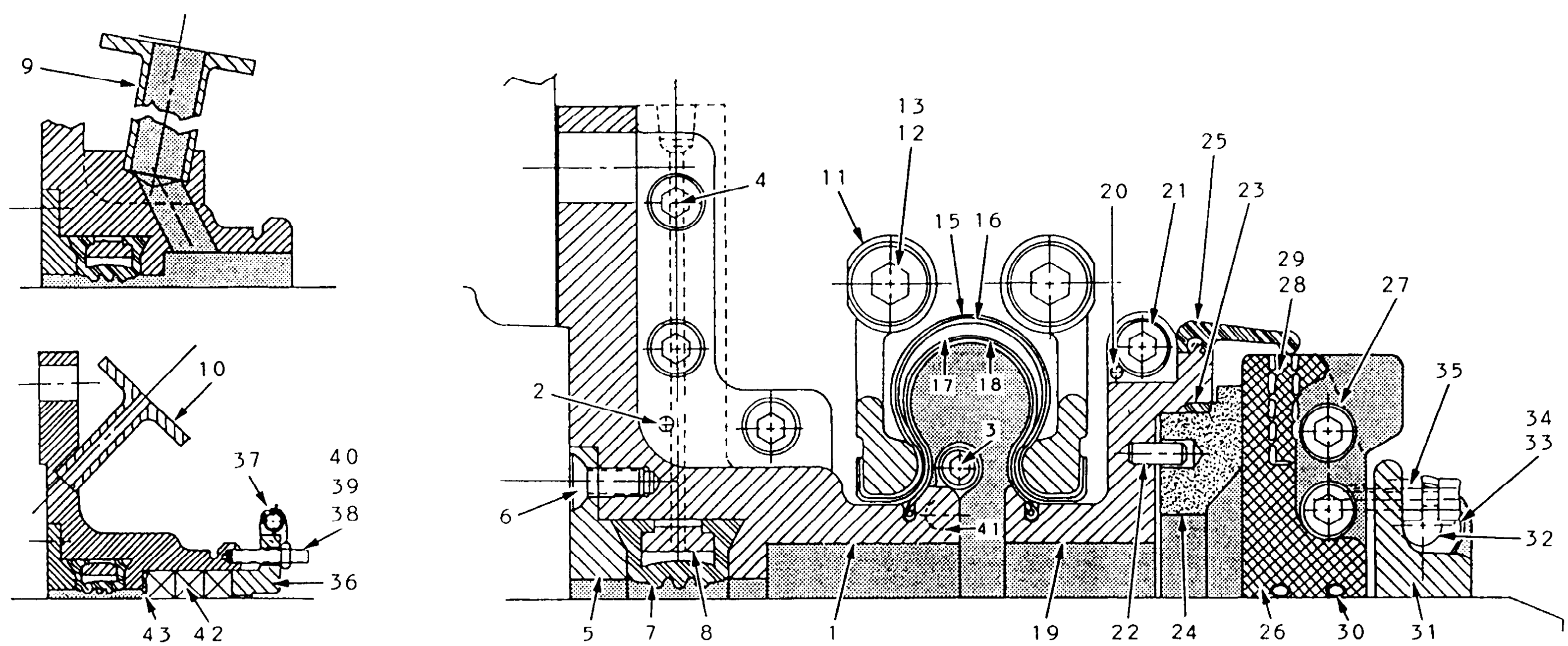
Properly operated bearings will give years of satisfactory service. However, like all units of engine-room machinery, they require periodic tests, inspections, and maintenance. When bearings are originally installed, the manufacturer takes oil clearance readings. These are recorded according to the PMS. At regular intervals the ship's force must also take these readings. Any difference between the old and the new readings will be the amount of bearing wear.

Main engine bearing clearances may be taken by depth gauge, crown thickness readings, or leads. Normally, the depth gauge method is used. Crown thickness readings are taken only when bearings are removed and marked for these readings. In other cases, leads are taken. Crown thickness readings are almost always used for the main gear bearings. Leads may be used in a few older installations. They may also be used on auxiliary machinery or main shaft bearings. A few line shaft bearings have provisions for depth gauge readings as well.

For another example, a dial indicator is used to take thrust bearing clearances.

In all cases, bearings must be inspected at regular intervals according to the PMS MRCs.

In most cases, the first indication of bearing trouble is an abnormal or rapid rise in temperature.



1. Mounting Ring
2. Alignment Pin
3. Inner Butt Bolt
4. Outer Butt Bolt
5. Adaptor Ring
6. Bolt
7. Inflatable Seal
8. I.S. Support Ring
9. Flange Connector
10. Flange Connector
11. Main Clamp Ring
12. Butt Bolt
13. Nut
14. Compression Adaptor (not shown)
15. Backing Spring Assembly
16. Bridging Spring Assembly
17. Support Spring Assembly
18. Interlayer
19. Face Carrier
20. Alignment Pin
21. Butt Bolt
22. Face Drive Pin
23. Face Sealing Strip
24. Face Insert
25. Splash Guard
26. Seat
27. Butt Bolt
28. Alignment Pin
29. Alignment Pin Screw
30. "O"-Ring
31. Drive Clamp Ring
32. Butt Bolt
33. Drive Bolt
34. Alignment Bolt
35. Locknut
36. Gland Follower
37. Butt Bolt
38. Studding
39. Nut
40. Washer
41. Plug
42. Packing
43. Back-up Ring
44. Toolbox (not shown)

Figure 3-20.—A typical shaft seal.

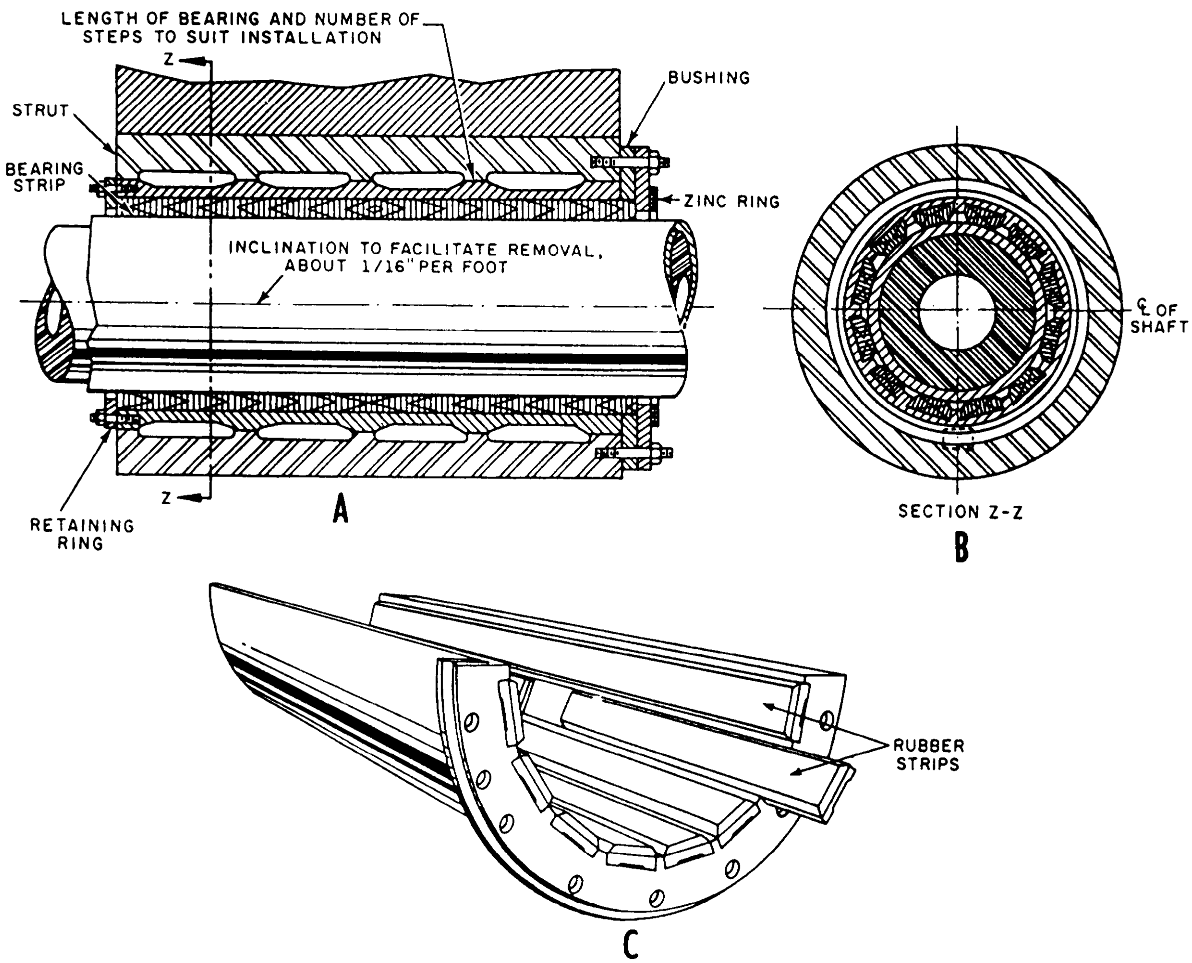


Figure 3-21.—Details of a strut bearing. A. Longitudinal view. B. Cross-sectional View. C. Rubber stripping in a bearing.

The temperature of oil discharged from a bearing, as measured by thermometer, must not exceed 180°F maximum or a rise of 50°F maximum above the oil cooler outlet temperature, whichever is less. This is true unless otherwise stated in the applicable technical manual or waived by NAVSEA on a case basis.

In addition to local-reading thermometers, some gear units have thermocouples or RTEs primarily for remote temperature indication. The element detector may be located either in the sight-flow fitting or mounted directly in the bearing babbitt. The applicable gear technical manual should be consulted for information on maximum allowable temperature limits.

If the temperature of a bearing increases above the normal running temperature, the quantity and quality of the lubricant supplied to the bearing should be checked. The temperature of the oil from the cooler should be maintained at the temperature recommended by the applicable gear technical manual. In most cases, this will range from 120°F to 130°F.

Erratic flow and/or a complete loss of flow of oil to a single sight-flow indicator at partial- to full-load conditions can cause a casualty. This can occur following reinstallation of a bearing that has been removed for inspection or renewal. This problem is generally caused by a restriction in the oil line from the bearing to the sight-flow fitting. The restriction is normally caused by improper assembly of the bearing cap on the shell. The oil passages are not exactly in line or improper handling has caused a nick or a burr at the edge of the passage. This condition should be checked and corrected at the earliest opportunity. Without the indicator, there is no positive way to determine that the bearing is receiving its proper supply of oil.

Chapter 241 (9420) of the *NSTM* contains information on wiped and otherwise damaged bearings and the requirements for repair and renewal.

SAFETY PRECAUTIONS FOR BEARINGS

Most bearings are similar in operation. Therefore, these safety precautions apply to all main engine, main shaft, and auxiliary machinery bearings. The following safety precautions help prevent most casualties:

1. NEVER use a piece of machinery if the bearings are known to be in poor condition.
2. Where possible, be sure that bearings have the proper quality and quantity of lube oil before starting the machinery.
3. Be sure the operating temperature of each bearing is not above the specified normal for the particular load and speed conditions. Investigate and report abnormal temperature immediately.
4. Remember that rapid heating of the bearing is a danger sign. A bearing that feels hot to the hand after an hour's operation may be all right, but the same heat reached in 10 or 15 minutes indicates trouble.
5. Newly installed bearings should be given a run-in period with no load applied.
6. Use clean rags (lint free) to clean bearings, shafting, and sumps.
7. When you assemble and install bearings with symmetrical halves, take care NOT to end-to-end one of the halves or to reverse the assembled bearing in its pedestal. This may cover the lube oil inlet passage.
8. Clean out wells of self-lubricated sliding-surface bearings at frequent intervals. See that the rings run freely and do not drag.
9. Refit or renew a wiped bearing.
10. When taking leads, be sure that the bearing halves are set up metal to metal.
11. Do not file or machine bearing joints.
12. After spotting-in a bearing, be sure that all shavings and dirt are cleaned from the parts.

PROPELLERS AND MAIN PROPULSION SHAFTING

The turbines and reduction gears convert the thermal energy of steam into usable mechanical energy. This mechanical energy is used through the propulsion shafting and the propeller.

MAIN PROPULSION SHAFTING

The main propulsion shafting may be up to 30 inches in diameter. It is divided into two environmental sections: the inboard or line shafting and the outboard or waterborne shafting (fig. 3-22). The main propulsion shafting is made of forged steel and is usually hollow in sizes of more than 6 inches in diameter.

The line shafting consists of several sections of shaft. These include the thrust shaft when the main thrust bearing is not located in the reduction gear casing. These sections are usually joined together by bolts through FLANGE COUPLINGS, which are forged integral with the shaft sections.

The outboard shafting consists of the propeller shaft, or tailshaft, upon which the propeller is mounted; the stern tube shaft, which penetrates the hull of the ship and thus makes the transition between inboard and outboard shafting; and in some cases, an intermediate, or dropout, shaft located between the propeller shaft and the stem tube shaft. In some single-shaft surface ships, the propeller shaft also functions as the stern tube shaft. The outboard shafting is protected from seawater corrosion by a covering of either plastic or rubber. Outboard shafting sections are usually joined to each other by integral flanges, although some older ships may have a removable outboard shaft coupling known as a MUFF-TYPE OUT- BOARD COUPLING. The stern tube shaft is connected to the line shafting by a removable coupling known as the INBOARD STERN TUBE COUPLING.

Circular steel or composition shields known as fair-waters are secured to the after end of the stern tube and to the struts. They are "faired in" to the shafting to reduce turbulence. This fairing is accomplished by a gradual reduction in diameter from that of the stern tube or strut to that of the shaft. In some cases, a flange is adjacent to a strut or the aft end of the stern tube. In these cases, the fairwater may either extend beyond the flange (either forward or aft as applicable) and fair into the shaft, it may fair into a rotating coupling cover that is attached to the flange and shaft. Some ships have watertight rotating coupling covers filled with tallow, which seals the flanged coupling from seawater.

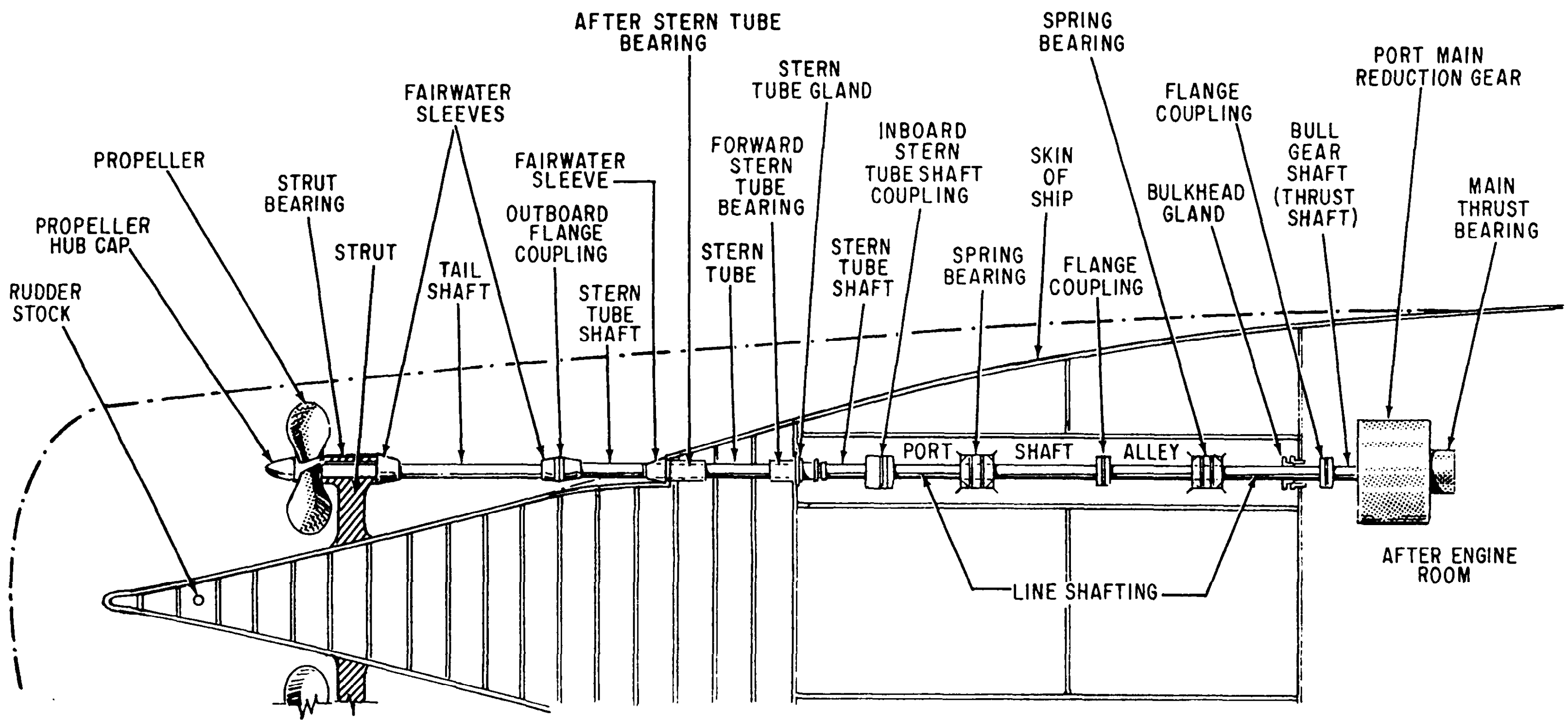


Figure 3-22.—Diagrammatic arrangement of a main propulsion system.

PROPELLERS

The propellers, where the mechanical energy produced by the main engine is finally used, are of various types of construction. They may be left-hand helices, turning counterclockwise in the ahead direction when viewed from astern. Or, they may be right-hand helices, turning clockwise. Normally, all starboard and centerline propellers turn clockwise and all port propellers turn counterclockwise. They may be of constant pitch, with pitch of blades identical at all points along the radius. They may be of variable pitch, with pitch of blades varying along the radius. Or, they may be of controllable pitch, with blades capable of being rotated within their sockets to change speed and direction of propeller thrust. They may be of solid construction, of single casting, or of built-up construction with individually cast blades bolted to the propeller hub. The number of blades will vary, usually from three to seven.

Controllable Pitch Propellers

Controllable pitch propellers (CPPs) used on some naval ships give excellent maneuverability and can develop maximum thrust at any given engine rpm. A ship with CPPs stops in shorter distances than a ship with fixed pitch propellers. These propellers are particularly useful for landing ships because they make it possible for the ships to hover offshore and make it easier to retract and turn away from the beach. Propulsion and speed control for the ship are furnished by the main propulsion plant and the CPP arrangement. The two systems operate in cooperation with each other in response to electronic contro1 signals received from various control stations in the ship. A typical main propulsion and CPP arrangement in the DD-963, DD-993, and DD-997 will be used for discussion. For further information on the arrangement for your class of ship, refer to the applicable technical manual.

Main Propulsion System

The main propulsion system (fig. 3-23) at includes two line shafts, one for each engine room. Each line shaft consists of two gas turbine engines coupled to a main reduction gear that turns a propeller shaft, attached hub assembly, and a five-blade propeller.

Controllable Pitch Propeller Arrangement

Each CPP arrangement, starboard and port, consists of an independent CPP with associated mechanical, hydraulic, and electronic pitch control systems (fig. 3-24). The CPP controls the position of the propeller blades. Blade pitch control permits a full range of ahead or astern thrust, including no thrust in the zero pitch position, while the main propulsion machinery operates at a constant speed, thus improving overall plant efficiency.

The major components of each CPP are (I) the electrohydraulic servocontrol assembly, (2) the oil

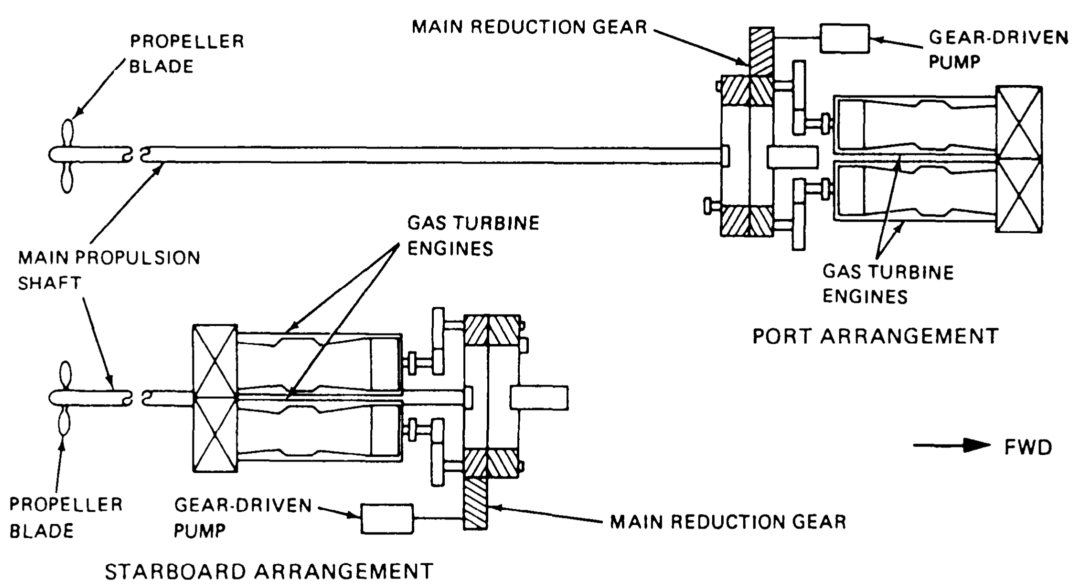


Figure 3-23.—Main propulsion system

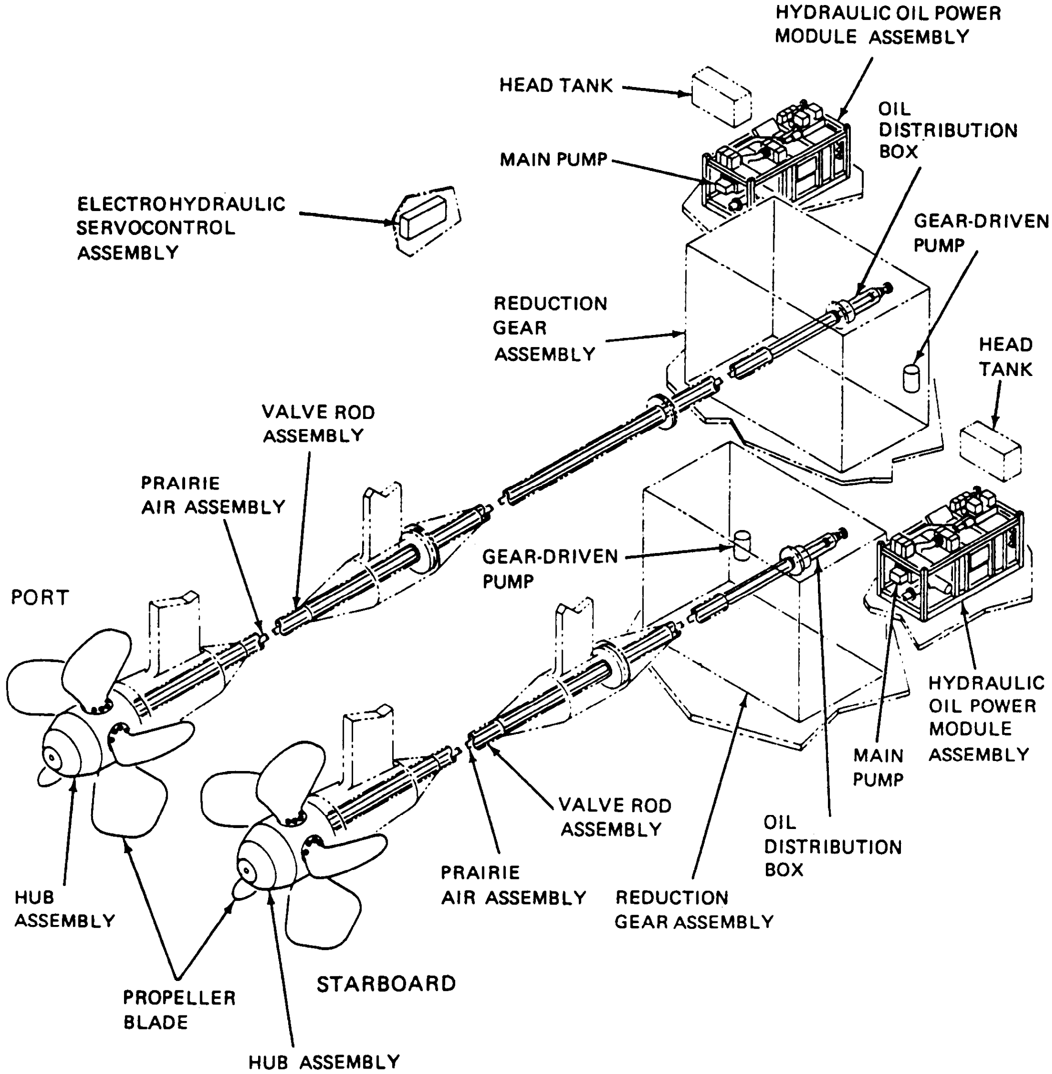


Figure 3-24.—Controllable pitch propeller in DD-963, DD-993, and DD-997 class ship.

distribution (OD) box, (3) the hydraulic oil power module assembly (HOPM), (4) the valve rod assembly, (S) the hub assembly, and (6) the prairie air system assembly, which is used to mask propeller sounds. Each of these will be described in the following sections:

1. The electrohydraulic servocontrol assembly is in an enclosure located in each engine room, which electronically controls, monitors, and actuates the display of propeller pitch settings and changes.

2. The OD box and its major components directs high-pressure (HP) oil to and from the hub assembly through the propeller shaft, operates the valve rod assembly, and provides passage for the prairie air tubing.

3. The HOPM provides low-pressure (LP) control oil to the OD box to operate the valve rod actuating mechanism and provides HP oil to the OD box to operate the hub piston mechanism. The HOPM is a self-contained, resiliently mounted unit consisting of various hydraulic components installed in a welded structure. The HOPM is connected by hydraulic piping to the sump tank, standby screw pump (gear driven), and manifold block assembly. C The main components of the HOPM are the ac motor, steelflex coupling, screw pump (main pump), pressure control assembly, suction strainer, oil filters, sensors, and indicators.

4. The valve rod assembly provides passage for the HP hydraulic oil from the OD box to the hub assembly, and it also translates hydraulic pitch

control commands in the OD box into pitch changes by the bladeturning mechanism in the hub assembly.

5. The hub assembly is attached to the aft end of each propulsion shaft. Five propellor blades are bolted symmetrically to each hub. A blade port cover and blade seal ring prevent seawater from entering the hub around each blade. Each hub contains a piston, piston rod assembly, piston nut, and propeller blade turning mechanism to change pitch and hold the pitch position of the blade. The piston and the aft end of the piston rod are located in the hub cone. The forward end of the piston rod is attached to the crosshead of the blade turning mechanism. These components move axially when HP oil is directed to either the forward or aft face of the hub piston. Five sliding blocks are fitted into the machined slots in the crosshead. An eccentric pin on the underside of each crankpin ring fits into the hole in the sliding block. Two dowel pins transmit torque from the crankpin ring to the blade, and eight blade bolts attach the blade to the crankpin ring.

6. The prairie air assembly tubing enters the CPP through the end cover at the forward end of the OD box. The tubing passes through the center of the OD box, and then through the bore of the valve rod to the propeller hub. The tubing consists of fabricated sections of seamless steel piping joined by threads and setscrews.

CHAPTER 4

LUBRICATION AND ASSOCIATED EQUIPMENT

Lubrication reduces friction between moving parts by substituting fluid friction for sliding or rolling friction. Without lubrication, you would have difficulty moving a 100-pound weight across a rough surface; however, with lubrication and properly designed bearing surfaces, with a very small motor you could move a 1,000,000-pound load. By reducing friction, lubrication lowers the amount of energy required to perform mechanical actions and causes less heat to be produced.

Lubrication is a matter of vital importance throughout the shipboard engineering plant. Moving surfaces must be steadily supplied with the proper kinds of lubricants. Lubricants must be maintained at specified standards of purity and at designed pressures and temperatures. Without proper lubrication, many units of shipboard machinery would grind to a screeching halt.

The lubrication requirements of shipboard machinery are met in various ways, depending on the machinery. In this chapter we will discuss the basic theories of lubrication, the lubricants used aboard ship, and the lubrication systems installed for many shipboard units. Also we will discuss the devices used to maintain lubricating oils in the required condition of purity. At the end of this chapter, you will find information on the Lube Oil Management Program.

THEORY OF LUBRICATION

Friction is the natural resistance to motion caused by surface contact, and the purpose of lubrication is to reduce this friction. The friction that exists between a body at rest and the surface upon which it rests is called STATIC friction. The friction that exists between moving bodies (or between one moving body and a stationary surface) is called KINETIC friction. Static friction is greater than kinetic friction. Static friction and inertia must be overcome to put a body in motion. To keep a body in motion, you must overcome kinetic friction.

There are three types of kinetic friction: sliding friction, rolling friction, and fluid friction. Sliding friction occurs when one solid body slides across another solid body. Rolling friction occurs when a curved body, such as a cylinder or a sphere, rolls across a surface. Fluid friction is the resistance to motion exhibited by a fluid.

Fluid friction occurs because of two properties of a lubricant: cohesion and adhesion. COHESION is the molecular attraction between particles which tends to hold a substance together. ADHESION is the molecular attraction between particles which tends to cause unlike surfaces to stick together. If a paddle is used to stir a fluid, for example, cohesion between particles of the fluid tends to hold the molecules together. This retards motion of the fluid. But adhesion of fluid particles causes the fluid to stick to the paddle. This further causes friction between the paddle and the fluid. In the theory of lubrication, cohesion and adhesion have a major role. Adhesion is the property of a lubricant which causes it to stick (or adhere) to the parts being lubricated; cohesion is the property which holds the lubricant together and enables it to resist breakdown under pressure. Later in this chapter, we will discuss other important properties of a lubricant.

Different materials have varying degrees of cohesion and adhesion. In general, solid bodies are highly cohesive but only slightly adhesive. Most fluids are highly adhesive but only slightly cohesive.

FLUID LUBRICATION

One of the qualities of a liquid is that it cannot be forced into a smaller space than it already occupies. A liquid is incompressible. This fact allows moving metal surfaces to be separated from each other. Because of this, liquid is used for most lubrication needs. As long as the lubricant film remains unbroken, fluid friction replaces sliding friction and rolling friction.

In any process involving friction, some power is consumed and some heat is produced. Overcoming sliding friction consumes the greatest amount of power and produces the greatest amount of heat. Overcoming fluid friction consumes the least power and produces the least amount of heat.

LANGMUIR THEORY

A presently accepted theory of lubrication is based on the Langmuir theory of the action of fluid films of oil between two surfaces, one or both of which are in motion. Theoretically, three or more layers or films of oil exist between two lubricated bearing surfaces. Two of the films are BOUNDARY films (indicated as I and V in figure 4-1A), one of which clings to the surface of the rotating journal and one of which clings to the stationary lining of the bearing. Between these two boundary films are one or more FLUID films (indicated as II, III, and IV in fig. 4-1A).

When the rotating journal is set in motion, a wedge of oil is formed (fig. 4-1B). Contact between the two metal surfaces is prevented when oil films II, III, and IV (fig. 4-1A) slide between the two boundary films. The theory is again illustrated in figure 4-1C. The position of the oil wedge, W, is shown with respect to the position of the journal as it starts and continues in motion.

The views shown in figure 4-1C represent a journal or shaft rotating in a solid bearing. The clearances are enlarged in the drawing to show the formation of the oil film. The shaded portion represents the clearance filled with oil. The stationary view shows the film in the process of being squeezed out while the journal is at rest. As the journal begins to turn and to increase speed, oil adhering to the surfaces of the journal is carried into the film. The film increases in thickness and tends to lift the journal, as shown in the starting view. As the speed increases, the journal takes the position shown in the running view. Varying temperatures cause changes in oil viscosity. These changes modify the film thickness and position of the journal. Viscosity will be discussed later in this chapter.

If conditions are correct, the two surfaces are properly separated. A momentary contact may occur at the time the motion is started.

FACTORS AFFECTING LUBRICATION

A number of factors determine the effectiveness of oil film lubrication. They include pressure, temperature, viscosity, speed, alignment, condition of the bearing surfaces, running clearances, and the purity of the lubricant. Many of these factors are interrelated and interdependent. For example, the viscosity of any given oil is affected by temperature, and the temperature is affected by running speed. Therefore, the viscosity is partially dependent on the running speed.

A lubricant must stick to the bearing surfaces and support the load at operating speeds. More adhesiveness is required to make a lubricant adhere to bearing surfaces at high speeds than at low speeds. At low speeds, greater cohesiveness is required to keep the lubricant from being squeezed out from between the bearing surfaces.

Large clearances between bearing surfaces require high viscosity and cohesiveness in the lubricant to ensure maintenance of the lubricating oil film. The larger the clearance, the greater must be the lubricant's resistance to being pounded out,

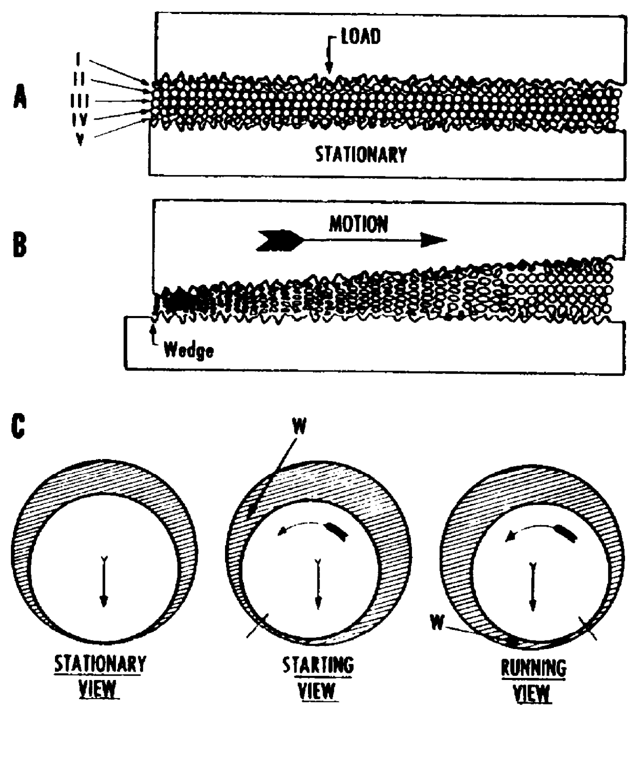


Figure 4-1.—Oil film lubrication.

with consequent destruction of the lubrication oil film.

High unit load on a bearing requires high viscosity of the lubricant. A lubricant subjected to high loading must be sufficiently cohesive to hold together and maintain the oil film.

LUBRICANTS

Although synthetic lubricants are used today, the Navy uses petroleum as their main source of oils and greases. By various refining processes, lubricating oils are extracted from crude petroleum and blended into a number of products. Sometimes additives (chemical compounds) are included in the process. Lubricating oils have to meet a wide range of lubrication requirements.

CAUTION

All lubricants are hazardous materials. All lubricants, especially synthetics, are toxic and hazardous to health. You should avoid prolonged skin and eye contact. Remove lubricant-soaked clothing promptly and wash skin thoroughly with soap and water. The Material Safety Data Sheet (MSDS) for each item includes precautions, disposal information, and hazards. If you need an MSDS, ask your supervisor.

Lubricating Oils

Lubricating oils approved for shipboard use are limited to those grades and types that are necessary to provide proper lubrication under all anticipated operating conditions.

Diesel engines use a detergent-dispersant type of additive oil to keep the engines clean. These lubrication oils must be fortified with oxidation and corrosion inhibitors. This allows long periods between oil changes and prevents corrosion of bearing materials.

Steam turbines use an oil of high initial film strength. This oil is fortified with anti-foaming additives and additives that control oxidation and corrosion. Also, extreme pressure (EP) additives are used. These additives help the oil carry the very high loading found in the reduction gear.

For general lubrication and in hydraulic systems using petroleum lubricants, the Navy must use certain oils. These special viscosity series of oils are strengthened with oxidation and corrosion inhibitors and antifoam additives. Deck machinery uses compounded oils, which are mineral oils with additives.

Special lubricating oils are available for a wide variety of services. The Federal Supply catalog has a list of these oils. Among the most important specialty oils are those used for lubricating refrigerant compressors. These oils must have a very low pour point and must be maintained with a high degree of freedom from moisture.

The main synthetic lubricants in naval use are (1) a phosphate-ester type of fire-resistant hydraulic fluid, used chiefly in the deck-edge elevators of carriers, and (2) a water-base glycol hydraulic fluid, used chiefly in the catapult retracting gears.

CLASSIFICATION OF LUBRICATING OILS.—The Navy identifies lubricating oils by number symbols. Each identification symbol consists of four digits and, in some cases, appended letters. The first digit shows the class of oil according to type and use; the last three digits show the viscosity of the oil. The viscosity digits are actually the number of seconds required for 60 milliliters (mL) of the oil to flow through a standard orifice at a certain temperature. Symbol 3080, for example, shows that the oil is in the 3000 series. It also shows that a 60-mL sample flows through a standard orifice in 80 seconds when the oil is at a certain temperature (210°F, in this instance). Another example is symbol 2135 TH. This symbol shows that the oil is in the 2000 series. It also shows that a 60-mL sample flows through a standard orifice in 135 seconds when the oil is at a certain temperature (130°F, in this case). The letters H, T, TH, or TEP added to a basic number show that the oil contains additives for special purposes.

PROPERTIES OF LUBRICATING OILS.—Lubricating oils used by the Navy are tested for a number of properties. These include (1) viscosity, (2) pour point, (3) flashpoint, (4) fire point, (5) auto-ignition point, (6) demulsibility, (7) neutralization number, and (8) precipitation number. Standard test methods are used for making all tests. The properties of lube oil are briefly explained in the following paragraphs.

1. VISCOSITY—The viscosity of an oil is its tendency to resist flow or change of shape. A liquid of high viscosity flows very slowly. In variable climates, automobile owners, for example, change oils in accordance with prevailing seasons. Oil changes are necessary because heavy oil becomes too sluggish in cold weather,

and light oil becomes too thin in hot weather. The higher the temperature of an oil, the lower its viscosity becomes; lowering the temperature increases the viscosity. The high viscosity or stiffness of the lube oil on a cold morning makes an automobile engine difficult to start. The viscosity must always be high enough to keep a good oil film between the moving parts. Otherwise friction will increase, resulting in power loss and rapid wear on the parts.

Oils are graded by their viscosities at a certain temperature. Grading is set up by noting the number of seconds required for a given quantity (60 mL) of the oil at the given temperature to flow through a standard orifice. The right grade of oil, therefore, means oil of the proper viscosity.

Every oil has a viscosity index based on the slope of the temperature-viscosity curve. The viscosity index depends on the rate of change in viscosity of a given oil with a change in temperature. A low index figure means a steep slope of the curve, or a great variation of viscosity with a change in temperature; a high index figure means a flatter slope, or lesser variation of viscosity with the same changes in temperatures. If you are using an oil with a high viscosity index, its viscosity or body will change less when the temperature of the engine increases.

2. POUR POINT—The pour point of an oil is the lowest temperature at which the oil will barely flow from a container. At a temperature below the pour point, oil congeals or solidifies. Lube oils used in cold weather operations must have a low pour point. (NOTE: The pour point is closely related to the viscosity of the oil. In general, an oil of high viscosity will have a higher pour point than an oil of low viscosity.)

3. FLASHPOINT—The flashpoint of an oil is the temperature at which enough vapor is given off to flash when a flame or spark is present. The minimum flashpoints allowed for Navy lube oils are all above 315 °F. However, the temperatures of the oils are always far below that under normal operating conditions.

4. FIRE POINT—The fire point of an oil is the temperature at which the oil will continue to burn when ignited.

5. AUTO-IGNITION POINT—The auto-ignition point of an oil is the temperature at which the flammable vapors given off from the oil will burn. This kind of burning will occur without the application of a spark or flame. For most lubricating oils, this temperature is in the range of 465° to 815°F.

6. DEMULSIBILITY—The demulsibility, or emulsion characteristic, of an oil is its ability to separate cleanly from any water present—an important factor in forced-feed systems. You should keep water (fresh or salt) out of oils.

7. NEUTRALIZATION NUMBER—The neutralization number of an oil is the measure of the acid content. The number of milligrams of potassium hydroxide (KOH) required to neutralize 1 gram of the oil defines the neutralization number. All petroleum products oxidize in the presence of air and heat. The products of this oxidation include organic acids. High amounts of organic acids have harmful results on galvanized surfaces and on alloy bearings at high temperatures. The demulsibility of the oil with respect to fresh water and seawater also relies on the amount of organic acids. High organic acid levels may cause decreased demulsibility. The formation of sludge and emulsions too stable to be broken by available means may result. This last problem may occur in turbine installations. An increase in acidity is a sign that the lubricating oil is breaking down.

8. PRECIPITATION NUMBER—The precipitation number of an oil is a measure of the amount of solids classified as asphalts or carbon residue contained in the oil. The number is reached by diluting a known amount of oil with naphtha and separating the precipitate by centrifuging—the volume of separated solids equals the precipitation number. The test helps you find out quickly the presence of foreign materials in used oils. An oil with a high precipitation number may cause trouble in an engine. It could leave deposits or plug up valves and pumps.

Lubricating Greases

Some lubricating greases are simple mixtures of soaps and lubricating oils. Others are more unusual, such as silicones and dibasic acids, which are exotic liquids. These may be thickened with metals or inert materials to provide enough lubrication. Requirements for oxidation inhibition, corrosion prevention, and extreme pressure performance are met by adding special substances (additives).

Lubricating greases are supplied in three grades: soft, medium, and hard. The soft greases are used for high speeds and low pressures; the medium greases are used for medium speeds and medium pressures; the hard greases are used for slow speeds and high pressures.

CLASSIFICATION OF LUBRICATING GREASES.—Navy specifications have been drawn to cover the several grades of lubricating greases. The grades most common in engineroom use are ball and roller bearing grease and extreme pressure grease.

1. BALL AND ROLLER BEARING GREASE, MIL-G-24508—Ball and roller bearing grease is for general use in equipment designated to operate at temperatures up to 300°F. For temperature applications above 300°F, high-temperature, electric-motor, ball and roller bearing grease (MIL-L-15719) must be used.

2. EXTREME PRESSURE GREASE, MIL-G-17740—Extreme pressure grease has anti-rust properties and is suitable for lubrication of semi-enclosed gears, or any sliding or rolling metal surfaces where loads may be high and where the equipment may be exposed to salt spray or moisture. It is intended for use in a temperature range of 0° to 140°F.

GRAPHITE GREASE, VV-G-671.—Graphite grease may be applied with compression grease cups to bearings operating at temperatures not to exceed 150 °F. The three grades of this grease are listed below:

Grade 1 Soft	For light pressures and high speeds
Grade 2 Medium	For medium pressures and medium speeds
Grade 3 Medium Hard	For high pressures and slow speeds

LUBRICATING SYSTEMS

The following paragraphs contain information about different lubricating systems and their related equipment. We will discuss the important functions and use of each system and describe their operating procedures.

MAIN LUBRICATING OIL SYSTEMS

Main lubricating oil systems in steam-driven ships provide lubrication for the turbine bearings and the reduction gears. In some ships, the main lube oil system also provides control oil for the main engine throttle control system and hydraulic gland seal regulators.

The main lube oil system generally includes a filling and transfer system, a purifying system, and separate service systems for each propulsion plant.

Most ships have three positive displacement pumps for main lube oil service. One pump is an attached pump driven by either the propulsion shaft or the quill shaft of the reduction gear. This pump provides main lube oil service when the main engines are turning fast enough for the pump to supply the required pressure. The other two pumps may be both electric-motor driven or a combination of one turbine-driven and one electric-motor driven. These pumps are used when lighting off, securing, and at low speeds when the attached pump is not supplying enough pressure. Another use is as a standby pump when the attached pump has the load.

Some ships have automatic features which provide for electric pumps to start and stop or shift speeds at various pressures and shaft rpm. This system automatically provides enough main lube oil pressure for all operating conditions.

Some ships have only two electric-motor driven main lube oil pumps. One pump is supplied by ac electrical power and the other by dc electrical power. One pump is always in standby for the running pump and will automatically start if oil pressure drops below a certain value.

Lube oil pressures which provide control features for the main lube oil system (such as

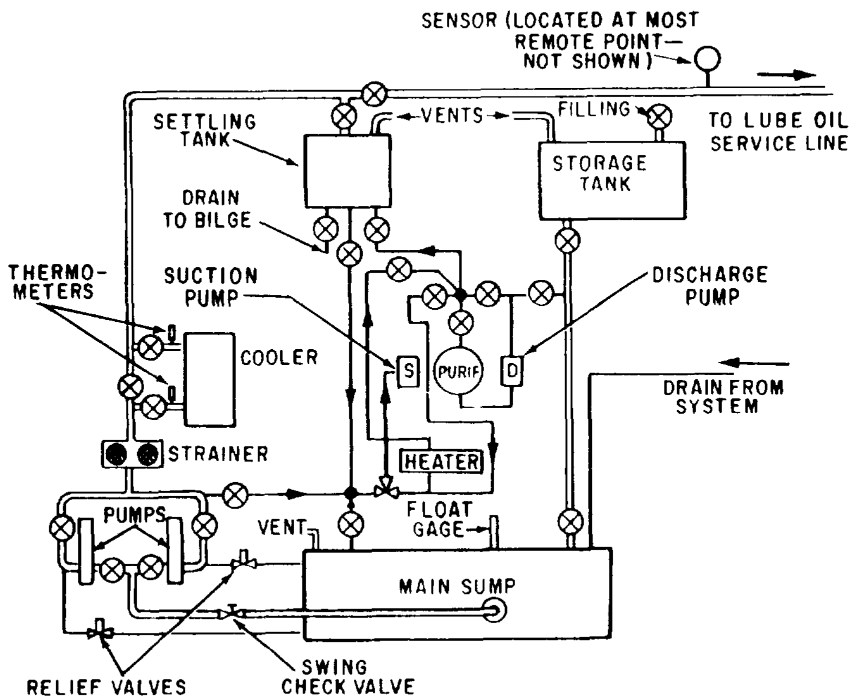


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Figure 4-2.—Typical lube oil system.

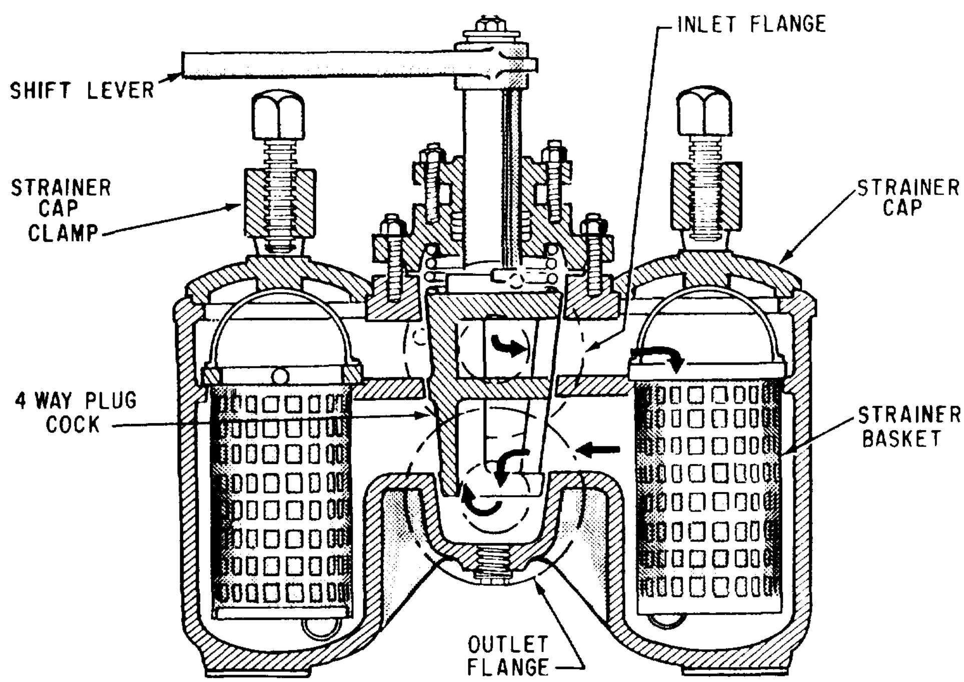

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Figure 4-3.—Duplex strainer.

alarms, pump standby features, etc.) are monitored at or near the bearing farthest from the lube oil supply (main lube oil pumps); this is known as the most remote bearing.

In a typical main lube oil system (fig. 4-2), the pump takes suction from the main sump and discharges the lube oil into the duplex strainers (fig. 4-3). From the strainer, the lube oil goes to the oil cooler (discussed in chapter 6 of this manual). The oil is cooled to 120 to 130°. This temperature is maintained by using the overboard valve to adjust the flow of seawater through the cooler. After leaving the cooler, the oil goes to the turbine and reduction gear bearings. In the main lube oil service line between the cooler and the bearing supply lines, an unloading valve is installed to dump excess pressure back to the main sump. This valve is set to maintain designed operating pressure to the most remote bearing and is normally spring loaded or air pilot controlled. After leaving the bearings, the lube oil returns to the main sump by gravity flow. Also, relief valves are installed in each pump discharge line to protect the pump against excessive pressure. An orifice or a needle valve is installed in each bearing supply line to regulate the flow of oil to the individual bearing. Figure 4-4 shows a forced-feed lubricated bearing.

AUXILIARY MACHINERY LUBRICATION SYSTEMS

Lube oil systems for auxiliary machinery have the same components as the main lube oil system and serve the same purpose. However, the construction and size of the components are different.

The lube oil pump is normally of the simple gear type and is driven by a pinion on the gear shaft. The lube oil filter is of the stacked disk type. You should keep this filter clean in accordance with PMS requirements. The cooler is a double-pass water-tube type. The water for this cooler is supplied by the auxiliary machinery cooling water system. The temperature of the lube oil leaving the cooler is controlled by regulating the cooling water flow with the inlet valve to the cooler. By using the inlet valve, you will not subject the lube oil cooler to the full pressure of the cooling water system. If you allow full pressure on the cooler, it could rupture. An orifice is installed in the cooling water line leaving the oil cooler. This orifice ensures that the cooler remains full so that no air pocket will form and reduce the performance of the cooler. A lube oil relief valve is located in the upper transmission housing. This valve protects the system from excessive pressure and should be set to maintain designed bearing oil pressure. The ship service turbogenerator and the main feed pump may have a different system. Their systems may use a duplex lube oil strainer and may also have a hand or electric lube oil pump for startup and securing.

Duplex lube oil strainers are installed in the main lube oil system and in some auxiliary lube oil systems to trap foreign matter. The installation of strainers prevents damage to the gears, bearings, and journals. The strainers (fig. 4-3) are of the duplex basket type. They are designed so that one strainer can be opened for inspection and cleaning while the other is in service. Also

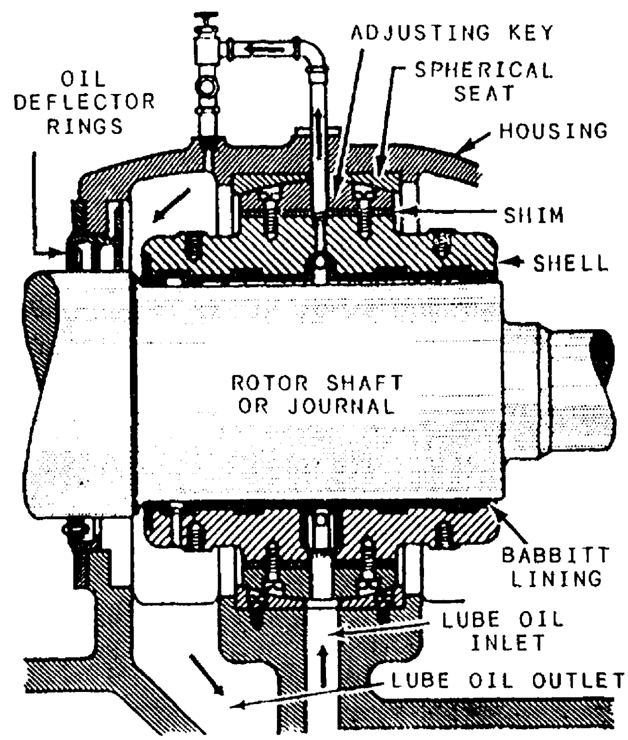

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Figure 4-4.—Adjustable spherical-seated bearing lubricated by force feed.

by having two strainers, a standby strainer is available if a casualty occurs. Most of these strainers contain a removable magnetic element (not shown in the figure) in each basket to remove ferrous (magnetic) particles from the oil. The strainers are usually shifted, inspected, and cleaned at the following intervals:

1. Once each watch for the first 24 hours underway

2. Once each watch for the first 48 hours underway if major work has been done on the lube oil system

3. Once each watch when operating at more than 85 percent of full power

4. Once every 24 hours after number 1 or 2 conditions have been satisfied

5. When the differential pressure (d/p) across the strainer in service raises more than 1 1/2 psi above normal (some strainers have valves which will automatically shift with an excessive d/p)

6. When required by casualty control procedures

If your particular PMS does not give the same intervals for shifting, inspecting, and cleaning the strainers as stated above, then follow the intervals given in your PMS.

Carefully follow the proper procedures when you are shifting the strainers. If you use improper procedures, you can cause a loss of lube oil pressure and/or a fire. The proper procedure for shifting is normally posted near the strainers. Routinely check your strainer cap gaskets and strainer shields to ensure they are in satisfactory condition. Also make sure the strainer in use is properly identified.

GREASE LUBRICATION SYSTEMS

Grease lubrication is used in many locations where it is difficult to keep lube oil at the bearing surface. The grease is applied either through grease cups or through pressure fittings, such as the Zerk type.

Grease Cup Lubrication

Dirt in lube oil will generally settle out, but dirt in grease remains mixed with the grease and becomes abrasive. For this reason, you should take particular care to prevent contamination, especially where grease cups are used. Before you open the container, carefully remove all dirt from the exterior. Do NOT allow any dirt to enter either the opening or the grease cups. You should often empty, clean, and refill the cups with fresh grease.

Pressure Greasing

Pressure fittings form an easy means of lubricating numerous low-speed, lightly loaded, or widely separated bearings. They are not, however, good for use on electric generators and motors. Pressure fittings used on these units may force grease out of the bearing and onto windings. These fittings are similar to those on an automobile, where grease guns are used for lubrication.

Before using the grease gun, clean the pressure fittings and gun tip. Apply pressure to the fitting until grease comes out around the edges of the bearing. In bearings fitted with felt or other seals, you must be careful to avoid breaking the seals by overpressure. Excessive pressure in the lubrication of needle-type roller bearings may unseat the needles.

BALL AND ROLLER BEARING LUBRICATION

The oil or grease used to lubricate ball and roller bearings (roller contact bearings) serves many important functions. It provides a lubricating film among the balls, rollers, and retainers and between the ends of the rollers and the races. The oil or grease disperses heat caused by friction and prevents corrosion of the highly polished parts. It also helps keep dirt, water, and other foreign matter out of the parts. You should use the lubricant recommended for each machine, and you should avoid too much lubrication.

LUBE OIL PURIFICATION

The forced-feed lubrication systems in modern naval ships rely on pure oil. Oil that stays pure can be used for a long time. LUBE OIL DOES NOT WEAR OUT—it is merely robbed of its lubricating properties by foreign substances.

Contaminants interfere with the ability of the oil to maintain a good lubricating film between metal surfaces. These contaminants must be removed or the oil will not meet lubrication requirements. Dirt, sludge, and other contaminants will act as abrasives to score and scratch the rubbing metal surfaces within engines, generators, pumps, and blowers. Water is the greatest source of contamination. Strainers, filters, settling tanks, and centrifugal purifiers are used in lubrication systems to keep the oil pure. Filters and strainers were discussed earlier in the chapter. This section will deal with settling tanks and centrifugal purifiers.

Lubricating oil piping is generally arranged to permit two methods of purification: batch purification and continuous purification. The batch process uses settling tanks while the continuous process uses centrifugal purifiers.

SETTLING TANKS

In the batch process, the lube oil is transferred from the sump to a settling tank by a purifier or transfer pump. Settling tanks permit oil to stand while water and other impurities settle out. Settling is caused by the force of gravity. A number of layers of contaminants may form in the bottom of the tank. The number of layers depends on the specific gravity of the various contaminating substances. For example, a layer of metal may form on the bottom, followed by a layer of sludge, a layer of water, and then the clean oil on top. Settling tanks are normally used when the ship is in port. After the oil is heated and allowed to settle for several hours, water and other impurities that have accumulated in the settling tanks are removed. The oil that is left in the tanks is then centrifuged and returned to the sump or storage tank.

CENTRIFUGAL PURIFIERS

When a ship is at sea or when time does not permit batch purification in the settling tanks, the continuous purification process is used. Centrifugal purifiers are used in this process. The purifier takes the oil from the sump in a continuous cycle. Before entering the purifier, the oil is heated to help remove the impurities.

Detailed instructions on constructing, operating, and maintaining purifiers are furnished by manufacturers' technical manuals, PMS, and the Engineering Operation Sequencing System (EOSS). Carefully follow these documents when you are operating or performing maintenance on purifiers. The following general information will help you understand the purification and the purposes and principles of purifier operation.

A purifier may be used to remove water and/or sediment from oil. When water must be removed, the purifier is called a SEPARATOR. When the main source of contamination is sediment, the purifier is used as a CLARIFIER. When used to purify lubricating oil, a purifier may be used as either a separator or a clarifier. Aboard ship, a purifier is almost always operated as a separator.

TYPES OF CENTRIFUGAL PURIFIERS AND THEIR OPERATING CHARACTERISTICS

Two types of purifiers are used in Navy installations. Both types operate on the same principle. The principal difference is in the design of the rotating units. In one type the rotating element is a bowl-like container which encases a stack of disks. This is the disk-type DeLaval purifier. In the other type, the rotating element is a hollow, tubular rotor and is the tubular-type Sharples purifier.

Disk-Type Purifier

A sectional view of a disk-type centrifugal purifier is shown in figure 4-5. The bowl is mounted on the upper end of the vertical bowl spindle, which is driven by means of a worm wheel and friction clutch assembly. A radial thrust bearing at the lower end of the bowl spindle carries the weight of the bowl spindle and absorbs any thrust created by the driving action. The parts of a disk-type bowl are shown in figure 4-6.

The flow of oil through the bowl and additional parts is shown in figure 4-7. Contaminated oil enters the top of the revolving bowl through the regulating tube. The oil then passes down the inside of the tubular shaft and out at the bottom into the stack of disks. As the dirty oil flows up through the distribution holes in the disks, the high centrifugal force exerted by the revolving bowl causes the dirt, sludge, and water to move outward. The purified oil flows inward and upward, discharging from the neck of the top disk. The water forms a seal between the top disk and the bowl top. (The top disk is the dividing line between the water and the oil.) The disks divide the space within the bowl into many separate narrow passages or spaces. The liquid confined within each passage is restricted so that it can flow only along that passage. This arrangement minimizes agitation of the liquid as it passes

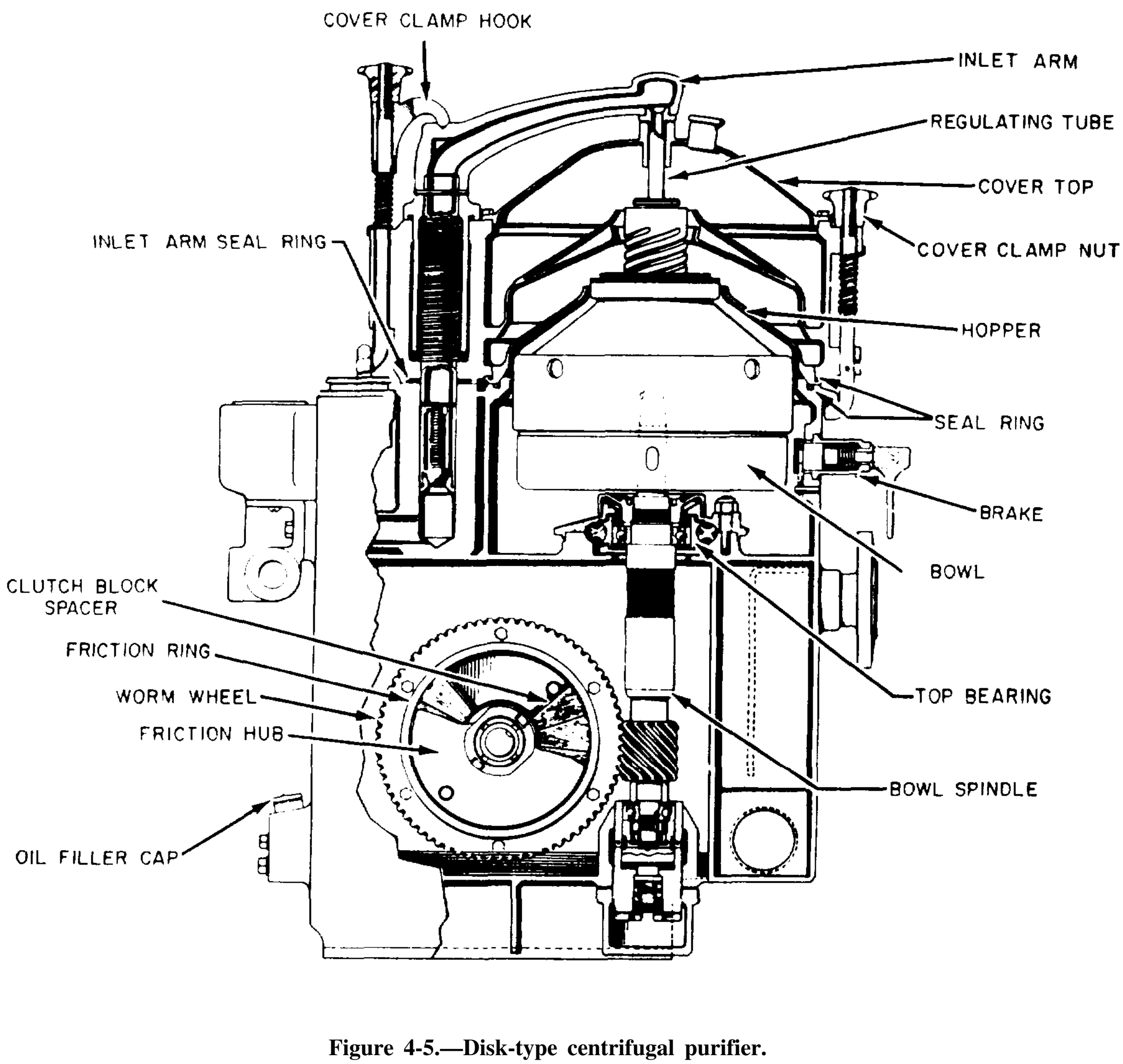

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Figure 4-5.—Disk-type centrifugal purifier.

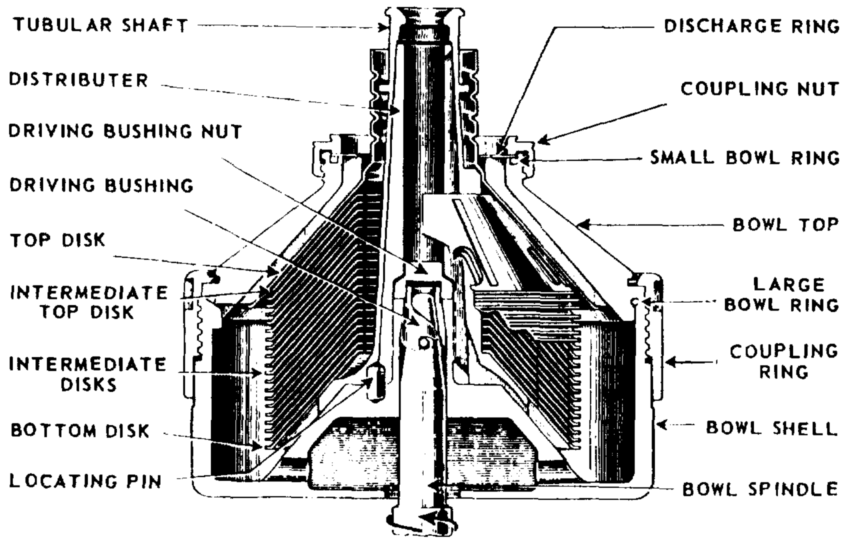

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Figure 4-6.—Part of a disk-type purifier bowl.

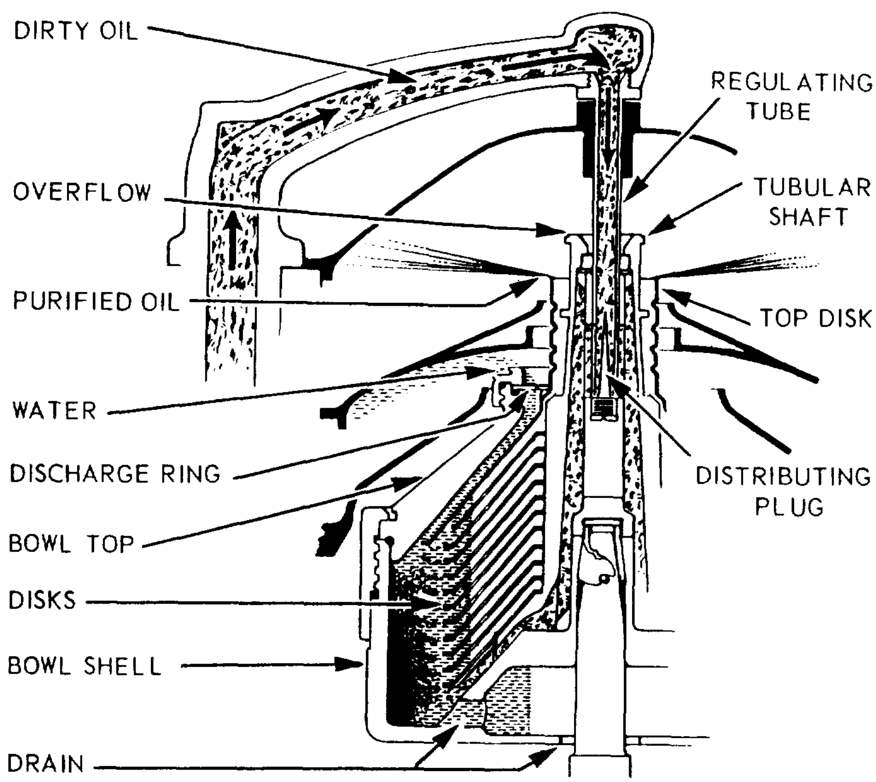

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Figure 4-7.—Path of oil through disk-type purifier.

through the bowl. It also makes shallow settling distances between the disks.

Most of the dirt and sludge remains in the bowl and collects in a more or less uniform layer on the inside vertical surface of the bowl shell. Any water, along with some dirt and sludge, separated from the oil, is discharged through the discharge ring at the top of the bowl.

Tubular-Type Purifier

A cross section of a tubular-type centrifugal purifier is shown in figure 4-8. This type of purifier consists essentially of a hollow rotor or bowl which rotates at high speeds. The rotor has an opening in the bottom to allow the dirty lube oil to enter. It also has two sets of openings at the top to allow the oil and water (separator) or the oil by itself (clarifier) to discharge (see insert, fig. 4-8). The bowl, or hollow rotor, of the purifier is connected by a coupling unit to a spindle. The spindle is suspended from a ball bearing assembly. The bowl is belt-driven by an electric motor mounted on the frame of the purifier.

The lower end of the bowl extends into a flexibly mounted guide bushing. The assembly restrains movement of the bottom of the bowl. But is also allows the bowl enough movement to center itself during operation. Inside the bowl is

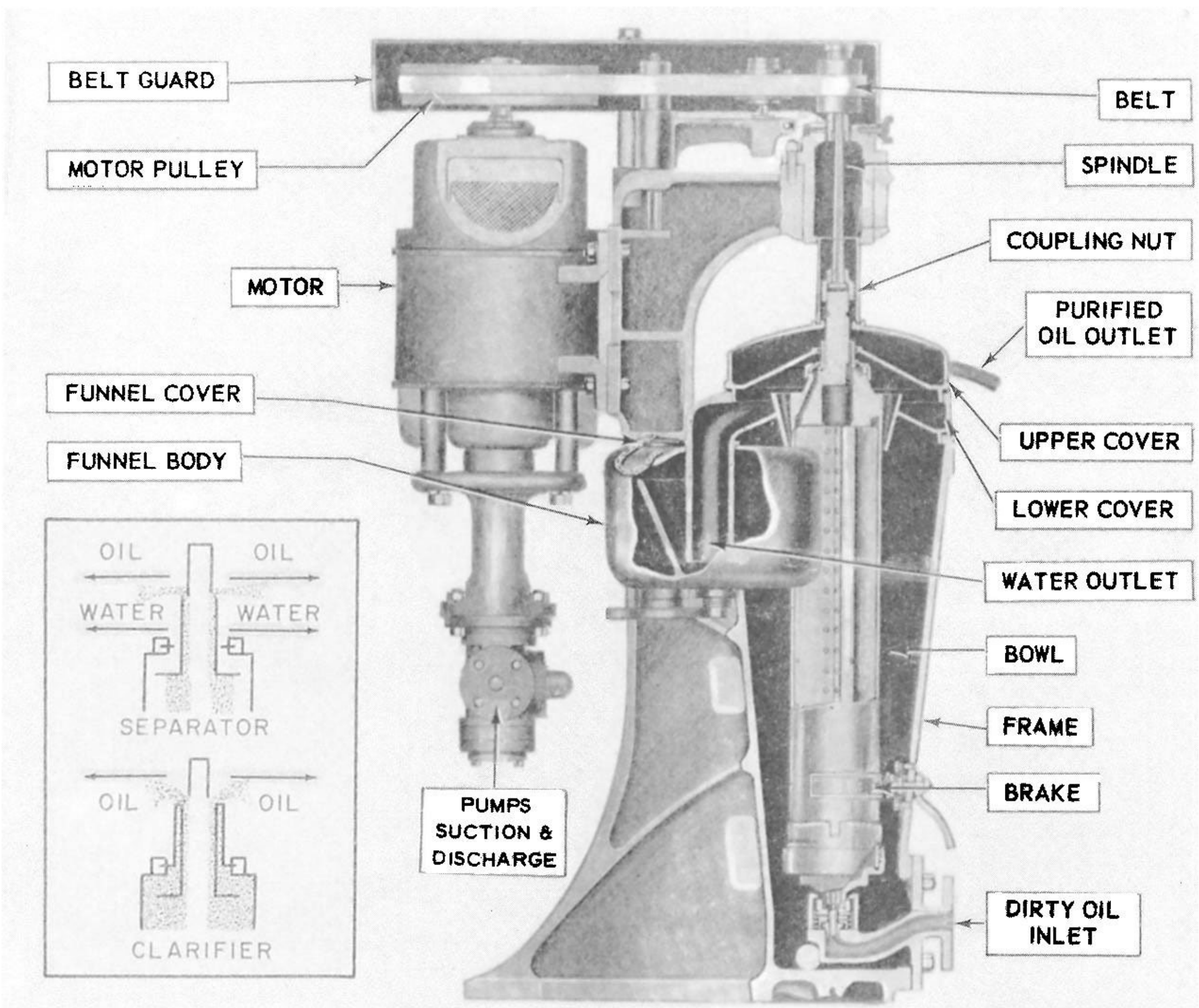

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Figure 4-8.—Tubular-type centrifugal purifier.

a device consisting of three flat plates equally spaced radially. This device is commonly referred to as the three-wing device, or just the three-wing. The three-wing rotates with the bowl and forces the liquid in the bowl to rotate at the same speed as the bowl. The liquid to be centrifuged is fed, under pressure, into the bottom of the bowl through the feed nozzle.

When the purifier is used as a lube oil clarifier, the three-wing has a cone on the bottom. The feed jet strikes against this cone in order to bring the liquid smoothly up to bowl speed without making an emulsion. This type of three-wing device is shown in figure 4-9.

Separation is basically the same in the tubular-type purifier as in the disk-type purifier. In both types, the separated oil assumes the innermost position and the separated water moves outward. Both liquids are discharged separately from the

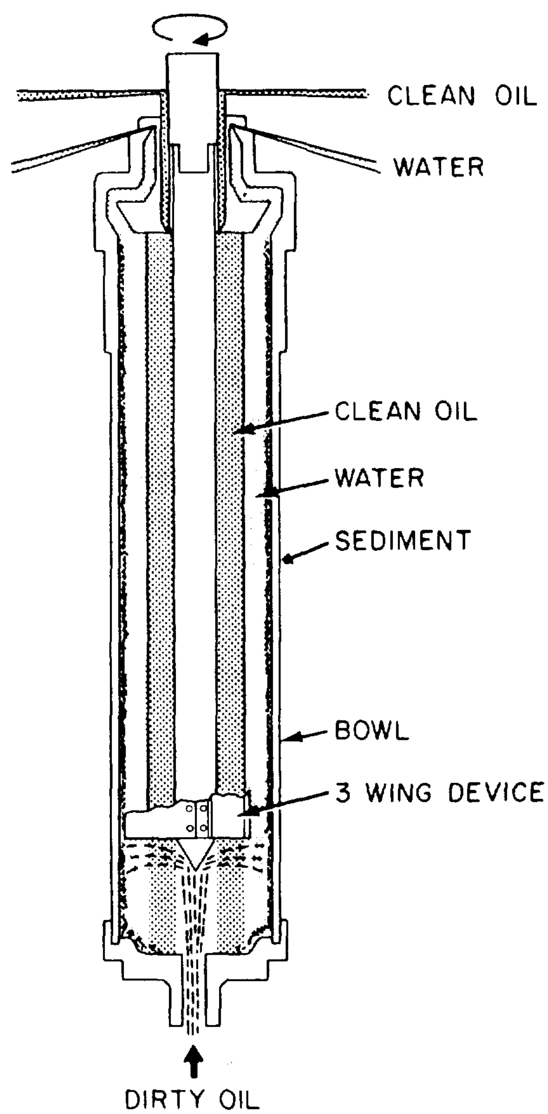

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Figure 4-9.—Principles of a centrifugal purifier.

bowls, and the solids separated from the liquid remain in the bowl (fig. 4-10).

GENERAL NOTES ON PURIFIER OPERATIONS

You should get the specific details from the instructions provided for operating a given purifier. The information provided here is general, and you can apply it to both types of purifiers.

For maximum efficiency, run purifiers at maximum designed speed and rated capacity. Since turbine oils are always contaminated with water from condensation, you should operate the purifier as a separator and not as a clarifier. However, do not run a purifier at designed rated capacity when a unit is used as a separator of 9000 series (compounded- or additive-type heavy-duty lube oils) detergent oil. Some engine installations using oils of the 9000 series are exposed to large quantities of water. If the oil becomes contaminated with water, the oil has a tendency to emulsify. The tendency is greater when the oil is new. This condition decreases during the first 50 to 75 hours of engine operation. When an emulsion appears, you should lower the purifier to 80 percent of the rated capacity. You should continue this operation as long as a noticeable amount of free water discharges along with the emulsion.

When a purifier is run as a separator, you should prime the bowl with fresh water before you open the suction valve. The water serves to seal

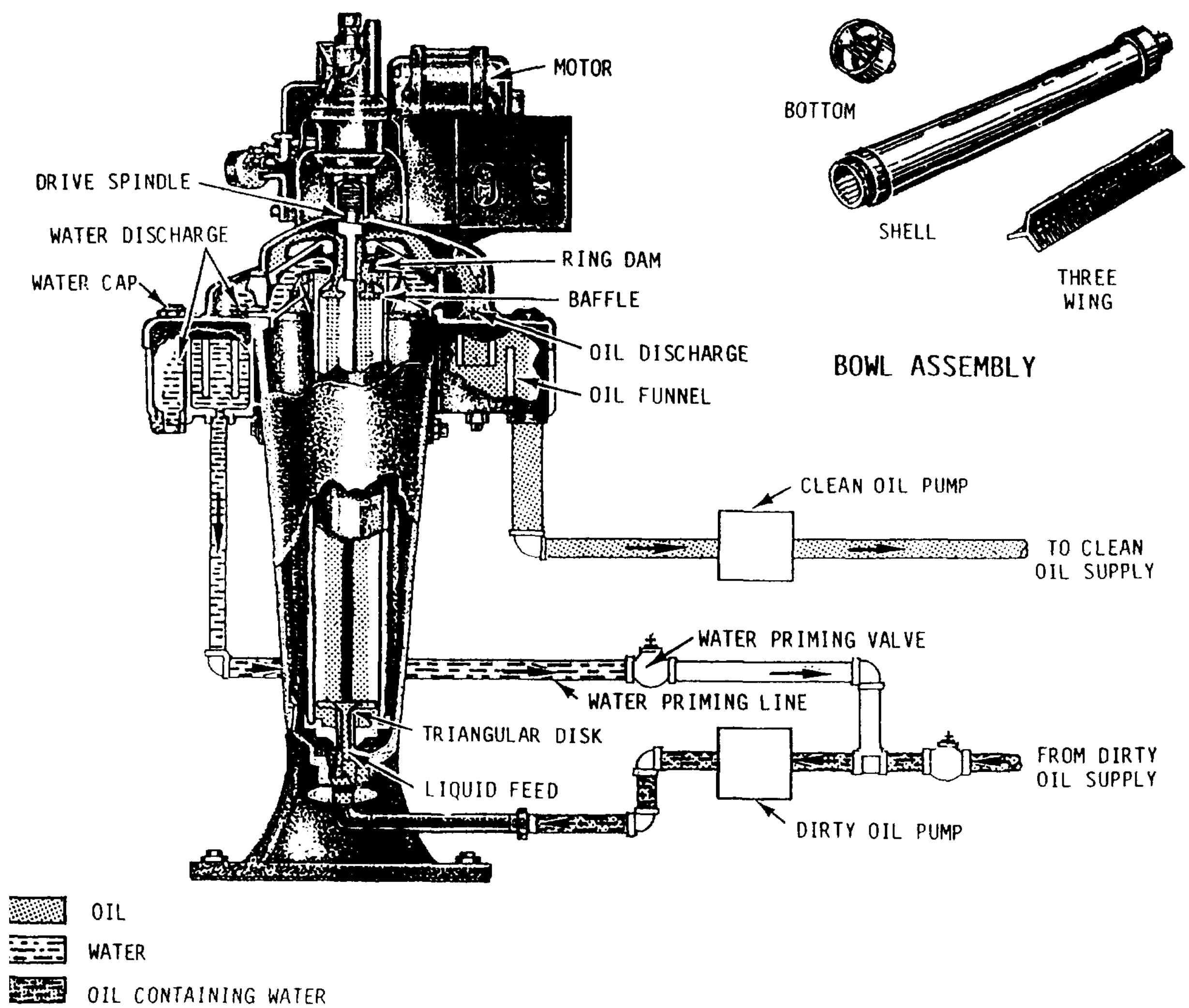

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Figure 4-10.—Path of oil through the bowl-type purifier.

the bowl and to make the liquid layers equal. If you do not prime the bowl, you will lose oil through the water discharge ports.

Influencing Factors in Purifier Operation

The time required for purification and the output of a purifier depend on many factors. The viscosity of the oil and the pressure applied to the oil are such factors. Two other important factors are the size of the sediment particles and the difference in the specific gravity of the oil.

The viscosity of the oil determines to a great extent the length of time required to purify lube oil. The more viscous the oil, the longer the time required to purify it to a given degree of purity. Decreasing the viscosity of the oil by heating will help purification.

Even though certain oils may be properly purified at operating temperatures, you will get greater purification by heating the oil to a higher temperature. To do this, the oil is passed through a heater. The oil reaches the proper temperature in the heater before it enters the purifier bowl.

Oils used in naval installations may be heated to specified temperatures without adverse effects. Prolonged heating at higher temperatures, however, is not recommended because of the tendency of such oils to oxidize. In general, oil should be heated enough to produce a viscosity of about 90 seconds, Saybolt Universal (90 SSU).

Pressure should not be increased above normal in order to force a high viscosity oil through the purifier. Instead, viscosity should be decreased by heating the oil. The use of excess pressure to force oil through the purifier will result in poor purification. But if you reduce the pressure of the oil as it is forced into the purifier, you will improve purification. This happens because you have increased the length of time the oil is under the influence of centrifugal force.

For clean oil to be discharged from a purifier and for the water discharged to be free of oil, you must use the proper size discharge ring (RING DAM). The size of the discharge ring depends on the specific gravity of the oil being purified. All discharge rings have the same outside diameter, but they have inside diameters of different sizes. Ring sizes are shown by even numbers; the smaller the number, the smaller the ring size. The size, in millimeters, of the inside diameter is stamped on each ring. Sizes vary by 2-mL steps. Charts provided in manufacturers' technical manuals show the proper ring size to be used with an oil of a specific gravity. Generally, the ring size shown on a chart will produce good results. However, the recommended ring may not produce good purification. In that case, you must determine the correct size by trial and error. In general, purification is best when you use the ring of the largest possible size to prevent loss of oil.

MAINTENANCE OF PURIFIERS

Proper care of an oil purifier requires that the bowl be cleaned often and that all sediment be carefully removed. How often you clean a purifier depends on the amount of foreign matter in the oil to be purified. If the amount of foreign matter in an oil is not known, you should shut down the machine and check it. The amount of sediment found in the bowl at this time will indicate how often you should clean the purifier. Thoroughly clean the bowl assembly each time lube oil is run through for batch purification from the settling tank.

While the purifier is operating on a sump of an operating unit, you should make checks to ensure that the purifier has not lost its seal. A casualty caused by a loss of lube oil can occur fairly rapidly. This happens if all the lube oil from a sump is dumped to the bilge or drain tank by an improperly operating purifier.

THE LUBE OIL MANAGEMENT PROGRAM

The Lube Oil Management Program was developed because of the importance of good quality lubricating oil. This program is in the form of an instruction. These instructions may vary somewhat in procedure, but their objectives are the same. Some of the major points covered by this instruction are listed below:

1. How often you should take oil samples
2. The type of equipment on which you should take oil samples
3. The required logs and records of lube oil
4. The type of testing you are required to do on oil samples
5. Your required action as a result of the tests

If this program is properly maintained, you can reduce the down time of your machinery caused by oil related failures. You should become very familiar with the Lube Oil Management Program and carefully follow each step and detail listed.

CHAPTER 5

PUMPS

Pumps are vital to the operation of the ship. If they fail, the plant they serve also fails. You will have to keep the pumps in good working order.

In this chapter, we will discuss the principles of operation, classification, and maintenance of some of the pumps you may have to maintain.

PRINCIPLES OF PUMP OPERATION

Pumps are used to move any substance which flows or which can be made to flow. Most pumps are used to move water, oil, and other liquids. However, air, steam, and other gases are also fluid and can be moved with pumps, as can such substances as molten metal, sludge, and mud.

A pump is essentially a device which uses an external source of power to apply a force to a fluid in order to move the fluid form one place to another. A pump develops no energy of its own; it merely transforms energy from the external source (steam turbine, electric motor, and so forth) into mechanical kinetic energy, which is manifested by the motion of the fluid. This kinetic energy is then used to do work. Here are some examples: to raise a liquid from one level to another, as when water is raised from a well; to transport a liquid through a pipe, as when oil is carried through an oil pipeline; to move a liquid against some resistance, as when water is pumped to a boiler under pressure; or to force a liquid through a hydraulic system, against various resistances, for the purpose of doing work at some point. Every pump has a POWER END, whether it is a steam turbine, a reciprocating steam engine, a steam jet, or some kind of electric motor. Every pump also has a FLUID END, where the fluid enters (suction) and leaves (discharges) the pump.

When a pump delivers energy to a liquid, it usually causes an increase in pressure, which is generally referred to as HEAD. There are four types of heads: (1) net positive suction head, (2) suction head, (3) discharge head, and (4) total discharge head.

The NET POSITIVE SUCTION HEAD (NPSH) is the suction pressure minus the vapor pressure expressed in feet of liquid at the pump suction. An example is a feed booster pump with a deaerating feed tank operation at saturated conditions. The NPSH on this pump equals the pressure resulting from the height of the water above the booster pump suction.

The SUCTION HEAD on a pump means the total pressure of the liquid entering the pump. In a deaerating feed tank operating under saturated conditions, the suction head of the feed booster pump is equal to the NPSH plus the auxiliary exhaust pressure.

The DISCHARGE HEAD means the pressure of liquid leaving the pump and/or the level of liquid with respect to the level of the pump on the discharge side.

The TOTAL HEAD is the net difference between the suction head and the discharge head.

Suction head is usually expressed in feet of water if positive, and in inches of mercury if negative. When a pump operates below the level of a liquid, its suction end receives the liquid under a gravity flow. When the pump is located above the level of the liquid being pumped, the pump must be able to establish a vacuum at the inlet to move the liquid into the pump. Atmospheric pressure, acting on the surface of the liquid, will then provide the necessary pressure to move the liquid into the pump.

PRINCIPLE OF SUCTION FORCE

The principle of suction force, or suction lift, as applied to reciprocating pumps, is illustrated in figure 5-1. In diagram a, the piston cylinder is open at both the top and bottom so the liquid level at A and B is the same. In diagram b, the cylinder is closed at the bottom. A piston has been inserted and partly withdrawn, thus creating a partial vacuum. In diagram c, the foot valve (check valve) at the bottom of the cylinder opens as a result of the lower pressure in the cylinder. The liquid then rises up into the cylinder, which causes the liquid level in the well to drop. Assuming the liquid is water and that there is a perfect vacuum below the piston, atmospheric pressure will push water up into the cylinder to a height of 34 feet, even though the piston may be raised higher than 34 feet.

You must understand that the preceding example is for the theoretical condition of a perfect vacuum. In practice, leakage between the piston and the cylinder, friction (fluid) in piping, and gases dissolved in the liquid limit the suction lift of a pump to a height of approximately 22 feet, as shown in diagram d of figure 5-1.

When a pump is pumping certain liquids, such as hot water, oil, or gasoline, some of the liquid will vaporize because of the vacuum on the suction side of the pump. This may cause the pump to become vapor bound, which will reduce the possible suction lift.

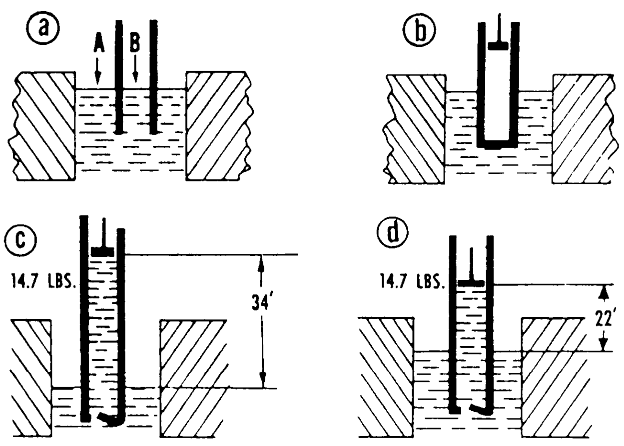

Figure 5-l.—Diagrams illustrating the principle of suction force.

The suction force principle applies to other types of pumps, as well as to the reciprocating type, though to a lesser degree and in a somewhat different manner. The centrifugal, propeller, and rotary pumps all use suction force to a certain extent. Here a partial vacuum can be produced by the revolving mechanisms instead of by the reciprocating plunger. An additional characteristic of centrifugal pumps is that they are not self-priming because they will not pump air. Their casing must be flooded before they will function. In the eductor (jet pump), flow is maintained by the suction force created by a jet of water, compressed air, or steam passing through a nozzle at high velocity. These principles are explained in more detail later in this chapter.

TYPES OF PUMPS

Pumps are by far the most numerous units of auxiliary machinery aboard ship. They include (1) centrifugal pumps, (2) propeller pumps, (3) variable stroke pumps, (4) reciprocating pumps, (5) positive displacement rotary pumps, and (6) eductors. The training manual, *Fireman,* NAVEDTRA 14104, describes these pumps. Simple language and diagrams explain the basic principles of each of the general classes of pumps. This book also discusses the characteristics of each type that make it adaptable to a particular service in the various engineering systems. Be sure to review that material carefully before studying this chapter.

CENTRIFUGAL PUMPS

Centrifugal pumps are widely used aboard ship for pumping nonviscous liquids. In the engine room you will find several important centrifugal pumps: the feed booster pump, the fire and flushing pump, condensate pumps, auxiliary circulating pumps, and the main feed pump.

The centrifugal pump uses the throwing force of a rapidly revolving IMPELLER. The liquid is pulled in at the center or EYE of the impeller and is discharged at its outer rim.

By the time the liquid reaches the outer rim of the impeller, it has acquired a considerable velocity (kinetic energy). The liquid is then slowed down by being led through a volute or through a series of diffusing passages. As the velocity of the liquid decreases, its pressure increases; and thus its kinetic energy is tranformed into potential energy.

Types of Centrifugal Pumps

There are many different types of centrifugal pumps, but the two which you are most likely to encounter aboard ship are the volute pump and the volute turbine, or diffuser, pump.

VOLUTE PUMP.—In the volute pump, shown in figure 5-2, the impeller discharges into a volute (a gradually widening spiral channel in the pump casing). As the liquid passes through the volute and into the discharge nozzle, a great part of its kinetic energy is converted into potential energy.

DIFFUSER PUMP.—In the diffuser pump, shown in figure 5-3, the liquid leaving the impeller is first slowed down by the stationary diffuser vanes which surround the impeller. The liquid is forced through gradually widening passages in the diffuser ring (not shown) and into the volute. Since both the diffuser vanes and the volute reduce the velocity of the liquid, there is an almost complete conversion of kinetic energy to potential energy.

Classification of Centrifugal Pumps

Centrifugal pumps may be classified in several ways. For example, they may be either SINGLE-STAGE or MULTISTAGE. A single-stage pump has only one impeller. A multistage pump has two or more impellers housed together in one casing; as a rule, each impeller acts separately, discharging to the suction of the next stage impeller. This arrangement is called series staging. Centrifugal pumps are also classified as HORIZONTAL or VERTICAL, depending upon the position of the pump shaft. Generally, large, multistage, high-capacity pumps are horizontal. Most other pumps are vertical.

The impellers used on centrifugal pumps may be classified as SINGLE SUCTION or DOUBLE SUCTION. The single-suction impeller allows liquid to enter the eye from one direction only; the double-suction type allows liquid to enter the eye from two directions.

Impellers are also classified as CLOSED or OPEN. Closed impellers have side walls which extend from the eye to the outer edge of the vane tips; open impellers do not have these side walls. Most centrifugal pumps used in the Navy have closed impellers.

Construction of Centrifugal Pumps

As a rule, the casing for the liquid end of a pump with a single-suction impleller is made with an end plate which can be removed for inspection and repair of the pump. A pump with a double-suction impeller is generally made so that one-half of the casing may be lifted without disturbing the pump.

The impellers rotate at very high speed. Therefore they must be carefully machined in order to minimize friction, and they must be balanced in order to avoid vibration. A close radial clearance must be maintained between the outer hub of the impeller and that part of the pump casing in which the hub rotates. This is necessary in order to minimize leakage from the discharge side of the pump casing to the suction side.

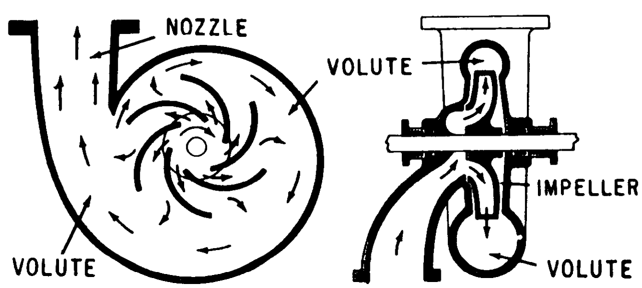

Figure 5-2.—Simple volute pump.

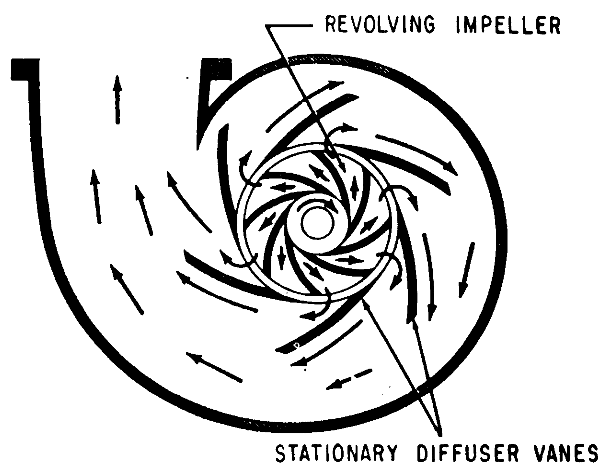

Figure 5-3.—Diffuser (volute turbine) pump.

The impeller has a high rotational speed and necessarily close clearance. Therefore the running surfaces of both the impeller hub and the casing at that point are subjected to relatively rapid wear. To eliminate the need to renew an entire impeller and pump casing solely because of wear in this location, centrifugal pumps are designed with replaceable wearing rings. One ring is attached to the hub of the impeller, and rotates with the impeller. A matching ring is attached to the casing, and is therefore stationary. The replaceable ring on the hub of the impeller is called the IMPELLER WEARING RING, and the ring attached to the casing is called the CASING WEARING RING. (Wearing rings are shown on the main feed pump illustrated in fig. 5-4.)

Some small pumps with single-suction impellers are made with a casing wearing ring only and no impeller ring. In this type of pump, the casing wearing ring is fitted into the end plate.

In many cases the pump shaft is fitted with shaft sleeves (fig. 5-5). These sleeves protect the shaft from becoming grooved. A shaft that is in direct contact with the packing will become grooved because of its rotation in the packing. It is much cheaper to replace the shaft sleeves than to replace pump shaft. The shaft sleeves are also used to position the impeller axially on the pump shaft.

Recirculating lines are installed on some centrifugal pumps to prevent them from overheating and becoming vapor bound when the discharge is entirely shut off. Seal piping (liquid seal) is also installed to cool the shaft and the packing, to lubricate the packing, and to seal the joint between the shaft and the packing against air leakage. A lantern ring (spacer) is inserted between the rings of the packing in the stuffing box. Seal piping (fig. 5-5) leads liquid from the discharge side of the pump to the annular space within the lantern ring. The web of the ring is

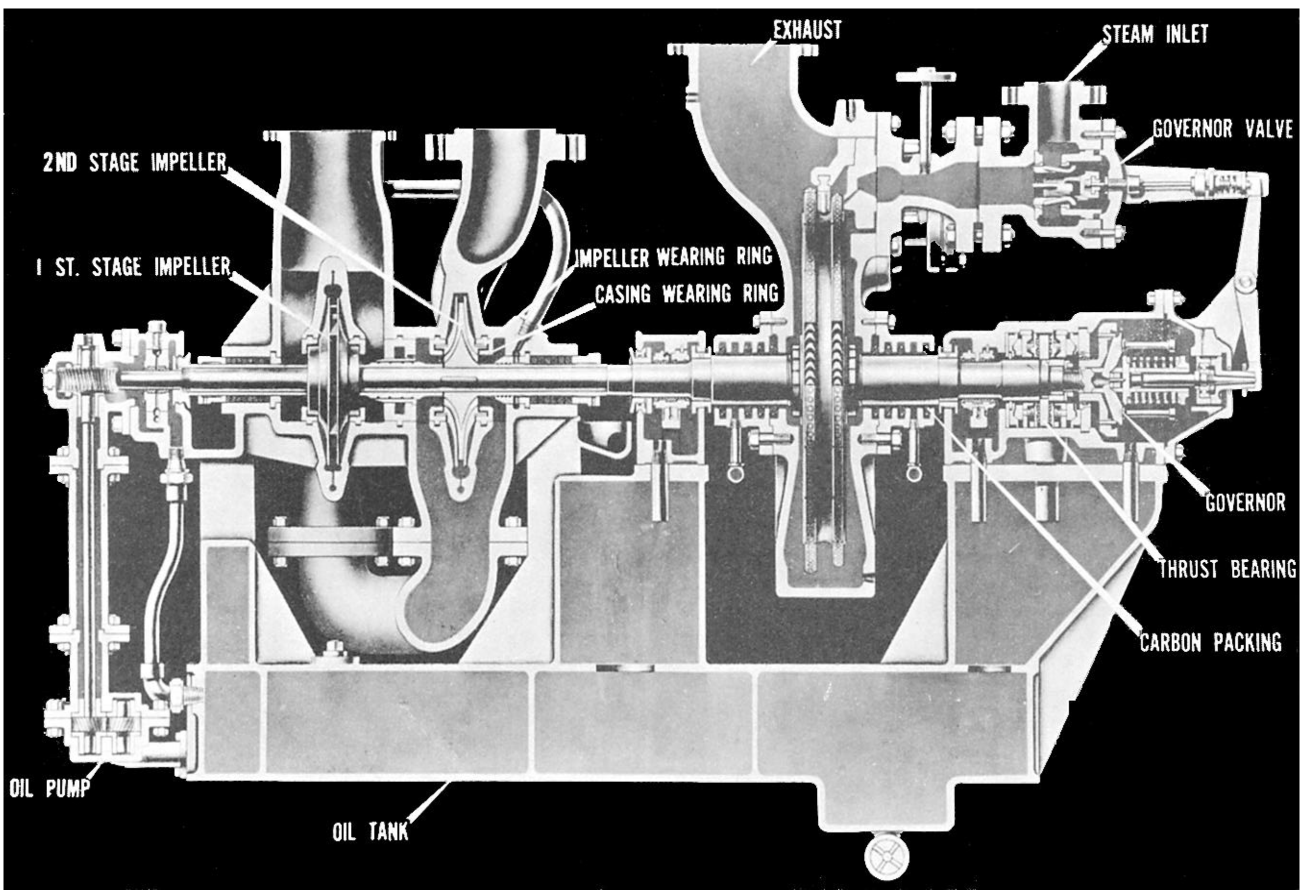

Figure 5-4.—Two-stage main feed pump.

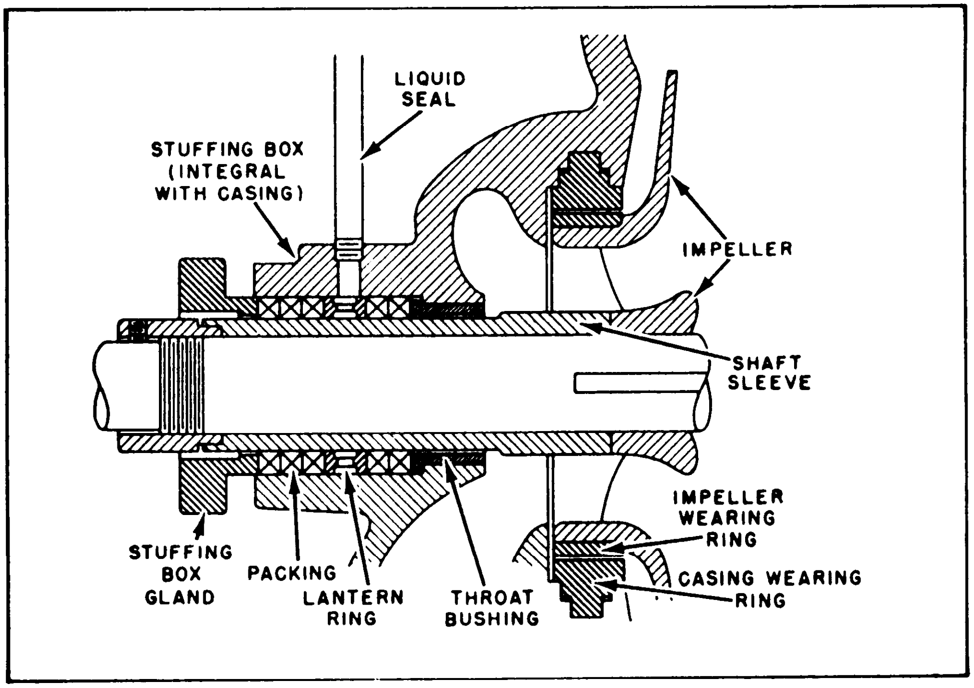

Figure 5-5.—Stuffing box on a centrifugal pump.

perforated so that water can flow in either direction along the shaft, between the shaft and the packing.

Mechanical seals are used instead of packing in a variety of centrifugal pumps. One type of mechanical seal is shown in figure 5-6. Spring pressure keeps the rotating seal face snug against the stationary seal face. The rotating seal and all of the assembly below it are affixed to the pump shaft. The stationary seal face is held stationary by the seal gland and packing ring. A static seal is formed between the two seal faces and the sleeve. System pressure within the pump helps the spring keep the rotating seal face tight against the stationary seal face. The type of material used for the seal faces will depend upon the service of the pump. Most water service pumps use a carbon material for the seal faces. When the seals wear out, they are simply replaced. New seals should not be touched on the sealing face because body acid and grease will cause the seal face to prematurely pit and go bad.

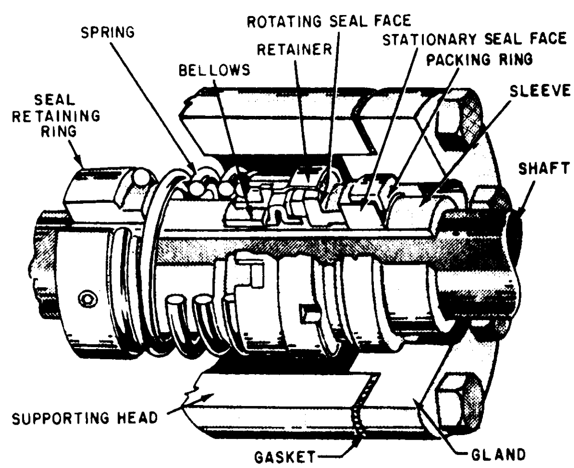

Figure 5-6.—Type-1 mechanical seal.

Bearings support the weight of the impeller and shaft, and maintain the position of the impeller, both radially and axially. Some centrifugal pumps have a built-in bearing lubrication system, complete with lube oil pump, sump, cooler, strainer, and temperature and flow indicators. Other bearings are grease-lubricated with grease cups and vent plugs in the housing to allow for periodic relubrication.

The power end of a centrifugal pump may be either a steam turbine or an electric motor. For most constant-speed applications, the turbine drive has no particular advantage over the motor drive.

The turbines used for centrifugal pumps are usually single-stage impulse turbines. As a rule, high-pressure centrifugal pumps are direct drive-that is, the impeller rotates at the same rpm as the turbine. However, some low-pressure centrifugal pumps have reduction gears between the turbine and the impeller.

Centrifugal Pump Maintenance

When properly installed, maintained (using PMS), and operated, centrifugal pumps are usually trouble free. Some of the corrective maintenance actions that will be required are discussed in the following sections.

REPACKING.—Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When operating a centrifugal pump, be sure that there is always a slight trickle of water coming out of the stuffing box or seal.

How often the packing in a centrifugal pump should be renewed depends on several facts-such as the type of pump, condition of the shaft sleeve, and hours in use.

To ensure the longest possible service from pump packing, make certain that the shaft or sleeve is smooth when packing is removed from a gland. Rapid wear of the packing may be caused by roughness of the shaft sleeve (or shaft where no sleeve is installed). If the shaft is rough, it should be sent to the shop for a finishing cut to smooth the surface. If it is very rough, or has deep ridges in it, it will have to be renewed. It is absolutely necessary to use the correct packing. Navy packing is identified by symbol numbers as explained in chapter 10 of this manual. To find the right packing, check the maintenance requirement card (MRC) or packing chart for the particular pump. The MRC lists the symbol numbers and the size and number of rings required.

When replacing packing, be sure that the packing fits uniformly around the stuffing box. If you have to flatten the packing with a hammer, YOU ARE NOT USING THE RIGHT SIZE.

Packing the box loosely, and set up the packing gland lightly. Allow a liberal leak-off for stuffing boxes that operate above atmospheric pressure. Next, start the pump. Let it operate for about 30 minutes before you adjust the leak-off. This gives the packing time to run-in and swell, if it is going to. When this requirement has been satisfied, you may begin to adjust the packing gland. Tighten the adjusting nuts one flat at a time. Wait about 30 minutes between adjustments. Be sure to tighten the same amount on both adjusting nuts. If you pull up the packing gland unevenly (or cocked), it will cause the packing to overheat and score the shaft sleeves. Once you have the desired leak-off, all you have to do is check it regularly to ensure that sufficient flow is maintained.

MECHANICAL SEALS.—Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on centrifugal pumps. Mechanical seals eliminate the problem of excessive stuffing box leakage which causes failure of pump and motor bearings and motor windings. Mechanical seals are ideal for pumps operating in closed systems (such as air conditioning, chilled water systems, and various sonar, radar, and other electronic cooling systems). They not only conserve the fluid being pumped but also improve system operation. Mechanical seals are well suited for pumps operating under varying discharge pressures such as submarine sea-connected pumps.

Mechanical seals are now used for most centrifugal pumps that may operate under vacuum conditions (such as condensate and ships' potable water pumps).

Fire pumps and all seawater pumps in surface ships are being provided with mechanical shaft seals with cyclone separators. The glands incorporate two or more rings of packing for use in the event of a mechanical shaft seal failure. Opposing seal faces are constructed of tungsten carbide against carbon, or tungsten carbide against tungsten carbide. The tungsten carbide seal ring(s) are of solid construction. The cyclone separators are constructed of nickel-copper alloy. Fittings for abrasive separators and pump casing are of the straight thread type with O-ring seal. They are constructed of nickel-copper alloy. Tubing is copper-nickel (70-30), according to MIL-F-16420.

Replace mechanical seals whenever the seal is removed for any reason or whenever the leakage rate exceeds 5 drop per minute.

Mechanical shaft seals are positioned on the shaft by stub or step sleeves. Mechanical shaft seals shall not be positioned by setscrews. Shaft sleeves are chamfered on outboard ends for easy mechanical seal mounting.

Mechanical shaft seals are positioned on the shaft by stub or step sleeves. Mechanical shaft seals shall not be positioned by setscrews. Shaft sleeves are chamfered on outboard ends for easy mechanical seal mounting.

Where mechanical shaft seals are used, they ensure that positive liquid pressure is supplied to the seal faces under all conditions of operation. They also ensure adequate circulation of the liquid at the seal faces to minimize the deposit of foreign matter on the seal parts.

CARE OF LANTERN RINGS, SLEEVES, AND FLINGERS.—When a stuffing box is fitted with a lantern ring, be sure to replace the packing beyond the lantern ring at the bottom of the stuffing box. Also be sure that the sealing water connection to the lantern ring is not blanked off by the packing. (See fig. 5-5.) Sleeves fitted at the packing on the pump shafts must always be tight. These sleeves are usually made secure by shrinking or keying them to the shaft. Ensure that water does not leak between the shaft and shaft sleeve.

Water flinger rings are fitted on the shaft between the packing gland and the pump bearing housing. These flingers prevent water from the stuffing box from following along the shaft and entering the bearing housing.

Shaft sleeves are made fast to the pump shaft in various ways. Some slip on and are held in place by a nut. Some may screw on. In this case, the threads will be cut so that the sleeve tightens in the opposite direction from the pump rotation.

Some sleeves have O-rings between the shaft and the abutting shoulder to prevent water leakage between the shaft and the sleeve. Others may use packing or tight-fitting threads. Use the manufacturers' technical manual for detailed information.

ALIGNMENT OF SHAFTING AND COUPLINGS.—Shaft alignment must be checked frequently. If the shafts are out of line, the unit must be realigned. This will prevent shaft breakage and damage to bearings, pump casing wearing rings, throat bushings. Check the shaft alignment with all piping in place. If the pump is turbine driven, or if it pumps a hot liquid, recheck the alignment after it has operated for several hours and is up to operating temperature.

The driving unit may be connected to the pump by a FLEXIBLE COUPLING. Remember that flexible couplings (fig. 5-7) are intended to take care of only slight misalignment. Misalignment should never exceed the amount specified by the pump manufacturer. If the misalignment is excessive the coupling parts are subjected to severe punishment, which causes frequent renewal of pins, bushings, and bearings.

The driving unit may be connected, or coupled, to the pump by a FLANGE COUPLING. Here too, frequent realignment of the shafting may be necessary. Each pump shaft must be kept in proper alignment with the shaft of the driving unit. Misalignments are indicated by such things as abnormal temperatures, abnormal noises, and worn bearings or bushings.

Shims are placed on the bushings of both the driven and driving units to facilitate alignment when the machinery is installed. Jacking screws may also be used to level the units. The pump or driving unit, or both, may need to be shifted sidewise to align the couplings. This is made easier by side brackets welded in convenient spots on the foundations, and large setscrews used to shift the units sidewise or endwise.

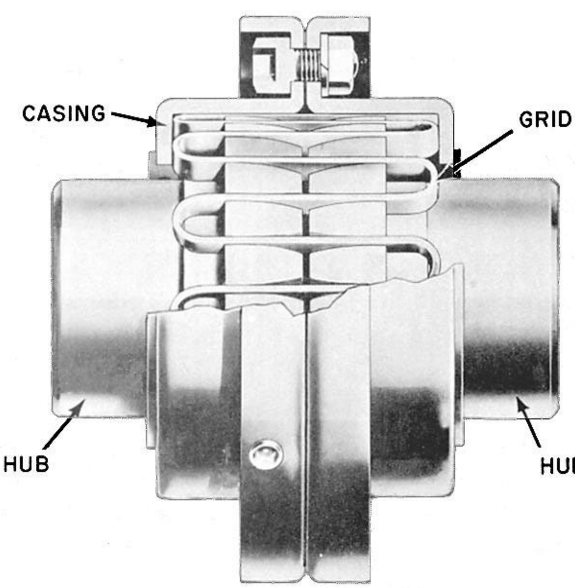

Figure 5-7.—Grid-type flexible coupling.

The shims must be adjusted so that the outside diameters and faces of the coupling flanges run true as they are manually revolved. When that is done, the chocks should be fastened, the units should be securely bolted to the foundation, and the coupling flanges should be bolted together.

The ALIGNMENTS MUST BE CHECKED from time to time, and misalignments must be promptly corrected. There are three methods in general practice for checking the alignments:

1. Use of a 6-inch scale
2. Use of a thickness gauge
3. Use of a dial indicator

Shaft alignment should be checked whenever the pump is opened up and whenever you feel a noticeable vibration. If shafts are found out of line or inclined at an angle to each other, the unit should be realigned. This will avoid shaft breakages and renewal of bearings, pump casing wearing rings, and throat bushings. Consult the appropriate MRC or technical manual in aligning the pump.

MEASURING BEARING CLEARANCES.— Some centrifugal pump installations are fitted with a water-lubricating bearing inside the pump casing (such as condensate pumps). An adequate supply of clean water must be supplied to this bearing for lubricating and cooling.

Check the condition of the internal water-lubricated bearings frequently to guard against excessive wear which results in misalignment and possible shaft failure.

On oil-lubricated sleeve or shell-bearings, measure the bearing clearances following procedures described on the MRC for the pump. Maintain clearances within the limits shown on the MRC or in the manufacturer's technical manual.

RENEWAL OF WEARING RINGS.—The clearance between the impeller wearing ring and the casing wearing ring (figure 5-8) must be maintained as shown in the manufacturer's plans. When the maximum allowable clearance is exceeded the wearing rings must be replaced. In most cases, this can be done by the ship's force. However, if your machine shop does not have the proper lathe, then you must send the pump out for repairs.

All necessary information on disassembly of the unit, dimensions of the wearing rings, and reassembly of the pump is specified by PMS. It can also be found in the manufacturer's technical manual.

In deciding whether the wearing rings need renewing, you must consider the capacity and discharge pressure of the pump. On low-pressure pumps the wearing ring diametral clearance may be 0.015 to 0.030 inch more than the designed amount without any appreciable effect on the pump's capacity. For pumps having a discharge pressure up to 75 psi, a wear of 0.030 to 0.050 inch is permissible.

The percentage of capacity loss, with a wearing ring clearance of 0.030 inch in excess of standard, may be large with a small pump, but comparatively small with a large pump. Increased wearing ring clearance on a high-pressure boiler feed pump is readily noticeable in the efficiency and maximum capacity of the pump. The wearing rings on high-pressure pumps should be renewed when the clearance shown on the manufacturer's plans is exceeded by 100 percent. It is usually not necessary to renew wearing rings unless the wear is at least 0.015 inch.

If a pump has to be diassembled because of some internal trouble, check the wearing rings for clearance. Measure the outside diameter of the impeller wearing ring with an outside micrometer and the inside diameter of the casing wearing ring with an inside micrometer. The difference between the two diameters is the actual wearing ring diametral clearance. By comparing the actual wearing ring clearance with the maximum allowable clearance, you can decide whether to renew the rings before you reassemble the pump. The

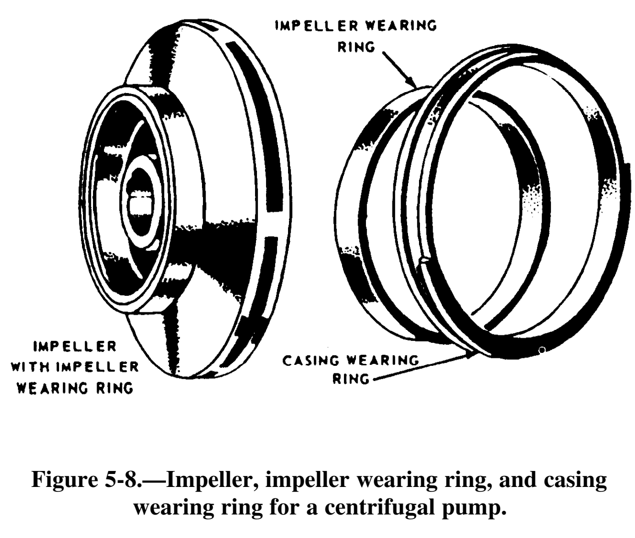

Figure 5-8.—Impeller, impeller wearing ring, and casing wearing ring for a centrifugal pump.

applicable MRCs are a readily available source of information on the proper clearances.

Wearing rings for most small pumps are carried as part of the ship's repair parts allowance. These may need only a slight amount of machining before they can be installed. For some pumps, such as main condensate and main feed booster pumps, spare rotors are carried aboard. The new rotor can be installed and the old rotor sent to a repair activity for overhaul. Overhauling a rotor includes renewing the wearing rings, the bearings, and the shaft sleeve.

TROUBLESHOOTING TECHNIQUES.— Some of the operating troubles you may have to deal with in centrifugal pumps, together with the probable causes, are described in the following paragraphs.

If a centrifugal pump DOES NOT DELIVER ANY LIQUID, the trouble may be caused by (1) insufficient priming; (2) insufficient speed of the pump; (3) excessive discharge pressure, such as might be caused by a partially closed valve or some other obstruction in the discharge line; (4) excessive suction lift; (5) clogged impeller passages; (6) the wrong direction of rotation; (7) clogged suction screen (if used); (8) ruptured suction line; or (9) loss of suction pressure.

If a centrifugal pump delivers some liquid but operates at INSUFFICIENT CAPACITY, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage into the stuffing boxes in pumps operating at less than atmospheric pressure; (3) insufficient speed of the pump; (4) excessive suction lift; (5) insufficient liquid on the suction side; (6) clogged impeller passages; (7) excessive discharge pressure; or (8) mechanical defects such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump DOES NOT DEVELOP ENOUGH DISCHARGE PRESSURE, the trouble may be caused by (1) insufficient speed of the pump; (2) air or gas in the liquid being pumped; or (3) mechanical defects such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump WORKS FOR A WHILE AND THEN FAILS TO DELIVER LIQUID, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage in the stuffing boxes; (3) clogged water seal passages; (4) insufficient liquid on the suction side; or (5) excessive heat in the liquid being pumped.

If a motor-driven centrifugal pump TAKES TOO MUCH POWER, the trouble will probably be indicated by overheating of the motor. The basic cause may be (1) operation of the pump to excess capacity and insufficient discharge pressure; (2) too high viscosity or specific gravity of the liquid being pumped; or (3) misalignment, a bent shaft, excessively tight stuffing box packing, worn wearing rings, or other mechanical defects.

VIBRATION of a centrifugal pump is often caused by (1) misalignment; (2) a bent shaft; (3) a clogged, eroded, or otherwise unbalanced impeller; or (4) lack of rigidity in the foundation. Insufficient suction pressure may also cause vibration, as well as noisy operation and fluctuating discharge pressure, particularly in pumps that handle hot or volatile liquids.

If the pump fails to build up pressure when the discharge valve is opened and the pump speed is increased, proceed as follows:

1. Secure the pump.

2. Prime the pump and be sure that all air is expelled through the air cocks on the pump casing.

3. Open all valves on the pump suction line.

4. Start the pump again. If the pump is electric driven be sure the pump is rotating in the correct direction. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, or an impeller may be broken. It is also possible that air is being drawn into the suction line or into the casing. If any of these conditions exist, stop the pump, try to find the source of the trouble, and correct it, if possible.

Centrifugal Pump Control and Safety Devices

Turbines, used to drive pumps, are fitted with devices to control or limit the speed of the turbine, or to regulate the discharge pressure of the unit.

These devices are seldom found on reciprocating pumps. However, all turbine-driven rotary and centrifugal pumps have some type of governor. Where discharge pressure has to be controlled, both a constant-pressure governor and a speed-limiting governor are installed.

The speed-limiting governor was covered in chapter 2. Therefore we will discuss only the constant-pressure governor in this chapter.

CONSTANT-PRESSURE GOVERNOR.— Many turbine-driven pumps are fitted with constant-pressure pump governors which maintain a constant pump discharge pressure under varying conditions of load. The governor is installed in the steam line to the pump. It controls the pump discharge pressure by controlling the amount of steam admitted to the driving turbine.

The operating principles for the types of constant-pressure pump governors are discussed in following paragraphs.

A constant-pressure pump governor for a main feed pump is shown in figure 5-9. The governors used on fuel oil service pumps, lube oil service pumps, fire and flushing pumps, and various other pumps are almost identical. The chief difference between governors used for different services is in the size of the upper diaphragm. A governor used for a pump that operates with a high discharge pressure has a smaller upper diaphragm than one used for a pump that operates with a low discharge pressure.

Two opposing forces are involved in the operation of a constant-pressure pump governor. Fluid from the pump discharge, at discharge pressure, is led through an actuating line to the space below the upper diaphragm. The pump discharge pressure thus exerts an UPWARD force on the upper diaphragm. Opposing this, an adjusting spring exerts a DOWNWARD force on the upper diaphragm.

When the downward force of the adjusting spring is greater than the upward force of the pump discharge pressure, the spring forces both the upper diaphragm and the upper crosshead downward. A pair of connecting rods connects the upper crosshead rigidly to the lower crosshead, so the entire assembly of upper and lower crossheads moves together. When the crosshead assembly moves downward, it pushes the lower mushroom and the lower diaphragm downward. The lower diaphragm is in contact with the controlling valve. When the lower diaphragm is moved downward, the controlling valve is forced down and open.

The controlling valve is supplied with a small amount of steam through a port from the inlet side of the governor. When the controlling valve is open, steam passes to the top of the operating piston. The steam pressure acts on the top of the piston, forcing it down and opening the main valve. The extent to which the main valve is open controls the amount of steam admitted to the driving turbine. Increasing the opening of the main valve therefore increases the supply of steam to the turbine and so increases the speed of the turbine.

The increased speed of the turbine produces an increased discharge pressure from the pump. This pressure is exerted against the under side of the upper diaphragm. The pump discharge pressure increases to the point that the upward force acting on the underside of the upper diaphragm is greater than the downward force exerted by the adjusting spring. The upper diaphragm is then moved upward. This action allows a spring to start closing the controlling valve. This action, in turn, allows the main valve spring to start closing the main valve against the now-reduced pressure on the operating piston. When the main valve starts to close, the steam supply to the turbine, the speed of the turbine, and the pump discharge pressure are reduced.

It might seem that the controlling valve and the main valve would be constantly opening and closing and that the pump discharge pressure would be continually varying over a wide range. This does not happen, however, because the governor prevents excessive opening or closing of the controlling valve. An intermediate diaphragm bears against an intermediate mushroom which, in turn, bears against the top of the lower crosshead. Steam is led from the governor outlet to the bottom of the lower diaphragm and also, through a needle valve, to the top of the intermediate diaphragm. A steam chamber is provided to ensure a continuous supply of steam at the required pressure to the top of the intermediate diaphragm.

Any up or down movement of the crosshead assembly is therefore opposed by the force of the steam pressure acting on either the intermediate diaphragm or the lower diaphragm. The whole arrangement prevents extreme reactions of the controlling valve in response to variations in pump discharge pressure.

Limiting the movement of the controlling valve in this manner, reduces the amount of hunting the governor must do to find each new position. Under constant-load conditions, the controlling valve takes a position that causes the main valve to remain open by the required amount. A change in load conditons results in momentary hunting by the governor until it finds the new position required to maintain pump discharge pressure at the new load.

A pull-open device, consisting of a valve stem and a handwheel, is fitted to the bottom of the governor. Turning the handwheel to the open position draws the main valve open and allows full steam flow to the turbine. When the main valve is opened by this bypass, the turbine must be controlled manually. Under all normal operating conditions, the bypass remains closed

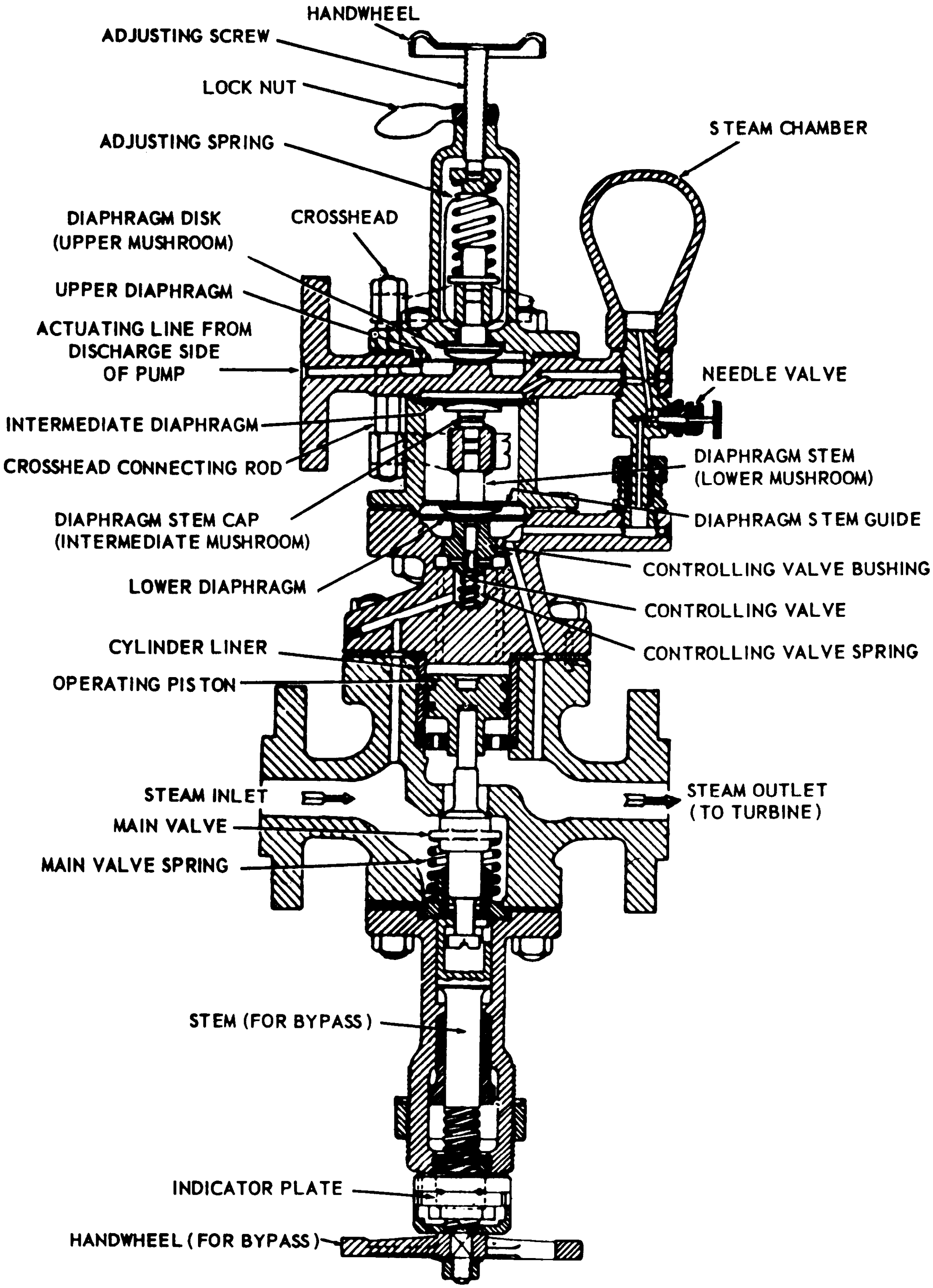

Figure 5-9.—Constant-pressure governor for main feed pump.

and the pump discharge pressure is raised or lowered, as necessary, by increasing or decreasing the tension on the ajusting spring.

The mainfeed pumps on some newer ships are fitted with a differential-pressure governing system instead of the constant-pressure governor. This system maintains a constant differential pressure across the feedwater regulating valve. This valve is located in the discharge piping of the pump. When this system is used, the mainfeed pump will normally be located in the fire room.

AUTOMATIC SHUTDOWN DEVICE.—An automatic shutdown device shuts down the main feed pump. This protects the pump from damage in the event of loss of feed booster pump pressure (which is the same as main feed pump suction pressure).

The device consists of an auxiliary pilot valve and a constant-pressure pump governor, arranged as shown in figure 5-10. The governor is similar to the governor just described except that it has a special top cap. In the regular governor, the steam for the operating piston is supplied to the controlling valve through a port in the governor valve body. In the automatic shut-down device, the steam for the operating piston is supplied to the controlling valve through the auxiliary pilot valve. The auxiliary pilot valve (fig. 5-11) is actuated by the feed booster pump discharge pressure. When the booster pump discharge pressure is inadequate, the auxiliary pilot valve will not deliver steam to the controlling valve of the governor. Thus, inadequate feed booster pump pressure allows the main valve in the governor to close, shutting off the flow of steam to the feed pump turbine.

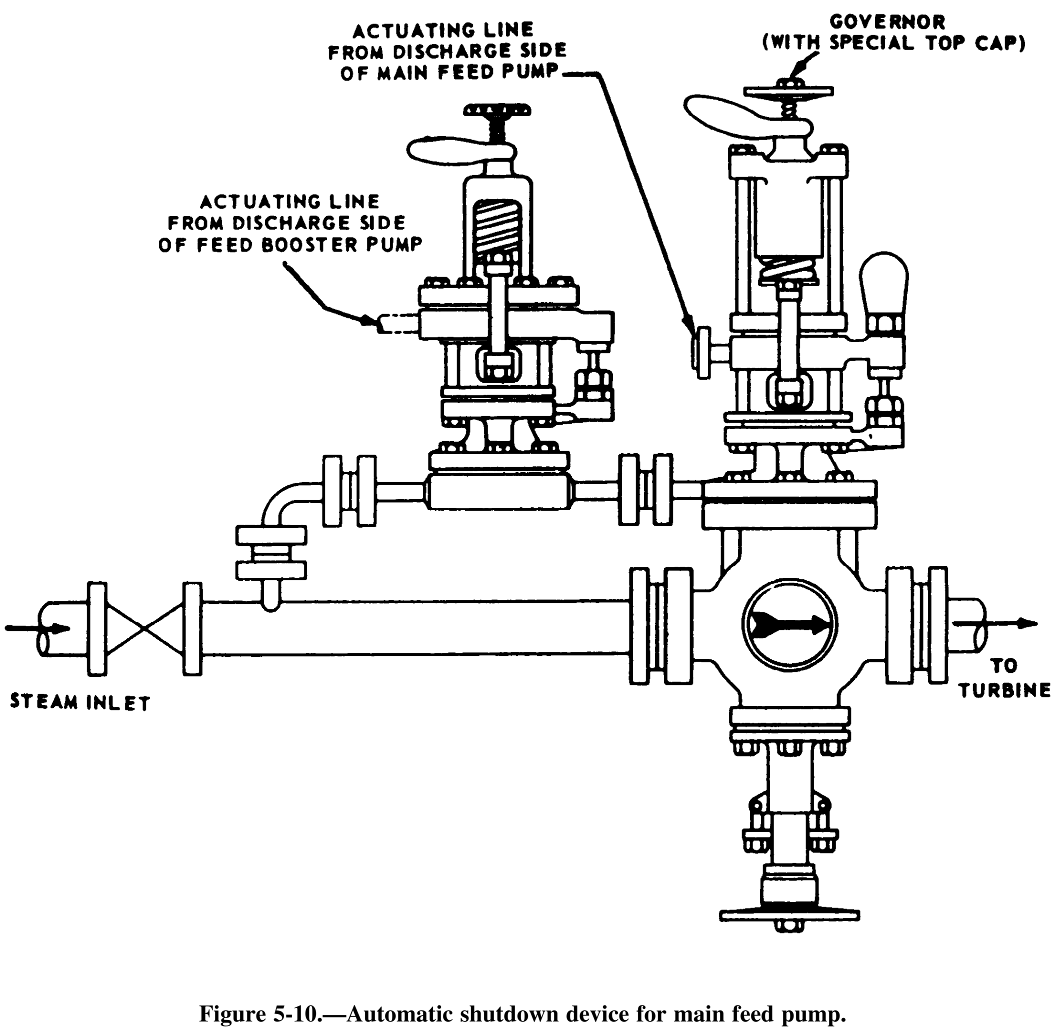

Figure 5-10.—Automatic shutdown device for main feed pump.

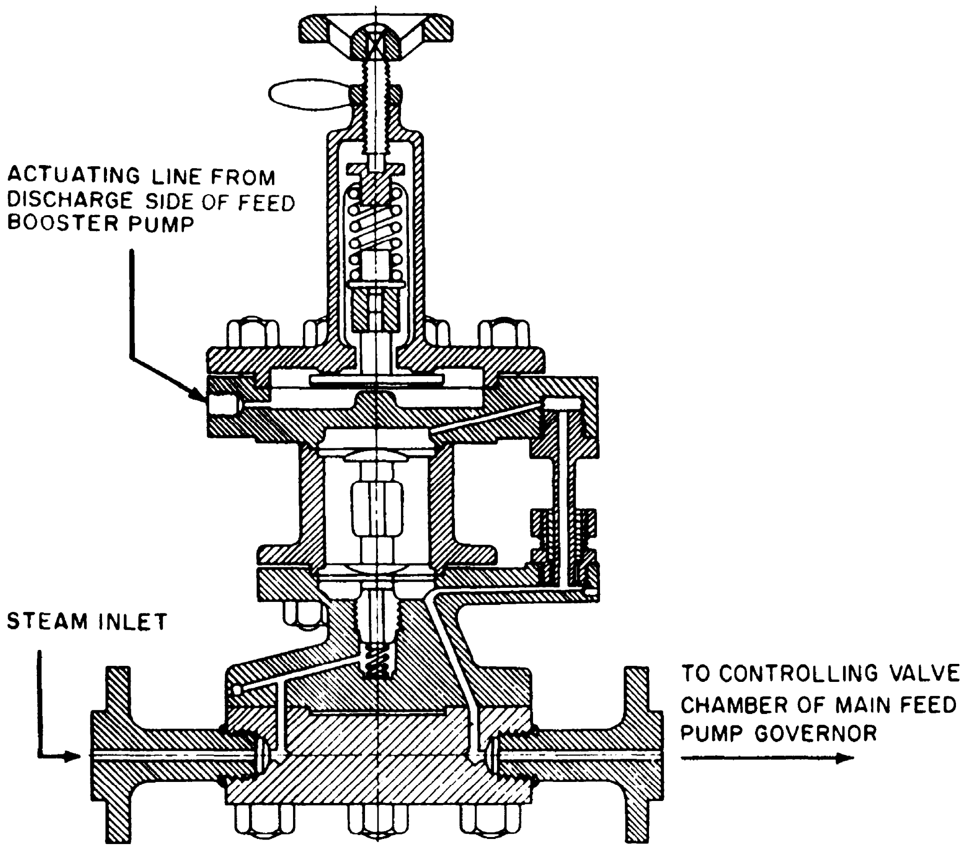

Figure 5-11.—Auxiliary pilot valve for automatic shutdown device.

MAINTENANCE AND REPAIR OF GOVERNORS.—The maintenance and repair of governors should be accomplished according to the applicable MRCs or manufacturer's instructions for the specific equipment. The information which follows is general in nature.

There is very little wear in speed-limiting governors. However, the governor must be kept clean. Dirt or other foreign matter can foul the spring. More force is needed to move the weights, thereby allowing the pump to overspeed. Rust on the governor lever fulcrum pin will cause the lever to bind and not function properly. All pins in the linkage and the valve stem must be kept free of paint, rust, and dirt so that the linkage can move freely. Occasionally, a test should be made to determine whether the poppet valve is leaking. The test may be made by pushing the valve onto its seat by hand. If the valve is leaking the turbine will continue to rotate.

When constant-pressure governors are disassembled, carefully inspect all diphragms. If indications of failure are found, renew the affected part(s). However, routine overhaul maintenance of pump governors may be necessary to replace serviceable diaphragms. They may be distorted beyond the manufacturer's prescribed limits because of normal operating pressure. Distortion of diaphragms within the manufacturer's prescribed limits is normal and has no adverse affect on the operation of governors. Unless manufacturer-furnished diaphragms are used, refer to finished plans for guidance as to proper dimensions and materials.

The pilot control valve may be a source of trouble. Steam passing through the control valve is continuously throttled, and the valve is subjected to considerable erosion (wiredrawing). Inspect the control valve and valve seat frequently. When reassembling the control valve or installing a new one, it is very important to maintain the correct clearance between the control valve stem and the lower diaphragm. If the clearance is excessive, the lower diaphragm cannot fully open the control valve, and the pump capacity is reduced. If there is not enough clearance, the diaphragm will hold the control valve open and the pump cannot be stopped without closing the root steam valve. It is also necessary that steam does not leak through the control valve bushing. Leaking steam will hold the main valve open, allowing steam to flow to the turbine.

Faulty governor operation may also result from the wearing of grooves in the cylinder liner. The grooves, which limit the travel of the main valve, become worn when the piston is moved through a short travel. This reduces the capacity of the pump and causes failure of the governor. Whenever a constant-pressure governor is disassembled, check the liner carefully. If it is grooved excessively, replace the liner according to the manufacturer's recommendations for the specific unit.

Inspect control valve springs frequently. If the spring breaks or is weak, it cannot close the control valve, which allows a full flow of steam to the turbine.

Centrifugal Pump Safety Precautions

The following safety precautions must be observed in connection with the operation of centrifugal pumps.

1. Ensure that all relief valves are tested at the appropriate intervals as required by the PMS. Ensure that relief valves function at the designated pressure.

2. Never attempt to jack over a pump by hand while the throttle valve to the turbine is open or the power is on.

3. Do not attempt to operate a pump while either the speed-limiting governor or the constant-pressure governor is inoperable. Be sure that the speed-limiting governor and the constant-pressure governor are properly set.

4. Do not use any boiler feed system pump for any service other than boiler or feed water service, except in an emergency.

PROPELLER PUMPS

Propeller pumps are used primarily where there is a large volume of liquid with a relatively low total head requirement. These pumps are usually limited to where the total head does not exceed 40 to 60 feet.

The chief use of the propeller pump is for the main condenser circulating pump (illustrated in *Fireman,* NAVEDTRA 14104). In most ships this has an emergency suction for pumping out the engine room.

The main condenser circulating pump is of the vertical propeller type. The pump unit consists of three major parts: the propeller, together with its bearings and shaft; the pump casing; and the driving unit, which may be an auxiliary steam turbine or electric motor.

The propeller is a multibladed screw propeller having a large pitch. The blades are thick at the roots and flare out toward the tips. The blades and hubs are cast or forged in one piece and are then machined and balanced. The lower shaft bearing is a water-lubricated, sleeve bearing. The shaft packing gland prevents excessive leakage of water between the casing and the shaft.

RECIPROCATING PUMPS

A reciprocating pump moves water or other liquid by a plunger or piston that reciprocates (travels back and forth) inside a cylinder. Reciprocating pumps are positive-displacement pumps; each stroke displaces a definite quantity of liquid, regardless of the resistance against which the pump is operating.

Classification of Reciprocating Pumps

Reciprocating pumps are usually classified as the following:

1. Direct acting or indirect acting
2. Simplex (single) or duplex (double)
3. Single acting or double acting
4. High pressure or low pressure
5. Vertical or horizontal

The reciprocating pump shown in figure 5-12 is a direct-acting, simplex, double-acting, high-pressure, vertical pump. Now let's see what all these terms mean about the pump shown in the illustration.

DIRECT-ACTING AND INDIRECT-ACTING PUMPS.—The pump shown is direct acting because the pump rod is a DIRECT extension of the piston rod and, therefore, the piston in the power end is

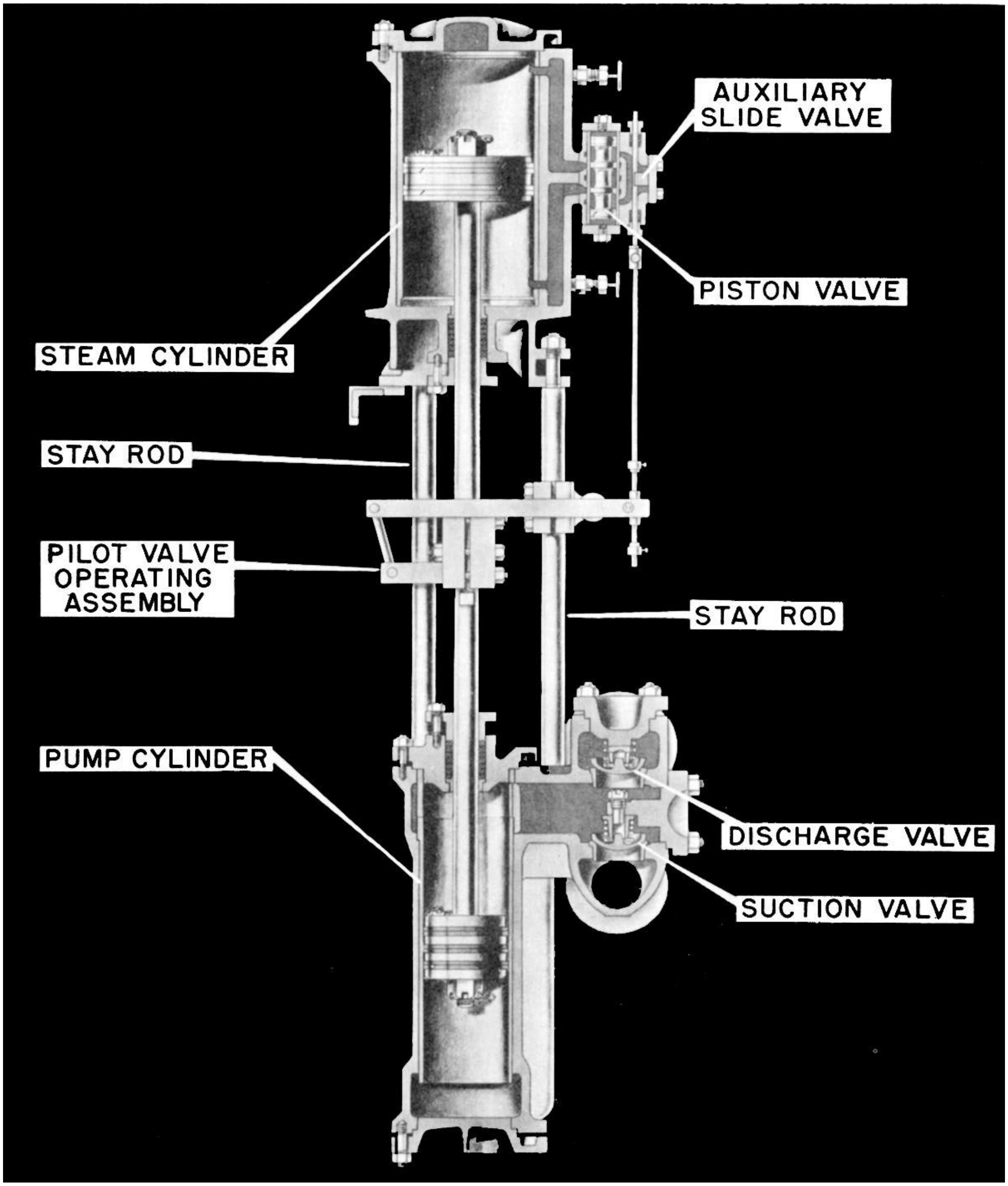

Figure 5-12.—Reciprocating pump.

DIRECTLY connected to the plunger in the liquid end. Most reciprocating pumps used in the Navy are direct acting. In an indirect-acting pump, there is some intermediate mechanism between the piston and pump plunger. The intermediate mechanism may be a lever or a cam. This arrangement can be used to change the relative length of the strokes of piston and plunger or to vary the relative speed between piston and plunger. Or the pump may use a rotating crankshaft such as a chemical proportioning pump in a distilling unit.

SIMPLEX AND DUPLEX PUMPS.—The pump shown in figure 5-12 is called a single or simplex pump becasue it has only one liquid cylinder. Simplex pumps may be either direct acting or indirect acting. A double or duplex pump is an assembly of two single pumps placed side by side on the same foundation; the two steam cylinders are cast in a single block, and the two liquid cylinders are cast in another block. Duplex reciprocating pumps are seldom found in modern combatant ships, but were commonly used in older ships.

SINGLE-ACTING AND DOUBLE-ACTING PUMPS.—In a single-acting pump, the liquid is drawn into the liquid cylinder on the first or SUCTION stroke and is forced out of the cylinder on the return or DISCHARGE stroke. In a double-acting pump, each stroke serves both to draw in liquid and to discharge liquid. As one end of the cylinder is filled, the other end is emptied; on the return stroke, the end which was just emptied is filled and the end which was just filled is emptied.

The pump shown in figure 5-12 is double acting. (**NOTE:** Only one of two sets of valves is shown in fig. 5-12.)

HIGH-PRESSURE AND LOW-PRESSURE PUMPS.—The pump shown in figure 5-12 is designed to operate with a discharge pressure which is higher than the pressure of the steam operating the piston in the steam cylinder; in other words, it is a high-pressure pump. In a high-pressure pump the steam piston is larger in diameter than the plunger in the liquid cylinder. Since the area of the steam piston is greater than the area of the plunger in the liquid cylinder, the total force exerted by the steam against the steam piston is concentrated on the smaller working area of the plunger in the liquid cylinder. Therefore, the pressure per square inch is greater in the liquid cylinder than the steam cylinder. A high-pressure pump discharges a comparatively small volume of liquid against a high pressure. A low-pressure pump, on the other hand, has a comparatively low discharge pressure but a larger volume of discharge. In a low-pressure pump, the steam piston is smaller than the plunger in the liquid cylinder.

The standard way of designating the size of a reciprocating pump is by giving three dimensions, in the following order:

1. The diameter of the steam piston
2. The diameter of the pump plunger
3. The length of the stroke

For example, a $12 \times 11 \times 18$-inch reciprocating pump has a steam piston which is 12 inches in diameter, a pump plunger which is 11 inches in diameter and a stroke which is 18 inches in length. The designation enables you to tell immediately whether the pump is a high-pressure or a low-pressure pump.

VERTICAL AND HORIZONTAL PUMPS.—Finally, the pump shown in figure 5-12 is classified as vertical because the steam piston and the pump plunger move up and down. Most reciprocating pumps in naval use are vertical; however, you may occasionally encounter a horizontal pump, in which the piston moves back and forth rather than up and down.

The following discussion of reciprocating pumps is generally concerned with direct-acting, simplex, double-acting, vertical pumps. Most reciprocating pumps used in the Navy are of this type.

Construction of Reciprocating Pumps

The power end of a reciprocating pump consists of a bored cylinder in which the steam piston reciprocates. The steam cylinder is fitted with heads at each end; one head has an opening to accommodate the piston rod. Steam inlet and exhaust ports connect each end of the steam cylinder with the steam chest. Drain valves are installed in the steam cylinder so that water from condensation may be drained off.

Automatic timing of the admission and release of steam to and from each end of the steam cylinder is accomplished by a valve operating assembly. This assembly connects the pilot valve operating rod and the pump rod (fig. 5-13). As the crosshead arm (sometimes called the rocker arm) is moved up and down by the movement of the pump rod, the moving tappet slides up and down on the pilot valve rod. The tappet collars are adjusted so that the pump will make the full designed stroke.

The piston valve gear, commonly used for automatic timing, consists of a piston slide valve and a pilot slide valve. The position of the pilot slide valve is controlled by the position of the main piston in the

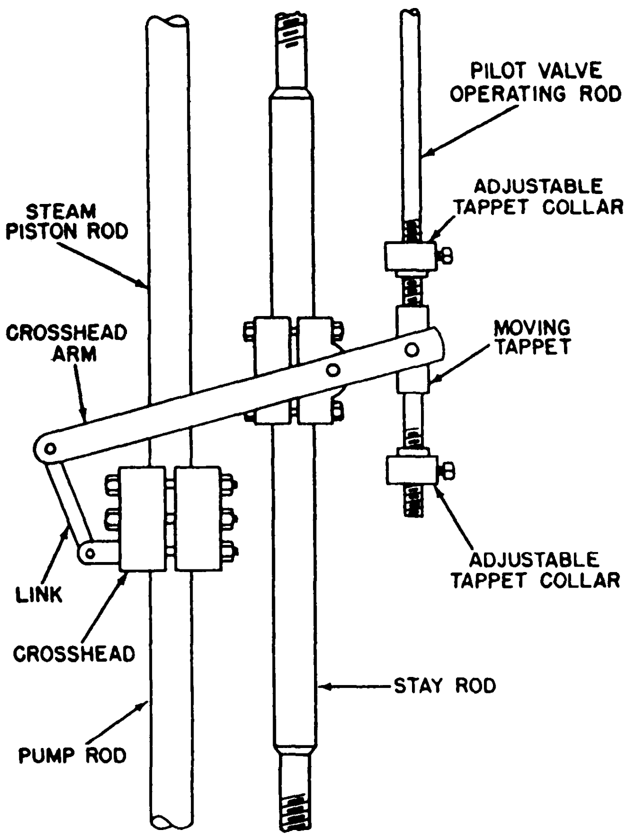

Figure 5-13.—Valve operating assembly.

steam cylinder. At the completion of the down stroke of the pump, the crosshead arm moves the tappet against the upper adjustable tappet collar to actuate the pilot slide valve. This movement admits steam to reposition the floating piston. The movement of the floating piston opens ports to admit steam to the underside of the piston in the steam cylinder and to exhaust the steam above the piston. This causes the piston to move upward. Once the pump has completed the up-stroke, the cycle repeats itself in reverse. Piston valves are used for steam pressures in excess of about 150 to 200 psi. Floating piston valves also eliminate unbalanced loads and minimize steam leakage and wear.

The liquid end of the reciprocating pump has a piston and cylinder assembly similar to that of the power or steam end. The piston in the liquid end is often called a PLUNGER. A VALVE CHEST, sometimes called a WATER CHEST, is attached to the liquid cylinder. The valve chest contains two sets of suction and discharge valves: one set to serve the upper end of the liquid cylinder and one to serve the lower end. The valves are so arranged that the pump takes suction from the suction chamber and discharges through the discharge chamber on both the up and down strokes.

As in all Navy pumps, a relief valve is installed in the discharge piping between the pump and the discharge valve. The relief valve is to protect the pump and the piping against excessive pressure.

Reciprocating Pump Care and Maintenance

Reciprocating pumps are easy to operate and usually are very reliable units.

They do, however, require routine maintenance and, upon occasion, some repair work. Consult the manufacturer's technical manaul for details concerning the repair of a specific unit. Routine maintenance, however, is performed according to PMS requirements. For additional information, check the *Naval Ships' Technical Manual.*

Before repairing or examining a pump, assemble the MRCs and all the pertinent blue-prints, drawings, and available data. These drawings and data will give you the required clearances, tools, measurements, materials, and other important information to be used. In addition, you should have the complete history of the pump being repaired. You will know what has been done previously, when repairs were made, and what kind of trouble has been encountered with this particular pump.

Whenever reciprocating pumps are opened for repairs, you should take micrometer or caliper measurements of the main cylinders and the valve chest cylinders. Make these measurements on the fore and aft and athwartships diameters at the top, middle, and bottom. Record the results with accompanying remarks on a diagrammatic sketch showing the measurements and the date on which they were made.

Remember that the steam end of a reciprocating pump should NOT be dismantled until a thorough check reveals that the water end is satisfactory. Most reciprocating pump troubles, however, are caused by fouled water cylinders, worn valves, or faulty conditions in the pipe connections external to the pump.

VARIABLE STROKE PUMPS

Variable stroke (also called variable displacement) pumps are most commonly used on naval ships as part of an electrohydraulic transmission. They are used on anchor windlasses, cranes, winches, steering gear, and other equipment. You will have to maintain and make minor repairs to hydraulic and related equipment outside your ship's engineering spaces.

There are two general types of variable stroke pumps in common use: the axial-piston pump and the radial-piston pump. In the axial-piston pump (fig. 5-14), the pistons are arranged parallel to each other and to the pump shaft. In the radial-piston pump, the pistons are arranged radially from the shaft.

Variable Stroke Axial-Piston Pump

The variable stroke axial-piston pump usually has either seven or nine single-acting pistons which are evenly spaced around a cylinder barrel. An uneven number of pistons is always used in order to avoid pulsations in the discharge flow. (Note that the term "cylinder barrel," as used here, actually refers to a cylinder block which holds all the cylinders.) The piston rods make a ball-and-socket connection wiht a socket ring. The socket ring rides on a thrust bearing carried by a casting called the TILTING BOX or TILTING BLOCK.

When the tilting box is at a right angle to the shaft, and the pump is rotating, the pistons do not reciprocate; therefore, no pumping takes place. When the box is tilted away from a right angle, however, the pistons reciprocate and the liquid is pumped.

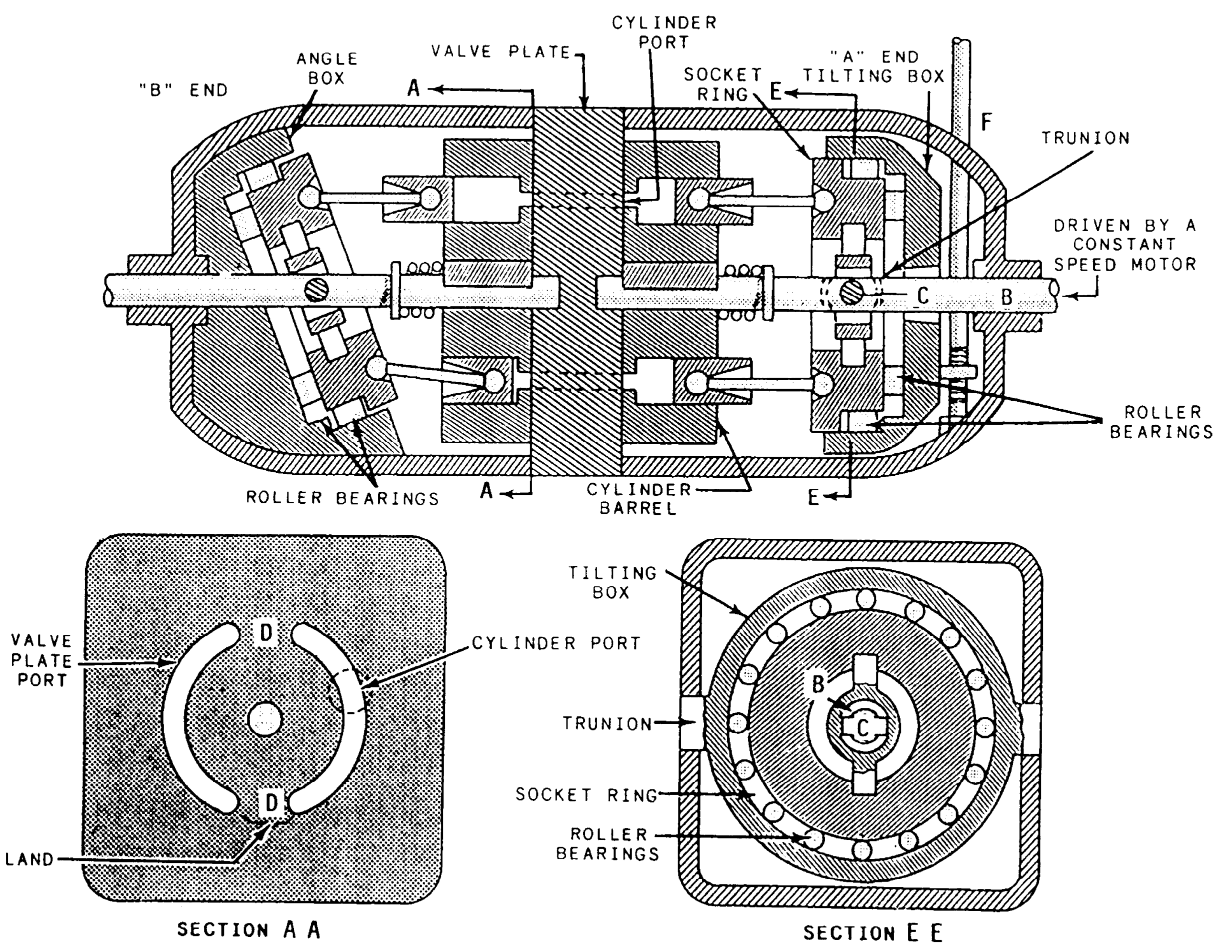

Figure 5-14.—Axial piston hydraulic speed gear.

The variable stroke axial-piston pump is often used as a part of a variable speed gear such as electrohydraulic anchor windlasses, cranes, winches, and the power transmitting unit in electrohydraulic steering engines. In those cases, the tilting box is so arranged that it may be tilted in either direction. Thus it may be used to transmit power hydraulically to pistons or rams, or it may be used to drive a hydraulic motor. In the latter use, the pump is driven by a constant-speed electric motor and is called the A-end of the variable speed gear. The hydraulic motor is called the B-end.

The B-end unit of the hydraulic speed gear is exactly the same as the A-end of the variable stroke pump mentioned previously. However, it generally does not have a variable stroke feature. The tilting box is installed at a permanently fixed angle. Thus, the B-end becomes a fixed-stroke axial-piston pump. Figure 5-14 illustrates an axial-piston hydraulic gear with the A-end and B-end as a single unit. It is used in turrets for train and elevation driving units. For electro-hydraulic winches and cranes, the A-end and B-end are in separate housings connected by hydraulic piping.

Hydraulic fluid introduced under pressure to a cylinder causes the piston to be pushed out. In being pushed out, the piston, through its connecting rod, will seek the point of greatest distance between the cylinder barrel and the socket ring. The resultant pressure of the piston against the socket ring will cause the cylinder barrel and the socket ring to rotate. This action occurs during the half revolution while the piston is passing the intake port of the motor, which is connected to the pressure port of the pump. After the piston of the motor has taken all the hydraulic fluid it can from the pump, the piston passes the valve plate land and starts to discharge oil through the outlet ports of the motor to the suction inlet of the pump, and thence to suction pistons of the pump. The pump is constantly putting pressure on one side of the motor while it is constantly receiving hydraulic fluid from the other side. The fluid is merely circulated from pump to motor and back again.

Variable Stroke Radial-Piston Pump

The variable stroke radial-piston (fig. 5-15) pump is similar in general principle to the axial-piston

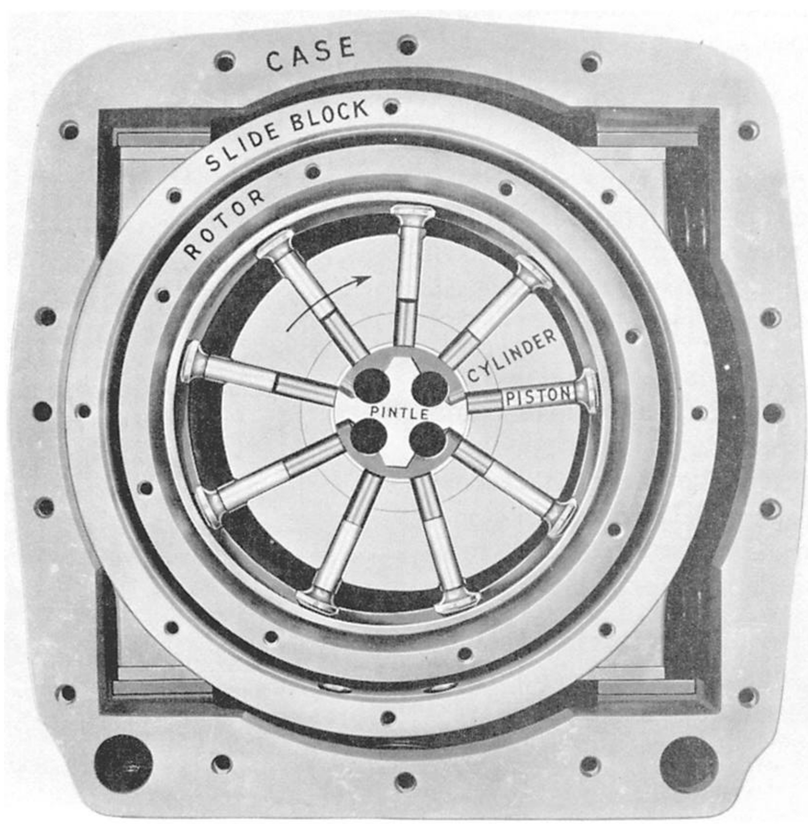

Figure 5-15.—Nine-piston radial piston pump.

pump just described, but the arrangement of component parts is different. In the radial-piston pump, the cylinders are arranged radially in a cylinder body which rotates around a nonrotating central cylindrical valve. Each cylinder communicates with horizontal ports in the central cylindrical valve. Plungers or pistons, which extend outward from each cylinder, are pinned at their outer ends to slippers which slide around the inside of a rotating floating ring and housing.

The floating ring is so constructed that it can be shifted off center from the pump shaft When it is centered, or in the neutral position, the pistons do not reciprocate and the pump does not function, even though the electric motor is still causing the pump to rotate. If the floating ring is forced off center to one side of the pump shaft, the pistons reciprocate and the pump operates. If the floating ring is forced off center to the other side, the pump also operates but the direction of the flow is reversed. Therefore, the direction of flow and the amount of flow are both determined by the position of the cylinder body relative to the position of the floating ring.

The shipboard application of reversible variable stroke pumps is in such hydraulic transmission gear as steering mechanisms and windlasses.

For further information, refer to *Naval Ships' Technical Manual* (chapter 556) and the manufacturer's technical manual.

ROTARY PUMPS

Rotary pumps, like reciprocating pumps, are positive displacement pumps. The rotary pump is used to pump liquids over a wide range of viscosities. As an example, it is used in the engine room to pump lube oil. These pumps may be steam- or motor-driven.

Rotary pumps are designed with very small clearances between rotating parts and stationary parts. This minimizes leakage (slippage) from the discharge side back to the suction side. They operate at relatively slow speeds to maintain these clearances. Operation at higher speeds causes excessive wear, which results in increased clearances with a decrease in pumping capacity.

Classification of rotary pumps is generally based on the type of rotating element. In the following paragraphs, the main features of some common types of rotary pumps are discussed.

Simple Gear Pump

The simple gear pump (fig. 5-16) has two spur gears which mesh together and revolve in opposite directions. One is the DRIVING GEAR, and the other is the DRIVEN GEAR. Clearances between the gear teeth (outside diameter of gear) and the casing and between the end face and the casing are only a few thousandths or an inch. As the gears turn, the gears unmesh and liquid flows into the pockets which are vacated by the meshing gear teeth. This creates the suction that draws the liquid into the pump. The liquid is then carried along in the pockets formed by the gear teeth and the casing. On the discharge side, the liquid is displaced by the meshing of the gears, and forced out through the discharge side of the pump.

HERRINGBONE GEAR PUMP.—In the herringbone gear pump (fig. 5-17), a modification of the simple gear pump, one discharge phase begins before the previous discharge phase is entirely complete; this overlapping tends to give a steadier discharge pressure than is found in the simple gear pump. Power-driven pumps of this type are sometimes used for low-pressure fuel oil service, lubricating oil service, and diesel oil service.

HELICAL GEAR PUMP.—The helical gear pump (fig. 5-18) is still another modification of the simple gear pump. Because of the helical gear design,

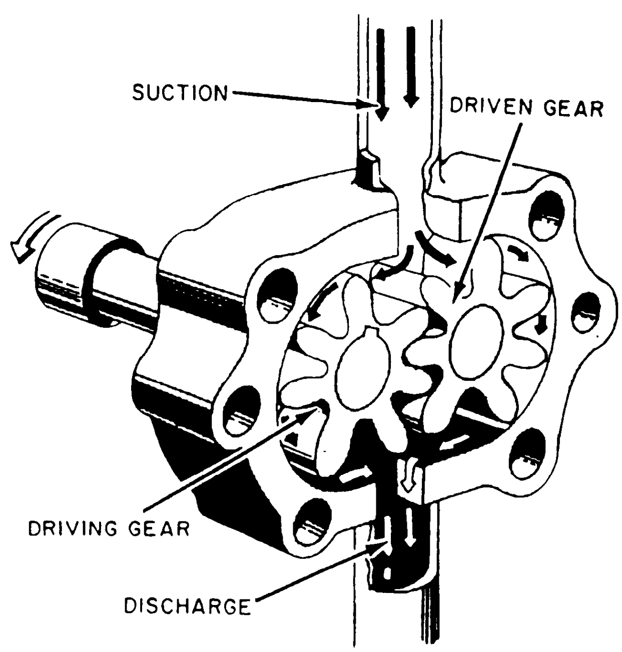

Figure 5-16.—Simple gear rotary pump.

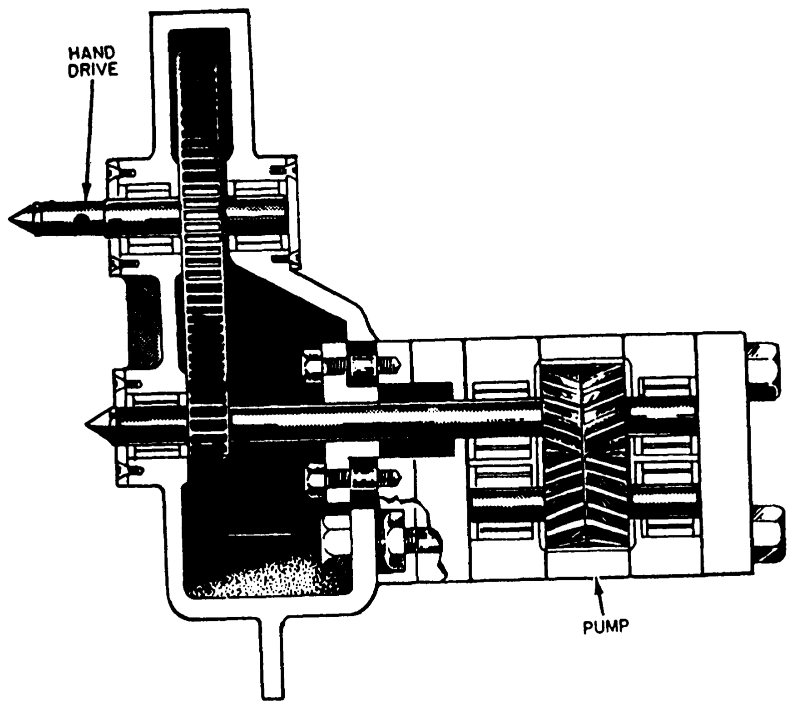

Figure 5-17.—Herringbone gear pump.

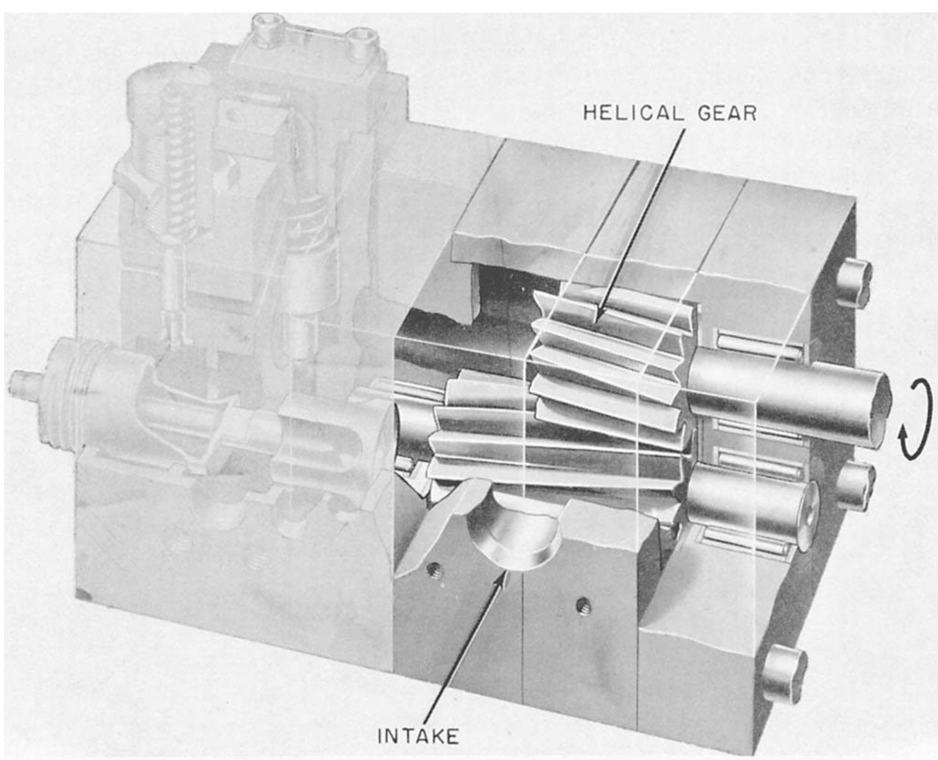

Figure 5-18.—Helical gear pump.

the overlapping of successive discharges from spaces between the teeth is even greater than it is in the herringbone gear pump. The discharge flow is, accordingly, even smoother. Since the discharge flow is smooth in the helical gear pump, the gears can be designed with a small number of large teeth, thus allowing increased capacity without sacrificing smoothness of flow.

The pumping gears in this type of pump are driven by a set of timing and driving gears, which also function to maintain the required close clearances while preventing actual metallic contact between the pumping gears. Metallic contact between the teeth of the pumping gears would provide a tighter seal against leakage. However, it would cause rapid wear of the teeth because foreign matter in the pumped liquid would be present on the contact surfaces.

Roller bearings at both ends of the gear shafts maintain proper alignment, thereby minimizing the friction loss in the transmission of power. Stuffing boxes are used to prevent leakage at the shafts. The helical gear pump is used to pump nonviscous liquids and light oils at high speed. At lower speed, it can be used to pump heavy, viscous materials.

LOBE PUMP.—The lobe pump is still another variation of the simple gear pump. A lobe pump (heliquad type) is illustrated in figure 5-19. The lobes are considerably larger than gear teeth, but there are only two or three lobes on each rotor. The rotors are driven by external spur gears on the rotor shafts. Some lobe pumps are made with replaceable inserts (gibs) at the extremities of the lobes. These inserts take up the wear which would otherwise be sustained by the ends of the lobes. In addition, they maintain a tight seal between the lobe ends and the casing. The inserts are usually seated on a spring. In this way, they automatically compensate for considerable wear of both the gibs and the casing. Replaceable cover plates (liner plates) are fitted at each end of the casing where the lobe faces cause heavy wear.

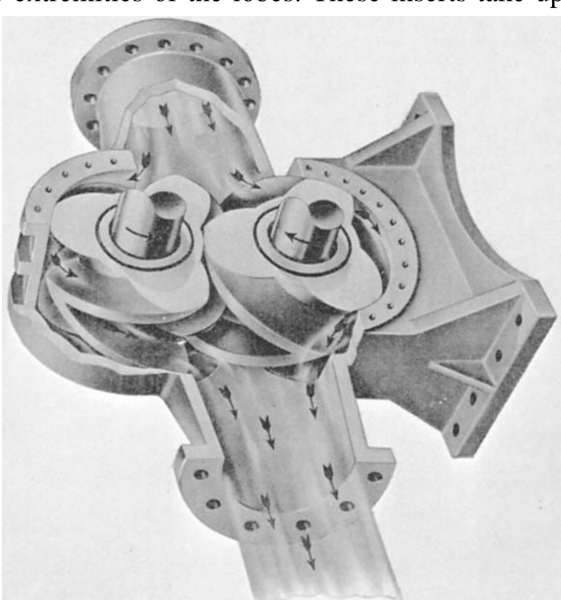

Figure 5-19.—Lobe pump (heliquad type).

Screw Pump

There are several types of screw pumps. The main points of difference between the various types are the number of intermeshing screws and the pitch of the screws. Figures 5-20 and 5-20A show a positive displacement, double-screw, low-pitch pump. Screw pumps are primarily used for pumping all viscous fluids such as JP-5 and diesel oil. Hydraulic systems on some ships use the screw pump as the pressure supply for the system. The pump may be either motor-driven or turbine-driven.

In the screw pump, liquid is trapped and forced through the pump by the action of rotating screws. As the rotor turns, the liquid flows in between the threads at the outer end of each pair of screws. The threads carry the liquid along within the housing to the center of the pump where it is discharged.

Information on the operation may be obtained from the EOSS; *NSTM,* chapter 503; and the manufacturer’s manuals. Maintenance should be performed according to PMS requirements.

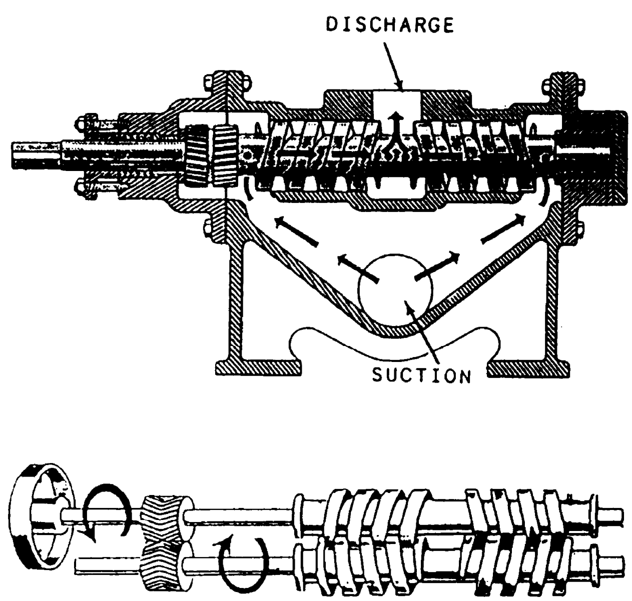

Figure 5-20.—Positive displacement, double-screw, low-pitch pump.

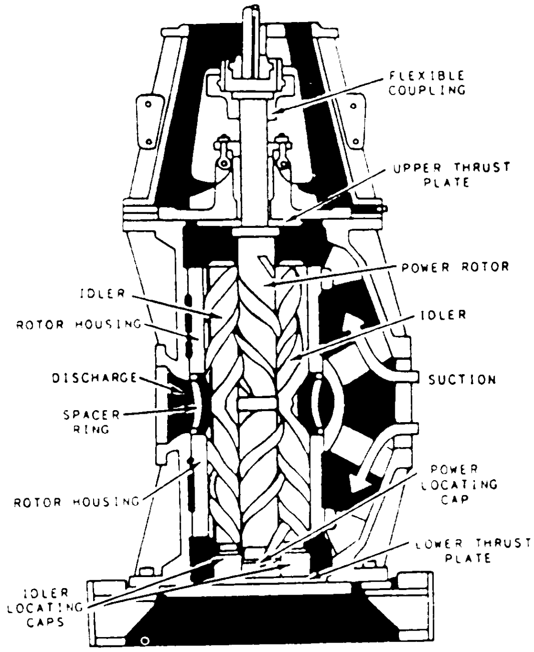

Figure 5-20A.—Triple-screw high-pitch pump.

Safety Precautions

All personnel concerned with the operation of rotary pumps MUST observe the following safety precautions:

1. Before they are fitted, test relief valves to see that they function at the designed pressure or as PMS directs.
2. NEVER attempt to jack a pump by hand while the steam valve to the driving unit is open.
3. Do NOT tie down, or otherwise render inoperative, the overspeed trip, the speed-limiting governor, or the speed-regulating governor.
4. NEVER operate a postive-displacement rotary pump with the discharge valve closed unless the discharge is protected by a properly set relief valve of a size sufficient to prevent a dangerous rise in pressure.

EDUCTORS

Although the pumps that we have discussed so far in this chapter were either motor- or steam-driven, the eductor (fig. 5-21) is a jet pump and has no moving

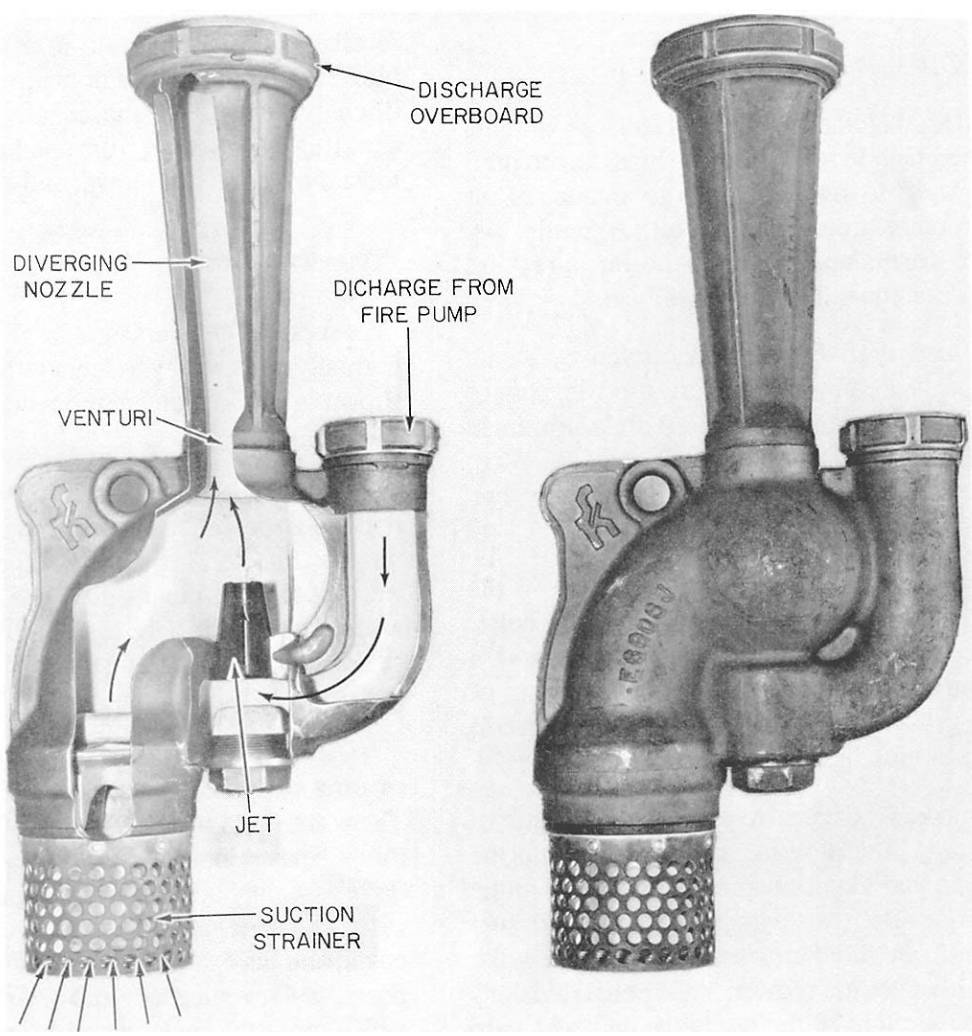

Figure 5-21.—Eductor.

parts. It is actuated by steam or water. It basically operates on the same principle as the air ejector nozzle assembly discussed in chapter 6.

Eductors are designed to pump large volumes of water. In modern ships, eductors have replaced fire and bilge pumps as a primary means for pumping bilges, deballasting, and dewatering compartments. Educators allow centrifugal fire pumps to serve indirectly as drainage pumps without the risk of becoming fouled with debris from the bilges. The centrifugal pumps pressurize the fire main, and water from the fire main is used to actuate the eductors. The eductors in modern combat ships have a much larger pumping capacity than fire and bilge pumps. They are installed as part of the piping in the drainage system and are flanged to permit easy removal and disassembly when repairs are necessary.

CAUTION: Improper lighting off and securing of an eductor can cause rapid flooding of the space being pumped. Always follow the proper procedure!

FORCED DRAFT BLOWERS

A forced draft blower is essentially a large-volume, LP, high-speed fan. In steam-driven ships, forced draft blowers are used to furnish the large amount of air required for combustion of the fuel oil. As a rule, two blowers are furnished for each boiler; they are synchronized for equal distribution of load.

Most forced draft blowers are driven by steam turbines. However, blowers that are used in port or during light-off and some main forced draft blowers in auxiliary ships are driven by electric motors. Most turbine-driven blowers are direct-drive rather than geared.

Balanced automatic shutters are installed in the discharge ducts between each blower and the boiler casings. As a precaution, these shutters are locked in the closed position when the blower is taken out of service to keep the blower from being rotated in reverse by another operating blower.

The air intake is screened to prevent the entrance of foreign objects. The blower casing merges into the discharge duct, and the discharge duct is joined to the boiler casing. Diffuser vanes are installed just downstream from the fan wheel to straighten the airstream as it leaves the blower. Additional divisions in the curving sections of the discharge duct also help to control the flow of air.

TYPES OF FORCED DRAFT BLOWERS

Two main types of forced draft blowers are used in naval ships: centrifugal blowers and propeller blowers. The main difference between the two types is in the direction of airflow. The centrifugal blower takes air in axially at the center of the fan and discharges it tangentially off the outer edge of the blades. The propeller blower moves air axially—that is, it propels the air straight ahead in a direction parallel to the axis of the shaft. Most forced draft blowers now in use are of the propeller type; however, some older ships and some auxiliaries have centrifugal blowers.

Centrifugal Blowers

Centrifugal blowers can be either horizontal or vertical. A centrifugal unit consists of the driving turbine (or other driving unit) at one end of the shaft and the centrifugal fan wheel at the other end of the shaft. Inlet trunks and diffusers are fitted around the blower fan wheel to direct the air into the fan wheel and to receive and discharge air from the fan. Centrifugal blowers are fitted with automatic shutters (flaps) in the discharge ducts. In the event of a casualty to one centrifugal blower, air from another blower blows back toward the damaged blower and closes the flaps.

Propeller Blowers

Propeller blowers are large propeller-type fans normally powered by a steam turbine. All the blowers shown in this section are propeller type.

FORCED DRAFT BLOWER TURBINE.—The following is a general description of one type of horizontal propeller blower. The forced draft blower turbine (fig. 5-22) is a Curtis-type turbine having two rows of blading mounted on one wheel. The turbine assembly consists of the casing, turbine elements, steam seals, combined exhaust and relief valve, blower governor, and steam inlet valve.

Casing.—The casing supports and encloses the rotating parts and directs the flow of steam and air. There are three main divisions of the casing: (1) the thrust bearing bracket and cover, with lubricating oil drive assembly and governor assembly; (2) the turbine case, which includes the exhaust case, the turbine case cover, and the exhaust case cover with inlet valves and nozzle valves attached; and (3) the discharge elbow, which forms the center barrel of the unit and carries the two main shaft bearings. The turbine casing assembly

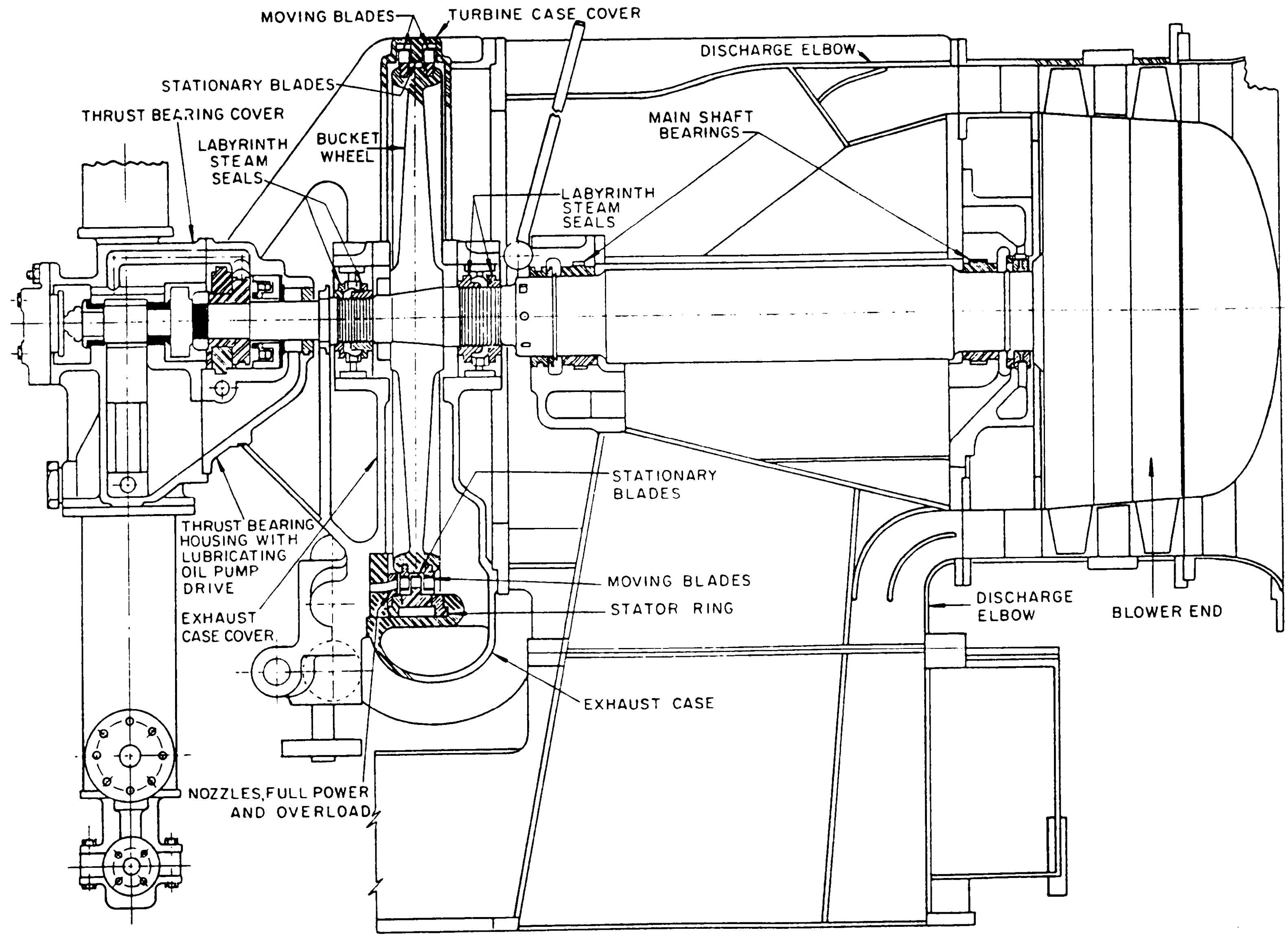

Figure 5-22.—Forced draft blower turbine.

bolts to one end of the elbow, and the blower casing bolts to the other end.

Turbine Elements.—The working elements of the turbine consist of a bucket wheel with two rows of moving blades mounted on its outer rim and the stator ring, which carries the stationary blading and nozzle block and contains two sets of nozzles.

Steam Seals.—The steam seals used on the turbine are of the labyrinth type. Each brass labyrinth seal is made in four spring-loaded sections. The annular space between the two sealing elements in each packing gland is connected to the leak-off connection.

Combined Exhaust and Relief Valve.—This valve (fig. 5-23), is a combined spring-loaded exhaust and relief valve installed in the exhaust line from the forced draft blower. The valve body, seat, and yoke are made of cast carbon steel. The screw spindle, main disk, and spring are made of corrosion-resistant steel. The stem packing is made of asbestos rod braid with wire inserted. The combined exhaust and relief valve is designed to function with inlet pressure up to 50 psig, outlet pressure up to 35 psig, and steam temperature up to 700°F.

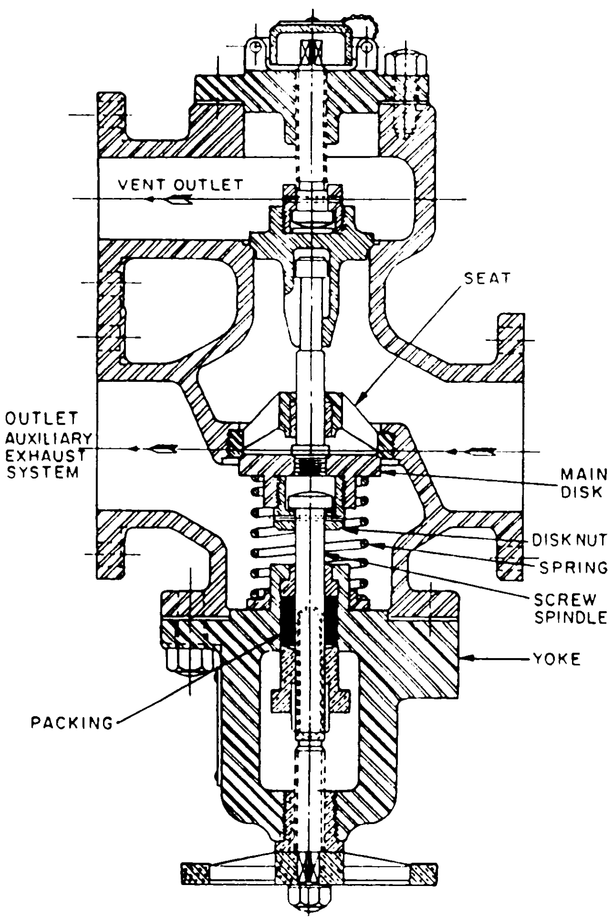

Figure 5-23.—Combined exhaust and relief valve.

Blower Governor.—The governor controls blower speed by throttling the turbine inlet steam valve. The governor is essentially a centrifugal flyweight type. The spring tension controlling the flyweight is varied by hydraulic force, which is controlled by a pneumatic signal pressure. The hydraulic force can be controlled by a manual knob, located on the front of the Woodward governor, when the pneumatic signal pressure is not used.

Steam Inlet Valve.—The steam inlet valve (fig. 5-24) is a 2-inch, single-seated valve with a lever mechanism that is operated by the blower governor. Its function is to admit steam to the turbine and to control the speed of the turbine.

VERTICAL-TYPE PROPELLER BLOWER.—High-powered, two-stage or three-stage vertical-type propeller blowers are installed in most combatant ships. One model of a two-stage vertical propeller blower is shown in figure 5-25. This model

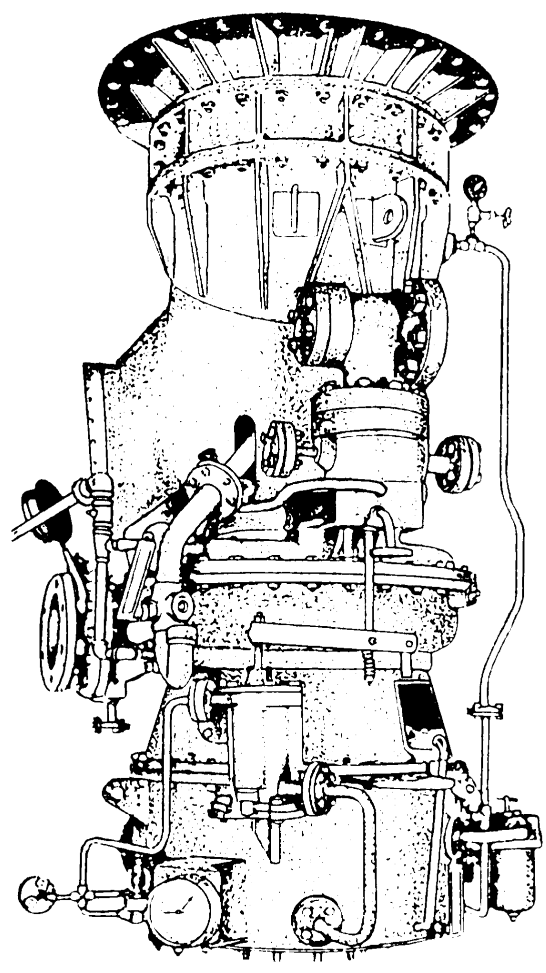

Figure 5-25.—View of a two-stage vertical propeller-type blower from the steam chest side.

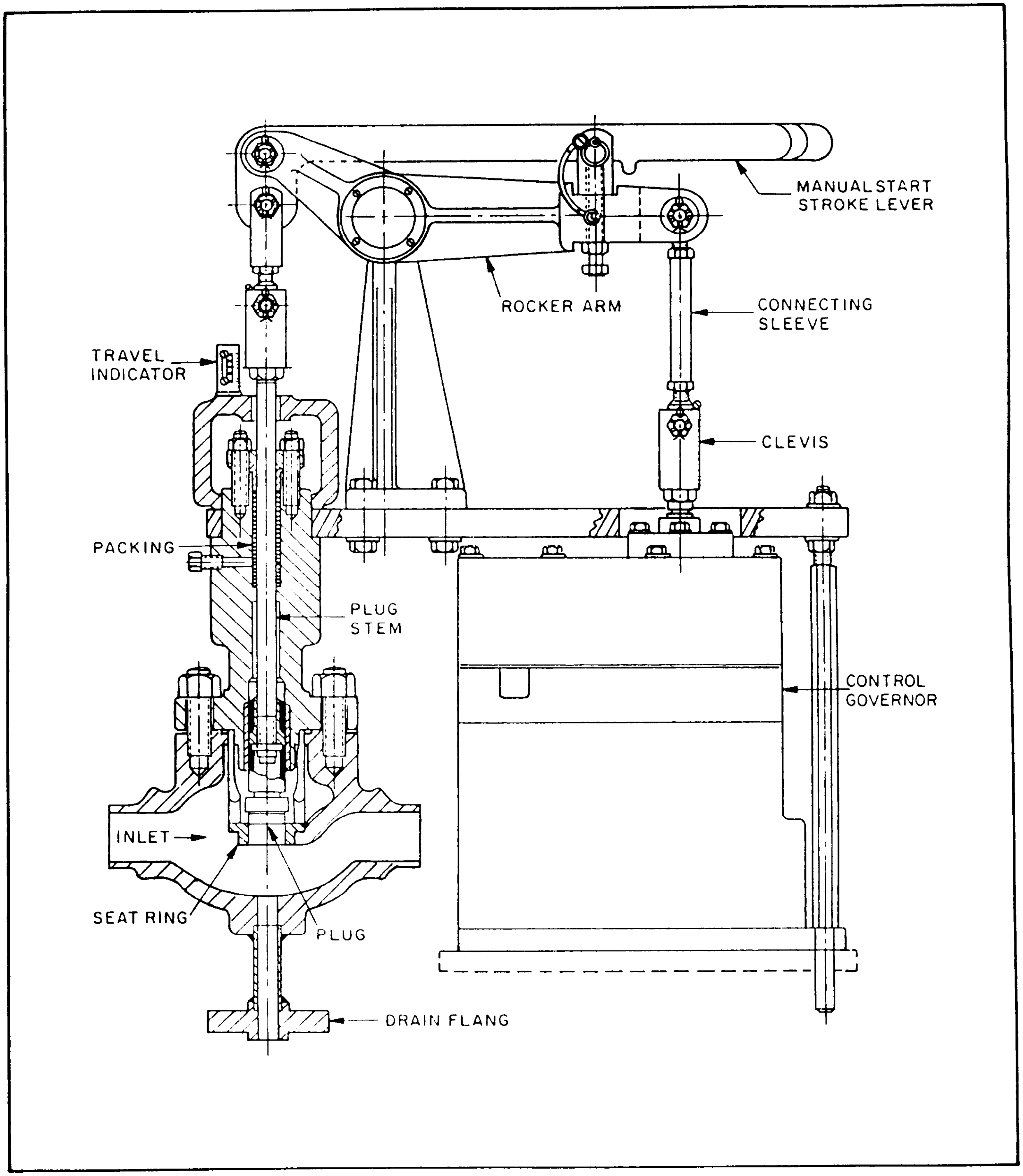

Figure 5-24.—Steam inlet valve.

of forced draft blower is a self-contained unit consisting of a two-stage, axial-flow, vertical-type propeller blower mounted on a common shaft with a two-stage turbine rotor.

The first-stage and second-stage propellers take air from on deck and deliver it into airtight casings surrounding the boilers. Each propeller consists of a forged propeller disk and forged propeller blades. The blades have bulb-shaped roots, which are entered in matching grooves, broached across the hub at a suitable angle.

The blades are secured in place by a shear-type locking pin and a spring. As the blade is set into place, the pin is depressed, automatically rising into its locking position by the spring as the slot in the blade root passes over the pin. The blades are tightened in place by unsetting the metal in the disk at one point immediately beneath the blades on both inlet and outlet sides of the hub.

This vertical propeller-type blower is driven by a turbine. The rotor, mounted with a shrink fit, is secured to the rotor shaft by a key; the lower face of the rotor is held against a shoulder on the shaft by a nut, which is threaded on the shaft and pressed against the upper face. The nut is secured in place by a setscrew. The turbine blading consists of two rows of moving blades secured to the rotor disk by a "Christmas-tree" type of root fastening (pine-tree dovetail). The rotor disk is made from a steel forging. Each of the rows contains evenly spaced grooves parallel to the axis of the disk.

Another model of a two-stage vertical propeller blower is shown in figure 5-26. The blower element consists of two propeller-type fan wheels. Each fan wheel is followed by a set of stationary stator blades or guide vanes, which serve to straighten the airflow for the following fan wheel. Stator blades for this stage have shanks, which are pressed into the casing section and secured by square plates to the shank ends. These plates are a safety retainer for the blades since one flat side of each plate bears against a register. The blades are locked at the correct angle. The second-stage stator assembly has heavy blading welded to both the outer and inner annular members. The inner member forms the support for the uppermost or blower bearing.

The fan wheels are steel-forged, tin-plated, with radial slots into which the roots of the stainless-steel blades are inserted. The blades are retained by dowels. The second-stage fan wheels have an integral spacer shrunk onto the wheel rim, thus forming a faring between the wheels. Both fan wheels are mounted on the shaft in one continuous taper. The lower- or second-stage fan wheel bears against a shoulder on the shaft, and the first-stage bears against the second and is retained by a nut and lock plate.

The diameter of the tapered bores and the length of the central bosses of all fan wheels are accurately controlled during manufacture to ensure the correct amount of prestressing.

This vertical propeller-type blower is driven by a reaction turbine. The working elements of the turbine are the bucket wheel, six nozzles, and reversing bucket assemblies.

Three journal bearings support the rotating element, the lower bearing being combined with a double-acting thrust bearing. Of the two remaining bearings, one is mounted on top of the turbine casing, and the other is mounted just below the fan wheel. Both of these bearings have split shells with locating dowels, and all bearing shells are interchangeable. The thrust bearing consists of a central housing containing a babbitted journal bearing. The two sets of equalizing babbitted bearing shoes are arranged one at the top and one at the bottom. A differential pressure transmitter is attached which is used to provide an oil pressure signal indicating the speed to the blower. The signal transmitted is produced by the pressure drop across an orifice. The pressure signal from this unit will depend on the blower overspeed setting and, to some extent, on the viscosity of the oil. For information on the control system for a blower with a specific combustion control system, consult the technical manual on the applicable feedwater and combustion control system.

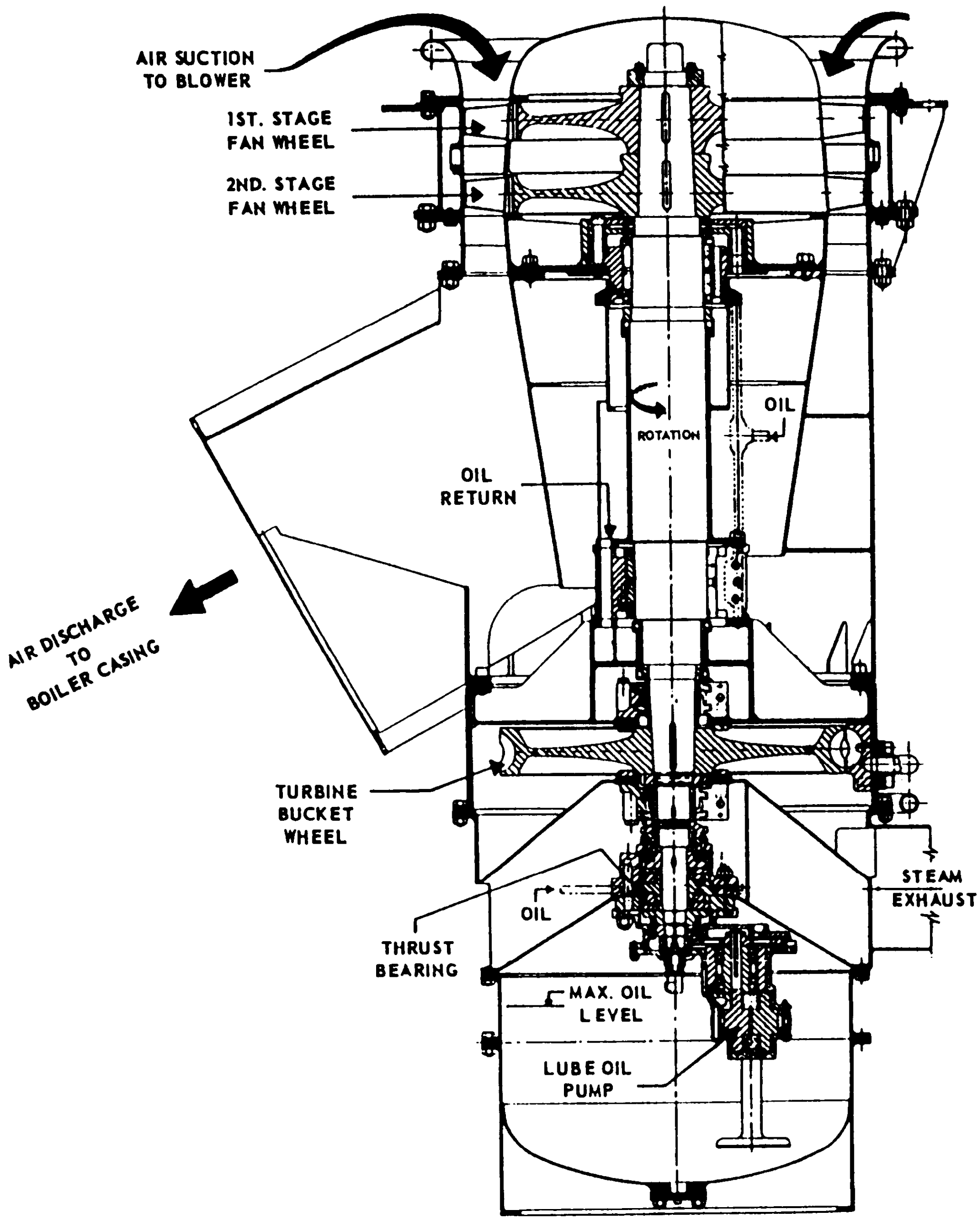

Figure 5-26.—Sectional view of a two-stage vertical propeller-type blower.

A three-stage vertical propeller blower is shown in figure 5-27. As you may see, there are three propellers at the fan end. Each propeller consists of a solid forged disk to which are attached a number of forged blades. The blades have bulb-shaped roots, which are entered in grooves machined across the hub; the blades are kept firmly in place by locking devices. Each propeller disk is keyed to the shaft and secured by locking devices.

This vertical propeller-type blower is driven by a velocity-compounded impulse turbine (Curtis stage) with two rows of moving blades. The turbine wheel is keyed to the shaft. The lower face of the turbine wheel bears against a shoulder on the shaft; a nut screwed onto the shaft presses against the upper face of the turbine wheel.

The entire rotating assembly is supported by two main bearings. One bearing is just below the propellers, and one is just above the thrust bearing in the oil reservoir.

The blower casing is built up of welded plates. From the upper flange down to a little below the lowest propeller, the casing is cylindrical in shape. The shape of the casing changes from cylindrical to cone and then to square. The discharge opening of the blower casing is rectangular in shape. Guide vanes in the casing not only control the flow of air but also serve to stiffen the casing. The part of the casing near the propellers is made in sections and is split vertically to allow inspection of the three propellers. The lower part of the casing, below the air duct, houses the turbines. The lower part of the turbine casing is welded to the oil reservoir structure.

Although all vertical propeller blowers operate on the same principle and may look very much the same from the outside, they are not identical in all details. The major differences to be found among vertical forced draft blowers are in connection with the lubrication systems. Some of these differences are discussed in the following section.

BLOWER LUBRICATION SYSTEMS

Since forced draft blowers must operate at very high speeds, correct lubrication of the bearings is absolutely essential. A complete pressure lubrication system for supplying oil to the bearings is an integral part of every forced draft blower. Most forced draft blowers have at least two radial bearings and one thrust bearing. Some blowers have two turbine bearings, two fan bearings, and a thrust bearing.

Horizontal-Type Blowers

The lubrication system for a horizontal forced draft blower includes a pump, an oil filter, an oil cooler, a filling connection, relief valves, oil level indicators, thermometers, pressure gauges, oil sight-flow indicators, and all necessary piping. The pump, which is usually turned by the forced draft blower shaft, is geared down approximately one-fourth the speed of the turbine. The lube oil is pumped to the bearings from the oil reservoir through the oil filter and the oil cooler. Oil then drains back to the reservoir by gravity.

The gear pump uses an internal gear as the driver, an idler gear as the driver member, and a crescent for the sealing between the two members. For all practical purposes, the delivery of this pump is directly proportional to the speed. The idler gear is supported by a pin which, in turn, is supported by a rotating part called the IDLER CARRIER. The crescent is integral with the idler carrier. As the shaft changes its rotation, the idler carrier rotates in the pump cover 180° about the shaft at centerline. The rotation of the idler carrier is governed by stops, cast in the pump cover, which limit the arc of travel. In reversing, the crescent always travels through the suction zone of the pump if the boss, or the direction arrow cast in the pump cover, is pointing in the direction of the suction side of the pump. If this is not the case, the idler carrier will not shift when the shaft reverses; when the idler carrier does not shift, the pump takes a suction on the bearings, causing the unit to fail.

Vertical-Type Blowers

Although some vertical blowers are fitted with a gear pump and lubrication system similar to the system used on horizontal blowers, most vertical blowers have different lubrication systems.

HOLLOW SHAFT ARRANGEMENT.—One type of lubrication system used on some vertical forced

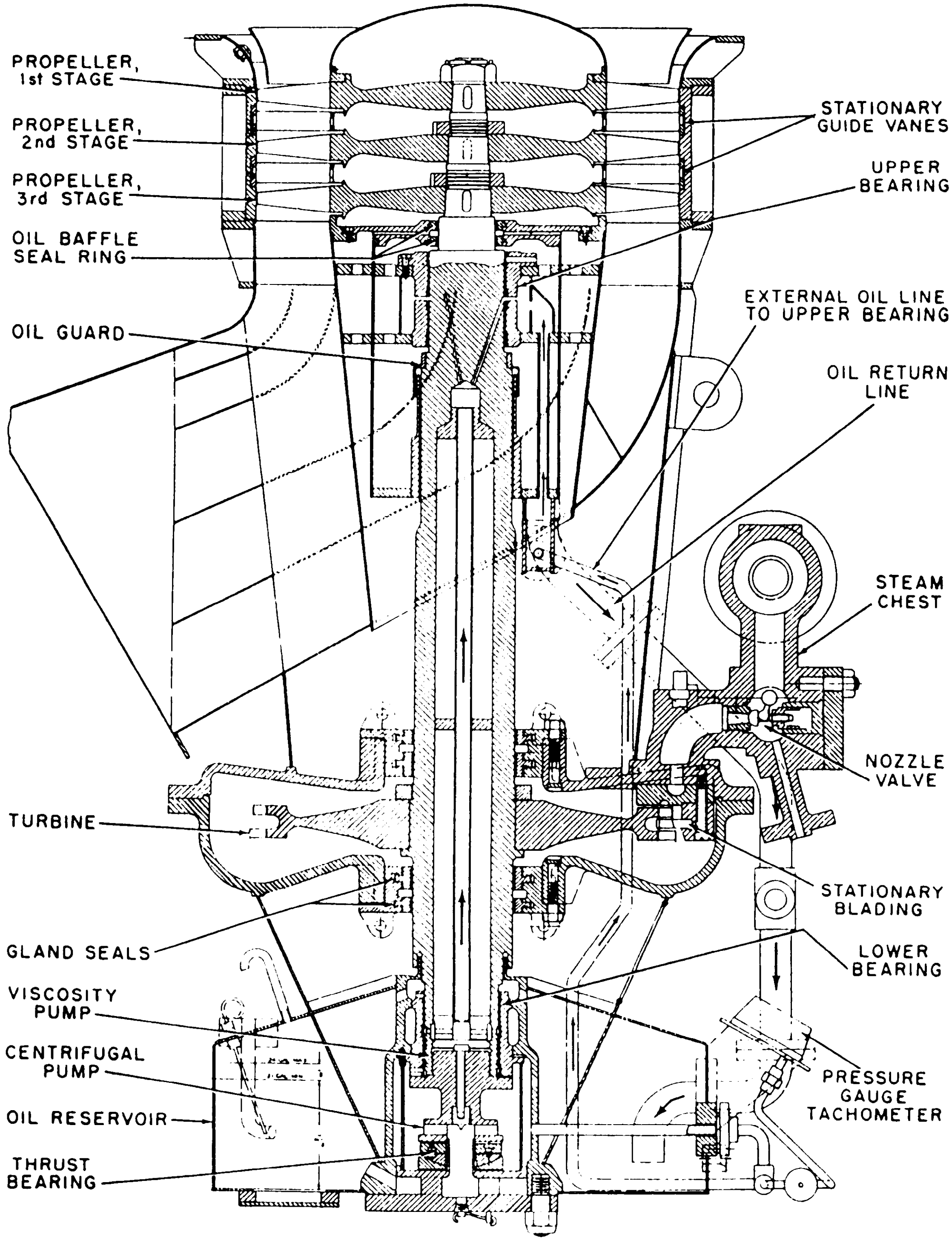

Figure 5-27.—Sectional view of a three-stage vertical propeller-type blower.

draft blowers is shown in figure 5-28. In this system, the gear pump is replaced by a centrifugal pump and a helical-groove viscosity pump. The centrifugal pump impeller is located on the lower end of the main shaft, just below the lower main bearing. The viscosity pump (also called friction pump or screw pump) is located on the shaft, just above the centrifugal pump impeller, inside the lower part of the main bearing. As the main shaft turns, lubricating oil flows to the lower bearing and from there, by way of the hollow shaft, to the upper bearing. In addition, part of the oil is pumped directly to the upper bearing through an external supply line. The oil is returned from the upper bearing to the oil reservoir through an external return line.

In this system, the oil from the reservoir is constantly being circulated through an external filter and an external cooler and then back to the reservoir.

The viscosity pump is needed because the pumping action of the centrifugal pump impeller is dependent on the rpm of the shaft. At low speeds, the centrifugal pump cannot develop enough oil pressure to adequately lubricate the bearings. At high speeds, the centrifugal

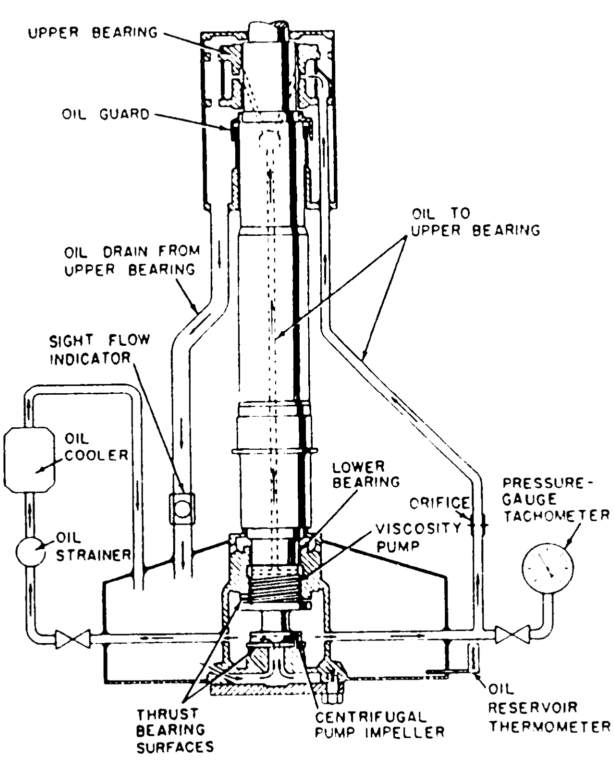

Figure 5-28.—Lubrication system for a vertical forced draft blower (oil supplied through hollow shaft and through external supply line).

pump would develop more oil pressure than is needed for lubrication, and the excessive pressure would tend to cause flooding of the bearings and loss of oil from the lubrication system. The viscosity pump, which is a shallow helical thread (groove) on the lower part of the shaft, assures sufficient lubrication at low speeds and prevents the development of excessive oil pressures at high speeds.

EXTERNAL OIL SUPPLY.—The hollow-shaft lubrication system just described is still found on some vertical forced draft blowers made before 1952. Newer vertical blowers do not use a hollow shaft to supply oil to the upper bearings. The oil is pumped to the bearings through an external supply line and passes through an oil filter and an oil cooler on the way to the bearings. Most new vertical blowers have, in addition to a gear pump, an oscillating-vane type of hand pump, which is used to initiate lubrication when the blower is being started. Other vertical blowers have a centrifugal pump and a viscosity pump, which have a completely external oil supply to the bearings.

ANTIROTATION DEVICE.—Some vertical blowers have an antirotation device on the shaft of the lubricating pump. This device prevents windmilling of the blower in a reverse direction in the event of leakage through the automatic shutters. This antirotation device is continuously lubricated through a series of passageways, which trap some of the leakage from the thrust bearing.

NONREVERSING CLUTCH.—Some vertical blowers' lube oil systems have a nonreversing clutch mounted in the oil reservoir. The clutch assembly is a driving gear, which is secured to the rotor shaft and drives the gear with the clutch assembly mounted in the hub. The inner race of the clutch assembly is securely keyed to the shaft. The shaft is supported in and keyed to the fabricated structure of the reservoir and to a cover plate.

The nonreversing clutch is constructed of a full complement of sprags inserted in the annular space between the inner and outer concentric race. Contact with both surfaces is maintained by energizing springs. Torque is delivered from one concentric race member to the other through the full complement of sprags. With any reversing motion of the blower shaft, the sprags are instantaneously engaged between the inner and outer races. When the torque is removed, all the sprags are released instantaneously.

During normal operation, the speed is such that the centrifugal force overcomes the force of the energizing springs, and the sprags are held away from the stationary shaft. This action reduces wear to a minimum.

Oil is supplied to the clutch from the main oil pump through an internal passage from the reservoir to the shaft, the upper end of which forms an oil spray. Clutch lubrication is constant while the blower is in operation.

CONTROL OF BLOWER SPEED

Forced draft blowers are manually controlled in all naval ships except those that have automatic combustion control systems for their boilers. Speed-limiting governors are fitted to all forced draft blowers to prevent the turbine from exceeding the maximum safe operating speed.

One type of blower speed control device used in ships that have automatic combustion control systems regulates the blower speed by determining the position of the steam admission valve in the steam chest. The initial speed settings and subsequent speed adjustments are made by remote manual signal air pressure from the console or, automatically, by demands of the ship's combustion and feedwater control systems. Once a setting is made, the governor maintains this setting within close limits.

Blower speed is manually controlled by a valve arrangement that controls the amount of steam admitted to the turbines. In some blowers, a full head of steam is admitted to the steam chest; steam is then admitted to the turbine nozzles through nozzle valves that are controlled by a manually operated lever or handwheel. The lever or handwheel may be connected by linkage for remote operation. The nozzle valves are so arranged that they open in sequence, rather than all at the same time. The position of the manually operated lever or handwheel determines the number of valves that will open, and thus controls the amount of steam that will be admitted to the driving turbine. The steam chest nozzle valve shafts of all blowers serving one boiler are mechanically coupled to provide synchronized operation of the blowers. If only one blower is to be operated, the cutout valve in the steam line to the idle blower must remain closed so that steam will not be admitted to the line.

In other installations, a single throttle valve controls the admission of steam to the steam chest. From the steam chest, the steam enters the turbine casing through all of the nozzles. Thus the nozzle area is fixed and cannot be changed. Varying the opening of the throttle valve varies the steam pressure to the steam chest and thus varies the speed of the turbine. For emergency control of blowers (and for normal control of blowers in a few older ships) the same throttle valve controls the admission of steam to all blowers serving any one boiler. This throttle valve is installed in the blower steam line. If only one blower is to be operated, the cutout valve in the branch line to the idle blower must be kept closed.

When the admission of steam is controlled by a multiple-nozzle valve arrangement, no additional nozzle area is required to bring the blower up to maximum speed. In the single valve arrangement, a special hand-operated nozzle valve is provided for high-speed operation. This nozzle valve, which is sometimes called an overload nozzle valve, is used whenever it is necessary to increase the blower speed beyond that obtainable with the fixed nozzles. The use of the overload nozzle valve is required only when steam pressure is below normal or when the boiler must be fired above its full-power rating.

Most ships have been equipped or refitted with pneumatic diaphragm-actuated steam throttle valves, which provide excellent control of blowers operating in parallel. The most recent forced draft blowers combine the functions of speed-limiting and throttling in a single governor.

CHECKING BLOWER SPEED

Use constant-reading, pressure-gauge, electric, portable, stroboscopic, and vibrating-reed tachometers to check blower speed.

Constant-Reading Tachometer

Many forced draft blowers are fitted with constant-reading, permanently mounted tachometers for checking blower speed. Sometimes the tachometer is mounted on top of the governor and is driven by the governor spindle. The governor spindle is driven by the main shaft through a reduction gear and, therefore, does not rotate at the same speed as the main shaft. However, the rpm of the governor spindle is proportional to the rpm of the main shaft. The tachometer is calibrated to give readings that indicate the speed of the main shaft rather than the speed of the governor spindle.

Pressure-Gauge Tachometer

Some blowers are equipped with a special kind of tachometer called a pressure-gauge tachometer. This instrument, which may be seen in figure 5-28, is actually a pressure gauge that is calibrated in both psi and rpm. The pressure-gauge tachometer depends for its operation on the fact that the oil pressure built up by the centrifugal lube oil pump has a definite relation to the speed of the pump impeller; the speed of the impeller, of course, is determined by the speed of the main shaft. Thus, the pressure-gauge tachometer can be calibrated in both psi and rpm.

Electric Tachometer

Some forced draft blowers of recent design are equipped with electric tachometers that have indicating gauges at the blower and at the boiler operating station. The electric tachometer (generator) consists of a wound stator and a permanent magnet rotor mounted on the blower shaft. The electric tachometer generates its own power and does not require an external power source.

Portable Tachometers

Occasionally, you may have to use portable tachometers to check the speed of forced draft blowers. On some blowers, the tachometer can be applied directly to the end of the main shaft. On others, a portable tachometer must be applied to a separate shaft from which readings may be taken. The small shaft is driven by the main shaft, through gearing. It may rotate at the same speed as the main shaft or its speed may be reduced by the gear arrangement. If the small shaft rotates at a speed different from the speed of the main shaft, the tachometer reading must be converted to obtain the speed of the main shaft.

Stroboscopic Tachometer

A stroboscopic tachometer is sometimes used to measure the rpm of a forced draft blower. This instrument may be adjusted so that a mark on the main shaft of the blower appears to be motionless. At this point, the rpm of the shaft may be read directly from the dial.

Vibrating-Reed Tachometer

Vibrating-reed tachometers are another type of tachometer used as onboard tools for many blowers on which the other types of portable tachometers cannot be used.

SAFETY PRECAUTIONS

Some of the most important safety precautions to be observed in connection with forced draft blowers are as follows:

1. BEFORE starting a blower, always be sure that the fan is free of dirt, tools, rags, and other foreign objects or materials. Check the blower room for loose objects that might be drawn into the fan when the blower is started.
2. Do NOT try to move the automatic shutters by hand if no other blower serving the same boiler is already in operation.
3. When only one blower on a boiler is to be operated, be sure that the automatic shutters on the idle blower are CLOSED and LOCKED.
4. NEVER try to turn a blower by hand when steam is being admitted to the unit.
5. Keep the speed-limiting governor in good operating condition and ensure it is properly set at all times.
6. Observe all safety precautions required in connection with the operation of a driving turbine.

PUMP CARE AND OPERATION

Pump operation and safety precautions should be according to the Engineering Operational Procedures (EOP) subsystem of the Engineering Operational Sequencing System (EOSS) if your ship has EOSS, or *Naval Ships' Technical Manual* and/or the instructions posted on or near each individual pump. The manufacturer's technical manual or MRCs (for PMS related maintenance) should be followed for all maintenance work

Now that you have read this chapter, you understand the relationship of a pump to the system it serves. You can readily see the importance of pumps and, therefore, you can see the necessity to keep them operating at top efficiency through proper maintenance.

CHAPTER 6

HEAT EXCHANGERS AND AIR EJECTORS

A heat exchanger is any device or apparatus that allows the transfer of heat from one substance to another. Boilers, distilling plants, and deaerating feed tanks (DFTs) are examples of heat exchangers.

For heat to transfer from one substance to another, there must be a difference in the temperature of the two substances. Heat flow or heat transfer can occur only from a substance at a higher temperature to a substance at a lower temperature. Assume two objects at different temperatures are placed in contact with (or near) each other. Heat will flow from the warmer object to the cooler one until both objects are at the same temperature. Heat transfer occurs at a faster rate when there is a larger temperature difference. As the temperature difference approaches zero, the rate of heat flow also approaches zero.

Heat exchangers may raise or lower the temperature of a substance depending on the purpose of the heat exhanger.

CLASSIFICATION OF HEAT EXCHANGERS

Heat exchangers may be classified in many ways. Those in common use by the Navy are described in the following sections in terms of the basic method of classification.

PATH OF HEAT FLOW

When classified according to the path of heat flow, heat exchangers are of two basic types. In the INDIRECT or SURFACE type of heat exchanger, the heat flows from one fluid to the other through some kind of tube, plate, or other surface that separates the two fluids. In the DIRECT-CONTACT type of heat exchanger, the heat is transferred directly from one fluid to another as the two fluids mix. The DFT is a direct-contact heat exchanger. Practically all other heat exchangers used aboard ship are of the indirect or surface type.

DIRECTION OF FLUID FLOW

In surface heat exchangers, the fluids may flow parallel to each other, counter to each other, or at right angles to each other (crossflow).

Parallel Flow

In parallel flow (fig. 6-l), both fluids flow in the same direction. Initially, there is a large temperature difference between the two fluids. This results in a high rate of heat transfer at the inlet end of the cooler. As the flow continues, the fluid temperatures approach a common value. As the temperatures of the fluids become closer, the heat transfer is slower and the cooler is less effective at this point.

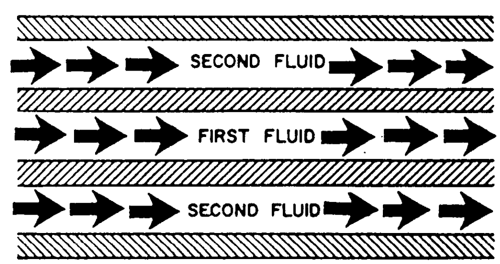

Figure 6-1.—Parallel flow in a heat exchanger.

Counterflow

In counterflow (fig. 6-2), the two fluids flow in opposite directions. Less area is required than in the parallel flow to remove the same amount of heat. The highest temperatures of both fluids occur at the same end of the cooler. Therefore, the temperature difference and the heat transfer is at a maximum throughout the cooler.

Crossflow

In crossflow (fig. 6-3), one fluid flows at right angles to the other. Crossflow is particularly useful for removing latent heat. Crossflow is used for most condensers, including the main and auxiliary condensers.

Counterflow and crossflow heat exchangers are more commonly used aboard ship than the parallel flow. In many heat exchangers, the types of flow are combined in various ways so that it is not always easy to determine whether the flow is basically parallel, counter, or cross.

NUMBER OF PASSES

Surface heat exchangers may be classified as SINGLE-PASS units if one fluid passes another only once. They are MULTIPASS units if one fluid passes another more than once. Multipass flow may be obtained in one of two ways. One is through the arrangement of the tubes and the fluid inlets and outlets. The other is by the use of baffles to guide a fluid so it passes the other fluid more than once before it leaves the heat exchanger.

TYPE OF SURFACE

Surface heat exchangers are known as PLAIN SURFACE units if the surface is relatively smooth. They are known as EXTENDED SURFACE units if the surface is fitted with rings, fins, studs, or some other kind of extension. The main advantage of the extended surface is that the extensions increase the heat transfer area without requiring any substantial increase in the overall size and weight of the unit. The choice depends on the situation.

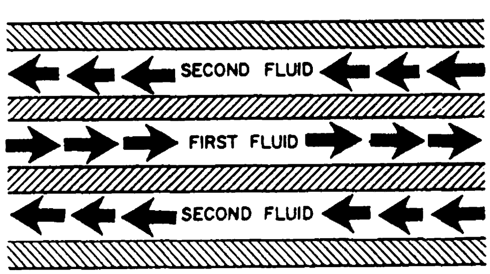

Figure 6-2.—Counterflow in a heat exchanger.

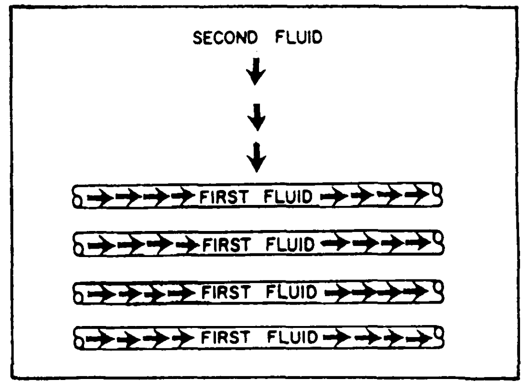

Figure 6-3.—Crossflow in a heat exchanger.

TYPE OF CONSTRUCTION

Surface heat exchangers are often given names that indicate general features of design and construction. Basically, all surface heat exchangers are of SHELL-AND-TUBE construction. These include (1) straight-tube, (2) U-bend tube, (3) helical- or spiral-tube, (4) double-tube, (5) strut-tube, and (6) plate-tube heat exchangers.

Straight Tube

In straight-tube heat exchangers, the tubes are usually arranged in a bundle and enclosed in a cylindrical shell. The ends of the tubes may be expanded into a tube sheet at each end of the bundle. They may also be expanded into one tube sheet and packed and ferruled into the other.

The ferrules allow the tube to expand and contract slightly with temperature changes.

U-Bend Tube

U-bend tube heat exchangers, sometimes called RETURN BEND heat exchangers, consist of a bundle of U-shaped tubes inside a shell. Since the tube are U-shaped, there is only one tube sheet. The shape of the tubes provides enough allowance for expansion and contraction.

Helical or Spiral Tube

Helical- or spiral-tube heat exchangers have one or more coils of tubing installed inside a shell. The tubes may connect with headers at each end of the shell. In relatively simple units such as boiler-water sample coolers, the ends of the tubing may pass through the shell. They serve as the inlet and the outlet for the fluid that flows through the coil of tubing.

Double Tube

Double-tube heat exchangers have one tube inside another. One fluid flows through the inner tube, and the other fluid flows between the outer and the inner tubes. The outer tube may thus be regarded as the shell for each inner tube. The shells, or outer tubes, are usually arranged in banks. They are connected at one end by a common tube sheet with a partitioned cover that serves to direct the flow. Many double-tube heat exchangers are of U-bend construction to allow for expansion and contraction.

Strut Tube and Plate Tube

Strut-tube and plate-tube heat exchangers are noticeably different in design from the other shell-and-tube heat exchangers. The tubes in both strut-tube and plate-tube heat exchangers consist of pairs of flat, oblong strips. One fluid flows inside the tubes, and the other fluid flows around the outside. Strut-tube and plate-tube heat exchangers are used primarily as water coolers and lubricating oil coolers in internal-combustion engines. They are also used as lube oil coolers for some small auxiliary turbines.

STEAM CONDENSERS

A condenser is a type of heat exchanger used to remove latent heat from a vapor, thereby changing the vapor to a liquid. There are main condensers and auxiliary condensers. Since the main condenser is one of the most important units in the steam plant, we will discuss it in some detail.

MAIN CONDENSERS

The main condenser is the heat receiver of the thermodynamic cycle. In other words, it is the heat "sink" or lowest temperature receiver, of the main propulsion plant. In simple terms, exhaust steam from the low-pressure turbines enters the main condenser where the steam's latent heat is removed by the circulating (cooling) water.

The main condenser is also used to recover and return feedwater to the feed system. Imagine a shipboard propulsion plant in which there is no main condenser and the turbines exhaust to atmoshpere. Next, consider the vast quantities of feedwater that would be required to support even one boiler generating 150,000 pounds of steam per hour. It is immediately apparent that the main condenser serves a vital function in recovering feedwater.

One type of main condenser system is illustrated in figure 6-4. Two separate circuits are involved in the

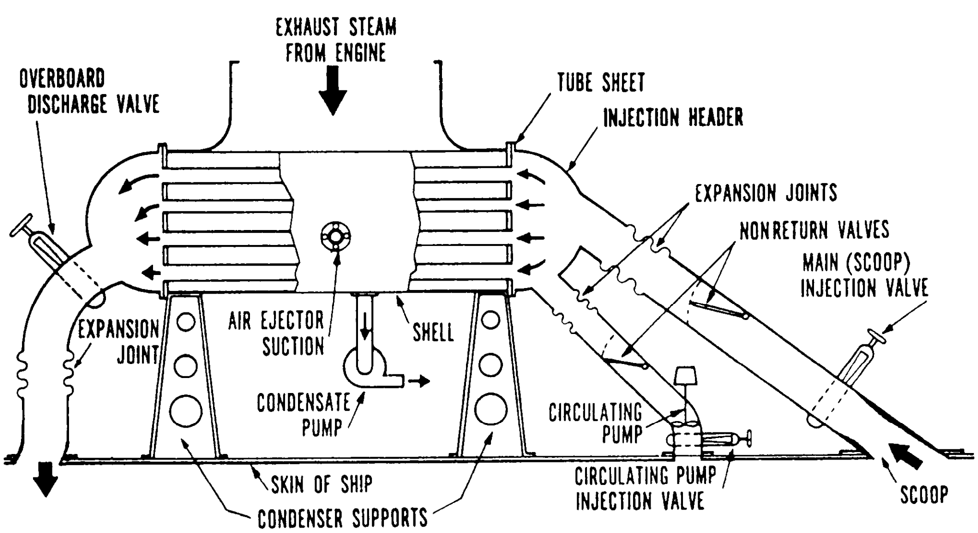

Figure 6-4.—Schematic arrangement of a main condensing system.

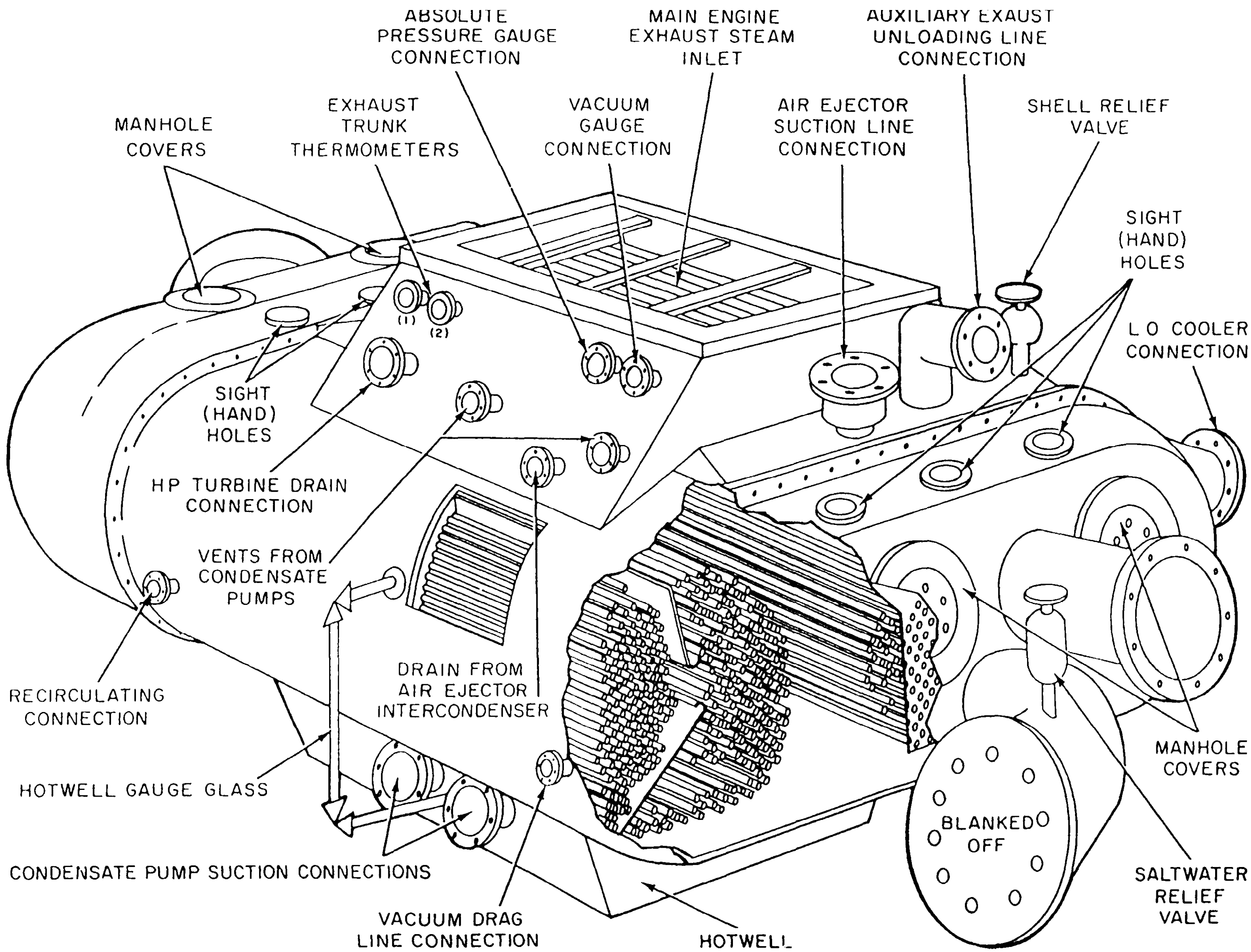

Figure 6-5.—Cutaway view of a main condenser.

condensation of steam in a condenser of this type. They are vapor-condensate and cooling-water circuits.

Vapor-Condensate Circuit

The first circuit is the vapor-condensate circuit. Exhaust steam from the propulsion turbines is condensed as it comes in contact with tubes through which seawater is flowing. The condensate then falls to the bottom of the condenser, drains into a space called HOTWELL (seen in fig. 6-5), and is removed by the condensate pump. Air and other noncondensatable gases, which enter with the exhaust steam, are drawn off by the air ejector (discussed later in this chapter).

Cooling-Water Circuit

The second circuit in the condenser is the cooling-water circuit. During normal operation, seawater flow through the condenser is provided automatically by the INJECTION SCOOP. The scoop is located below the waterline. The forward motion of the ship (at a sufficient speed) causes seawater to flow through the condenser. A major advantage of scoop injection is that it provides a flow of cooling water at a rate that is controlled by the speed of the ship and, therefore, is automatically correct for various conditions. Scoop injection is standard for naval combatant ships, except submarines, and for many of the auxiliary ships. STRAINER BARS are installed in the sea chest to strain out debris which could foul the piping and the condenser tubes. The injection and overboard discharge lines are provided with expansion joints. These prevent undue strains which could result from a change in either the temperature or the working of the hull.

Circulating Pump

A main circulating pump provides a flow of water through the condenser at times when scoop injection is inadequate. Examples are when a ship is stopped, backing down, or moving ahead at a very slow speed. A large SWING-CHECK VALVE or NONRETURN VALVE in the main injection line prevents backflow of water. Another one is installed in the main circulating pump discharge line. Water flows into the condenser through the main injection line. The nonreturn valve in the main circulating pump discharge line prevents the backflow of water through the pump. When the circulating pump is in operation, the nonreturn valve in the main injection line prevents backflow of water through that line.

In all cases, the main circulating pump must have a large capacity. The pump is usually of the propeller type. It is provided with a bilge suction line so that it can be used to pump water overboard in case of serious flooding in the engine room.

Construction

Proper maintenance of a condenser requires certain installation and construction features that you should understand. Most installations suspend the condenser from the turbine rather than have the condenser support the turbine. This provision allows for greatly reduced weight and makes an expansion joint between the turbine and the condenser unnecessary.

All main condensers that have scoop injection are of the straight-tube, single-pass type. They are usually of the general construction shown in figure 6-5.

A main condenser may contain from 2,000 to 10,000 copper-nickel alloy tubes, usually of 5/8-inch diameter. The length of the tubes and the number of tubes depend on the size of the condenser. This, in turn, depends on the capacity requirements. The tube ends are usually expanded into the tube sheet at the inlet end and are flared after expansion. The outlet tube ends are either expanded or packed and ferruled into the tube sheet. Condensers having tubes ferruled into each tube sheet are found in some older ships.

The tube sheet serves as a divider between the saltwater side and the freshwater side of the condenser. Access to the tube sheets is through manholes found in each header.

Various methods of construction are used to allow for expansion and construction. It is sometimes enough to pack the tubes at the outlet end, which allows the tubes to slide within the tube sheet. The shell may have an expansion joint where the tubes are expanded into each tube sheet. In some condensers, the tubes are bowed upward in the middle. This allows for expansion and contraction and also provides a means of draining the tubes. Expansion joints are also provided in the scoop injection and overboard lines, as shown in figure 6-4. In other installations, additional means are provided to allow for expansion and contraction between the condenser and its supporting structure. Examples are a flexible support foot or sliding feet.

As the steam is condensed on the tubes, the condensate drips down and collects on the receiving tray. There is a section in the main condenser where no tubes are installed. It is called the central steam lane. This allows some of the turbine exhaust to get to the receiving tray and reheat the condensate. The condensate drains from the receiving tray into the hotwell where it is removed by the condensate pump.

Main condensers have internal baffle arrangements to separate air and steam. This is done so that the air ejector will not become overloaded by having to pump large quantities of steam. One arrangement that provides separate air-cooling sections is shown in figure 6-6. The air baffles are extended up the side of the condenser shell.

For further information on condenser construction, refer to the manufacturer's technical manual and the *Naval Ships' Technical Manual (NSTM),* chapter 254.

Operation

Under conditions of warming up, standing by, getting underway, cooling down, and securing the main engines, the condenser vacuum should be regulated according to the engineering operational procedures (EOP).

You should keep in mind two basic rules that apply to the operation of single-pass main condensers: (1) The overboard temperature should be approximately 10°F higher than the injection temperature. (This may vary depending on the ship.) (2) The condensate temperature leaving the hotwell should be within 2°F of the condensing temperature corresponding to the vacuum in the condenser. If this temperature is exceeded, you have excessive condensate depression. This means that you are removing unnecessary heat that must be put back somewhere in the system. Excessive

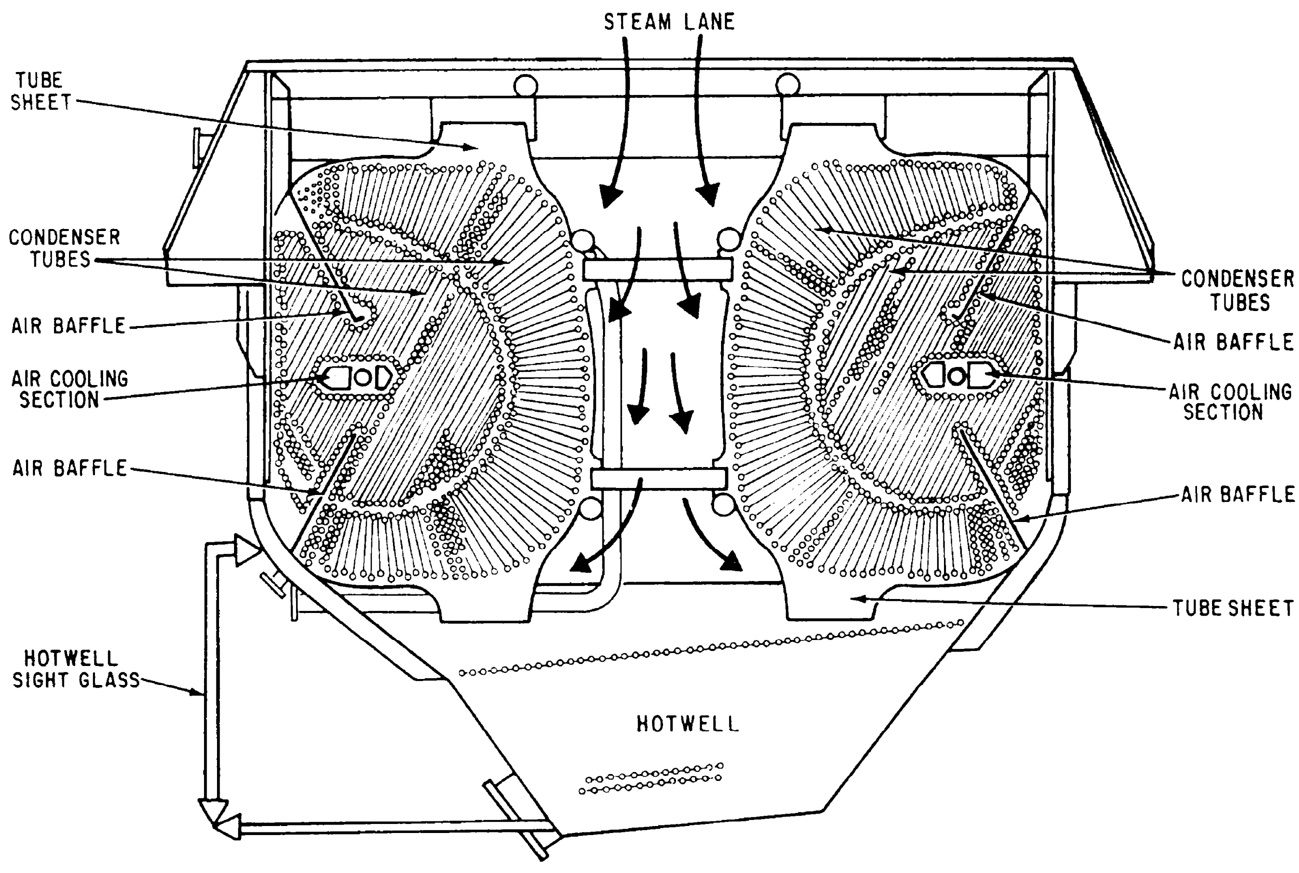

Figure 6-6.—Cross-sectional view of the internals of a main condenser.

condensate depression will normally occur only when the ship is operating in cold water.

NOTE: The accompanying chart lists vacuums (based on a 20.00-inch barometer) and corresponding (steam) condensing temperatures.

Condenser Vacuum (Inches of mercury)	Corresponding Saturation Temperature	
	(°F)	(°C)
29.6	53	11.7
29.4	64	17.8
29.2	72	22.2
29.0	79	26.1
28.8	85	29.3
28.6	90	32.2
28.4	94	34.4
28.2	98	36.6
28.0	101	38.3
27.8	104	40.0
27.6	107	41.7
26.5	120	48.9

If the condenser vacuum is not as high as it should be in relation to the condenser load and the cooling water overboard temperature, some part of the condensing system is not functioning properly. Air ejectors may not be properly removing air from the condenser. The condensate pump may not be keeping the correct condensate level. There may be an air leak in the condenser or in some other part of the system under vacuum.

The condensate should be kept at the correct level at all times. Condensate should not rise into the condenser shell. If you allow the level to rise slightly higher than the top of the hotwell, the condensate temperature will be lower than normal. This happens because the path for the flow of reheating steam is partially blocked by the condensate. Reheating steam is the steam that enters the hotwell by way of the central steam lane. If the condensate level is allowed to rise to the bottom row of tubes, the flow of reheating steam is further restricted. This means an even greater drop in condensate temperature. At this point, the high condensate level begins to interfere with the flow of air toward the air removal areas. This causes a gradual loss of vacuum. If the condensate level rises to the lower end of the air baffles, it will cause a rapid loss of vacuum. This loss will be accompanied by a rapid increase in condenser shell and exhaust trunk temperatures.

You must maintain an adequate flow of cooling water to the main condenser during operation. Insufficient cooling water will cause overheating, loss of vacuum, and a pressure buildup in the freshwater side of the main condenser.

Steam or air connections are provided to clear foreign matter from sea chests. Sometimes, however, thick accumulations of marine growth on or around sea valve openings cannot be blown clear. When maximum pressure fails to clear a sea chest, the obstruction must be removed by a diver.

Air vents must be kept open under all operating conditions where air is vented overboard through the hull or where the inlet water chest is vented to the discharge water chest or piping. This will minimize air erosion of the tubes and keep the condenser from becoming air bound. Vents that are piped to the bilges should be kept slightly open at all times when the condenser is in use. As long as a trickle of water escapes, the unit will not become air bound and the circulating water flow will not be obstructed.

AUXILIARY CONDENSERS

Condensers into which turbogenerators exhaust are known as auxiliary condensers. Although much smaller than main condensers, auxiliary condensers operate on the same principle. In an auxiliary condenser, however, the cooling water is pumped through the condenser at all times instead of being scoop injected. Also, most auxiliary condensers are of two-pass rather than single-pass construction.

Figure 6-7 shows a two-pass auxiliary condenser. The seawater chest is divided into an inlet chamber and a discharge chamber. In other construction features, including the metals used, auxiliary condensers similar to main condensers.

Auxiliary exhaust steam, in excess of that required for units such as the DFT and the distilling plants, may be directed either to the auxiliary condenser or to the main condenser. When the ship is in port, the auxiliary exhaust goes only to the auxiliary condenser. When the ship is getting underway, the exhaust goes to the auxiliary condenser until the vacuum in the main condenser is high enough to accept it.

Plant efficiency depends a great deal on the proper operation of the condenser. You should always use your EOP when you light off, operate, or secure a condenser.

MAINTENANCE OF STEAM CONDENSERS‘

Proper maintenance of condensers is necessary to ensure continuous ship operation and equipment longevity. PMS should be conducted according to the 3-M systems, as described in the following sections.

Air Leaks

The desired condenser vacuum cannot be maintained if the condenser leaks. Leaks at flange joints and through porous castings can usually be stopped temporarily with an application of shellac when the condenser is under vacuum. Leaks around valve stems can sometimes be eliminated by tightening the packing. Small leaks around porous castings, flange nuts, and valve stems can sometimes be located by the candle test. Hold a lighted candle close to areas where leaks are suspected and see whether the flame flickers.

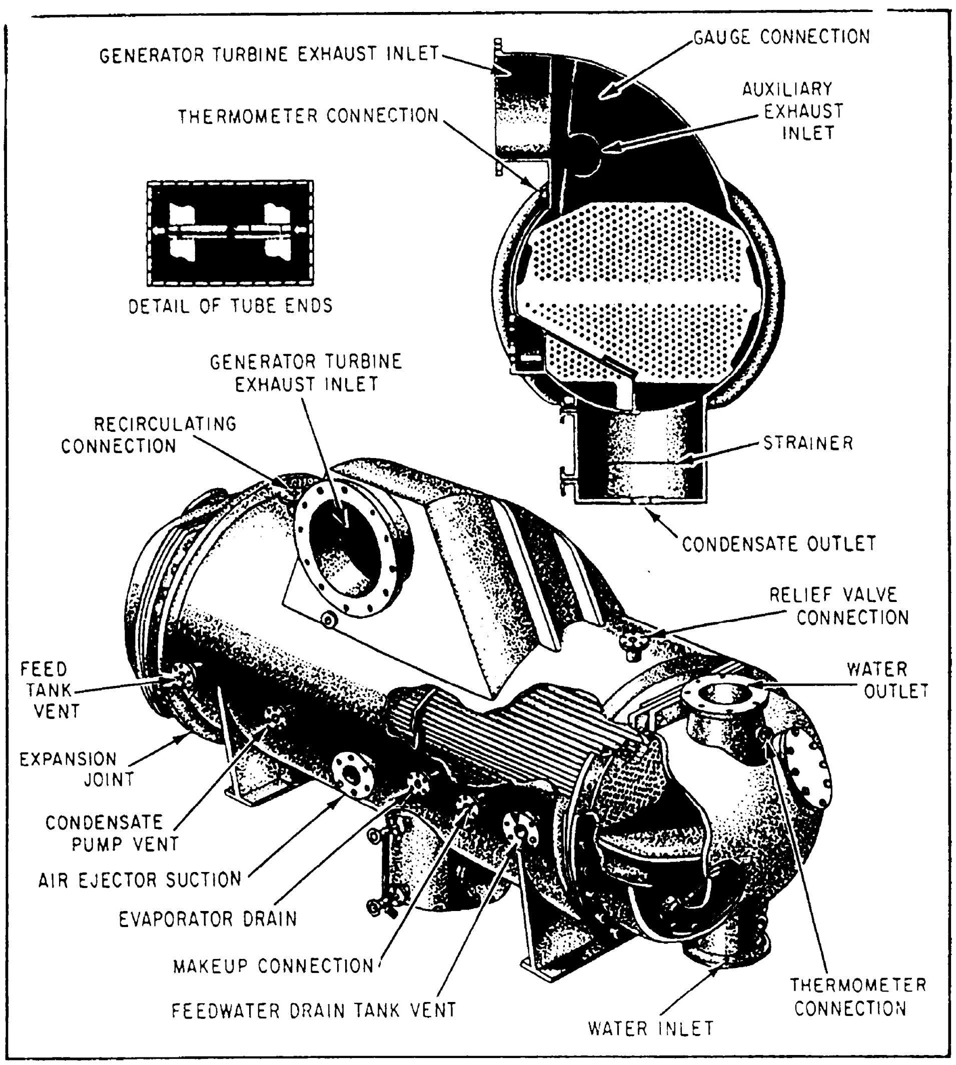

Figure 6-7.—Auxiliary condenser (turbogenerator).

The soapsuds test is a more reliable means of locating condenser air leaks. This test is done while steam side of the condenser is under pressure. Refer to *NSTM,* chapter 254, to learn how to conduct this test.

Cleaning Condensers

Foreign matter, grease, and dirt in the steam side of a condenser will reduce the rate of heat flow from the steam to the circulating water in the tubes. This, in turn, will reduce the maximum vacuum that can be obtained and lower the efficiency of the plant. The grease and dirt may be removed by boiling it out with a mixture of water and trisodium phosphate. It should not be necessary to boil out a condenser more than once every overhaul. The *NSTM,* chapter 254, gives the correct procedure for boiling out a condenser.

The seawater side of the tubes should be cleaned as often as necessary. The intervals depend on the rate at which slime, marine growth, scale, mud, oil, and grease are deposited on the tube walls. The amount of such deposits depends upon existing conditions. Operation in shallow water, for example, may cause this type of fouling.

For ordinary cleaning of the seawater side of a condenser, an air lance should be pushed through each tube. The tube sheets should be washed clean with fresh water, and all foreign matter should be removed from the water chest. In cases of more severe fouling, a water lance should be pushed through each tube to remove foreign matter adhering to the tube interior. Extreme fouling, such as that caused by oil or grounding, should be handled in one of two ways: One way is to run a rotating bristle brush through the tubes. Another is to drive soft rubber plugs (fig. 6-8) through the tubes with an air or water gun, followed by the use of a water lance. Be extremely careful that you do not abrasive tools capable of scratching or marring the tube surface.

In cleaning either the steam or seawater side of a condenser, consult the procedures and precautions in chapter 254 of the *NSTM* and appropriate PMS material.

Care of Idle Condensers

Organisms and urchins will grow in an idle unit when seawater is left in it. These growths will block tubes, insulate heat transfer surfaces, and lead to corrosion.

If seawater is drained and the condenser is not flushed with fresh water, the growth will dry out and form a hard scale. This scale also reduces heat transfer.

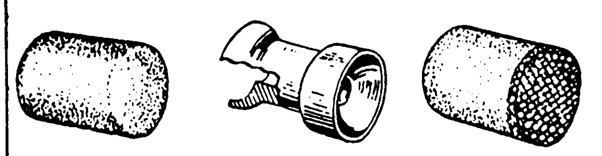

Figure 6-8.—Types of rubber plugs used for cleaning condenser tubes.

Proper lay-up of idle condensers is essential to condenser operation. Improper care can cause degraded performance. The lay-up procedure to be used will depend upon the length of time the condenser will be idle.

Saltwater side

Lay-up requirements for the saltwater side of the condensers are divided into the following three conditions:

1. Short-term—up to 1 week: The saltwater side should be kept full. Circulate the water once a day for at least 10 minutes by running the circulating pump. If you are unable to circulate the water for 3 days in succession, drain the water and refill with fresh water of potable or feedwater quality.

2. Mid-term—more than 1 week and less than 4 months: Drain the condenser and fill with fresh water of potable or feedwater quality. After the first 2 to 3 weeks, drain the condenser and refill with fresh water of potable or feedwater quality. This replaces the initial fresh water fill, which may have become deoxygenated and stagnant due to decay of organic matter. Thereafter, keep the saltwater side of the condenser filled with fresh water until the ship returns to operation or until the saltwater side is cleaned.

3. Long-term—idle for periods of 4 months or longer: Open the saltwater side and clean it as soon as practical. After cleaning, keep it drained.

Consult your PMS and the *NSTM,* chapter 254, for further information on procedures and safety precautions.

Saltwater Leaks

Salt water leaking into the condensate through even one of the thousands of tubes will contaminate the feedwater. Saltwater leakage into the system is serious. The entire feed system will salt up and the ship's boilers may become badly damaged.

You may learn of a leak by watching the salinity indicator (described in chapter 9 of this manual). The indicator is usually located at a position convenient to the main control station in the engine room. It must be kept in operative condition at all times. Salinity cells must be checked frequently. When the salinity reading goes above normal, determine the cause as soon as possible.

Saltwater leakage cannot always be detected by the conductivity type of salinity indicators installed in the condensate system. This is because of the large quantity of condensate that generally flows. The first indications of saltwater leakage in the active tube length between the tube sheets may be a chloride buildup in the boiler.

Make a careful investigation to make sure the source of chloride contamination is not in the piping connected to the condenser rather than in the condenser tubes. Pay special attention to those sections of the condensate, drain, or makeup tied piping, which are normally under vacuum and located in the bidge area. Experience shows bilge water may leak into joints of this piping and not be detected until after considerable time and effort have been used to search for a tube leak. Any of these pipes and joints located in the bilge area should be uncovered by lowering the level of water in the bilges. All joints should be inspected while the condenser and the piping are filled with fresh water under pressure. This should be done when using one of the leakage detection methods described in chapter 254 (9460) of the *NSTM.*

CONDENSER SAFETY PRECAUTIONS

The following safety precautions apply to all condensers in the engineering plant and must be followed:

1. Always be on the alert to detect and eliminate air leaks in the vacuum system.
2. If a large air leak occurs, the condenser vacuum will be immediately reduced by a large amount. Take corrective measures immediately.
3. If, at any time, a loss of vacuum is accompanied by a hot or flooded condenser, slow down or stop the unit, exhausting into it until the condensing unit is again put into proper working order. Examine and lift by hand the condenser shell relief valves before you test a condenser or put it into operation.
4. Do NOT subject condenser saltwater chests of surface ships to a pressure in excess of 15 psig.
5. Examine and lift by hand the saltwater chest relief valves whenever you secure condensers.
6. Keep the condensate level in condensers at the correct lever under all operating conditions. Make sure condensate does not collect in condensers and overflow into turbines or engines. Keep the steam side of idle condensers drained and dry.
7. Make sure sufficient circulating water flow is continuously provided when a condenser is in operation.
8. Keep the saltwater side of operating condensers free of air.
9. Do not make any permanent connection between any condenser and a water supply system that could subject the seawater side to a pressure of more than 15 psig.
10. Make every effort to ensure that salt water is NOT fed into the feed system. Electrically test the condensate from main condenser every 15 minutes underway and every 30 minutes while standing by. Test auxiliary condenser condensate every 30 minutes. Keep the salinity indicator systems in continuous operation when there is flow in the condensate system.
11. Keep idle condensers dry and clean whenever practical, especially in polluted waters.
12. Close valves admitting steam to an idle condenser.
13. Follow the tag-out procedures described in OPNAVINST 3120.32, make sure all sea openings are tightly shut, tagged, and wired against accidental opening.
14. Before entering a freshly opened condenser, be sure the gas free engineer has tested it.
15. NEVER bring an open flame or anything that will cause a spark close to a freshly opened saltwater side of a condenser until it has been thorougly blown out with steam or air. Hydrogen and/or methane (sewer) gases may be present.

These and other safety precautions are contained in chapter 254 (9460) of the *NSTM.*

OTHER HEAT EXCHANGERS

Some of the variety of heat exchangers aboard ship are discussed in this manual in relation to the systems of which they are a part. Information on some of the other shipboard heat exchangers is given in the following sections.

DEAERATING FEED TANK

The DFT is a direct-contact heat exchanger. It serves three purposes: (1) It frees the condensate of oxygen and noncondensate gases, (2) it heats the feedwater, and (3) it stores the feedwater.

The feedwater is heated by direct contact with auxiliary exhaust. The DFT operates at approximately 15 psig and 250°F. In the FF-1052 and FF-1078 class ships, the DFT is not located high enough to give sufficient static head for the booster pump suction. Therefore, the booster pump will cavitate. To prevent cavitation, a feedwater cooler is installed between the feedwater outlet and the booster pump suction. The condensate passes through the feedwater cooler before entering the DFT. This preheats the condensate and cools the feedwater so that it does not flash to steam as it enters the booster pump suction.

One type of DFT is shown in figure 6-9. The condensate enters the DFT through an inlet pipe and flows into the spray manifold. The spray manifold

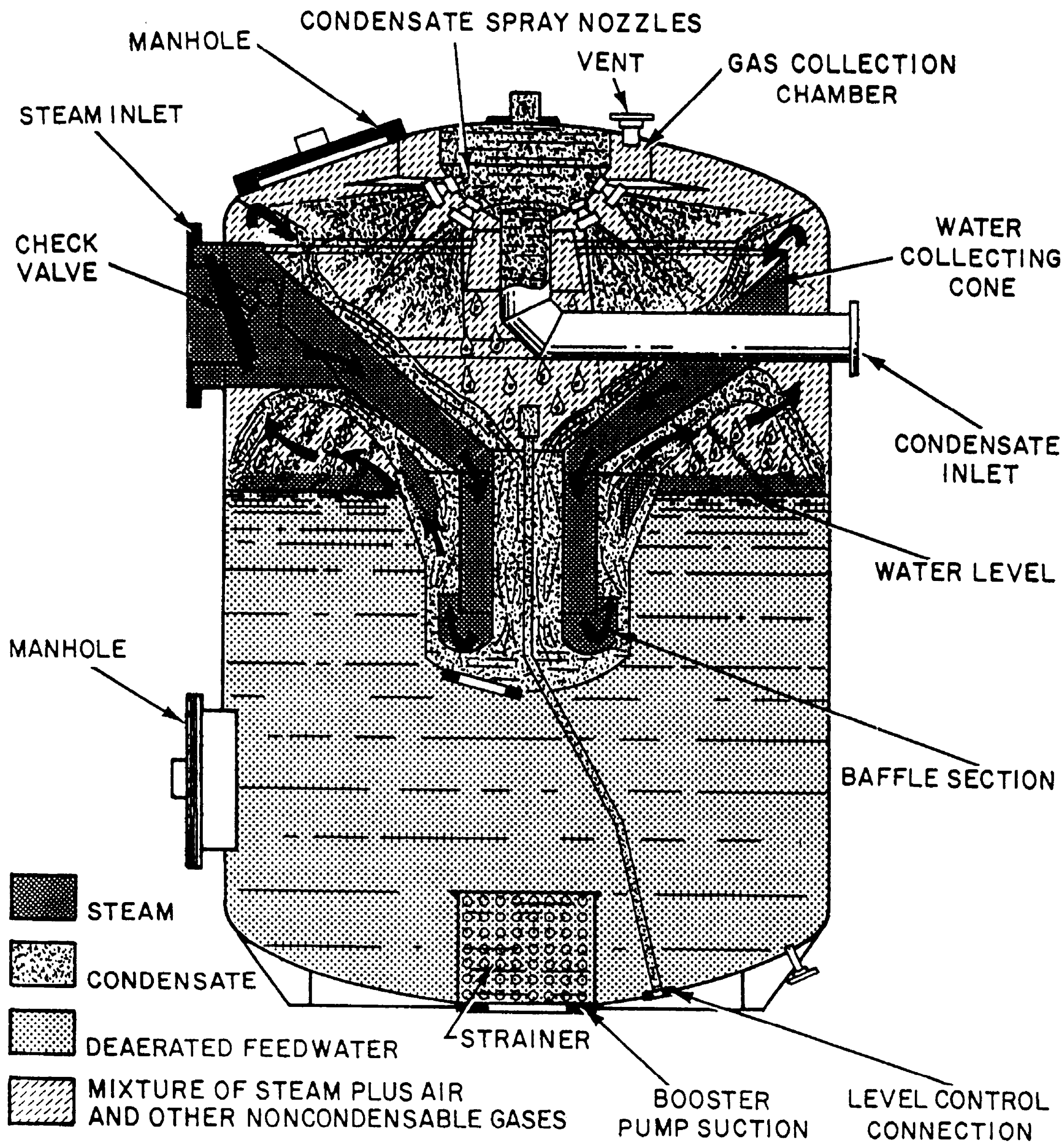

Figure 6-9.—Deaerating feed tank.

contains a number of spring-loaded poppet-type spray valves. These valves form the flow stream first into conical sheets, then into jet streams, and finally into fine particles directly in contact with steam. Thus, the condensate is heated to approximately the steam temperature. The efficient heating and counterflow patterns of the steam and water in the spray chamber release all but a small amount of oxygen and other dissolved gases. The water spray surface is partially enclosed by baffles to maintain this strict counterflow relationship and to provide a zone for cooling the released gases before they are ventilated from the tank.

The spray is directed into the water collection cone. The water in the cone drains by gravity through a downtake pipe to the deaerating compartment. From there it is drawn up into the steam scrubbing and mixing passage by the adductor action of steam leaving and steam passage. This high-velocity steam and water

mixture is jetted from the water passage through the baffle space and strikes on the conical impingement baffle. The baffle deflects the flow of water downward into the storage section of the DFT. The water is now deaerated, heated, and ready to be pumped to the boiler.

The steam from the auxiliary exhaust line, to enter the initial heating chamber, must break through the baffle section. The steam carries with it any gases released from the water by its jet action; this prevents gas accumulation above the deaerated water in the storage compartment. After starting its upward travel, the steam and released gases break through the water film into the spray chamber. There they come in direct contact with cold water entering the spray chamber. The spray chamber is where the initial heating and deaeration take place.

The major portion of the steam entering the spray chamber is condensed. the uncondensed steam and gases released from the water pass along the spray water surfaces within the confines of the flow restrictive surfaces. The steam and gas mixture passes through a series of holes in the flow restrictive surfaces and is directed into the water spray. Here further condensation of the steam and cooling of the released gases takes place. The gas passes to the collection chamber where the released gases and a trace of uncondensed steam is vented out of the DFT.

A strainer is located in the bottom of the tank to prevent any foreign matter from entering the feed booster pump suction.

Operation

During normal operation of the DFT, the only control necessary is to maintain the proper water level. If the water level is too high, the tank cannot properly remove the air from the feedwater. A low water level may endanger the main feed booster pumps, the main feed pumps, and the boilers.

A common method of DFT level control is the use of automatic makeup feed and excess feed valves. When the tank level drops to a specified point, the level-sensing system will transmit an air signal to the makeup feed valve. The valve will then open and allow vacuum drag to draw water into the associated condenser from the reserve feedwater tank on service. As the DFT level increases, the makeup feed valve will shut. If the level continues to rise, the level-sensing system will cause the excess feed valve to open. This will dump condensate into the on-service reserve feed tank.

The DFT removes gases from the feedwater by using the principle that the solubility of gases in feedwater approaches zero when the water temperature approaches the boiling point. During operation, water is sprayed so that it comes in contact and mixes with the steam from the auxiliary exhaust line. The quantity of steam must always be proportional to the quantity of water. If not, the result will be faulty operation or a casualty.

In most DFTs, a manhole provides access for inspection of spray nozzles; other tanks are so designed that the spray nozzle chamber and the vent condenser (if installed) must be removed for inspection of the nozzle.

Auxiliary exhaust steam flows directly into the deaerating unit. A check valve is located either in the deaerating tank or in the line leading to the tank. This valve allows the steam to flow from the auxiliary exhaust line whenever the pressure inside the deaerating tank is less than the pressure in the exhaust line. The check vavle also prevents the return flow of water into the auxiliary exhaust line, in the event that the deaerating tank becomes flooded. Specific procedures for lining up, warming up, and securing the DFT are contained in the EOP.

GLAND EXHAUST CONDENSER

Condensate from the steam expelled by the turbine glands and DFT is recovered by a gland exhaust condenser. This condenser is normally located in the same shell as the aftercondenser of the air ejector (discussed later in this chapter). However, in some cases it may be a separate condenser. The steam condensed in the gland exhaust condenser drains to the freshwater drain collecting tank. The air and noncondensable gases are drawn out by a gland exhauster, a small motor-driven fan. The gland exhauster will normally discharge to a main exhaust vent in the engine room or fireroom.

MAIN LUBE OIL COOLERS

Main lube oil coolers are usually of the shell-and-tube type and may be of single-pass or multipass construction. Figure 6-10 is an example of a counterflow heat exchanger. Notice that the flow of oil and cooling water is in opposite directions. The size of an oil cooler depends on the quantity of heat that must be removed per unit of time from the lube oil to maintain proper bearing temperature.

The lube oil cooler consists of a cylindrical shell with a header at each end. Inside the shell is a bundle of straight, copper-nickel tubes through which the cooling water flows from one header to the other. Hot lube oil enters at the top of the shell, at the end opposite the water outlet, and flows across the tubes and around the annular jacket. The cooled oil comes out of the top of the cooler at the other end, near the water inlet. The baffles and tube support plates direct the oil flow.

TURBOGENERATOR LUBE OIL COOLERS

Turbogenerator lube oil coolers are similar to main lube oil coolers in construction, but much smaller in size. A three-way selector valve is placed in the oil line to route oil through the cooler or to bypass oil around the cooler. Each turbogenerator is served by a single lube oil cooler.

Salt water is pumped through the turbogenerator lube oil cooler by the auxiliary condenser circulating pump. If this pump should fail, cooling water may be

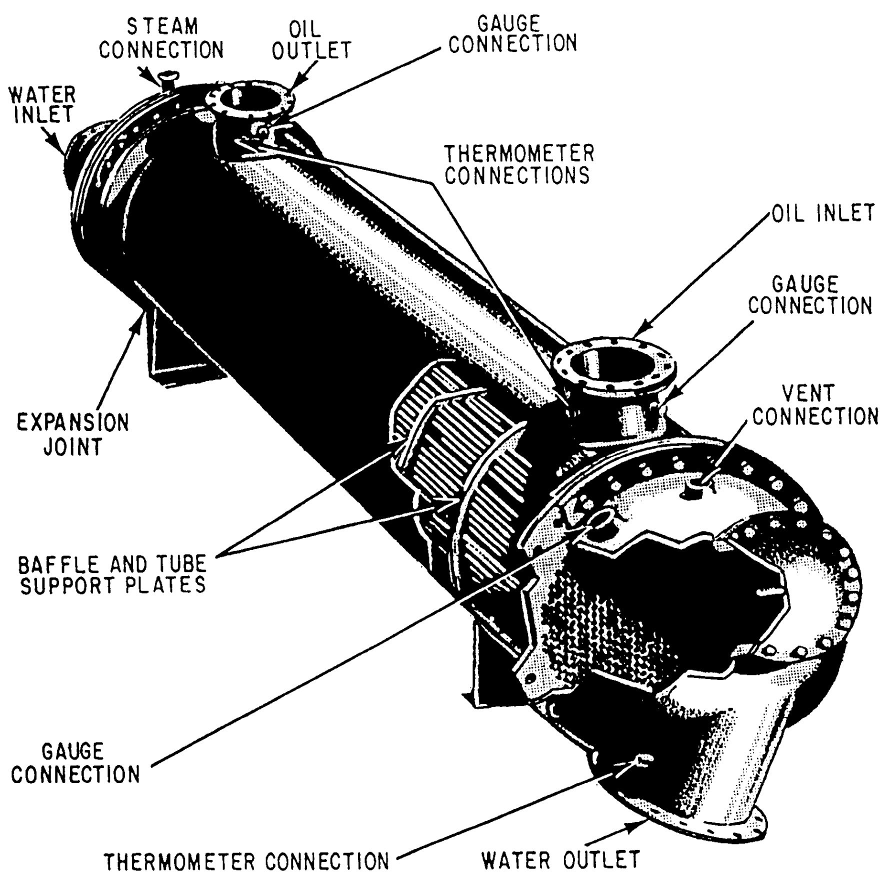

Figure 6-10.—Main lube oil cooler.

taken from the firemain through a cooling water reducer, which can be regulated to the desired pressure.

LUBE OIL PUMP COOLERS

Lube oil coolers for pumps may be of the shell-and-tube type, the strut-tube type, or the plate-tube type. A strut-tube of cooler and a plate-tube type of cooler are shown in figure 6-11. Small lube oil pump coolers are usually multitube single-pass coolers. In some, the water flows through the tubes and the lube oil flows through the shell. In others, the water flows through the shell and the lube oil flows through the tube.

Figure 6-11, view A, shows a strut-tube type of oil cooler in which the water passes through the tubes. In this cooler, heat transfer is accelerated by stamped dimples in the strut-tube plates. The strut-tube plates are assembled so that the convex sides of the dimples touch.

Figure 6-11, view B, shows a plate-tube type of oil cooler for a pump. In this cooler, the lube oil passes through the tubes. The grid distributor strip accelerates the transfer of heat from the tubes.

Strut-tube coolers and plate-tube coolers have replaceable core assemblies. Several spare core assemblies are usually carried aboard ship. In

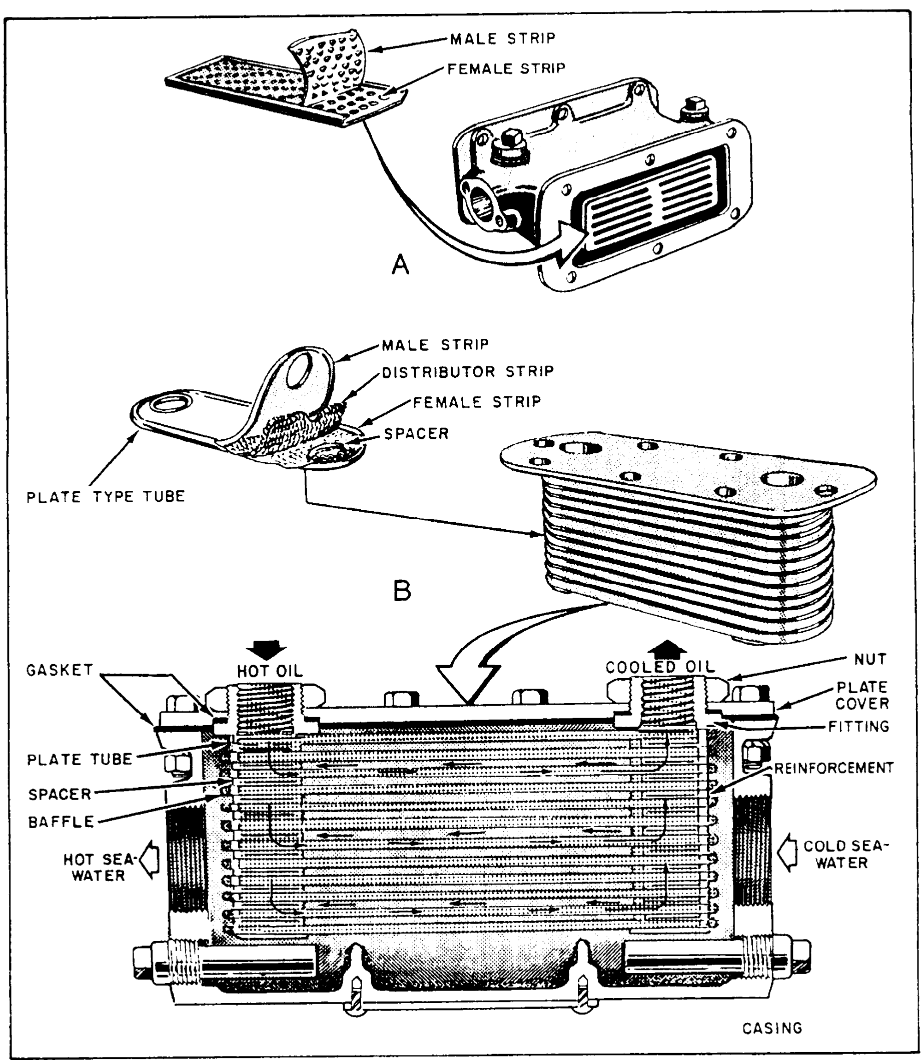

Figure 6-11.—Oil coolers for pumps. A. Strut-tube type. B. Plate-tube type.

practically all cases of failure, core replacement is all that is required to correct the trouble. It is seldom necessary to replace the entire cooler.

AIR COOLERS

Air coolers are installed on shipboard propulsion motors and generators to keep them from overheating. The air cooler is connected to the air intake and air discharge openings of the motor or generator by suitable ducts. The only characteristic difference between a lube oil cooler and a propulsion motor or generator air cooler is that the latter is of double-tube construction, with the outer tubes having high fins.

The air cooler consists of double-wall fin tubes through which the cooling water flows. The ends of the tubes at the front and rear of the cooler are enclosed by headers. Cooling water may make one or more passes through the cooler. Hot air from the motor or generator passes through the air cooler tube bank in a path perpendicular (crossflow) to the tubes (fig. 6-12).

The tubes are of double-wall construction. The inner tube is of a copper-nickel alloy, and the outer tube is of brass or other nonferrous material. The smooth-surfaced inner tube carries the water. The outer tube has internal longitudinal ribs or lands that make contact with the outer surface of the inner tube. The internal ribs of the outer tube and the cooling fins

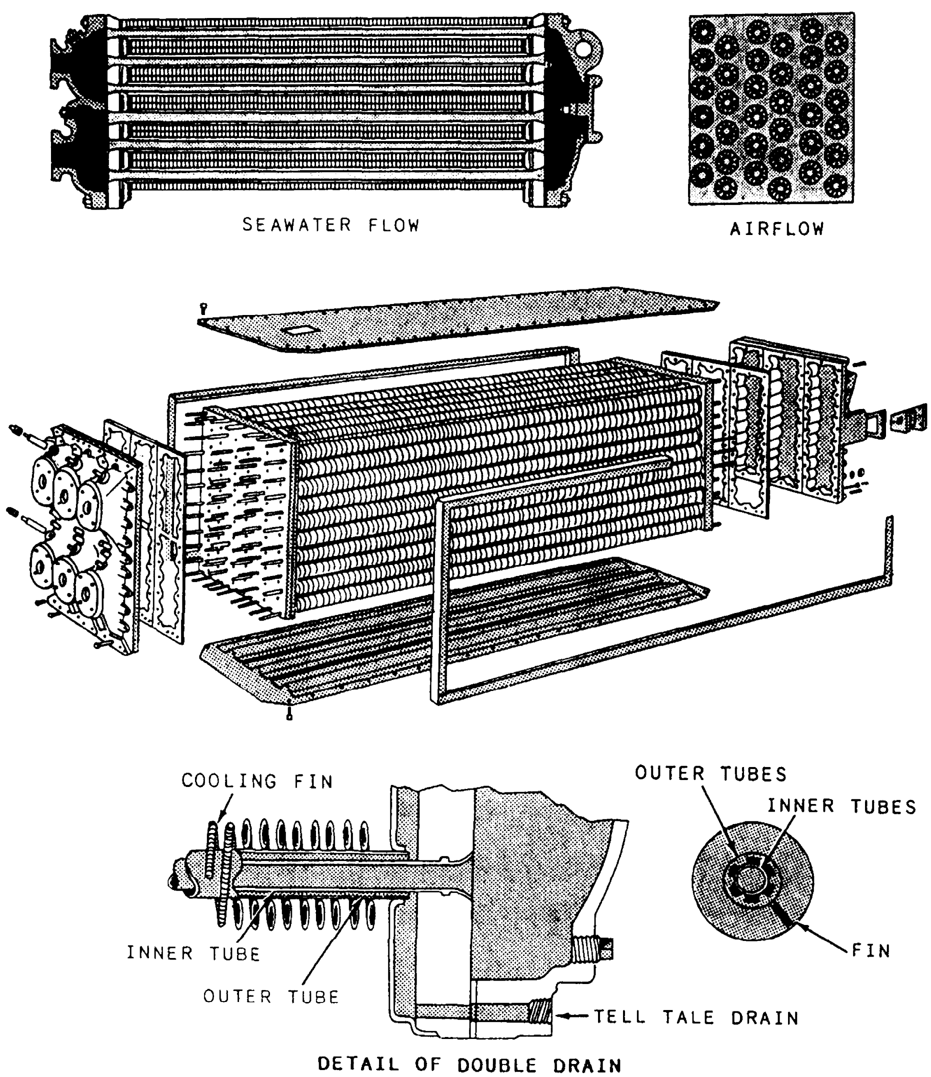

Figure 6-12.—Air cooler for a motor generator.

mounted on the outside surface of the outer tube facilitate the transfer of heat to the cooling water.

The failure of an inner tube can be detected by water leakage from the telltale drains in the front and rear headers.

A connection for draining water from the cooler is located at the bottom of the front header, and to the right of the leakage drain plug. A vent plug is located at the top of the front and rear header. These air relief plugs should be removed whenever the cooler, after having been drained of water, is to be refilled. The plugs should be removed from the telltale drain system to allow detection of leaks from the tube section of the cooler.

AIR EJECTORS

The air ejector removes air and noncondensable gases from the condenser. The Navy uses various types of air ejectors. All of them remove air from the condenser in basically the same way. Some ships use a vacuum pump to remove air from the condenser. However, the air ejector is the most common means of removing air and noncondensable gases from the condenser. The most commonly used air ejector will be discussed in the following section.

In this section we will often say that the air ejector "take a suction." Actually, it creates a low pressure area into which the air and noncondensable gases can exhaust. Vacuum does not suck anything. The flow of a substance from a higher pressure area to a lower pressure area gives you the impression that the low pressure area (vacuum) is sucking the substance. For example, when you open the make-up feed valve, the vacuum in the main condenser (lower pressure area) does not suck the water in.

Instead, the water flows from the reserve feed bottom (higher pressure area) to the main condenser. However, for the sake of familiarity, we will continue to use the word *suction.*

An air ejector is a jet pump. Figure 6-13 shows the flow of the steam, air, and noncondensable gases in one type of air ejector unit. Keep in mind that this is only a flow diagram and does not resemble an actual air ejector unit. In most cases all of the components of the unit are contained in one shell (fig. 6-14).

The shell is rectangular and is divided by a longitudinal plate into the intercondenser and aftercondenser sections. In many ships, the gland exhaust condenser is incorporated within the shell of the aftercondenser.

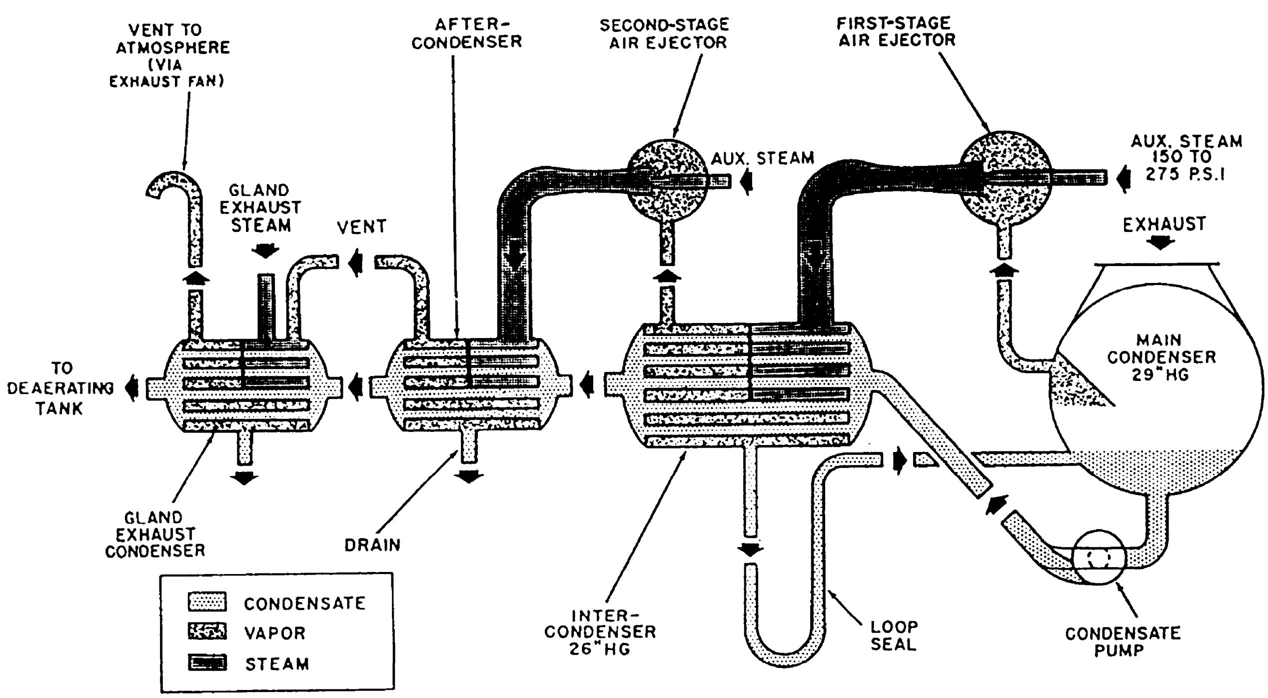

Figure 6-13.—Flow diagram of a two-stage air ejector.

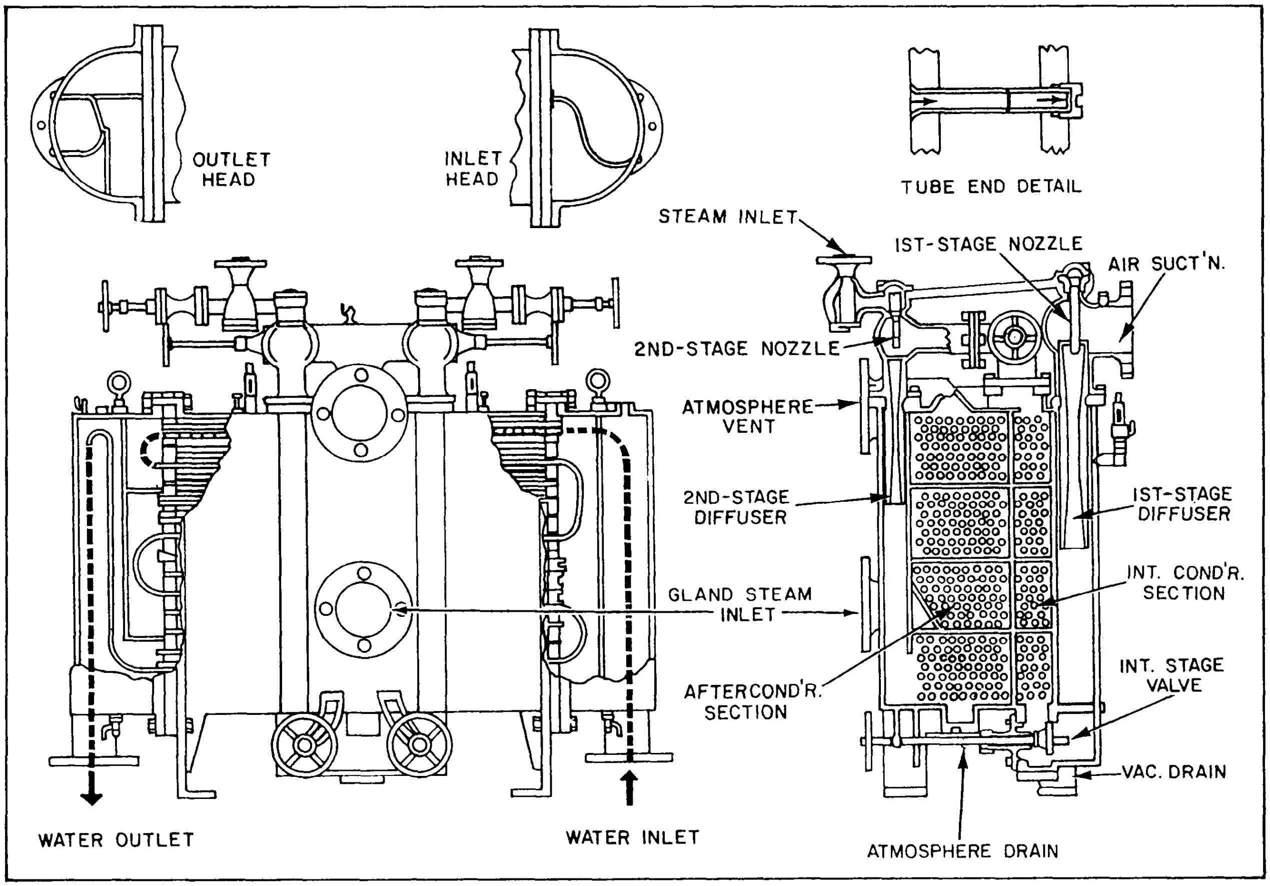

Figure 6-14.—A main air ejector and condenser assembly.

To provide continuous operation, two sets of nozzles and diffusers are furnished for each stage of the air ejectors. Only one set is necessary for the plant to operate. The other set is maintained ready for use in case of damage or unsatisfactory operation of the set in use. The two sets can be used simultaneously when excessive air leakage into the condenser calls for additional pumping capacity.

PRINCIPLES OF OPERATION

The first-stage air ejector nozzle takes a suction on the main condenser and discharges it to the intercondenser. The steam is condensed and drains through a U-shaped line (the loop seal line) to the main condenser. The air and noncondensable gases pass on to the suction of the second stage. The second-stage nozzle takes a suction on the intercondenser and discharges to the aftercondenser. The steam from the second-stage nozzle is condensed in the aftercondenser and drains to a freshwater drain collecting system. The air and noncondensable gases are vented to the atmosphere normally by way of the gland exhauster fan.

Condensate from the main condenser is used as the cooling water in the air ejector intercondenser and aftercondenser. The air ejectors remove air only from the condenser, not from the condensate.

The intercondenser is under a vacuum of approximately 26 inches of mercury. The aftercondenser is at approximate atmospheric pressure.

Sufficient cooling water for proper operation of the air ejectors is necessary when raising vacuum, while standing by, and at fractional power (cruising); this is done by a condensate recirculating line and valve installed either at the cooling water outlet from the aftercondenser or on the vent condenser inlet header. Most air ejector recirculating lines are fitted with thermostatically controlled valves, discussed in chapter 10 of this manual. These make recirculation automatic and prevent overheating of the air ejector condenser.

A manually controlled valve allows bypassing of the thermostatic recirculating valve during the warming-up period. This bypass valve is also used in case the thermostatic valve is inoperative. When the required condenser vacuum is obtained, the manually controlled bypass valve is secured. Under normal operating conditions, recirculation to the main condenser at light loads is automatically controlled by the thermostatic recirculating valve.

As previously noted, the condensate formed in the intercondenser is returned to the main condenser through the loop seal. If there were a direct connection between the intercondenser and the main condenser, the vacuum would be equalized in the two condensers. Since the main condenser carries a higher vacuum than the intercondenser, some form of seal must be maintained in this drain line to prevent this equaliation of vacuum. A water level in the U-shaped loop seal line provides this seal.

Refer to the operating procedures for lining up, starting, shifting, and securing air ejectors for the main and auxiliary condensers. You can find them in the EOP subsystem of the EOSS.

CARE AND MAINTENANCE OF AIR EJECTORS

If an air ejector fails to maintain the proper vacuum, the problem may be traced to one of the following causes:

1. Faulty steam pressure
2. Clogged steam strainer
3. Insufficient cooling water
4. Air leaks
5. Fouled nozzles
6. Unstable loop seal

AIR EJECTOR SAFETY PRECAUTIONS

The following safety precautions should be used with air ejectors:

1. When starting an air ejector, always open the discharge valves before admitting steam to the nozzles. When securing an air ejector, always close tightly the steam supply valves to the nozzles before closing the discharge valves.
2. Before starting an air ejector, always drain the steam supply line, and open the drain valves in the intercondenser and aftercondenser drain lines.
3. Should retubing or any other major repairs to an air ejector assembly be necessary, hydrostatically test all parts following reassembly.

CONDENSATE SYSTEM

The condensate system starts in the condenser and ends after the water is deaerated in the DFT. The steam condensed in the condenser, the freshwater drains, and makeup feed are all pumped through the condensate system to the DFT.

The objective is to deliver the cleanest, purest water possible to the boiler. Three pieces of equipment do it: (1) The DFT takes the air out of the water; (2) the morpholine injection system treats the condensate system; (3) the demineralization unit treats the makeup feed. (NOTE: All ships do not have the morpholine system and the demineralization unit.) We discussed the DFT in the previous section. The following sections discuss the morpholine injection system and the demineralization unit.

MORPHOLINE INJECTION SYSTEM

Morpholine is a water treatment chemical that raises the pH of the water. When water has a low pH, it is acidic and causes corrosion of the condensate and feedwater piping. The morpholine is injected into the freshwater drain collecting tank (FWDCT). From the drain tank, it goes to the condenser and is pumped through the condensate system by the condensate pump.

Morpholine is hazardous to personnel and equipment if it is not handled and used properly. Follow the appropriate instructions and safety precautions when mixing and injecting morpholine into the system. Goggles and protective gloves are mandatory when mixing and handling morpholine. An emergency eye wash station must be installed in the vicinity in case of eye contact with the chemical.

DEMINERALIZATION UNIT

The markup feed demineralizer is an automatic on-line system. The process is also known as deionization. It is an extremely useful process, since it appreciably reduceds the sludge buildup in the boiler water.

The makeup feedwater to be treated enters the tank through the demineralizer inlet valve. It is distributed by the water inlet strainer and flows down through the resin bed. The resin is retained within the mixed bed demineralizer and is prevented from passing through the outlet connection in the bottom of the tank by the underdrain strainer.

The mixed bed resin consists of a chemically equivalent mixture of a strong acidic cation and a strong basic anion resin. The water to be treated passed through the resin bed. All of the metallic and nonmetallic substances are removed, and the positively charged hydrogen ions (H5+4) and the negatively charged hydroxide ions (OH4-5) are substituted. These combine with the water that is taken from the bottom of the unit as the discharge effluent. Together they form water of an extremely high degree or purity. The anion resin will exchange hydroxide for anions, such as sulfite, carbonate, chlorides, and nitrates. When water containing calcium chloride is run through a mixed resin, the calcium is captured by the cation resin, and a hydrogen ion is released in its place. The hydrogen chloride then encounters the anion resin in which the chloride is captured, and a hydroxide ion is released. The hydrogen and hydroxide ions combine to form water. Similar reactions occur with other dissolved salts.

As the resin bed uses up its exchange capacity, the makeup feed conductivity will quickly rise above 1.0 micromho/cm. At this time the resin must be replaced.

NOTE: If the reserve feedwater has a consistently high suspended solids content, the filtration action may clog the resin bed. When that happens, the resin will need to be changed sooner than it normally would.

You can see that by using the demineralizer and the morpholine we have improved our chances of reaching our goal, which is to deliver clean, pure water to the boiler.

CHAPTER 7

ENGINEERING OPERATIONS

In this chapter we will deal primarily with the engineering operational sequencing system (EOSS), watch standing, operating notes, and casualty control. All of these are very important in proper operation of the engine room/fireroom.

All steam-turbine propulsion plants are basically the same. There are many differences in the specific details of operation, but it would not be practical to try to cover them all in detail. The information in this chapter will be general and will apply to most steam-turbine driven, multiscrew, surface ships.

ENGINEERING OPERATIONAL SEQUENCING SYSTEM (EOSS)

Each new ship that joins the Navy is more technically advanced and complex than the one before. The main propulsion plants call for engineering skills at ever higher levels of competence. That means more and better training of personnel who must keep the ships combat ready. The need for training and the problem of frequent turnover of trained personnel call for some kind of system that can be used to keep things going smoothly during the confusion. The EOSS was developed for that purpose.

EOSS is a set of manuals that were designed to eliminate problems because of operator error when aligning piping systems and starting and stopping machinery. It involves the participation of all personnel from the department head to the fireman on watch. EOSS consists of a set of detailed written procedures, using charts, instructions, and diagrams. These aids were developed for safe operation and casualty control of a specific ship's engineering plant and configuration. EOSS improves the operational readiness of the ship's engineering plant by providing positive control of the plant. This, in turn, reduces operational casualties and extends machinery life.

EOSS is divided into two subsystems: (1) engineering operational procedures (EOP) and (2) engineering operational casualty control (EOCC).

ENGINEERING OPERATIONAL PROCEDURES (EOP)

EOPs are prepared specifically for each level of operation: plant supervision (level 1), space supervision (level 2), and component/system operator (level 3). The materials for each level or stage of operation contain only the information necessary at that level. All materials are interrelated. They must be used together to maintain the proper relationship and to ensure positive control and sequencing of operational events within the plant. Ships that do not have EOSS should use operating instructions and a casualty control manual for plant operations.

ENGINEERING OPERATIONAL CASUALTY CONTROL (EOCC)

This subsystem of EOSS enables plant and space supervisors to RECOGNIZE the symptoms of a possible casualty. They can then CONTROL the casualty to prevent possible damage to machinery, and RESTORE plant operation to normal. The documents of the EOCC subsystem contain procedures and information that describe symptoms, causes, and actions to be taken in the most common engineering plant casualties.

WATCH STANDING

You will spend much of your time aboard ship as a watch stander. How you stand your watch is very important to the reliability of the engineering plant and the entire ship. You must have the skills to detect unusual noises, vibrations, or odors which may indicate faulty machinery operation. You must also take appropriate and prompt corrective measures. You must be ready, in emergencies, to act quickly and independently. You must know the ship's piping systems and HOW, WHERE, and WHY they are controlled. You must know each piece of machinery: how it is constructed, how it operates, how it fits into the engineering plant, and where related equipment is controlled. You must read and interpret measuring instruments. You must understand how and why protective devices function (relief valves, speed-limiting governors, overspeed trips, cut-in and cutout devices). You must recognize and remove fire hazards, stow gear that is adrift, and keep deck plates clean and dry. You must NEVER try to operate a piece of equipment that is defective. You must report all unsafe conditions to the space and/or plant supervisor.

Whatever your watch station, you must know the status of every piece of machinery at your station. You must promptly handle any necessary change in speed or setup and record correctly all data concerning the operation and maintenance of the machinery. You must be sure that the log is up-to-date and that the status boards are correct. You must know what machinery is operating and what the night orders and standing orders are before you relieve the watch. Above all, if you don't know—ASK. A noise, odor, or condition may seem abnormal to you, but you may not be certain whether it is a problem. When that happens call your immediate watch supervisor.

You can best gain the respect and confidence of your supervisors and shipmates if you stand a good watch. Relieve the watch on time or even a little early if possible to be sure you know the condition of the machinery and what you need to do. DON'T TRY TO RELIEVE THE WATCH FIRST AND FIGURE OUT THE SCORE LATER. The same applies when you are being relieved; don't be in a big hurry to take off. Be sure your relief understands the situation completely. Before you are relieved, make sure your station is clean and squared away. These little considerations will get you a good reputation and improve the overall quality of watch standing within the department.

PREPARATION FOR GETTING UNDERWAY

The procedures discussed in the following sections are basic steps of plant operation. They do not contain every step that must be taken when lighting off, operating, or combating casualties in *the engineering plant. During plant light off and operation, use your EOSS.*

Normally, the first step in lighting off a turbine unit is to check the cold rotor positions of the turbines. Log these readings in the operating log and indicate that they are cold readings. Next, check the main lube oil system for the following: proper sump level, system integrity (that is, strainers cleaned, inspected, and closed; drains shut; valves properly lined up), and proper temperature. This check normally requires you to start a lube oil pump to establish normal system pressure. If the lube oil is too cold, you will need to energize electrical immersion heaters, or line up steam to the heater for the lube oil purifier and direct the flow through this heat exchanger. Check oil delivery to all turbine and gear bearings by observing flow through the bearing oil sight-flow glasses.

Check low lube oil pressure alarm, standby and emergency pump pickup set points, and alternate pump power supplies during or before oil warmup.

Some installations require a lube oil temperature of 70°F (21 °C) before the main engine is rotated with the turning gear, and 90°F (32°C) before turning with steam. Others require a lube oil temperature of 90°F (32°C) before the engine is turned by any method. CAUTION: You must have permission from the OOD before turning the main shaft. Divers or other obstructions may be in the vicinity of the screw. In ships with a main shaft clutch, the main engines may be turned with the clutch disengaged without OOD permission, in most cases.

Ensure that the main shaft bearings have sufficient oil level and the stem tube has the proper leak off.

Properly line up all turbine and associated main steam drains for warmup of the main engines. Engage the turning gear and start the drive motor.

The next step is to establish a vacuum in the assoicated condenser(s). First, you must provide adequate circulating cooling water. Start the main circulating pump or main seawater pump(s), depending on the plant. Cut in the gland sealing steam and start the gland exhaust fan (if provided). **NOTE:** Any time steam is being supplied to the turbine (including gland sealing steam), the turbine must be rotating. Stationary periods of more than a few (usually 3 minutes are allowed by the manufacturer) will cause uneven heating (temperature gradients) along the length of the rotor and will result in rotor bowing.

During the turbine warmup period, a reduced condenser vacuum is normally maintained to provide for maximum heating of the turbine rotors.

After the turbine rotors have been turned with the turning gear motor for the specified period, the turbines are ready to be turned with steam. First (with OOD's permission), stop the drive motor and disengage the turning gear from the turbines. Next, admit steam to the throttle valves and, then, spin the turbines astern and ahead. Remember that only 3 minutes are normally allowed from the time the turning gear is disengaged to the time the turbines roll with steam. Steam passing through the turbine with the rotors stationary will come in contact with only a small portion of the blading and cause uneven heating. Therefore, the throttle opening should be wide enough to cause the turbine rotors to begin rotating quickly. The turbines are to be spun alternately astern and ahead. This facilitates even heating of the rotor and prevents putting way on the ship. Maximum shaft rpm limits may also be specified while spinning to help reduce ship movement. Some ships may specify spinning ahead first, then astern, then ahead. Other ships use the reverse order. Unless the equipment technical manual is specific as to which throttle valve to open first, the engineer officer will decide.

When the main engines have been tested and warmed up, you are ready to answer all bells. Open the first stage of the air ejector by following the EOSS.

During standby to answer all bells, spin the main engines every 3 to 5 minutes.

CAUTION: If for any reason the turbine rotors cannot be rotated within 5 minutes, secure the engine.

Take the "hot rotor positions" and log them in the operating log after the turbines are warmed up. When underway, realign the turbine and associated main steam drains.

PROCEDURES FOR STANDING BY

When you receive orders to stand by, the procedure to be followed will depend on the length of time the ship will be in standby.

If the ship will be in standby for only a short period of time, you may be required to (1) spin the main engine until the ship gets underway again, or (2) get permission from the OOD and secure the guarding valve and engage the jacking gear. When standing by for extended periods of time, you may be required to secure one of the engineering plants (on a two-plant ship).

NOTE: When standing by with the jacking gear engaged, secure the first stage of the main air ejector.

UNDERWAY OPERATION

Carry out underway procedures in a manner that enables the ship to accomplish its mission with the greatest economy possible. Economical and efficient operation of a propulsion plant under varying conditions and speeds calls for a high vacuum.

Importance of High Vacuum

To attain the greatest operating economy, you must maintain the vacuum for which the turbines were designed. Therefore, you should realize the necessity for the prevention and detection of air leaks in the vacuum system.

When the steam pressure within the turbine becomes greater than atmospheric pressure, steam tends to leak from the turbine to the surrounding atmosphere. On the other hand, when the pressure in the turbine is less than that of the atmosphere, air tends to leak into the turbine and impair the vacuum. To prevent air leakage into the turbine, maintain pressure on the glands slightly greater than atmospheric pressure, generally 1/2 to 2 psi.

To ensure that you maintain optimum vacuum, take care that the astern throttles do not leak. Any leakage of steam past a closed throttle tends to raise the temperature and increase the pressure within the turbine. Observe the following precautions to maintain the prescribed vacuum:

1. Keep gland packing in good condition.

2. Maintain a steam pressure between 1/2 and 2 psi on the glands when the engines are lit off.

3. Ensure that there are no air leaks in the condenser, exhaust trunks, throttles, lines to air ejectors, gauge lines, idle condensate pump packing and valves, makeup feed lines and related components.

4. Maintain adequate water in the drain collecting or reserve feed tank on which the vacuum drag is being taken.

5. Supply adequate cooling water to the main condenser and air ejector condenser.

Routine Underway Inspections

Make periodic inspections of the propulsion plant to keep it operating efficiently. When a ship is underway, check the following items at short intervals during each watch:

1. Check all main engine and reduction gear bearing thermometers to detect signs of overheating.

2. Check oil sight-flow indicators for proper oil flow.

3. Check clearance indicators for proper rotor position.

4. Check all thermometers, pressure gauges, and vacuum gauges for a normal reading.

5. Check the oil level in the main sump for a normal indication.

6. Keep a constant check on salinity indicators.

7. Check the lube-oil temperature from the lube-oil cooler; maintain oil temperature at 120° to 130°F by throttling the cooling water as required.

8. Check the auxiliary machinery cooling water for proper pressure.

9. Be constantly alert for unusual sounds and vibrations.

10. Clean lube-oil strainers at prescribed intervals.

A sight-flow indicator is fitted on most units in the lube oil line of each main engine bearing and each reduction gear bearing. When a lube-oil service pump is in operation, each indicator should show a steady flow of lube oil. Make frequent inspections of the sight-flow indicators to detect any interruption to the flow of lube oil.

At a specified frequency, check the rotor-position indicator for each turbine and log the rotor position in the operating log to determine the position of the rotor in respect to casing. Thoroughly investigate any abnormal reading. If the axial movement of the rotor is allowed to exceed the safe limit in either direction, the moving blades will strike the stationary blades or nozzles and cause great internal damage to the turbine.

One of the first indications of trouble in any steam plant is abnormal readings on thermometers or gauges. Check all thermometers and gauges frequently to detect and prevent casualties. NEVER take for granted that an abnormal reading is due to the fault of the gauge or thermometer.

NOTE: Many severe machinery casualties in an engineering plant can be traced directly to uncalibrated, inoperative, or missing instruments.

Check and log the oil level in the main engine sump at least each hour. However, you should make more frequent checks. An increase in the oil level may mean that water is entering the lube-oil system or that the system is gaining oil in some improper manner. The lube-oil transfer and purification system may be lined up improperly. A decrease in the oil level of the main engine sump usually indicates that there is a leak in the lube-oil system or that the lube oil purifier is discharging oil to the contaminated drain system. An increase or a decrease in the main sump oil level should NEVER be neglected. It could mean costly repairs to main engine bearings and reduction gears.

A properly operating main engine and reduction gear installation has a definite sound which trained personnel can recognize. Investigate any abnormal sound. Operate the unit with caution until you find the cause of the sound and correct the problem.

For safe efficient operation, keep the water level in a steaming deaerating feed tank (DFT) within the normal operating range. This is controlled automatically on most ships by an automatic excess feed valve and makeup feed valve. During abnormal or casualty situations, however, the operator will need to control DFT level. If the water is allowed to go above the maximum level, the deaerating effect is lost. Large quantities of comparatively cold water admitted to the DFT will reduce the pressure in the tank. This reduces the main feed booster pressure, which may result in casualties to the main feed pump and boiler. CAUTION: A vacuum can be created in a DFT by admitting cold water to a hot DFT which has the auxiliary exhaust steam supply secured. This action can reduce pressure within 6 seconds to the point that DFT deformation will result This situation can, in most cases, be avoided by observing the following precautions:

1. Do not refill the DFT after plant shutdown until shell temperature drops to ambient.

2. When carrying out propulsion plant casualty control procedures, secure the condensate to the DFT. Do this before you secure the auxiliary exhaust steam, and cut in the auxiliary exhaust steam before cutting in the condensate.

If the water level is below minimum, a sudden demand for feedwater for the boilers may empty the DFT. This will cause casualties to the boiler, the main feed booster pump, and the main feed pump.

Most ships have a salinity indicator meter and alarm panel near the throttle board in each engine room. This system detects the entrance of chemical contamination into the condensate system. Check the meter frequency because a small amount of salt in the condensate system will contaminate a steaming boiler beyond allowable limits. Check an abnormal reading; seek and isolate the source of contamination. You will find more information about salinity indicators in chapter 9 of this manual and in the appropriate manufacturer's technical manuals.

SECURING THE PLANT

Before entering port and shutting down a plant, you need to make certain preparations to ensure a smooth and orderly shutdown. Certain auxiliary machinery to be used in port must be placed in standby operation, system lineups must be altered, and many other tasks must be accomplished. These procedures are outlined in the EOP.

A cool-down procedure is specified for the main engines of each ship type. Normally, you must circulate main lube oil until it cools to near-ambient (room) temperature.

Circulate seawater through the main condenser until the exhaust trunk temperature cools to near ambient. Rotate the main turbines with the turning gear for a specified length of time or specified temperature decrease.

NEVER break vacuum in a condenser through the turbine glands by securing the gland sealing steam. The shock of cold air flowing over the hot turbine glands and rotor can cause damage to the glands.

Open all turbine drains and leave them open for the period of time specified by EOP procedures. Do not get in a big hurry to shut down. You can cause serious casualties when you have your hand on a valve and your mind somewhere else. Shut down in a controlled, orderly fashion and save yourself a lot possible grief later.

ENGINEERING CASUALTY CONTROL

The best form of casualty control is prevention. If you do not let it happen, you will not have to fix it.

Preventive maintenance is one of the principal factors of casualty control. Preventive inspections, tests, and maintenance are vital to casualty control. These actions minimize casualties caused by MATERIAL failures. Continuous detailed inspections are necessary to discover worn or partly damaged parts, which may fail at a critical time. These inspections eliminate maladjustment, improper lubrication, corrosion, erosion, and other enemies which could cause early failure of a vital piece of machinery.

The inspections, tests, and maintenance called for in the 3-M System must be conscientiously performed since they are based on the known requirements of preventive maintenance.

Still, casualties do happen. When they do, the success of your mission, the safety of your ship, and the lives of your shipmates may depend on your ability to handle the situation. That means continuous training and frequent refresher drills to be sure you can do your part, and do it well.

Engineering casualty control is used to prevent, minimize, and correct the effects of operational and battle casualties. These casualties will be on engineering space machinery, related machinery outside of engineering spaces, and the piping installations relative to the various pieces of machinery. The mission of engineering department personnel is to maintain all engineering services in a state of maximum reliability under all conditions. If you cannot provide these services, the ship may not be able to fight.

The use of EOCC procedures was discussed at the beginning of this chapter. These procedures are prepared and approved for your ship.

Steps involved in handling engineering casualties can be divided into three general phrases:

1. Immediate action to prevent further damage.

2. Supplementary action to stabilize the plant condition.

3. Restoration action to restore equipment to operation after a casualty. Where equipment damage has occurred, repairs may be necessary to restore machinery, plants, or systems to their original condition.

Communication of accurate information is one of the major problems in casualty control. Be sure you know the names and operations of the equipment at your normal watch station and your battle station. Be sure you know what the casualty is before you take corrective action. If you are reporting a casaulty to the bridge or main control, be sure that you use the correct terminology and that they understand what your casualty is.

The primary sources of instructions used to handle any engineering casualty and to maintain the overall damage resistance to your ship are listed below.

1. The engineering operation and casualty control (EOCC) procedure
2. The ship's casualty control manual (for ships without EOCC)
3. The ship's damage control manual
4. The ship's damage control bills
5. The ship's organization and regulation manual (SORM)

SYMPTOMS OF OPERATIONAL CASUALTIES

You must always be on the alert for even the most minor sign of faulty operation of machinery. Pay particular and continuous attention to the following symptoms of malfunctioning.

1. Unusual noises
2. Vibrations
3. Abnormal temperatures
4. Abnormal pressures
5. Abnormal operating speeds
6. Leakage from systems or associated equipment

You should become thoroughly familiar with the normal operating temperatures, pressure, and speeds of equipment specified for each condition of operation; departures from normal will then be readily apparent. NEVER assume that an abnormal reading on a gauge or other indicating instrument is due to a problem with the instrument. Investigate each case to learn the casue of the abnormal reading. Substitute a spare instrument or perform a calibration test to quickly show whether an instrument error exists. Trace abnormal readings that are not caused by faulty instruments to their source. Some specific advance warnings of failure are outlined in the following paragraphs.

The safety factor commonly incorporated in pumps and similar equipment can allow a considerable loss of capacity before you see any external evidence of trouble. In pressure-governor-controlled equipment, changes in operating speeds from normal for the existing load should be viewed with suspicion. Variations from normal in chest pressures, lubricating oil temperatures, and system pressures indicate either improper operation or poor condition of the machinery. When a material failure occurs in any unit, promptly inspect all similar units to determine whether they are subject to the same type of failure. Prompt inspection may eliminate a wave of similar casualties.

Abnormal wear, fatigue, erosion, or corrosion of a part may indicate that the equipment is not being operated within its designed limits of loading, velocity, and lubrication. It also may indicate a design or material deficiency. If any of these symptoms have appeared, you should routinely carry out special inspections to detect damage unless you can take action to ensure that such a condition will not recur.

ENGINE ROOM CASUALTIES

Even with the best-trained personnel and the best-planned maintenance programs, casualties will occur. In the following section we will discuss some of the most common casualties and the action to be taken. *However, the action will be general in nature and should not be used as standard procedure. When combating an engine room casualty, use your EOCC.*

When a casualty occurs in a space other than main control, make all reports to main control. They will keep the bridge informed.

To keep things simple, we will assume the following conditions for the casualties that we discuss in this chapter.

1. The ship is underway under normal steaming conditions.
2. The ship is multiscrew.
3. The ship is steam turbine driven.
4. All casualties will occur in main engine control.

Locking and Unlocking the Main Engine Shaft

Normally the ship will have a maximum designated safe speed at which a shaft can be locked. If a speed is not designated, slow the ship's speed to not more than one-half of full-power speed. However, if you have to lock the shaft, you can begin your stopping and locking procedure while you are waiting for the unaffected shaft(s) to slow to the proper speed.

There are five casualties that require you to stop and lock the shaft immediately. These casualties are (1) loss of lube oil pressure to the engine, (2) an uncontrollable hot bearing, (3) a metallic sound in the turbine, (4) a loud roaring noise in the reduction gears, and (5) a major lube-oil leak.

CAUTION: If the shaft is locked for more than 5 minutes, you must break vacuum and secure the gland seal. If this is not done the turbine rotor may become bowed.

Never secure the lube oil to an engine whose shaft is locked while the ship is underway.

When stopping and locking a shaft while underway, take the following steps:

1. Notify the bridge and ring up STOP on the engine order telegraph (EOT).

2. Close the ahead throttle and open the astern throttle, or reverse the procedure if operating astern.

3. When the shaft is stopped and holding, the throttleman should note the astern steam pressure, and note and record the unaffected shaft rpm.

CAUTION: The shaft must remain stationary while being locked.

4. When the affected shaft is stopped and the unaffected shaft is at ordered rpm, engage the jacking gear and set the brake.

5. When the shaft is locked, have everyone clear the area of the jacking gear and slowly close the astern throttle valve.

6. Notify the bridge that the shaft is locked, and report the maximum speed available on the unaffected shaft or shafts.

When unlocking the shaft use the following procedure:

If possible, unlock the shaft with no way on the ship. To use this method, bring the unaffected shaft(s) to a stop. When the ship has stopped moving in the water, disengage the jacking gear and let the shaft trail. If the engine has been secured, restore it to service following the EOP.

When it is not permissible to stop the ship to unlock the shaft, use the following steps:

1. Return the unaffected shaft(s) to the rpm that was in use when the affected shaft was locked.

2. Remove the lockpin from the engaging lever.

3. Apply a steady pressure toward the disengaging position on the jacking-gear engaging lever.

4. Slowly increase astern steam pressure until the jacking gear disengages. When the jacking gear is disengaged, slowly close the astern throttle valve.

5. Report to the bridge that the shaft is unlocked and trailing.

6. Return unaffected shaft(s) back to the ordered speed.

CAUTION: Maintain control of the shaft speed. You can do this with astern steam or, when possible, by slowing the unaffected shafts. Increase the shaft speed in increments. Inspect the engine at each increment. If the inspection is satisfactory, you may increase the shaft speed another increment. Continue this procedure until the engine is ready to answer all bells.

7. Report to bridge that the engine is ready to answer all bells, and report the maximum speed available.

Remember that locking and unlocking a shaft can be very dangerous to equipment and personnel if it is done improperly. *Use you EOCC. Remember that this section and the sections to follow are very general and cover only the major steps.*

Loss of Lube-Oil Pressure to the Main Engine

If you lose lube-oil pressure to the main engine, take the following steps:

1. Notify the bridge of the casualty; tell them that you are stopping and locking the shaft.

2. Ring up STOP on the EOT.

3. Stop and lock the affected main engine shaft.

4. When the shaft is locked, report that fact to the bridge.

5. Report the maximum speed available on the unaffected engines.

6. Shift the lube-oil strainers.

7. Investigate and determine the cause of the casualty. Use the EOCC to make your checks. Some of the major checks and action to be taken are listed below.

a. If the shaft is to be locked for more than 5 minutes, cross-connect the drains and exhaust and cut them out of the main condenser. When this has been done, secure the turbine gland seal and the main air ejector.

b. Get a sample of water from the main lube oil cooler and a sample of oil from the sump. Check the water for signs of lube oil and the lube oil for water.

c. Check the lube-oil strainer that was in use at the time of the casualty. Determine if there is any bearing metal present.

d. Check the bearing temperatures and the rotor-position indicators.

e. Check out the lube-oil pump that was in use and the standby lube-oil pump.

f. Check the main engine sump level.

g. If the lube-oil purifier is in operation, check it for proper operation and proper line up.

h. Check all lube-oil piping for leaks.

i. Make repairs when the cause has been determined.

j. Check the turbine and reduction gear bearings for wiping.

k. Report any bearing damage and the estimate time for repairs.

1. Complete the bearing repairs under the supervision of the engineer officer (if required).

m. Report to the OOD that repairs have been made and request permission to light off and test the main engine.

n. If permission is granted, light off and test the main engine using the EOSS.

o. When the engine test is satisfactory, report to bridge that the engine is ready to answer all bells.

Metallic Noise in the Main Turbine

When a metallic noise is heard in the main turbines, take the following actions:

1. Ring up STOP on the EOT.

2. Report that casualty to the bridge: tell them that you are stopping and locking the affected main shaft.

3. Report to the bridge when the shaft is locked.

4. Report the maximum speed available on the unaffected engines.

5. Check all bearing temperatures, sight-flow indicators, and rotor-position indicators.

6. Shift and inspect the lube-oil strainer. Determine if any metal is present.

7. Check foundation bolts and inspection covers for tightness.

NOTE: If there is no apparent external cause of the noise, then you must inspect the internals.

8. When the cause has been determined, report the estimated time of repairs to the bridge.

9. When repairs have been made, request permission to light off (if secured) and test the main engine.

10. If permission is granted, light off and test the main engine using the EOSS.

11. If the main engine test is satisfactory, report to the bridge that the main engine is ready to answer all bells, and report the maximum speed available.

Hot Bearing on the Main Engine

A hot bearing exists under these conditions: (1) the bearing lube-oil outlet temperature is above normal operating temperature but less than 180°F; (2) the inlet/outlet temperature differential is less than 50°F. A hot bearing condition also exists when normal operating temperatures can be maintained only by adjusting the lube-oil supply temperature and/or pressure, by using artificial cooling, or by slowing the shaft. On bearings which have a babbitt-implanted RTD, a hot bearing exists when the bearing temperature is above normal but less than 20°F above the maximum bearing temperature measured on sea trials. It also must be less than 250°F for journal bearings and 270°F for thrust bearings. Other criteria is the same as previously stated for a hot bearing. If a hot bearing condition exists, take the following actions:

1. Notify the bridge of the casualty.

2. Increase oil flow to the hot bearing by:

a. Increasing the pressure on the lube-oil system.

b. Increasing the opening of the needle control valve, if one is installed.

3. Increase the flow of cooling water through the main lube-oil cooler. (The temperature of the lube oil

leaving the cooler will be maintained between 120°F and 130°F.)

4. Slow the main engine as necessary to a speed which will maintain the temperature of the bearing within safe limits. Indicate speed changes on the EOT.

5. Station a person to watch the bearing temperature continuously.

6. Shift and inspect the lube-oil strainers.

7. Determine if any bearing metal is present.

8. Get a sample of lube oil from the system and check for water and debris.

9. Place the lube-oil purifier on sump-to-sump operation.

10. Apply artificial cooling using portable blowers and/or water-soaked rags.

NOTE: Do not spray cold water over the bearing cover except in an emergency.

When the bearing temperature is controllable and has been reduced to a safe temperature range, take the following actions:

1. Remove the artificial means of cooling.

2. Restore the lube-oil pressure to the normal operating limits.

3. Reduce the excess cooling-water flow through the lube-oil cooler.

4. Proceed at an engine speed which will keep the bearing temperature within a satisfactory range.

5. Indicate speed changes on the EOT

6. Monitor the bearing continuously while increasing engine speed.

7. Shift and inspect the lube-oil strainers.

8. Determine if any bearing metal is present.

9. Inform the bridge of the maximum speed available on the affected engine.

10. Request permission from the bridge to adjust speed as necessary.

11. Notify the bridge when repairs have been made.

Uncontrolled Hot Main Engine Bearing

An uncontrolled hot bearing exists under these conditions: (1) the temperature of the oil leaving the bearing is 180°F or more, and/or (2) the inlet/outlet temperature differential of the bearing oil is 50°F or more.

On bearings with babbitt-implanted RTDs, an uncontrolled hot bearing exists under these conditions: (1) the bearing temperature is equal to or exceeds 20°F above the maximum bearing temperature measured on sea trials, (2) the bearing temperature equals or exceeds 250°F for journal bearings and 270°F for thrust bearings. If an uncontrolled hot bearing exists on the main engine, take the following actions:

1. Ring up STOP on the EOT.

2. Notify the bridge of the casualty and tell them you are stopping and locking the shaft.

3. When the shaft is stopped and locked, notify the bridge and tell them the maximum speed available.

4. Notify the bridge of the estimated time for inspection and repair.

5. When repairs have been made, request permission to light off and test the affected main engine.

6. With permission, light off and test the main engine using EOSS.

7. If the test is satisfactory, report to the bridge that the engine is ready to answer all bells. Tell them the maximum speed available.

Jammed Throttle

The throttle is jammed when it will not control the speed of the turbine.

CAUTION: Do not use the opposite throttle to control the engine speed except when it is necessary to stop the shaft in an emergency.

In case of a jammed throttle, take the following actions:

1. Notify the bridge of what throttle is jammed (ahead or astern) and at what rpm.

2. Take control of the main engine speed with the guarding valve.

3. Report to the bridge when you have control with the guarding valve and the maximum speed available.

4. Check for the cause of the casualty using the EOCC. Some of the causes for a jammed throttle are listed below:

a. Pins fallen out of the linkage

b. Sheared gears

c. Broken cams

d. Broken cam springs

e. Bent, seized, or broken valve stems

5. When the cause of the casualty has been determined, tell the bridge and give the estimated time of repairs.

6. When repairs have been made, request permission from the bridge to test the throttle.

7. With permission, test the throttle.

8. If the throttle test is satisfactory, take control with the throttle valve.

9. When you have control with the throttle valve, open the guarding valve all the way.

10. Report to the bridge that you have control with the throttle valve and that you are ready to answer all bells.

Loss of Main Condenser Vacuum

A loss of vacuum in the main condenser that is not handled properly can be very damaging to the turbines and the engineering plant. If a loss of vacuum occurs to the main condenser, take the following actions:

1. Notify the bridge of the casualty.

2. Make checks using the EOCC.

Some of the major causes of loss of vacuum are listed below:

1. Improper operation of the air ejectors

2. Improper operation of the main circulating water pump (if lit off)

3. A dry makeup feed bottom

4. Improper operation of the freshwater drain collecting tank

5. The appropriate non-return valve not open

6. The non-return valve not in use is stuck open

7. Leaks in vacuum lines

8. A broken condenser sight glass

9. A flooded condenser

10. Improper operation of the main condensate pump

11. Improper lineup of the standby condensate pump

12. Improper recirculation of condensate

If the cause is not found and corrected and the vacuum continues to drop, take the following actions:

1. At 21 inches of mercury, reduce to two-thirds speed.

2. At 18 inches of mercury, reduce to one-third speed.

3. At 15 inches of mercury, indicate stop on the EOT and isolate the steam side of the main condenser.

4. When the cause of the casualty is found, inform the bridge and tell them the estimated time of repair.

5. When the cause is corrected and vacuum is returning, cut in the exhaust and drains using the EOCC.

6. When the condenser vacuum reaches 16 inches of mercury, come to one-third speed.

7. When the condenser vacuum reaches 19 inches of mercury, come to two-thirds speed.

8. When the condenser vacuum reaches 22 inches of mercury, bring the engine to ordered speed and report to the bridge that you are ready to answer all beds.

NOTE: Indicate all speed changes on the EOT.

Hot Condenser

You have a hot condenser casualty if the main condenser inlet and seawater overboard temperature is 140°F or higher or if only the overboard temperature is 140°F or higher. If a hot condenser casualty occurs, take the following actions:

1. Report the casualty to the bridge.

2. Ring up STOP on the EOT.

3. Close the throttle valve.

4. Cross-connect the exhausts and drains.

5. Isolate the steam side of the condenser.

6. Stop the main circulating pump (if an operation).

NOTE: On ships with a main circulating pump that starts automatically, the auto-start feature must be disabled to prevent an unwanted start.

7. Open the air vents on the overboard header.

8. Close the overboard valve.

CAUTION: Do not use the main circulating pump to restore normal or increased seawater flow through the condenser before the condenser overboard temperature is below 140°F. It could cause chill shocking and tube failure.

9. Investigate and determine the cause of the casualty. Some causes of a hot condenser are listed below:

a. The improper securing of the main condenser when securing the plant

b. The improper securing of main condenser during a casualty

c. The steam valve(s) leaking through to an idle condenser

d. The overboard or injection valve closed during operation

e. The improper operation or failure of the main circulating pump when it was in use

f. A plugged sea chest or tubes

g. A flapper valve stuck open or closed

h. An air-bound condenser

i. A loss of way on the ship

10. When the cause of a casualty has been corrected and the condenser overboard temperature is less than 140°F. place the main condenser back into operation using the EOSS.

11. When the condenser is back in operation and the plant is in a normal operating status, report to the bridge that you are ready to answer all bells.

Turbogenerator Casualties

Turbogenerator casualties are handled in basically the same way as main engine casualties. Of course, you cannot stop and lock the rotor of a turbogenerator. Therefore, in nearly all turbogenerator casualties, the electrical load will be shifted and the generator will be manually tripped.

In some casualties, such as a hot bearing or vibration, it is necessary to keep the generator rolling at a reduced speed. This is done by using the throttle valve.

For further information on turbogenerator casualties, refer to *Naval Ships' Technical Manual,* chapter 079, volume 3. To combat a casualty to the turbogenerator, use the procedures in the EOCC.

Engine Room Fires

An engine room fire is a very serious casualty. You must take the proper action immediately to get the fire under control and put out. Equipment damage, personnel injuries and even deaths have been caused by engine room fires. Some actions to be taken to reduce fire hazards in the engine room are listed below:

1. Keep the bilge clean and oil free.
2. Keep flange shielding properly installed.
3. Keep strainer shielding in good condition.
4. Do not store paint or flammable liquids in the engine room.
5. Replace oil-soaked lagging.
6. Keep oil wiped off of machinery.
7. Keep rags properly stored.

If a fire occurs, it is vital that you know what to do. Study and practice the procedures set forth in *Naval Ships' Technical Manual,* chapter 079, volume 2, and chapter 555 (9930), *The Main Space Fire Doctrine,* and *The Ship Damage Control Manual.*

PROPULSION BOILER PRELIGHT OFF

Cold plant prelight-off checks are conducted before the boiler is lit off. They are incorporated in the EOSS prelight-off checklist and are designed to help you find problems that cannot be corrected after the plant is put in operation. They also preclude the operation of equipment that has inoperative or ineffective safety devices. Cold plant checks are conducted according to the EOP. These checks include such items as the safety walk-through, safety valve hand easing gear, remote operating gear for valves, fuel oil system piping and strainers, burner front fuel valves, and safety shut off devices.

NOTE: The contents of the above checklist should not be construed as the minimum requirements for cold plant prelight-off checks. Use your EOSS.

BOILER INSPECTION

The furnace should be inspected with a boiler inspection device (BID) to verify that the boiler deck is clear of unburned fuel before inserting the torch. The presence of visible wet spots, the smell of fuel, the fogging of the inspection device, or the presence of white or black smoke indicates unburned fuel. Fuel can leak into the bottoms of air casings and go undetected until there is a serious casing fire. You can prevent this condition by frequently inspecting casing bottoms. Take every precaution to prevent unburned oil from collecting in the furnace since hot brick gasifies the oil and can cause a violent explosion. Proper precautions will eliminate such dangers. Do not assume that the furnace purge period will eliminate unburned fuel collected in the furnace. This is especially true after an unsuccessful burner light-off attempt in a boiler that is hot from previous steaming or in a boiler in which burner fires have been suddenly extinguished.

BOILER PURGE

The boiler is purged by an airflow through the boiler firesides that continues long enough to clear explosive vapors from the furnace and uptakes. To accomplish this, five volumetric air changes of the boiler furnace, uptake, and smoke pipe associated with each boiler are required. Because of differences in boiler size and equipment, each boiler requires a different purge time. These times have been calculated, together with wind box pressure, as an index of airflow.

Purge times have been issued to all ships. Purge times are printed on metal plates that are installed in clear view of the operator. The proper minimum purge time is listed next to the wind box pressure. Periodically, you should observe the periscope during purge. This is especially important before light off of a hot boiler. By doing this, you can spot white smoke. White smoke indicates there are combustible gases in the firebox that might explode on burner light off.

BOILER LIGHT OFF

Purging and preparing the boiler front for lighting fires should be completed simultaneously. If necessary, continue to purge until boiler front preparations are complete. If fires are not lighted within 5 minutes after completion of the purge, purge the boiler again. The 5-minute period begins when all registers except No. 1 are closed.

Initial burner light off is a two-man procedure—one man operates the burner fuel oil supply manifold valve and the other man inserts the lighting off torch, opens the safety shutoff device/atomizer valve, and operates the air register. The torch man wears fire-retardant engineering coveralls, eye shield, and gloves. When lighting fires, he should stand well clear of the burner air register and the lighting off port to avoid injury in case of a flareback.

If ignition fails to occur within 2 to 3 seconds, you should shut the burner fuel oil supply manifold valve and safety shutoff device/atomizer valve. Make sure the fuel oil manifold recirculating valve remains open. Before making any further attempt to relight the fires, you must determine the reason for the unsuccessful ignition and correct this condition.

Light-off procedures vary from ship to ship. **To have a safe light off on your ship, use your EOSS for every light off.**

RAISING PRESSURE

Do not exceed the boiler firing rate of 5 percent full power until the boiler is on the line unless a higher light off and pressure raising cycle firing rate is authorized. When the boiler is cold, the elapsed time required to bring it to operating pressure is generally 2 1/2 to 3 hours. Lighting off from a steam blanket usually requires 1 1/2 to 2 hours. The boiler heat-up rate should be controlled by regulating the superheater protection steam and fuel oil pressure. Do not secure fires to achieve slower heat-up rates.

PLACING THE BOILER ON THE LINE

To place the boiler on the line, you should take the following steps:

- When the steam drum reaches 50 psi, you should shift the superheater from the low-pressure drain to the high-pressure drain main.
- At 160 psi, open the main and auxiliary steam stop warmup/bypass valve to warm up the steam piping.
- When the drain lines are clear of condensate, shift the main and auxiliary drains from the freshwater drain main/bilge to the high-pressure drain main.
- When the drum pressure reaches 200 psi, blow down the gauge glass.
- When the boiler steamdrum pressure is between 200 and 400 psi, you are ready to bring the boiler on the line.

To bring the boiler on the line, open the boiler auxiliary steam stop valve and shut the boiler auxiliary stop warmup/bypass valve. Then, start the first main feed pump and maintain normal steam drum water level. Next, start the first steam-driven forced-draft blower (FDB). Place it on the line and stop the motor-driven FDB.

NOTE: Make sure the motor-driven FDB air shutters are shut and locked just before stopping the extricable FDB.

Next, you are ready to start placing all reducing stations on the line. Report to the EOOW when the reducers are in operation and the crossover valve is shut. Shift boiler combustion from air atomization to steam atomization. Shift automatic boiler combustion control to remote manual one knob control. When the steam drum pressure is at set point, shift the automatic boiler combustion control from manual one knob control to automatic. Finally, place the remaining required equipment on standby.

PROPULSION BOILER SECURITY PROCEDURES

In an emergency, a boiler can be shut down quickly by tripping the boiler fuel supply quickclosing valve. After tripping this valve, you should shut the burner safety shutoff devices/atomizer valves, crack open the fuel oil manifold recirculating valve, and shut the burner fuel oil and atomizing steam (if applicable) manifold valves. Visually verify that fires are out and shut all air registers.

The general procedures for cutting out and securing an oil-fired boiler when burning distillate fuel are as follows:

1. Blow tubes with steam soot blowers, if practical.
2. Sample, test, and chemically treat the boiler according to *NSTM,* chapter 220, volume 2.
3. Before you secure the last burner on the last boiler on the ship (or in the propulsion group), raise the water level to plus 8 inches.
4. When steam is no longer required, secure the burners using the following procedures:
   a. Shut the burner fuel oil manifold valve.
   b. Open the fuel oil manifold recirculation valve when securing the last burner in the boiler.
   c. Shut the burner atomizing steam manifold valve, if applicable.
   d. Shut the safety shutoff device/atomizer.
   e. Shut the burner air register.
   f. Remove atomizers from the burner.
   g. When the last burner is secured, visually verify that fires are out.
5. When the last boiler in a space is secured, stop the fuel oil service pump according to the EOSS or the applicable technical manual.
6. Remove all atomizers from the registers as soon as possible after the burner is secured. Intense heat from the furnace rapidly carbonizes the oil remaining in tips and may cause the expanding oil to drip down the boiler front. Carbonization injures plugs and sprayer tips, making them difficult to clean.
7. Supply combustion air until all burners are cut out. Then, you may stop the blowers. After shutting off the oil supply, run the blower long enough to make sure that residual fires burn out and that the furnace is clear of all gases.
8. Tightly close the air doors on the boiler front and other openings to the furnace when all atomizers are extinguished and all blowers are secure. This action prevents entry of air into the heated interior, which might cause sudden cooling. Sudden cooling causes serious damage to the hot refractory lining of the furnace.
9. Shut the boiler steam stops.
10. After securing the boilers (except the last boiler), raise the water level to plus 8 inches. Do not secure the feed system while the boiler is still generating steam. Carefully watch the hot well or feed tank level until all boilers being secured have completed this operation. After hard steaming, it may be necessary to occasionally pump additional water into the boiler to maintain the desired water level because the intense heat of brick walls may continue to form steam.
11. Bottom blow the boiler according to the *NSTM,* chapter 220, volume 2.
12. Clean out the oil accumulations in all drip pans. Wipe up floor plates before the watch leaves the fireroom. Clean out any oil accumulations in the bottom of the air casings and drips on the inner fronts of all air-encased boilers.
13. Put on the stack cover when all boilers connecting with that stack have been secured.
14. When boilers have been secured and the space is on cold iron or otherwise not manned, oil should be drained from the torch pots.

FIREROOM CASUALTIES

Most casualties that occur to a boiler will require that the boiler be secured. Therefore, it will require action by engine room personnel. Here are some examples of these actions:

1. Cross-connecting the plant
2. Conserving steam by closing down on the throttle
3. Draining steam lines
4. Splitting out the plant once the boiler is back on the line
5. The EOOW keeping the bridge and unaffected spaces informed of the plant condition.

Boiler casualties that are not handled properly can cause boiler damage, personnel injury, or death. For example, if a boiler has a ruptured tube and you cross-connect the plant before the affected boiler is secured, you would put the steam from the unaffected boiler into the affected boiler. This could cause the loss of the unaffected boiler. It could also cause injury or death to the fire room personnel in the affected space.

Familiarize yourself with the casualties that may occur to the boiler. Know the actions that you may be required to perform in case of a casualty. When a boiler casualty occurs, use procedures in the EOCC.

If you have read this chapter, you should understand the importance of casualty prevention and control. When done properly, it will reduce equipment down time due to casualties. When it is not done properly, it can be unbearably expensive in the cost of equipment, mission, and, perhaps, human life.

CHAPTER 8

ENGINEERING ADMINISTRATION

There are many things to be done to ensure the proper and safe operation of the engineering plant. There are management programs to follow, logs and records to be maintained, reports to be made to higher authority, and operating orders to be carried out.

This chapter discusses some of these programs, logs and records, and operating orders. It also discusses some of the systems and programs that reduce equipment downtime and protect personnel during operation and maintenance.

ENGINE ROOM/FIREROOM LOGS AND RECORDS

Logs should be properly maintained and kept as a record. They can warn you of upcoming equipment problems or help you troubleshoot an existing problem. They can also give you the information you need to make reports to higher authority. There are also legal requirements for certain logs, which will be discussed later in this chapter.

In most cases, each major piece of machinery in the engineering plant will be covered by an operating log. This is a daily log, which runs from midnight to midnight. Readings are normally taken every hour when the equipment is in operation. The log will have a place to record important data about the piece of equipment covered by that log. Some examples are steam pressure, bearing temperatures, oil pressure, and so on. Also, the log will have the minimum and maximum readings allowed for normal operation. These readings give you a quick reference point for detecting abnormal operation. If a reading is below the minimum or above the maximum, circle it in red and take the necessary action to correct the problem. Note in the Remarks section what you did or are doing to correct it. For reasons previously mentioned, you should make sure that you enter the correct reading in the appropriate block on the log. Most operating logs are retained onboard ship for a period of 2 years. After this time they can be destroyed according to part III of the *Disposal of Navy and Marine Corps Records,* SECNAVINST P 5212.5.

LEGAL RECORDS

The Engineering Log, NAVSHIP 3120/2, and the Engineer's Bell Book, NAVSHIPS 3120/1, are legal records of the engineering department. Completed Engineering Log and Engineer's Bell Book sheets are preserved on board as permanent records. They will be given up only in obedience to a demand from a Navy court or board, or from the Navy Department. Sometimes these records or any portions thereof may need to be removed from the ship. If so, a photostatic copy of the material to be removed is prepared for the ship's files and certified as a true copy by the engineer officer. Completed Engineering Log and Bell Book sheets may be destroyed 3 years after the date of the last entries. Current Engineering Log and Bell Book sheets are forwarded to the nearest naval records management center when a ship is stricken from the list of naval ships. Sheets less than 3 years old (at time of inactivation) are retained on board when a ship is placed in an inactive status.

Engineering Log

The Engineering Log is in three parts: NAVSEA 3120/2A, Title Page; NAVSEA 3120/2B, Engineering Log; and NAVSEA 3120/2C, Continuation Sheet. The instructions for filling out these forms are in NAVSEA 3120/2D.

The Engineering Log is a complete daily record, by watches. It covers important events and data pertaining to the engineering department and the operation of the ship's propulsion plant. The log must show the following information:

1. The total engine miles steamed for the day
2. Draft and displacement upon getting underway and anchoring

3. The disposition of the engines, boilers, and principal auxiliaries and any changes in their disposition
4. Any injuries to engineering department personnel
5. Any casualties to engineering department machinery, equipment, or material
6. Such other matters as may be specified by competent authority

Entries in the Engineering Log must be made according to instructions given in (1) 3120/2D; (2) the *Naval Ships' Technical Manual (NSTM),* chapter 090; and (3) directives issued by the type commander (TYCOM). Each entry must be a complete statement 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 engineer officer must ensure compliance with these directives.

NOTE: Do not keep a rough log. Keep the Engineering Log current. Enter each event into the Engineering Log as it happens.

The original Engineering Log, prepared neatly and legibly in ink or pencil, is the legal record. The remarks should be prepared by—and signed by—the engineering officer of the watch (EOOW) (underway) or the engineering duty officer (EDO) (in port). No erasures are permitted in the log. When a correction is necessary, draw a single line through the original entry so that the entry remains legible. The correct entry must be clear and legible. Corrections, additions, or changes are made only by the person required to sign the log for the watch. This person then initials the margin of the page.

The engineer officer verifies the accuracy and completeness of all entries and signs the log daily. The commanding officer approves the log and signs it on the last calendar day of each month and on the date he or she relinquishes command. The log sheets must be submitted to the engineer officer in time to allow him or her to check and sign them before noon of the first day following the date of the log sheet(s). Completed pages of the log, filed in a post-type binder, are numbered consectively. They begin with the first day of each month and run through the last day of the month.

When the commanding officer (or engineer officer) directs a change or addition to the Engineering Log, the person concerned must comply unless he or she believes the proposed change or addition to be incorrect. In that event, the commanding officer (or engineer officer) enters his or her comments and signs the log. After the log has been signed by the commanding officer, it may not be changed without his or her permission or direction.

Engineer's Bell Book

The Engineer's Bell Book, NAVSHIPS 3120/l, is a record of all bells, signals, and other orders received by the throttleman for 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 are usually made by the assistant when the ship is entering or leaving port, or engaging in any maneuver that is likely to involve numerous or rapid speed changes. This procedure allows the throttleman to devote his or her undivided attention to answering the signals.

The Bell Book is mainained in the following manner:

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 that 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 single record.

2. The time of receipt of the order is recorded in column number 1.

3. The order received is recorded in column number 2. Minor speed changes (generally received via revolution indicator) are recorded by entering the number of rpm ordered. Major speed changes (normally received via engine order telegraph) are recorded using the following symbols:

a. l/3—ahead l/3 speed
b. 2/3—ahead 2/3 speed
c. I—ahead standard speed
d. II—ahead full speed
e. III—ahead flank speed
f. Z—Stop
g. B1/3—back l/3 speed
h. B2/3—back 2/3 speed
i. BF—back full speed
j. BEM—back emergency speed

4. The number of revolutions corresponding to the major speed change ordered is entered in column 3. 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 revolutions) at the time of the speed change is recorded in column 4. The shaft revolution counter reading—as

taken hourly on the hour while underway-also is entered in column 4.

Ships and craft equipped with controllable reversible pitch propellers record in column 4 the propeller pitch in feet and fractions of feet 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 helps in 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.

On ships with gas turbine propulsion plants, a bell logger provides an automatic printout each hour. This printout is also provided whenever propeller rpm or pitch is changed by more than 5 percent, when the engine order telegraph is changed, or when the controlling station is shifted. Provision must be made for manual logging of data in the event the bell logger is out of commision (OCC).

Before going off watch, the EOOW signs the Bell Book on the line following the last entry for his or her watch. The next officer of the watch continues the record immediately thereafter. In machinery spaces where an EOOW is not stationed, the bell sheet is signed by the watch supervisor.

NOTE: A common practice is also to have the throttle man sign the Bell Book before it is signed by the EOOW or his or her relief.

The Bell Book is maintained by bridge personnel in ships and craft equipped with controllable reversible pitch propellers and those 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 shows the time that control is shifted. The first entry made in the Bell Book in the engine room shows the time that control is taken by the engine room. Similarly, the last entry made by engine room personnel shows when control is shifted to the bridge. When the Bell Book is maintained by bridge personnel, it is signed by the officer of the 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.

OPERATING ORDERS

There are two important operating orders that are issued by the engineer officer. They are the steaming orders and the night orders.

Steaming Orders

Steaming orders are written orders issued by the engineer officer. They list the major machinery units and readiness requirements of the engineering department based upon the time set for getting the ship underway. 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
6. EOOW and principal watch supervisors

Steaming orders should be posted early to get a ship with a large engineering plant underway with a minimum of confusion.

Engineer Officer's Night Order Book

The engineer officer keeps a Night Order Book, which is preserved as a part of the engineering records. The engineer officer's orders are entered with respect to (1) operation of the engineering plant, (2) any special orders or precautions concerning the speed and operation of the main engines, and (3) all other orders for the night for the EOOW. The Night Order Book is prepared and maintained according to instructions issued by the TYCOM. 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 (mimeographed) form but specify certain contents of the book.

The engineer officer'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), according to 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.

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. Underway, 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 each leading duty petty officer of each engineering division. Each watch supervisor will also read and initial the Night Order Book

EQUIPMENT AND INSTRUMENT TAG-OUT

Whenever you make repairs to piping systems, you will be required to isolate and tag-out that section of the system. The tag-out program provides a procedure to be used when a component, a piece of equipment, a system, or a portion of a system must be isolated because of some abnormal condition. The tag-out program also provides a procedure to be used when an instrument becomes unreliable or is not operating properly. The major difference between equipment tag-out and instrument tag-out is that labels are used for instrument tag-out and tags are used for equipment tag-out.

Tag-out procedures are described in OPNAVINST 3120.32 and represent the minimum requirements for tag-out. These procedures are mandatory and are standardized aboard ships and repair activities. The following definitions are used in the tag-out bill:

1. Authorizing officer—This officer has the authority to sign tags and labels and to cause tags and labels to be issued or cleared. The authorizing officer

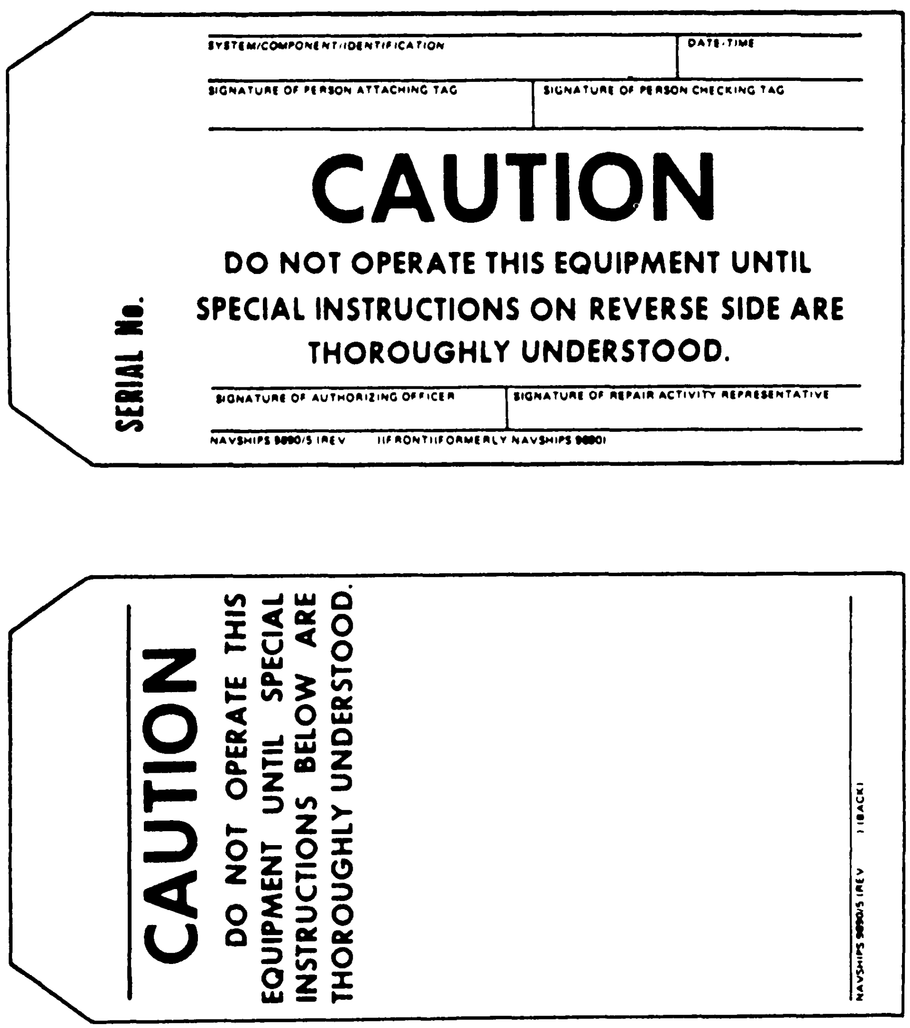

Figure 8-1.—CAUTION tag.

is always the officer responsible for supervising the tag-out log. The commanding officer designates authorizing officers by billet or watch station. The authorizing officer for engineering is normally the EOOW underway and the EDO in port.

2. Department duty officer (DDO) (repair activities only)—This officer is designated as DDO on the approved watch bill or plan for the day.

3. Engineering officer of the watch (EOOW)—This officer may be either the EOOW or the EDO, depending on engineering plant conditions.

4. Officer of the deck (OOD)—This officer may be either the OOD or the ship's duty officer, depending on the ship's condition.

5. CAUTION tag (See fig. 8-1.)—This is a YELLOW tag used as a precautionary measure. It provides temporary special instructions or warns that unusual caution must be used to operate the equipment. These instructions must state exactly why the tag is installed. Use of phrases such as DO NOT OPERATE WITHOUT EOOW PERMISSION is not appropriate. Equipment or systems are not operated without permission from the responsible supervisor. The CAUTION tag may not be used if personnel or equipment can be endangered while working under normal operating procedures. In such cases, a DANGER tag is used.

6. DANGER tag (See fig. 8-2.)—This is a RED tag used to prohibit the operation of equipment that could jeopardize the safety of personnel or endanger

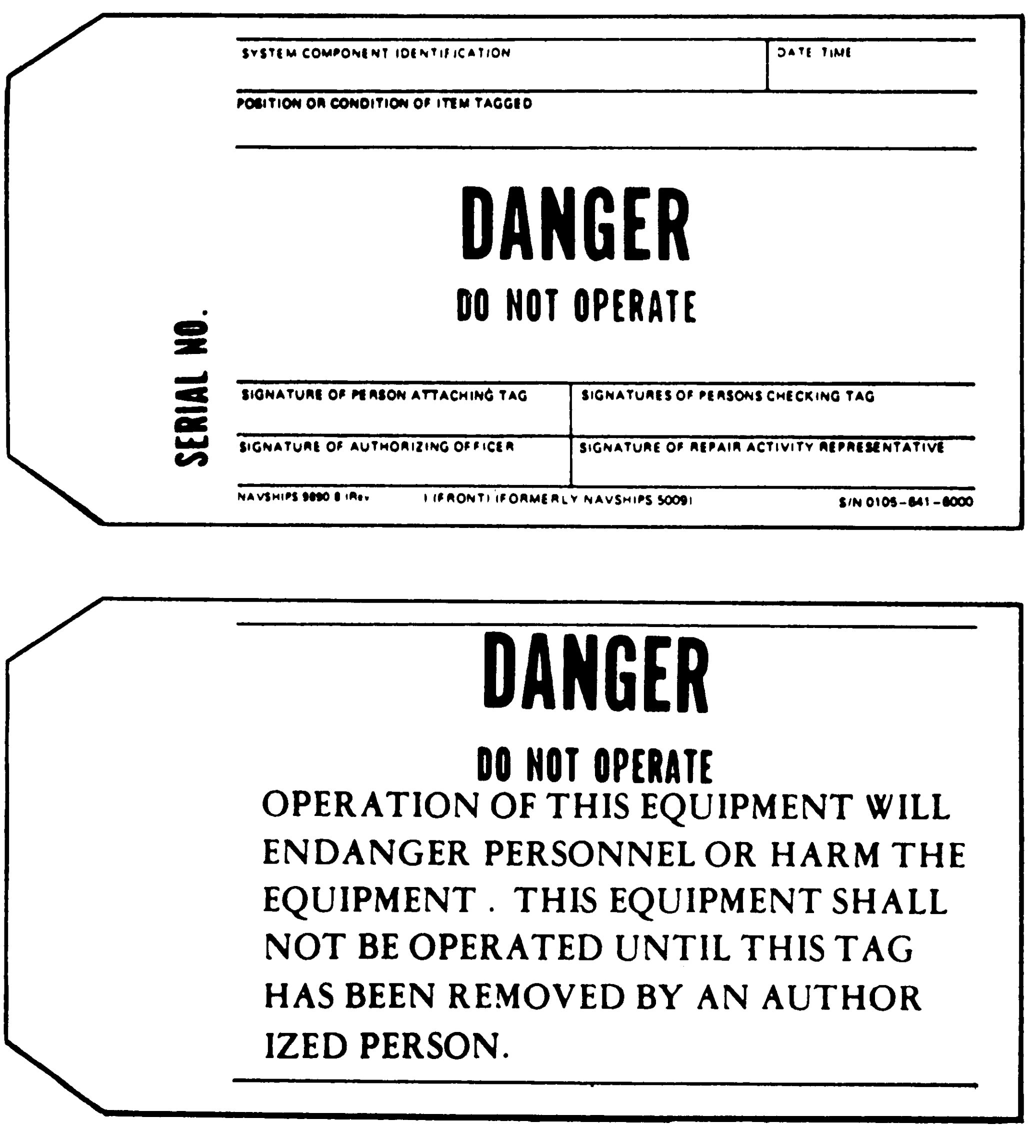

Figure 8-2.—DANGER tag.

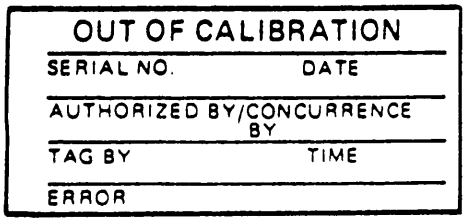

Figure 8-3.—OUT-OF-CALIBRATION label.

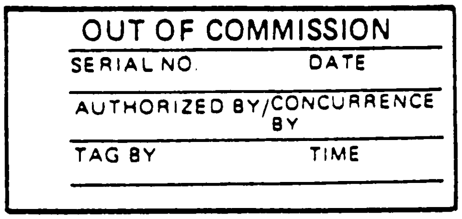

Figure 8-4.—OUT-OF-COMMISSION label.

equipment, systems, or components. Equipment may not be operated or removed when tagged with DANGER tags.

7. OUT-OF-CALIBRATION label (See fig. 8-3.)—This is an ORANGE label used to identify instruments that are out of calibration and do not give accurate readings. These labels warn that the instruments may be used for system operation, but only with extreme caution.

8. OUT-OF-COMMISSION label (See fig. 8-4.)—This is a RED label used to identify instruments that will not give accurate readings because they are either defective or isolated from the system.

9. Repair activity—This is any activity other than the ship's force that is involved in the construction, testing, repair, overhaul, refueling, or maintenance of the ship (intermediate or depot level maintenance activities).

10. Ship's force—These are personnel who are assigned to the ship and are responsible for the maintenance and operation of the ship's systems and equipment. Only qualified personnel are authorized to make a tag-out.

11. Tag-out log—This is the control document used to administer the entire tag-Out procedure.

TAG-OUT LOGS

The number of tag-out logs on a ship depends on the ship's size. For example, a minesweeper may need only one tag-out log; a major surface combatant may need a separate log for each major department. Individual force commanders specify the number of logs needed and their location.

A tag-out is a record of authorization of each effective tag-out action. It includes the following information:

1. A copy of OPNAVINST 3120.32 and any amplifying directives needed to administer the system.

2. The DANGER/CAUTION tag-out index and record of audits (index/audit record). This is a sequential list of all tag-outs issued. It provides a ready reference of existing tag-outs, ensures that serial numbers are sequentially issued, and is useful in conducting audits of the log. A sample of this index is shown in figure 8-5. Index pages with all tag-outs listed as cleared may be removed by the department head.

3. DANGER/CAUTION tag-out record sheets (figs. 8-6A and 8-6B). All tags that have been used in the tag-out of a system are logged on one

DANGER/CAUTION TAG-OUT INDEX AND RECORD OF AUDIT
(INDEX/AUDIT RECORD)

LOG SERIAL	DATE ISSUED	TYPE (DANGER/CAUTION)	DESCRIPTION (SYSTEM, COMPONENT, WORK PERMIT OR TEST DOCUMENT REFERENCE)	DATE CLEARED

Figure 8-5.—DANGER/CAUTION tag-out index and record of audits.

DANGER/CAUTION TAG-OUT RECORD SHEET
NAVSEA 9210/9 (REV 8-81) *(Cont'd on Reverse)*

DATE/TIME TAG-OUT ISSUED

SYSTEM OR COMPONENT

LOG SERIAL NO.

REASON FOR TAG-OUT

PERSONNEL/EQUIPMENT HAZARDS INVOLVED *(Mandatory for danger tags)*

AMPLIFYING INSTRUCTIONS *(Mandatory for caution tags)*

WORK NECESSARY TO CLEAR TAG(S) *(Including tests)*

INDEPENDENT TAG COVERAGE CHECKS MADE BY:

SIGNATURE OF PETTY OFFICER IN CHARGE OF WORK

SIGNATURE OF REPAIR ACTIVITY REP. *(When approp.)*

SIGNATURE OF SECOND PERSON

SIGNATURE OF OFFICER AUTHORIZING TAG(S) *(Watch/Duty Officer)*

OPERATIONS/WORK ITEMS INCLUDED IN TAG-OUT

APPLICABLE DOCUMENTATION (i.e., Job Order, Rip-Out, OIP, etc.) NUMBER & TITLE	ADDITIONAL TAG NUMBERS*	DATE/ TIME* ADDED	PETTY OFFICER IN CHARGE* / SECOND PERSON (Signature)*	AUTHORIZING OFFICER* / REPAIR ACTIVITY REP (When approp.)*	WORK COMPLETE / AUTH OFFICER / REPAIR ACTIVITY REP (When approp.)	DATE

☐ *Check box if continued on add'l sheet.*

**For added work items only. Where not appl. fill in "N/A."*

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Figure 8-6A.—DANGER/CAUTION tag-out record sheet (front).

DANGER/CAUTION TAG OUT RECORD SHEET
NAVSEA 9210/9 (REV 8-81) (BACK)

TAG NO	LOCATION	POSITION/ CONDITION	POSTED BY (Initials)	POSTING CHECKED BY (Initials)	CLEARANCE AUTHORIZED (Signature)		DATE TIME REMOVED	REMOVED BY (Initials)
					AUTHORING OFFICER	REPAIR ACTIVITY		

Tags removed & destroyed. System lineup check(s) completed when required. System or component returned to normal operating condition. (Delete inapplicable portions)	Date/Time	Condition Prescribed By
SIGNATURE OF WATCH OFFICER/DUTY OFFICER		☐ Continued on add'l sheet (Check box if applicable)

Figure 8-6B.—DANGER/CAUTION tag-out record sheet (back).

DANGER/CAUTION tag-out record sheet along with the reason for the tag-out. All effective sheets are kept in one section of the log.

4. Instrument log (fig. 8-7). Those tags used with OUT-OF-CALIBRATION (fig. 8-3) and OUT-OF-COMMISSION (fig. 8-4) instruments are logged in the instrument log.

5. Cleared DANGER/CAUTION tag-out record sheets. The sheets that have been cleared and completed are transferred to this section of the log until they are reviewed and removed by the department head.

TAG-OUT INFORMATION

A tag-out procedure is necessary because of the complexity of modem ships and the cost, delays, and hazards to personnel that can result from the improper operation of equipment. Learn and use the following guidelines:

1. Enforce the tag-out procedures at all times. It is necessary during normal operations as well as during construction, testing, repair, or maintenance.

2. Do not use tags or labels as a substitute for other safety measures. Examples are chaining or locking valves, removing fuses, or racking out circuit breakers. However, you must attach tags to the fuse panel, the racked-out circuit breaker cabinet, or a locked valve to show a need for action. You do not need to use tags where a device will be locked during normal operations.

3. Use tags to show the presence of, and the requirement for, freeze seals, blank flanges, or similar safety devices. When equipment or components are placed out of commission, use the tag-out procedures to control the status of the affected equipment. Examples are disconnecting electrical leads, providing jumpers, or pulling fuses for testing or maintenance.

4. Never use tag-outs to identify valves, to mark leaks, or for any purpose not specified in the tag-out procedure.

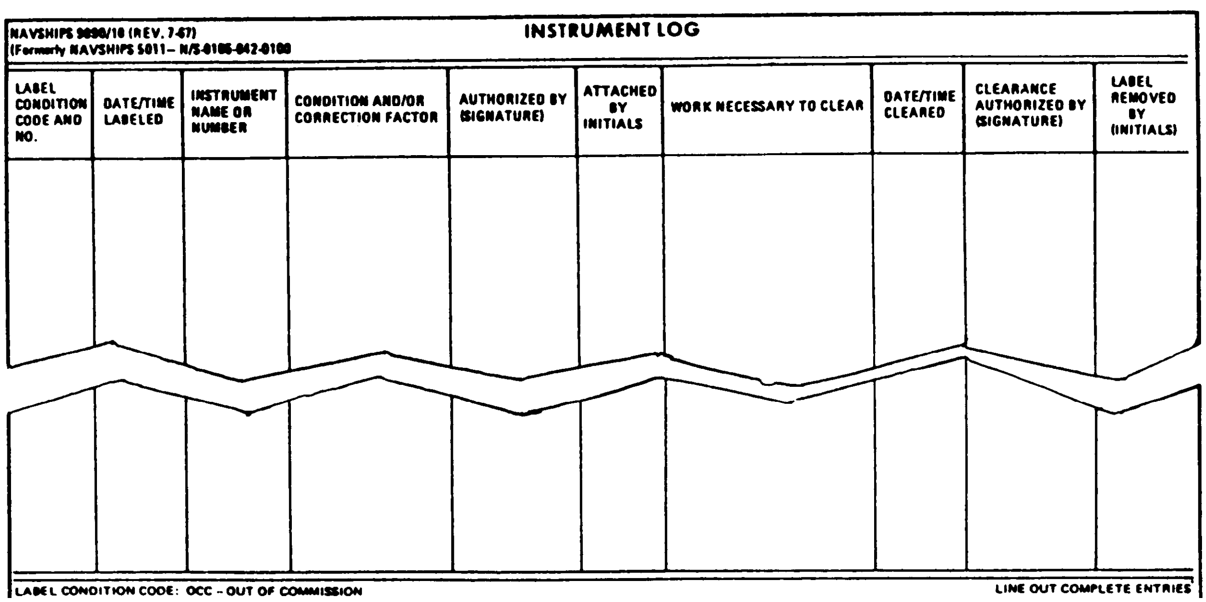
5. Do not laminate tags or labels for reuse. The reuse of tags or labels is not allowed.

6. The absence of a tag or label may not be taken as permission for unauthorized operation of equipment.

7. Whenever a tag or label is issued, correct the situation requiring the tag or label so that it can be removed as soon as possible.

8. The tag-out procedure is for use by the ship's personnel on the equipment and systems for which they are responsible. However, repair activity personnel should use the procedure to the maximum extent practicable with systems and equipment that are still under construction.

9. OPNAV Instruction 3120.32 is also required when work is being done by an intermediate level



NAVSHIPS 9890/10 (REV. 7-67)
(Formerly NAVSHIPS 5011– N/S-0105-842-0100

INSTRUMENT LOG

LABEL CONDITION CODE AND NO.	DATE/TIME LABELED	INSTRUMENT NAME OR NUMBER	CONDITION AND/OR CORRECTION FACTOR	AUTHORIZED BY (SIGNATURE)	ATTACHED BY INITIALS	WORK NECESSARY TO CLEAR	DATE/TIME CLEARED	CLEARANCE AUTHORIZED BY (SIGNATURE)	LABEL REMOVED BY (INITIALS)

LABEL CONDITION CODE: OCC – OUT OF COMMISSION

LINE OUT COMPLETE ENTRIES

Figure 8-7.—Instrument log.

maintenance activity on equipment or systems that are the responsibility of the ship's force. Sometimes a ship is under construction or assigned to a repair activity not under the control of the TYCOM. When that happens, the ship's force and the repair activity may have to agree on the use of tags and labels. In this case, the tag-out system should be formal in nature and familiar to both the repair activity and the ship's force.

10. Any person who knows of a situation requiring tags or labels should request that they be issued and applied.

11. When using labels, you should list on the log any associated requirements specified for installation procedures, test procedures, work permits (rip-out or reentries), or system turnover agreements.

12. Make each decision on a case-by-case basis as to whether an OUT-OF-COMMISSION or an OUT-OF-CALIBRATION instrument label is to be used. In general, if the instrument error is small and consistent, you can use an OUT-OF-CALIBRATION label and the operator may continue to use the instrument. When an OUT-OF-CALIBRATION label is used, mark on the label the magnitude and units of the required correction. However, when you use an OUT-OF-COMMISSION label, the instrument should not be used.

13. Use enough tags to completely isolate a section of piping or circuit being worked on, or to prevent the operation of a system or component from all stations that could exercise control. Use system diagrams or circuit schematics to determine the adequacy of all tag-out actions.

14. Careful planning of tag-outs can significantly reduce the number of record sheets and tags. Planning can also reduce the effort required to perform audits particularly during periods of overhaul or repair. For example, a system and the equipment serviced by the system can be isolated and tagged-out at its boundaries with other systems. Then several different actions can be performed within the boundaries. Also, only one tag-out record sheet with associated tags will be required for the work within the boundaries. When the tag-out is initiated, include all known work items in the Operations/Work Items Included in Tag-out section. When work items are added to a tag-out record sheet after initial issue, take the following action:

a. If no additional tags are required for the new work, the authorizing officer and, if required, the repair activity representative must make sure that the work is consistent with the purpose of the tag-out. New work must be fully described in the Operations/Work Items Included in Tag-out section of the record sheet. The reason for the tag-out, the hazards involved, amplifying instructions, and the work necessary to clear the tags on the record sheet must reflect the added work. The authorizing officer should make a thorough review to ensure the completeness and accuracy of the existing tag-out. This is the same procedure used to initiate a new tag-out record sheet for the added work. The authorizing officer (and repair activity representative) should sign the appropriate blocks next to the added item.

b. Additional tags may be needed to provide enough isolation for work that is to be added. If so, you must follow the procedures described later in this chapter for adding tags to an existing record sheet.

Some work to be added to a tag-out includes work on an already tagged component. In these cases, add additional tags providing isolation for all of the work, including the added work, to the tag-out record sheet. Issue the additional tags and install them before you remove the tag from the components already tagged.

PROCEDURES

Assume that a requirement for tags has been identified, and the affected system will be out of commission as a result of the tag-out action. At that time, the authorizing officer must ask the commanding officer and the responsible department head for permission to begin the tag-out. The authorizing officer must also notify the responsible division officer of the requirement for the tag-out. On ships having damage control central (DCC), the authorizing officer must notify the DCC if the affected system or component will be out of commission. The authorizing officer should have approval from either the OOD or the EOOW if the tag-out will affect systems under their responsibility. After permission has been obtained, the authorizing officer should direct the preparation of the tag-out record sheet and tags. The following procedures should be used. These procedures may be modified during overhaul periods at the discretion of the commanding officer.

1. PREPARATION OF TAGS AND RECORD SHEET. DANGER and CAUTION tags and the associated tag-out record sheet should be prepared as follows:

a. The person designated to prepare the tag-out is normally the ship's force petty officer in charge of the work. This person fills out and signs the record sheet and prepares the tags. Ditto marks, arrows, or similar devices may not be used on the tag-out record sheet.

b. A tag-out record sheet is prepared for a stated purpose. All tags used for that purpose are listed on one record sheet and continued on additional sheets as necessary. The stated purpose may include several work items. Each record sheet is assigned a log serial number in sequence. The index/audit record is used to assign log serial numbers. Log serial numbers are also used to identify all tags associated with a given purpose. Each tag is given its own sequential number as it is entered in the record sheet. For example, tag 7-16 would be the sixteenth tag issued on a single record sheet with the log serial number seven. To differentiate among tag-out logs, a prefix system, approved by the commanding officer, is used with the log serial numbers.

c. The tag-out record sheet includes references to other documents that apply. Some examples are work permits, work procedures, repair directives, reentry control forms, test forms, and rip-out forms. Certain information should be gotten either from reference documents or from the personnel requesting the work Some examples are the reasons for the tag-out, the hazards involved, the amplifying instructions, and the work necessary to clear the tags. This information should be detailed enough to give watch standers a clear understanding of the purpose of, and necessity for, each tag-out action.

d. Use enough tags to completely isolate the system, piping, or circuit being worked on. Be sure you use tags to prevent the operation of a system or component from all the stations that could exercise control. Use system diagrams or circuit schematics to determine the number of tags needed. Indicate the location and position/condition of each tagged item by an easily identifiable means. Some example are MS-1, STBD TG BKR, OPEN, SHUT, BLANK FLANGE INSTALLED.

e. After the tags and the tag-out record sheet have been filled out, have a second person make an independent check of the tag-out coverage and usage. That person should use the appropriate circuit schematics and system diagrams. The second person verifies the completeness of the tag-out action by signing the record sheet.

The authorizing officer then reviews the record sheet and tags for adequacy and accuracy. When satisfied, the officer signs the record sheet and the tags.

(1) If a tag-out is requested by a repair activity, the repair activity representative (shop supervisor or equivalent) must sign the tag-out record sheet. This shows that the repair activity is satisfied with the completeness of the tag-out. Verified tags alert all personnel that the repair activity must approve the removal of the tags.

(2) If the repair activity representative's concurrence is not required, this space on the record sheet need not be filled in.

(3) On ships with DCC, the authorizing officer annotates the tag-out record sheet in the upper right-hand concer with the words *DCC notified,* and then initials it. This ensures that DCC knows the extent of the tag-out and the status of the material condition of the unit.

(4) The authorizing officer then authorizes installation of the tags.

g. The person attaching the tag must make sure the item tagged is in the prescribed position/condition. If not, get permission from the authorizing officer to change an item to the prescribed condition or position. As each tag is attached and the position/condition verified, the person attaching the tag must sign the tag and initial the record sheet.

NOTE: Only qualified ship's force personnel may position equipment and affix tags and labels. Attach the tags so they will be noticed by anyone who wants to operate the component. Do not attach tags to breaker covers or valve caps that may be removed later.

h. After all tags have been attached, a second person must independently verify proper positioning and tag attachment, sign each tag, and initial the record sheet. If repair activity concurrence is required, a repair activity representative must witness a verification, sign the tags, and initial the tag-out record sheet.

NOTE: Only qualified ship's force personnel may perform the second check of tag installation.

i. Sometimes additional tags are required because of added work on an existing tag-out record sheet. In that case, the DANGER and CAUTION tags and tag-out record sheet must be handled as follows:

(1) The person preparing the change to the existing tag-out record sheet must ensure that the purpose of the existing record sheet remains unchanged by the new work and associated tags.

(2) Fill out the tag-out record sheet to reflect the added work Prepare whatever additional tags are required. Review the reason for the tag-out, the hazards involved, the amplifying instructions, and the work necessary to clear tags. Do this on the existing tag-out record sheet to ensure that it reflects the old work and the new work being added to the record sheet. After this review of the record sheet completed, the petty officer in charge of the work signs the first coverage check block next to the added work item.

(3) Number each tag added to the existing tag-out sequentially in the tag series for the original tag-out. Annotate the serial numbers of these tags next to the associated new work item on the record sheet. Enter the updated number of effective tags at the top of the record sheet by crossing through the previous number and adding the new number.

(4) After the new tags and the tag-out record sheet have been filled out and signed by the petty officer in charge of the work, a second review is made. The second person makes an independent check of the tag coverage and usage by referring to appropriate schematics and diagrams. This person signs the record sheet in the block for the new work item to show satisfaction with the completeness of the tag-out actions. This includes both the additional and the previously issued tags.

(5) The authorizing officer and the repair activity representative, when required, review the entire record sheet and new tags for completeness and accuracy. They then sign their respective blocks for the added work item. The authorizing officer then issues the tags.

j. Do not start work until all the DANGER tags required for the protection of personnel or equipment have been attached according to established procedures.

2. REMOVING DANGER AND CAUTION TAGS. Remove these tags immediately after the situation requiring the tag-out has been corrected. As each work item identified on the tag-out record sheet is completed, delete it from the tag-out record sheet. Completed work items listed in the Operations/Work Items Included in tag-out section of the record sheet must be signed off. This is done by the authorizing officer (and repair activity representative, when required) in the designated Signature block. All DANGER tags must be properly cleared and removed before a system or portion of a system can be operationally tested and restored to service. To remove individual tags, the authorizing officer must ensure that the remaining tags provide adequate protection for work, testing, or operations that still remain to be performed. Tags may only be removed following the signed authorization of the authorizing officer. When a tag-out action was initiated by a repair activity, an authorized representative of that repair activity must concur that the job is complete. A shop supervisor or equivalent must sign the tag-out record sheet before the tags may be removed. As the tags are removed, the date/time of removal must be initialed. Ditto marks are not allowed. All tags must be returned immediately to the authorizing officer. This officer then requires a system lineup or a lineup check. Tags that have been removed must be destroyed after they have been delivered to the authorizing officer. All tags associated with one tag-out action must be destroyed and the system or component returned to normal operating (shutdown) condition. The authorizing officer then certifies these actions by entering the date and the time when the system lineup or lineup check was completed. In a case where a system or component restoration was performed according to a specific document, reference to that document is made in the Condition Prescribed By block. Inapplicable portions of the statements on the record sheet are lined out and initialed when a valve lineup check is not required or the system is not returned to a normal condition. The authorizing officer must also enter the date and time cleared on the appropriate line of the tag-out index/audit record. The completed record sheets must be removed from the effective section of the log and placed in the completed section. They will be reviewed and removed by a designated officer. On ships having DCC, the authorizing officer must notify DCC that the tag-out has been cleared. The authorizing officer annotates the completed tag-out record sheet in the lower right-hand comer on the reverse side with the words *DCC notified,* and then initials it.

a. When any component is tagged more than once, the DANGER tag takes precedence over all other tags. All DANGER tags must be removed and cleared according to this procedure before the equipment may be operationally tested or operated.

b. A missing or damaged tag is reissued by indicating on the tag-out record sheet, on the line corresponding to the tag, that the tag was missing or damaged and that a replacement was issued. The new tag is issued using the next number in the tag-out record sheet. The authorizing officer should sign the tag-out record sheet to authorize the clearing of the damaged or missing tags and to authorize their replacement. Concurring repair activity signatures must be obtained as appropriate.

3. LABELS. Labels are issued and removed in a manner similar to that required for tags.

a. The authorizing officer authorizes the use of labels by signing the label and the instrument log. When required for reactor plant systems and reactor plant support systems, the repair activity representative concurs by signing on the label and in the instrument log next to that of the authorizing officer.

b. Second check signatures are not required on the label and the instrument log.

c. When labels like those shown in figures 8-3 and 8-4 are assigned, they must be affixed to the exterior surfaces of the affected instrument. This must be done so that operators can easily determine the instrument's status.

d. A different procedure is used for installed instruments not associated with propulsion plants on nuclear-powered ships and for portable test and radiac equipment. In these cases, the labels shown in figures 8-3 and 8-4 may be replaced by those affixed by a qualified instrument repair or calibration facility.

ENFORCEMENT

Tag-out logs are kept in the spaces designated. Supervisory watch standers must review the logs during watch relief.

A check of outstanding tags/labels and an audit of the tag-out log are conducted as described in the following sections. The authorizing officer ensures that the checks and audits are performed at the required frequency and that the results are reported to the cognizant officer.

1. All outstanding tags listed on each tag-out record sheet are checked as correctly installed. This is done by comparing the information on the tag with the record sheet and the item on which each tag is posted. When a valve or switch position is prescribed, a visual check of the item is made unless a cover, cap, or closure must be removed. Checking the operation of a valve or switch is not authorized as part of a routine tag-out audit. A spot check of installed tags must be conducted to ensure that the tags are effective; that is, that they are covered by an active tag-out record sheet. All discrepancies in actual position must be reported at once to the responsible watch/duty officer before continuing with the tag audit. The date, time, type of discrepancies (including corrective action), and signature of the person conducting the check must be logged on each tag-out record sheet.

2. All outstanding tag-out record sheets are audited against the index/audit record section. As part of the audit, each tag-out record sheet is checked both for completeness and to ensure that the installed tags were checked. The date, discrepancies noted, and the signature of the person conducting the audit must be logged by a line entry in the index/audit record section of the tag-out log.

3. The installation of instrument labels and the auditing of logs are also checked. A line entry is made in the instrument log containing the date, the time, the discrepancies noted, and the signature.

4. Checks and audits of all tag-outs are usually performed every 2 weeks.

5. Results of audits are reported to the responsible department head.

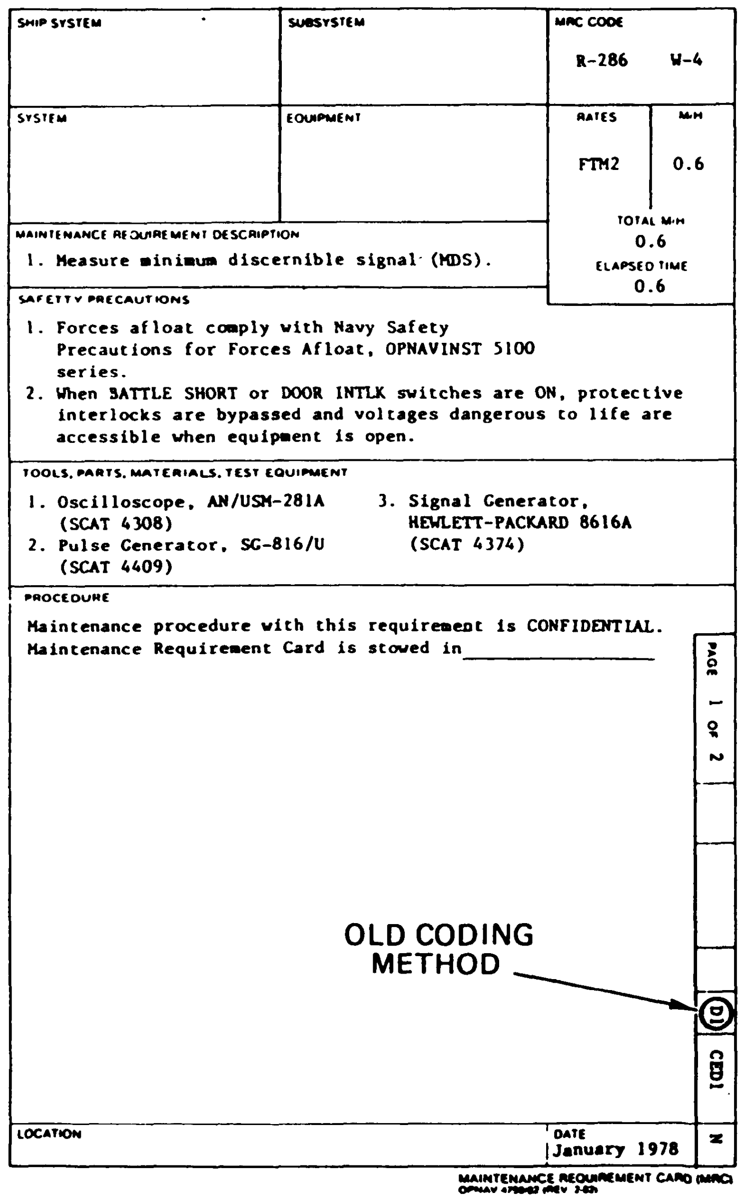
The responsible department head should frequently check the tag-out log, note errors, and bring them to the attention of the persons responsible. This is to ensure that tag-out/label procedures are being enforced properly. Completed tag-out record sheets and instrument logs should be removed after the review.

A violation of any tag-out compromises the entire tag-out system and may have serious consequences. Therefore, strict adherence to the tag-out procedure, without exception, is required of all personnel.

1. Labels must be removed immediately when the affected instrument has been satisfactorily repaired, corrected, replaced, and/or aligned or calibrated.

2. Tags that have been removed must be destroyed.

Remember, always insist on proper tag-out. It helps to prevent accidents, especially if the people involved are paying attention to the conditions stated on the tags.



SHIP SYSTEM | SUBSYSTEM | MRC CODE: R-286 W-4

SYSTEM | EQUIPMENT | RATES: FTM2 | M/H: 0.6

TOTAL M/H: 0.6
ELAPSED TIME: 0.6

MAINTENANCE REQUIREMENT DESCRIPTION

1. Measure minimum discernible signal (MDS).

SAFETY PRECAUTIONS

1. Forces afloat comply with Navy Safety Precautions for Forces Afloat, OPNAVINST 5100 series.
2. When BATTLE SHORT or DOOR INTLK switches are ON, protective interlocks are bypassed and voltages dangerous to life are accessible when equipment is open.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Oscilloscope, AN/USM-281A (SCAT 4308)
2. Pulse Generator, SG-816/U (SCAT 4409)
3. Signal Generator, HEWLETT-PACKARD 8616A (SCAT 4374)

PROCEDURE

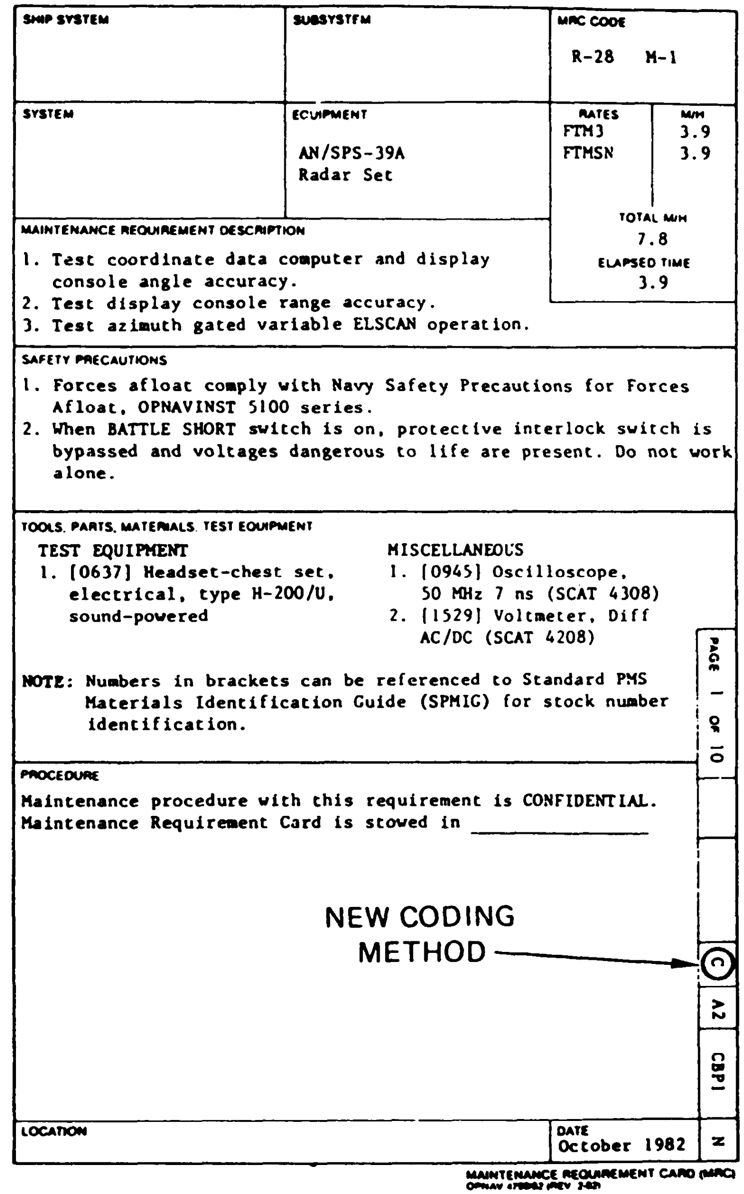
Maintenance procedure with this requirement is CONFIDENTIAL.
Maintenance Requirement Card is stowed in ____________

PAGE 1 OF 2 | D1 | CED1 | N

LOCATION | DATE: January 1978

MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4790/83 (REV 2-82)

Figure 8-8A.—MRC (front).



SHIP SYSTEM | SUBSYSTEM | MRC CODE: R-28 M-1

SYSTEM | EQUIPMENT: AN/SPS-39A Radar Set | RATES: FTM3, FTMSN | M/H: 3.9, 3.9

TOTAL M/H: 7.8
ELAPSED TIME: 3.9

MAINTENANCE REQUIREMENT DESCRIPTION

1. Test coordinate data computer and display console angle accuracy.
2. Test display console range accuracy.
3. Test azimuth gated variable ELSCAN operation.

SAFETY PRECAUTIONS

1. Forces afloat comply with Navy Safety Precautions for Forces Afloat, OPNAVINST 5100 series.
2. When BATTLE SHORT switch is on, protective interlock switch is bypassed and voltages dangerous to life are present. Do not work alone.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

TEST EQUIPMENT
1. [0637] Headset-chest set, electrical, type H-200/U, sound-powered

MISCELLANEOUS
1. [0945] Oscilloscope, 50 MHz 7 ns (SCAT 4308)
2. [1529] Voltmeter, Diff AC/DC (SCAT 4208)

NOTE: Numbers in brackets can be referenced to Standard PMS Materials Identification Guide (SPMIG) for stock number identification.

PROCEDURE

Maintenance procedure with this requirement is CONFIDENTIAL.
Maintenance Requirement Card is stowed in ____________

PAGE 1 OF 10 | C | A2 | CBP1 | N

LOCATION | DATE: October 1982

MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4790/83 (REV 2-82)

Figure 8-8B—MRC (back).

SHIP'S MAINTENANCE

There are basically two types of maintenance aboard ship: preventive and corrective. Corrective maintenance speaks for itself; therefore, we will discuss the preventive maintenance programs. When properly performed, preventive maintenance will minimize corrective maintenance.

SHIPS' MAINTENANCE AND MATERIAL MANAGEMENT (3-M) SYSTEMS

The primary objective of the ship's 3-M systems is to manage maintenance and maintenance support in a manner that will ensure maximum equipment operational readiness. There are basically two systems that make up the 3-M systems. They are the Planned Maintenance System (PMS) and the Maintenance Data System (MDS).

Planned Maintenance System

The PMS provides each user with a simple and standard means of planning maintenance on equipment. It is the most efficient program developed to date to minimize equipment downtime due to unexpected failure.

PMS dictates the minimum required maintenance to keep the equipment in a fully operational condition within specifications. If performed according to schedule, it will help you to identify and replace parts before they fail. PMS is therefore a preventive type of maintenance.

The PMS procedures and the frequency of accomplishment are developed for each piece of equipment. PMS is based on good engineering practice, practical experience, and technical standards. These procedures are written on cards called maintenance requirement cards (MRCs) (figs. 8-8A and 8-8B). MRCs provide the detailed procedures needed to perform preventive maintenance on a given piece of equipment. They will also contain such things as who should do the maintenance (rate and rating), what tools and material will be needed, and the safety precautions to be observed. When there are a number of the same type of items, it would not be practical to schedule each one. Therefore, an equipment guide list (EGL) (fig. 8-9) is used. This is a card to be attached to the MRC. The EGL is filled out by the ship's force. This card will

EQUIPMENT GUIDE LIST
OPNAV 4790/81 (2-76)
S/N 0107-LF-047-9405

PAGE OF

MIP NO. (Less last 2 characters) ______________ MRC PERIODICITY ______________

EQUIPMENT NAME NOMENCLATURE	SERIAL NO. QUANTITY	LOCATION	APPLICABLE DATA AS REQUIRED BY MRC

Figure 8-9.—Equipment guide list.

contain a list of each component by number and the location. If, for any reason, a change is needed to the MRC (except tools), you must submit a feedback report, which will be discussed later in this section.

PMS is a tool of command. The commanding officer uses it to determine whether his or her ship is being properly maintained. Reliability is greatly improved. Preventive maintenance reduces the need for major corrective maintenance, increases economy, and saves the cost of repairs.

Better leadership and management can be realized by reducing frustrating breakdowns and irregular hours of work. PMS offers a means of improving morale and thus enhances the effectiveness of all hands.

The PMS is not self-starting. It will not automatically produce good results; considerable professional guidance is required. Continuous direction at each echelon must be maintained. One individual must be assigned both the authority and the responsibility at each level of the system's operation.

Training in the maintenance steps as well as in the system will be necessary. However, no system is a substitute for the actual technical ability required of the petty officers who direct and perform the upkeep of the equipment.

Feedback Form

The PMS Feedback Report Form, OPNAV Form 4790/7B, is used to report discrepancies and problems, and to request PMS software. All PMS feedback reports are sent to NAVSEACENs or TYCOMs, based on the category of the feedback report.

Feedback reports are originated in the work center and must be signed by the originator. They are then screened and signed by the division officer and the engineer officer before being forwarded to the 3-M coordinator. The 3-M coordinator will date and sign the feedback report, serialize it, and return the green copy to the originating work center. The originating work center must file the green copy until an answer to the feedback report is received.

Maintenance Data System

The MDS is exactly what it implies. The system is used to collect maintenance data and store it for future use. From the MDS comes the current ship's maintenance project (CSMP), the automated work request, pre-INSURV deficiency, and a means for the fleet to report configuration changes to equipment. These are just some of the major uses of the MDS. In the following sections we will discuss two of the reports that make up the MDS. They are the ship's maintenance action form and the CSMP.

SHIP'S MAINTENANCE ACTION FORM.— The Ship's Maintenance Action Form, OPNAV Form 4790/2K, is used by maintenance personnel to report deferred maintenance and completed maintenance (including those previously deferred). This form also allows the entry of screening and planning information for management and control of intermediate maintenance activity (IMA) workloads.

The OPNAV Form 4790/2K is originated in the work center. It is screened by the division officer and engineer officer for accuracy and legibility. It is then initialed by the division officer and engineer officer before being forwarded to the 3-M coordinator. When the form is used to defer maintenance, the 3-M coordinator will send two copies of the form back to the originating work center to hold on file. When the deferred maintenance is completed, one of the copies is used to document the completion of the maintenance.

CURRENT SHIP'S MAINTENANCE PROJECT.—The standard CSMP is a computer-produced report. It lists deferred maintenance and alterations that have been identified through Maintenance Data Collection System (MDCS) reporting. Copies of the CSMP should be received monthly. The engineer officer gets a copy for each of the engineering department work centers. Each work center gets a copy with its own deferred maintenance only.

The purpose of the CSMP is to provide shipboard maintenance managers with a consolidated listing of deferred corrective maintenance so they can manage and control its accomplishment. The work center supervisor is responsible for ensuring the CSMP accurately describes the material condition of his or her work center.

Each month when a new CSMP is received, verified, and updated, the old CSMP may be destroyed.

OPNAVINST 4790.4, volumes I, II, and III, contains complete instructions and procedures for completing and routing all 3-M systems forms.

QUALITY ASSURANCE PROGRAM

The quality assurance (QA) program was established to provide personnel with information and guidance necessary to administer a uniform policy of maintenance and repair of ships and submarines. The

QA program is intended to impact discipline into the repair of equipment, safety of personnel and configuration control, thereby enhancing ship's readiness.

Purpose of QA Manuals

The various QA manuals set forth minimum QA requirements for both the surface fleet and the submarine force. If more stringent requirements are imposed by higher authority, such requirements take precedence. If conflicts exist between the QA manual and previously issued letters and transmittals by the appropriate force commanders, the QA manual takes precedence. Such conflicts should be reported to the appropriate officials.

The instructions contained in the QA manual apply to every ship and activity of the force. Although the requirements are primarily applicable to the repair and maintenance done by the force IMAs, they also apply to maintenance done aboard ship by ship's force. In all cases where specifications cannot be met, a departure-from-specifications request must be completed and reported.

Because of the wide range of ship types and equiqment and the varied resources available for maintenance and repair, the instructions set forth in the QA manual are necessarily general in nature. Each activity must implement a QA program to meet the intent of the QA manual. The goal should be to have all repairs conform to QA specifications.

Program Components

The basic thrust of the QA program is to ensure that you comply with technical specifications during all work on ships of both the surface fleet and submarine force. The key elements of the program are as follows:

1. Administrative. This includes training and qualifying personnel, monitoring and auditing programs, and completing the QA forms and records.

2. Job execution. This includes preparing work procedures, meeting controlled material requirements, requisitioning material, conducting in-process control of fabrication and repairs, testing and recertifying, and documenting any departure from specifications.

A properly functioning QA program points out problem areas to maintenance managers so they can take appropriate action to accomplish the following:

1. Improve the quality, uniformity, and reliability of the total maintenance effort.

2. Improve work environment, tools, and equipment used in the performance of maintenance.

3. Eliminate unnecessary man-hour and dollar expenses.

4. Improve the training, work habits, and procedures of maintenance personnel.

5. Increase the excellence and value of reports and correspondence originated by the maintenance activity.

6. Distribute required technical information more effectively.

7. Establish realistic material and equipment requirements in support of the maintenance effort.

THE QUALITY ASSURANCE ORGANIZATION

The QA program for naval forces is organized into different levels of responsibility. For example, the COMNAVSURFPAC QA program is organized into the following levels of responsibility: type commander, readiness support group/area maintenance coordinator, and the IMAs. The QA program for the Naval Surface Force for the Atlantic Fleet is organized into five levels of responsibility: force commander, audits, squadrons commanders, IMAs, and force ships.

The QA program organization (Navy) begins with the **commander in chief of the fleets,** who provides the basic QA program organization responsibilities and guidelines.

The **type commanders (TYCOMs)** provide instruction, policy, and overall direction for implementation and operation of the force QA program. TYCOMs have a force QA officer assigned to administer the force QA program.

The **commanding officers (COs)** are responsible to the force commander for QA in the maintenance and repair of the ships. The CO is responsible for organizing and implementing a QA program within the ship to carry out the provisions of the TYCOMs QA manual.

The CO ensures that all repair actions performed by ships force conform to provisions of the QA manual as well as other pertinent technical requirements.

The **quality assurance officer (QAO)** is responsible to the commanding officer for the organization, administration, and execution of the ship's QA program according to the QA manual.

The QAO is responsible for coordinating the ship's QA training program, maintaining ship's QA records, and for test and inspection reports. The QAO conducts QA audits as required and follows up on corrective actions to ensure compliance with the QA program.

The **ship quality control inspectors (SQCIs),** usually the work center supervisor and two others from the work center, must have a thorough understanding of the QA program. Some of the other responsibilities an SQCI will have are as follows:

1. Inspect all work for compliance to specifications.

2. Maintain ship records to support the QA program.

3. Ensure that only calibrated equipment is used in acceptance testing and inspection of work.

4. Witness and document all tests.

5. Ensure that all materials or test results that fail to meet specifications are recorded and reported.

LEVELS OF ESSENTIALITY

A number of early failures in certain submarine and surface ship systems are traced to use of the wrong materials. This led to a system for prevention involving levels of essentiality. A level of essentiality is simply a range of controls in two broad categories representing a certain high degree of confidence that procurement specifications have been met. These categories are

1. verification of material, and

2. confirmation of satisfactory completion of test and inspections required by the ordering data.

Levels of essentiality are codes, assigned by the ship according to the QA manual, that indicate the degree to which the ship's system, subsystem, or components are necessary in the performance of the ship's mission. They also indicate the impact that catastrophic failure of the associated part or equipment would have on the ship's mission capability and personnel safety.

LEVELS OF ASSURANCE

Quality assurance is divided into three levels: A, B, or C. Each level reflects certain quality verification requirements of individual fabrication in process or repair items. Here, verification refers to the total of quality of controls, tests and/or inspections. **Level A** assurance provides for the most stringent of restrictive verification techniques. This normally will require both quality controls and test or inspection methods. **Level B** assurance provides for adequate verification techniques. This normally will require limited quality controls and may or may not require tests or inspections. **Level C** assurance provides for minimum or "as necessary" verification techniques. This normally will require very little quality control of tests or inspections.

The QA concept involves preventing the occurrence of defects. Quality assurance covers all events from the start of a maintenance action to its completion and is the responsibility of all maintenance personnel.

By carefully following the methods and procedures outlined in your QA program manuals and by paying careful attention to the quality of work in your area, you will contribute greatly to the operational effectiveness of your ship as well as tended units. For further in-depth knowledge concerning the QA procedures and practices, consult your area *COMNAVSURFLANT/PACINST* QA manual.

MEASURE PROGRAM

All equipment requiring calibration and/or servicing should be maintained at maximum dependability. To meet this need, the Chief of Naval Material implemented the Metrology Automated System for Uniform Recall and Reporting (MEASURE).

As an MM you will be required to read gauges. These gauges must be accurate in order for you to determine if the equipment is operating properly. The gauges must be calibrated periodically to assure their accuracy. The MEASURE program helps you do this. In this section, we will discuss some of the major parts of the MEASURE system.

Meter Card

The meter card (fig. 8-10) is a five-part color-coded form to which the equipment identification and receipt tag is attached. It is filled out by either the customer or the calibrating activity. You will have a meter card for every item aboard ship that requires calibration.

This card is used to record a calibration action, to add or delete items from inventory, to reschedule calibration, to transfer custody, or to record man-hours for a completed calibration.

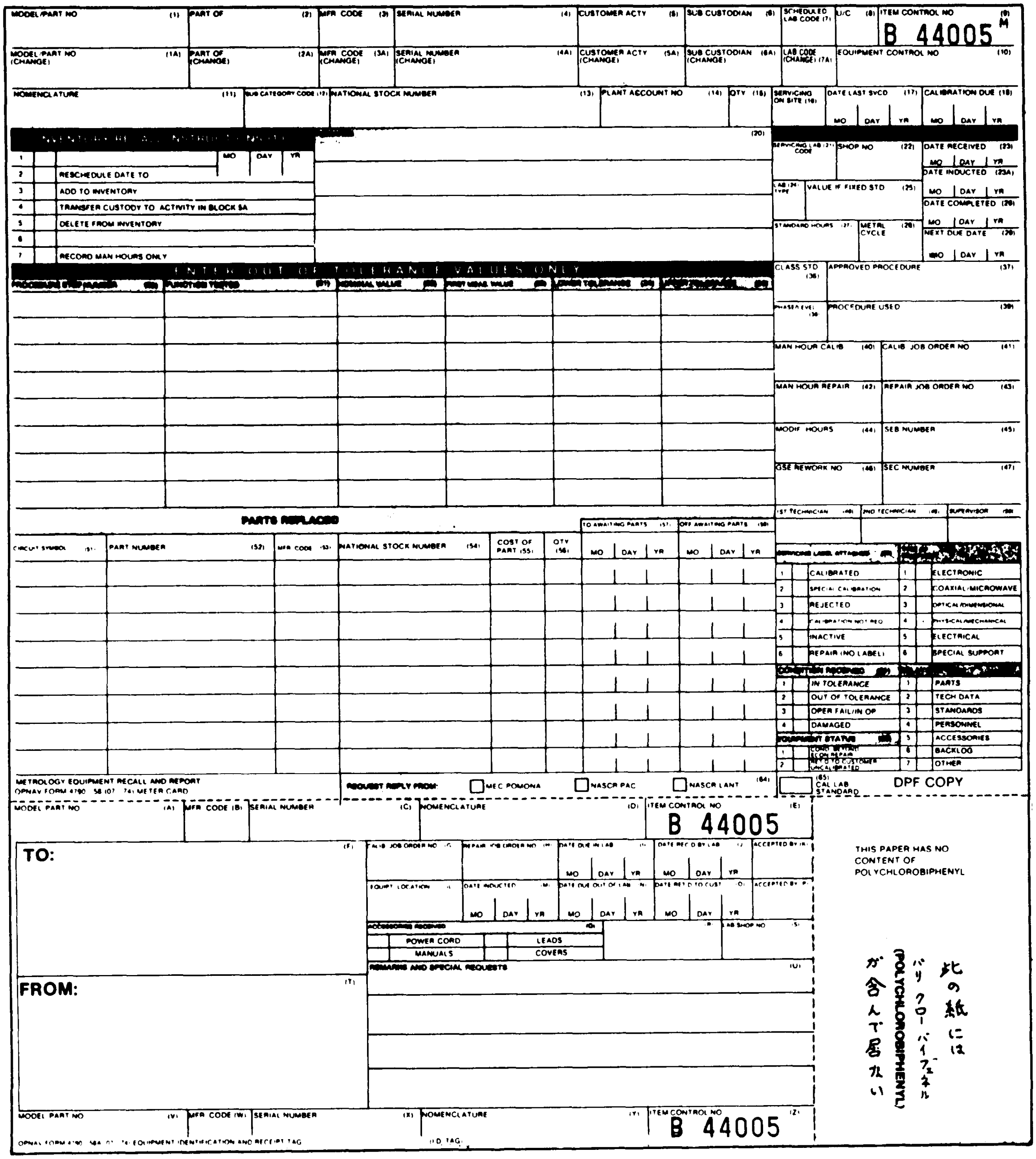


Figure 8-10.—MEASURE meter card.

The white copy of a completed meter card is sent to the Measure Operational Control Center (MOCC), where the information is keypunched into a computer to update the measure data base. The new information is then printed on another meter card and sent back to the customer activity to be used the next time another transaction is to be completed. Accurate data, completeness, and legibility in filling out the meter card is essential. Remember, a computer CANNOT think

Format 310

This format is sent to you every month and is an inventory of all your items, including overdue and delayed items. All additions, deletions, and corrections to this format are submitted to the MOCC on either the meter card or on the add-on-inventory form.

Format 350

This format is also received monthly and is for information purposes. It is prepared in a customer/subcustodian sequence to readily identify all items held on subcustodian basis by other activities. This format is produced concurrently with format 310. Both format 310 and 350 will have the last calibration dates of all items and the due dates of their next calibrations.

Format 802

Format 802 is a recall schedule. It is updated and distributed monthly. It tells you what equipment is due for calibration that month. It is sequenced by customer activity, by subcustodian, and by calibration laboratories.

The MEASURE system is a tool for your use. It is only as good as the information that is put into it. It is important that all the information be legible, accurate, and consistent.

NAVY OCCUPATIONAL SAFETY AND HEALTH PROGRAM

There are two health programs with which you will be directly involved in day-to-day operations in the engine room: heat stress and hearing conservation.

HEAT STRESS

Heat stress is a combination of air temperature, thermal radiation, humidity, air flow, and work load which strains the body as it attempts to regulate body temperature. Unwarranted excessively high heat and humidity in the engineroom are usually caused by the following correctable deficiencies:

- Excessive steam and water leaks.
- Missing, damaged, improperly installed, or deteriorated thermal insulation on steam piping, valves, and machinery.
- Ventilation systems deficiencies such as missing or damaged duct work, misdirected terminals, improper or clogged screens, closed or partially closed "Circle William" dampers, dirty ventilation ducting, and inoperative fan motors and controllers.

As an engineroom watch stander, you can help reduce excessively high temperatures and humidity by the following means:

- Perform corrective or preventative maintenance on piping, valves, pumps, and other components in accordance with proper procedures.
- When you work on a protected system, ensure that you restored thermal insulation to its proper condition to allow only for designed leakage.
- Look for, report, and correct when possible those system deficiencies that cause heat stress.

You can also take the following additional measures to protect yourself against heat stress.

- Ensure that a hanging dry bulb thermometer is permanently mounted to show the correct temperature at the watch station.
- Read and record the temperature at least once each watch period. (Take these readings hourly during space casualties, full power runs, casualty control exercises, during unusually hot and/or humid weather, and when doing hard work)
- Report to the EOOW a dry bulb temperature of 100°F or greater.
- Start WGBT meter monitoring whenever the dry bulb temperature is at least 100°F.
- Know your Physiological Heat Exposure Limit (PHEL), determined from WGBT meter monitoring at your watch station.
- Notify your supervisor if you expect to exceed the PHEL for your watch station.

If you are exposed to heat stress, take the following precautions:

- Eat three adequate, well-balanced meals daily.
- Drink plenty of water (a scuttlebutt must be readily available to you and working properly)—if not, notify your supervisor.
- Do not take salt tablets.
- Do not drink commercially prepared electrolyte supplements in place of water.
- Get at least 6 hours continuous sleep every 24 hours.
- Do not wear starched clothing.
- Wear clean clothing composed of at least 35% cotton (more natural fiber content means more evaporation). Work clothing issued and sold by the Navy meets this criteria.

Be aware of the symptoms of heat injury and take corrective action if you detect these symptoms within yourself or your shipmates. Obtain treatment for heat rash or heat cramps from sick bay. Heat exhaustion (indicated by profuse sweating, headache, tingling sensation in extremities, paleness, nausea, or vomiting) should be reported to supervisors and the individual should receive medical treatment. Heat stroke is a medical emergency; the individual should be cooled by any possible means and medical help should be immediately requested.

HEARING CONSERVATION

The loud, high-pitched noise produced by an operating propulsion plant can cause hearing loss. A hearing loss can seldom be restored. For this reason, ear protection must be worn in all areas where sound level is 84 dB or greater. In these places, warning signs must be posted cautioning about noise hazard that may cause loss of hearing.

Labeling of Hazardous Noise Areas and Equipment

Hazardous noise areas and equipment, which produce sound levels greater than 84 dB(A) or 140 dB peak sound pressure level, must be so designated and appropriately labeled. NAVMED 6260/2, Hazardous Noise Warning Decal, 8″ × 10-1/2″, and NAVMED 6260/2A, Hazardous Noise Labels (displayed on hand tools), 1″ × 1-1/2″, are the approved decals and labels for marking hazardous noise areas or equipment.

Personal Hearing Protective Devices

Hearing protective devices should be worn when entering or working in an area where noise levels are greater than 84 dB(A) sound level or when sound pressure level is 140 dB peak or greater.

A combination of insert-type and circumaural-type hearing protective services (double protection) should be worn in all areas where noise levels exceed 104 dB(A) sound level.

For further information on occupational safety and health programs, refer to OPNAVINST 5100.19, NAVOSH Program Manual for Forces Afloat, or OPNAVINST 5100.23, NAVOSH Program Manual (shore activities).

LUBE-OIL MANAGEMENT

Lube-oil management procedures were developed because of the importance of good quality lubricating oil. If these procedures are properly followed, they will significantly reduce the down time of machinery caused by oil related failures. You should become very familiar with the lube-oil management procedures outlined in *NSTM,* chapter 262.

SAMPLING

Proper oil sampling is very important. An improper sample produces unreliable test results. Thus, the responsibility of taking and preparing samples should be carefully delegated.

Samples should be representative of the oil to be tested. The most representative samples are obtained from an operating system. Standard sample bottles should be thoroughly cleaned, inspected, and flushed with the oil to be sampled, before use. All containers should be capped or closed promptly after the sample is taken to prevent contamination. Label the sample bottle to identify the following:

- Equipment
- Oil type
- Date
- Time

CAUTION

Always check for proper oil levels before and after sampling.

VISUAL OBSERVATION

A visual observation of an oil sample is used to determine the presence of free water and solid particulate matter. The criteria for this observation is a clear and bright appearance of the oil. The term *clear* refers to the absence of solid particulate matter in an oil sample. The term *bright* refers to the absence of visible free water in an oil sample.

TRANSPARENCY TEST

The transparency test is conducted only on auxiliary machinery oil samples that have failed the clear and bright criteria. The transparency test is conducted by placing a clean PMS card behind the sample bottle in a well-lighted area. The PMS card must be held against the sample bottle. You should then attempt to read the printed words on the PMS card through the bottle. If you can read the printed words on the PMS card, the oil sample has passed the transparency test.

BOTTOM SEDIMENT AND WATER TEST

A bottom sediment and water (BS&W) test will be conducted on all oil samples that fail the tranparency test. When an oil sample fails the BS&W test (BS&W greater than 0.01 mL or 0.1 percent), you must secure the machinery and transfer the contaminated oil to the settling tank for renovation. You must then determine the problem and clean the sump if necessary. After you have corrected the problem, replenish the sump with new or renovated oil and resample the system after 30 minutes of operation.

CAUTION

Lube oil contaminated with salt water cannot be renovated.

All test results, cause of contamination, and corrective actions must be annotated in the REMARKS section of the Lube-Oil Log.

For additional information on lube-oil management, refer to *NSTM,* chapter 262.

FUEL OIL MANAGEMENT

Personnel involved in fuel-oil management must have a thorough understanding of fuel-oil characteristics, and receiving, sampling, testing, and record maintenance procedures. Figure 8-11 shows an example of a locally prepared Fuel-Oil Management Log.

FUEL-OIL CHARACTERISTICS

Certain characteristics must be known with respect to each consignment of fuel oil. The most important of these are viscosity, flash point, gravity, and water and sediment content. These characteristics are determined by various tests. Some of the tests are so complicated that they can be performed only in a fully equipped laboratory; others are relatively simple and can be made aboard ship. You should known the purpose of each fuel-oil test and the procedures for performing those tests that are made on your own ship.

Viscosity

Viscosity is the measure of resistance to flow. There are numerous methods by which viscosity is measured. Observations in each case are recorded on an individual scale adapted to suit the instrument. With the majority of instruments, viscosity is stated as the time in seconds required for a given quantity of the sample fuel at a stated temperature to flow through a small orifice. Or, viscosity may be stated as a ratio of the flow time of the fuel sample to the flow time of water or oil (used as a standard at a stated temperature). When recording viscosity as determined by an orifice, the name of the viscometer used must be given, as well as the temperature at which the viscosity was determined. The most accurate method of measuring viscosity is to observe the slow flow of the liquid through capillary tubes.

Fuel viscosity is a primary concern, because it affects the fuel's behavior both when the fuel is pumped from storage tanks and when the fuel reaches the atomizing mechanism of the burners.

Flash Point

Flash point is the lowest temperature at which a liquid gives off sufficient vapor to form a flammable mixture with air above the liquid surface. A fuel will not form a flammable vapor-air mixture by evaporation at temperatures below its flash point temperature but will do so at the flash point temperature and above.

FUEL SAMPLE ANALYSES

DATE	FUEL TYPE	SAMPLE LOCATION	VISUAL	BS&W (%)	API GRAVITY	MK I (P/M)	MK III (MG/l)	FLASHPOINT (°F)	SHORE LABORATORY

OPERATIONAL PROCEDURE CHECK-OFF LIST SUMMARY

DATE	CENTRIFUGAL PURIFIER CLEANING	REPLACEMENT ACTION			TANK INSPECTIONS	
		PREFILTER	COALESCER ELEMENT	SEPARATOR ELEMENT	TYPE	FINDING

DATE	TANK STRIPPING	SERVICE TANK RECIRCULATION	FUEL ROTATION	TANK BALLASTING	FUEL RECEIPT (QUANTITY)

Figure 8-11.—Fuel-Oil Management Log (example).

Flash points are determined by the use of a closed-cup flash point tester on most combatant ships. A minimum flash point 60°C (140°F) is required for F-76 and JP-5 fuel oil.

Gravity

The gravity of a petroleum oil is an index of the weight of a given volume of the material at a temperature of 60°F (15.6°C). There are two scales used with petroleum products, specific gravity and API gravity.

Bottom Sediment and Water

Water and isoluble impurities are often present in heavy fuels. These materials are objectionable because of the danger of possible nozzle blockage and the likelihood of poor fuel combustion.

Although water is slightly soluble in fuels, only water in mechanical suspension in the fuel is of practical interest to the engineer. This suspended water is referred to as FREE WATER. Water and sediment are generally expressed as a single percentage by combined volume. However, it is more accurate to record them separately.

RECEIVING FUEL OIL

When fuel oil is coming aboard, the oil king must keep a constant check on all of the tanks receiving fuel. On large ships in particular, the oil king must follow a systematic procedure. The procedure allows all tanks to be properly filled without unnecessary loss of time. Also, the oil king must make sure that the stability of the ship is not impaired.

Each tank has a sounding rod or a tank capacity indicator. As oil is being received, a person should be assigned to each tank that is receiving fuel. If a sounding rod is being used, the tank should be sounded every 3 or 4 minutes. This is done until the tank is nearly three-fourths full. From this point on, soundings should be made continuously.

Tanks should be filled to the 95 percent level. The final level of oil in any tank should be at the 95 percent mark. Service tanks should never be filled directly from the deck filling connections. They should only be filled by transferring from the storage tanks.

When the last fuel oil tank is being filled, the sending ship is notified to drop the pump pressure or to slow the pump, as appropriate. The amount of fuel oil being received per minute is then determined and the sending ship is given a “stop pump” time.

SAMPLING AND TESTING FUEL OIL

The water and sediment that collects in fuel tanks are major factors contributing to the gradual deterioration of shipboard fuel service pumps, diesel engines, gas turbines, and steam boilers. It is essential that ship fuel tanks be regularly tested for contamination and that they be stripped whenever contamination is detected. Figure 8-12 shows shipboard sampling and testing requirements.

Fuel quality maintenance is an ongoing process, because fuel tanks can be contaminated by rust particles induced by ballasting or moisture drawn in through air vents, leakage of valves and tank seams, condensation on tank surfaces, and the setting of solids and residues picked up during fuel transfer. It cannot be assumed that the BS&W content will remain the same as that determined by the testing during initial dockside or at-sea refueling operations. Fuel quality maintenance procedures must be strictly followed to ensure the continued quality of fuel stowed in shipboard tanks.

RECORDING FUEL OIL SAMPLES AND TEST RESULTS

The Fuel-Oil Management Log (fig. 8-11) is prepared locally. It should have space for entering the results of all shipboard fuel tests. When test results exceed maximum parameters, a notation should be made indicating what action was taken to correct the problem.

The Fuel-Oil Management Log should include the following information:

1. A sequential listing of sample analysis
   a. Visual inspection
   b. Shipboard analysis
   c. Laboratory analysis
2. An operational procedure check-off list
3. Date and time centrifugal purifier was cleaned
4. Prefilter and filter/separator replacement actions

SHIPBOARD SAMPLING AND TESTING REQUIREMENTS

Fuel Source/ Location	Sampling/Testing Frequency	Type of Sample/ Location	Ship Applicability			Test/Procedures See Note 1	Requirements
			Steam Propelled	Gas Turbine	Diesel Propelled		
Shore storage	Each receipt from a commercial supplier Or, every time emergency substitute fuel received	Thief/All levels	X X X	X X X	X X X	Flashpoint/ Pensky-Martens API Gravity/ 60°F (15.6°C) BS&W/Centrifuge	60°C (140°F) Minimum Record 0.1% (Maximum)
Deck Connection(s)	Each refueling (a) At start midpoint, and end	Line/Deck connection	X	X	X	BS&W/Centrifuge	0.1% (Maximum)
	(b) Every15 minutes	Line/Deck connection	X	X	X	Visual/Glass sample bottle	No free water Clear and Bright
Ship storage tanks (not applicable to water compensated tanks. See Note 2).	(a) 24 hours after receiving fuel	Sounding/ Bottom	X	X	X	Water level/Water indicating paste	See Note 7
	(b) Before transfer to service tank	Thief/Bottom Sounding/ Bottom	X	 X	X* X See Note 4	BS&W/Centrifuge Water level/Water indicating paste	0.1% (Maximum) See Note 7
	(c) Weekly	Sounding/ Bottom		X		Water level/Water indicating paste	See Note 7
	(d) Monthly	Sounding/ Bottom	X		X	Water level/Water indicating paste	See Note 7
Ship Service tanks	Prior to use Prior to use	Thief/Bottom Thief/Bottom	X	 X	 X See Note 5	BS&W/Centrifuge	0.1% (Maximum)
Fuel Purifier	Every 30 minutes	Line Purifier discharge		X	X	Visual/Glass sample bottle	Clear and bright
Filter-separator	Every 4 hours	Line-Filter-separator discharge	X See Note 3	 X X	X See Note 6	Visual/Glass sample bottle Free water/AEL MK1 Contaminated fuel/AEK-MK III	Clear and bright 40 ppm (Maximum)** 2.64 mg/L (Maximum)**

*Diesel propelled ships without fuel purifier.

**AEL modified procedure calibration chart readings for F-76 of 5 ppm or less equates to approximately 40 ppm free water; 5 mg/L or less equates to 2.64mg/L sediment.

NOTE 1: JP-5 (F-44) that has been downgraded to F-76 for use in ship propulsion systems shall meet sampling and testing requirements for F-76.

NOTE 2: Ascertain sufficient fuel is available in tank group prior to transfer in order to eliminate the possibility of transfer of compensating water (ballast) to fuel service tanks.

NOTE 3: Applicable only to ship classes FF-1040, FF-1089, and FFG-1. Sample every 15 minutes during transfer operations.

NOTE 4: For MSO-422 Class ships, test with water indicating paste prior to initial transfer. Additional testing (water indication paste) is required only when the storage tank has not been on suction for 24 hours.

NOTE 5: For MSO-442 Class ships, and other ships with small service tanks that shall be filled every 24 hours or less, test by visual inspection.

NOTE 6: For MSO-422 Class ships, test once each time fuel is transferred from the storage tank to the service tank.

NOTE 7: If the water indicating paste test indicates a water level higher then the lowest recorded tank suction level, the tank must be stripped. Stripping must be continued until the BS&W content has fallen below 0.1% by volume.

Figure 8-12.—Shipboard sampling and testing requirements.

5. Tank inspections and findings

Fuel in ship stowage and service tanks must be tested according to the requirement set forth in NSTM, chapter 541.

NOTE: More frequent fuel tank testing is often required during wartime operations (that is, after the ship has been subjected to shock, near misses, depth charge, explosions, direct battle damage, or collision).

CHAPTER 9

STEAM OPERATED DISTILLING PLANTS

Fresh water is needed aboard ship for boiler/steam generator feed, drinking, cooking, bathing, washing, and cleaning. Therefore, a naval ship must be self-sufficient in producing fresh water. Space limitations permit only enough storage tanks for a couple of days' supply. The ship, therefore, depends on distilling plants to produce fresh water of high purity from seawater.

PRINCIPLES OF DISTILLATION

The principle by which distilling plants produce fresh water from seawater is quite simple. There are several different types of distilling plants. Each may appear very complicated at first, but they all work on the same basic principles. When water is boiled, it gives off steam vapor which is relatively free of salt and minerals. The distillation process heats seawater to the boiling point and condenses the vapor (steam) into fresh water. This leaves behind the impurities of the seawater. The process for a shipboard plant is illustrated very simple in figure 9-1. Notice that the seawater after boiling is identified as brine.

Seawater is a solution of water and various minerals and salts. Seawater also contains suspended matter such as vegetable and animal growths and bacteria and other microorganisms. When properly operated, naval distilling plants produce fresh water that contains only slight traces of chemical salts and no biological contaminants.

Distilling plants are not effective, however, in removing volatile gases or liquids which have a lower boiling point than water. These dissolved gases and liquids will simply boil into the vapor and be combined with the fresh water (distillate).

At this point, we need to mention the problem of distilling plant "carryover." Practically all cases of high salinity (salt content) in the distillate (fresh water) output of a distilling unit will be caused by internal seawater leakage (from a tube, basket, and so forth) or by carryover. Carryover actually consists of molecules of seawater. These are not filtered out of the vapor produced in a distilling plant before the vapor is condensed into distillate. All types of distilling plants have some type of device to prevent carryover. They are usually called moisture separators or vapor separators. If the plant is operated improperly, these separators will not function properly. Some seawater will pass through them and show up as high salinity in the distillate. This may occur when you attempt to increase the output of the plant beyond rated capacity.

Salinity, which is caused by chemical salts in seawater, is undesirable. Chemical salts in boiler feedwater will cause corrosion of the tubes. In addition, the normal operating temperature of a naval distilling plant may not be high enough to completely sterilize the distillate. Therefore, any carryover (or leakage) of seawater is a potential health hazard. Many types of microorganisms (primarily coliform bacteria) may be present. For these reasons, restrictions are placed on the operation of distilling plants aboard ships while operating in either contaminated water or fresh water.

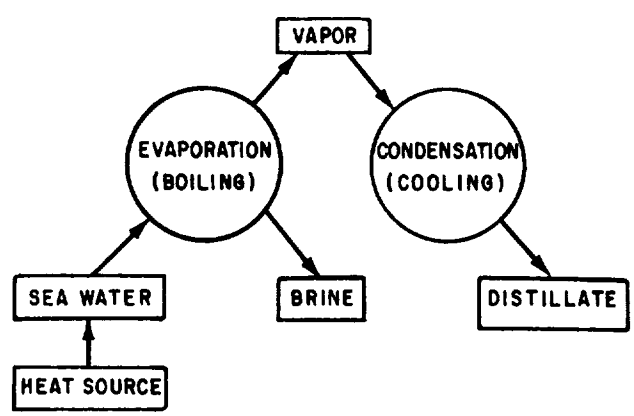


Figure 9-1.—Simplified diagram of shipboard distillation process.

Freshwater carryover may not have enough salinity to be detected by either the operator or the salinity indicating system. Restrictions for operation under these conditions are found in chapter 531 (9580) of the *Naval Ships' Technical Manual.*

There are two reasons why naval distilling plants are designed to operate at low pressures and low boiling temperatures. One is that low temperatures help to prevent the formation of harmful scale. Scale is formed when certain sea salts crystallize out of solution at high temperatures. The other reason is that a low-pressure plant is more efficient. Less heat is required to raise the temperature of the feedwater (seawater) to make it boil; therefore, less heat is wasted by the plant.

COMMON TERMS

Before getting into the discussion on the process of distillation, you should learn the meanings of the terms in the following paragraphs. These terms apply basically to all types of distilling plants now is in naval service. You should not try to read the rest of this chapter until you understand them.

DISTILLATION: The process of boiling seawater and then cooling and condensing the resulting vapor to produce fresh water.

EVAPORATION: The process of boiling seawater to separate it into freshwater vapor and brine. Evaporation is the first half of the process of distillation.

CONDENSATION: The process of cooling the freshwater vapor produced by evaporation to produce usable fresh water. Condensation is the second half of the process of distillation.

FEED: The seawater, which is the raw material of the distilling unit; also called SEAWATER FEED or EVAPORATOR FEED. Be careful how you use these terms. Do not confuse the "feed" (water) for the distilling units with the "feed' (water) for the boilers. Feed for the distilling units is nothing but raw seawater. Feed for the boilers is distilled water of very high purity.

VAPOR: The product of the evaporation of seawater feed.

DISTILLATE: The product resulting from the condensation of the steam (vapor) produced by the evaporation of seawater.

BRINE: As seawater feed is evaporated in the distilling plant, the concentration of chemical salts in the remaining seawater feed becomes greater. Any water in which the concentration of chemical salts is higher than it is in seawater is called brine.

SALINITY: The concentration of chemical salts in water is called salinity and is measured by electrical devices, called salinity cells (discussed later in this chapter), of either equivalents per million (epm) or parts per million ppm).

EFFECT: In a distilling plant, an effect is that part of a unit where a distillation process occurs. For example, the first place where boiling (or evaporation) of feed into vapor occurs is in the first effect. Most distilling plants have two, three, four, or five effects. This means that the feed is boiled more than once within the plant. An effect may also be called a STAGE.

SATURATED STEAM: The properties of saturated steam are defined in table 9-1 according to pressure and temperature.

SUPERHEATED STEAM: Vapor which is not adjacent or next to its liquid source and has been heated to a temperature above its saturation temperature.

DEGREE OF SUPERHEAT: The temperature difference of a superheated vapor between its saturation temperature and its existing temperature.

Let's take an example: The steam pressure past an orifice is 16 in.Hg and auxiliary exhaust steam temperature is 240°F (116°C). Table 9-1 gives the properties of saturated steam. Look in the column "Vacuum Inches of Hg Gage" and find 16.69 and 15.67. By interpolation (estimation), we find the saturation temperature (at the right) to be 176°F(80°C). However, the auxiliary exhaust steam is approximately 240°F (116°C). In this case, then, there is about 64°F (36°C) of superheat in the incoming steam (240°F - 176°F = 64°F).

TYPES OF DISTILLING PLANTS

Naval ships use two general types of distilling plants: the vapor compression type and the low-pressure steam distilling unit. The major differences between the two are the kinds of energy used to operate the units and the pressure under which distillation takes place. Vapor compression units use electrical energy (for heaters and a compressor). Steam distilling units use low-pressure steam from either the auxiliary exhaust sytems or the auxiliary steam system. In addition, vapor compression units boil the feedwater at a pressure slightly above atmospheric while the

Table 9-1.—Properties of Saturated Steam

Absolute Pressure			Temperature	
Lb. per Sq. In.	Inches of Hg	Vacuum Inches of Hg Gage	°C	°F
0.20	0.41	29.51	11.74	53.14
0.25	0.51	29.41	15.17	59.30
0.30	0.61	29.31	18.04	64.47
0.35	0.71	29.21	20.52	68.93
0.40	0.81	29.11	22.70	72.86
0.45	0.92	29.00	24.66	76.38
0.50	1.02	28.90	26.43	79.58
0.60	1.22	28.70	29.56	85.21
0.70	1.43	28.49	32.27	90.08
0.80	1.63	28.29	34.66	94.38
0.90	1.83	28.09	36.80	98.24
1.0	2.04	27.88	38.74	101.74
1.2	2.44	27.48	42.18	107.92
1.4	2.85	27.06	45.14	113.26
1.6	3.26	26.66	47.77	117.99
1.8	3.66	26.26	50.13	122.23
2.0	4.07	25.85	52.27	126.08
2.2	4.48	25.44	54.23	129.62
2.4	4.89	25.03	56.05	132.89
2.6	5.29	24.63	57.74	135.94
2.8	5.70	24.22	59.33	138.79
3.0	6.11	23.81	60.82	141.48
3.5	7.13	22.79	64.21	147.57
4.0	8.14	21.78	67.21	152.97
4.5	9.16	20.76	69.91	157.83
5.0	10.18	19.74	72.36	162.24
5.5	11.20	18.72	74.61	166.30
6.0	12.22	17.70	76.70	170.06
6.5	13.23	16.69	78.64	173.56
7.0	14.25	15.67	80.47	176.85
7.5	15.27	14.65	80.52	176.94
8.0	16.29	13.63	83.81	182.86
8.5	17.31	12.61	85.36	185.64
9.0	18.32	11.60	86.82	188.28
9.5	19.34	10.58	88.22	190.80
10.0	20.36	9.56	89.57	193.21
11.0	22.40	7.52	92.08	197.75
12.0	24.43	5.49	94.42	201.96
13.0	26.47	3.45	96.60	205.88
14.0	28.50	1.42	98.64	209.56

low-pressure steam units depend on a relatively high vacuum for operation.

The low-pressure steam distilling unit is used in all steam-driven and gas turbine-driven surface ships. MMs usually have prime responsibility for the maintenance and operation of the low-pressure plants.

Low-pressure steam distilling units are "low pressure" from two points of view: First, they use low-pressure steam as the source of energy; and second, their operating shell pressure is less than atmospheric pressure.

There are three major types of low-pressure steam distilling units: (1) submerged tube, (2) flash-type, and (3) vertical basket.

SUBMERGED TUBE DISTILLING PLANTS

There are three classifications, or arrangements, of submerged tube distilling plants: (1) two-shell double-effect, (2) double-effect, and (3) triple-effect. The principal difference between the double-effect type and the triple-effect type is the number of stages of evaporation.

In a submerged tube distilling plant, feed floods into the bottom of the unit and surrounds the tubes which contain circulating low-pressure steam. The steam in the tubes causes the surrounding feed to boil and produce steam (vapor). The vapor passes up into the moisture separators where any entrained (drawn in) seawater droplets are removed. The clean vapor then passes on and is condensed into distillate. Submerged tube distilling plants are found on older ships. We will use the double-effect plant as an example of distillation in a submerged tube plant.

As the name implies, the double-effect plant (fig. 9-2) is a double-effect distilling unit contained in a single shell. A division wall separates the two effects. Each effect has a set, or nest, of steam tubes in the bottom of its shell and a vapor separator unit in the upper part of its shell.

Follow along in figure 9-3 (foldout at the end of this chapter) as we trace the feed through several circuits on its way to becoming distillate. You may have to go through this material a few times before you get the “big picture,” but stick with it.

Locate the exhaust steam in figure 9-3 and trace it to the tubes of the first effect via a reducing valve. This steam may be from either the auxiliary exhaust system or the auxiliary steam system. The reducing valve controls the steam pressure going to the orifice located below the reducing valve in the supply to the first-effect tube nest. The orifice controls the quantity of steam to the first-effect tube nest. The output capacity of the plant can be altered by changing the size of the orifice plate. By passing through the orifice, the steam pressure is decreased to a vacuum. This is caused by the throttling (expanding) action of the orifice. Since the temperature of the steam is still at saturation temperature for existing auxiliary exhaust pressure, the steam is now superheated. Therefore, the steam is desuperheated in the inlet line by a spray of water from the tube nest drain pump. The desuperheated steam then passes on through the first-effect tubes. The steam in the tubes is indicated on the figure by the black dashed line. The first-effect tubes can be seen in detail in figure 9-2. The area surrounding the steam tubes is flooded with feed (seawater), indicated by the white area in figure 9-3. The steam gives up its heat to the feed and then condenses in the tubes. The condensate that forms in the tubes is continuously being removed by the tube nest drain pump. A portion of this condensate is used to desuperheat incoming steam, as described earlier; the rest is sent to the freshwater drain collecting tank or the main or auxiliary condenser. A drain regulator controls the discharge of the pump to maintain a water seal in the first-effect tubes. This prevents steam from entering the pump and prevents the steam from “blowing through” the tubes without condensing. As the surrounding feedwater absorbs latent heat from the steam, the steam condenses and the water boils.

Vapor Circuit

Some of the feed surrounding the tubes in the first effect will boil into vapor. The vapor, indicated by the light green area in the first-effect shell, passes up into the first-effect vapor separator via baffles. Located near the surface of the feedwater, these baffles trap some of the entrained moisture from the vapor near the feedwater surface. The vapor separator removes the rest. The vapor separator contains a series of battles or vanes which cause the vapor to change its direction of flow often and rapidly. Centrifugal force (caused by the steam changing directions) forces moisture droplets out of the vapor and onto the sides of the separator where the moisture collects and drains back down into the feed section of the first effect.

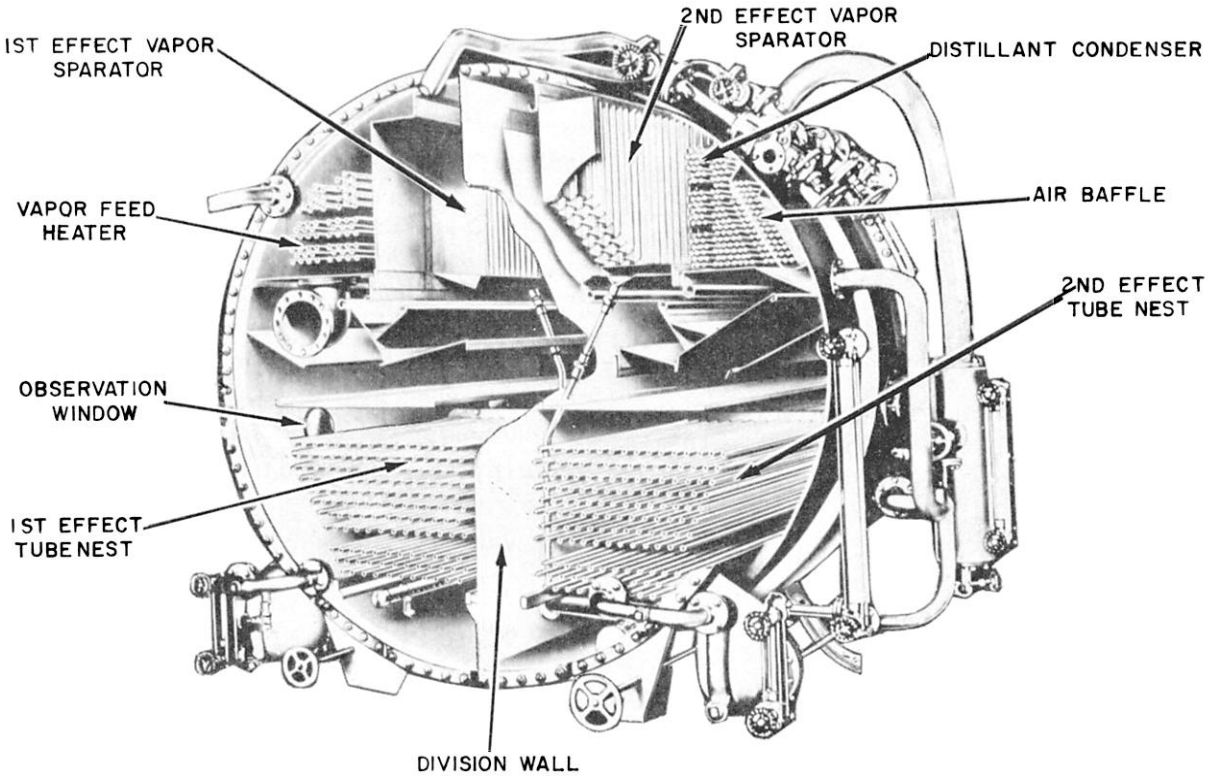


Figure 9-2.—Internal construction of a double-effect distilling plant.

The clean moisture-free vapor passes into the vapor feed heater. The vapor feed heater and vapor separator can also be seen in figure 9-2. In this section, incoming feedwater (flowing through tubes) is preheated by the first-effect vapor (surrounding the tubes). Some of the vapor will condense in this process.

The vapor and condensate leave the vapor feed heater through the line labeled 2ND EFFECT EVAPORATOR STEAM and pass into the tube nest of the second effect. As you can see, vapor from the first effect is used as a heating medium for the second effect. The shell pressure of the second effect is a vacuum of approximately 26 in.Hg. This lower pressure allows the use of the first-effect vapor to heat and boil the feedwater in the second effect. According to table 9-1, at a pressure of 26 in.Hg, the boiling point of water is approximately 125°F (52°C). As it passes through the second-effect tube nest, the vapor from the first effect is condensed.

Vapor produced in the shell of the second effect passes through baffles into the second-effect vapor separator. Then it passes into the distilling condenser. In the distilling condenser, the second-effect vapor condenses into distillate by circulating seawater and evaporator feed. (This also preheats the feed.) Distillate from the distilling condenser leaves via the red line labeled DISTILLATE FROM DISTILLER and is piped into the flash chamber. Distillate in the second-effect tubes (which was first-effect vapor) is also piped, via a drain regulator, into the flash chamber. The drain regulator maintains a water seal between the second-effect tube nest and the shell. The flash chamber has a line (green) labeled FLASH VAPOR TO DISTILLER. This line passes any flash vapors that may form from the hot distillate back to the distilling condenser. The vapors are vented to the condenser and recooled into distillate.

Distillate Circuit

Distillate that collects in the flash chamber is pumped by the distillate pump through a distillate cooler (red line) and to the test tank. From the test tank, the distillate is directed by a valve manifold (not shown) to either the potable water system or reserve feedwater tanks by the freshwater pump. If the water in the test tanks is contaminated with chloride, it can be sent to the bilge.

Seawater and Feed Circuits

Locate the sea chest (blue) at the lower right of figure 9-3 (two pages at the end of this chapter). Seawater is brought in the distilling condenser circulating water pump from the sea chest and strainer. The water is pumped through the distillate cooler into the distilling condenser (blue line) and overboard through a spring-loaded backpressure regulating valve. A back- pressure regulating valve provides a 5 psi backpressure on the circulating water. This valve sets the pressure head required for the evaporator feed (blue-striped line) which is tapped off the circulating water line as it leaves the distilling condenser. The evaporator feed passes through the feed heater section of the distilling condenser, through the tubes of the air ejector condenser, the vapor feed heater, and into the bottom of the shell of the first effect. Leaving the first effect, feed passes through a loop seal and manual regulating valve, into the bottom of the second-effect shell. The direction of flow from the first effect to the second effect is due to the pressure difference between the two effects (1st effect—16 in.Hg, 2nd effect—26 in.Hg).

Brine Circuit

Brine is removed (orange line) from the evaporator by the brine pump. The pump takes suction from the bottom of the second-effect shell and discharges the brine overboard. Gland sealing water for the brine pump is provided by the circulating water system.

Air Ejector Circuit

A two-stage air ejector unit (black-striped line) is located at the top of the plant. The air ejectors remove air and noncondensable gases such as carbon dioxide (CO_2) from the evaporator which helps maintain a high vacuum in the shell of the second effect. Steam discharged from the air ejector is condensed by the evaporator feed. The resulting condensate is returned (yellow line) to the ship's feed system through the freshwater drain collecting system.

The distillation process is similar for all submerged tube plants, whether they are two-shell, double-effect, or triple-effect. As a rule, submerged tube distilling plants are very large compared to other plant types of the same capacity. They have problems with scale formation on the steam tubes. For these reasons, primarily, the submerged tube plants are being phased out for naval use. You may, however, be assigned to a ship with these plants aboard.

FLASH-TYPE DISTILLING PLANTS

The flash-type distilling plant is widely used throughout the Navy. Flash-type plants have some distinct advantages over the submerged tube plant. One is that the flash type "flashes" the feed into vapor (steam) rather than boiling it inside the evaporator shell. The flashing process involves heating the feed before it enters the evaporator shell. The shell is under a relatively high vacuum. The feed is heated to a temperature at which it will flash into vapor when it enters the vacuum. This design has no submerged heat transfer surfaces within the evaporator shell, such as the steam tubes in the submerged tube unit. The elimination of these surfaces greatly reduces the scale formation problem of evaporators and allows prolonged operation at maximum efficiency. Any scale that may form is composed mainly of soft calcium carbonate compounds that are relatively easy to remove.

Two-Stage Flash

Figure 9-4 is an illustration of the major components of the two-stage flash distilling plant. Figure 9-5 (two pages at the end of this chapter) shows the major flowpaths through the two-stage, 12,000 gpd flash distilling plant. Follow along on the diagram during the explanation of the plant which follows.

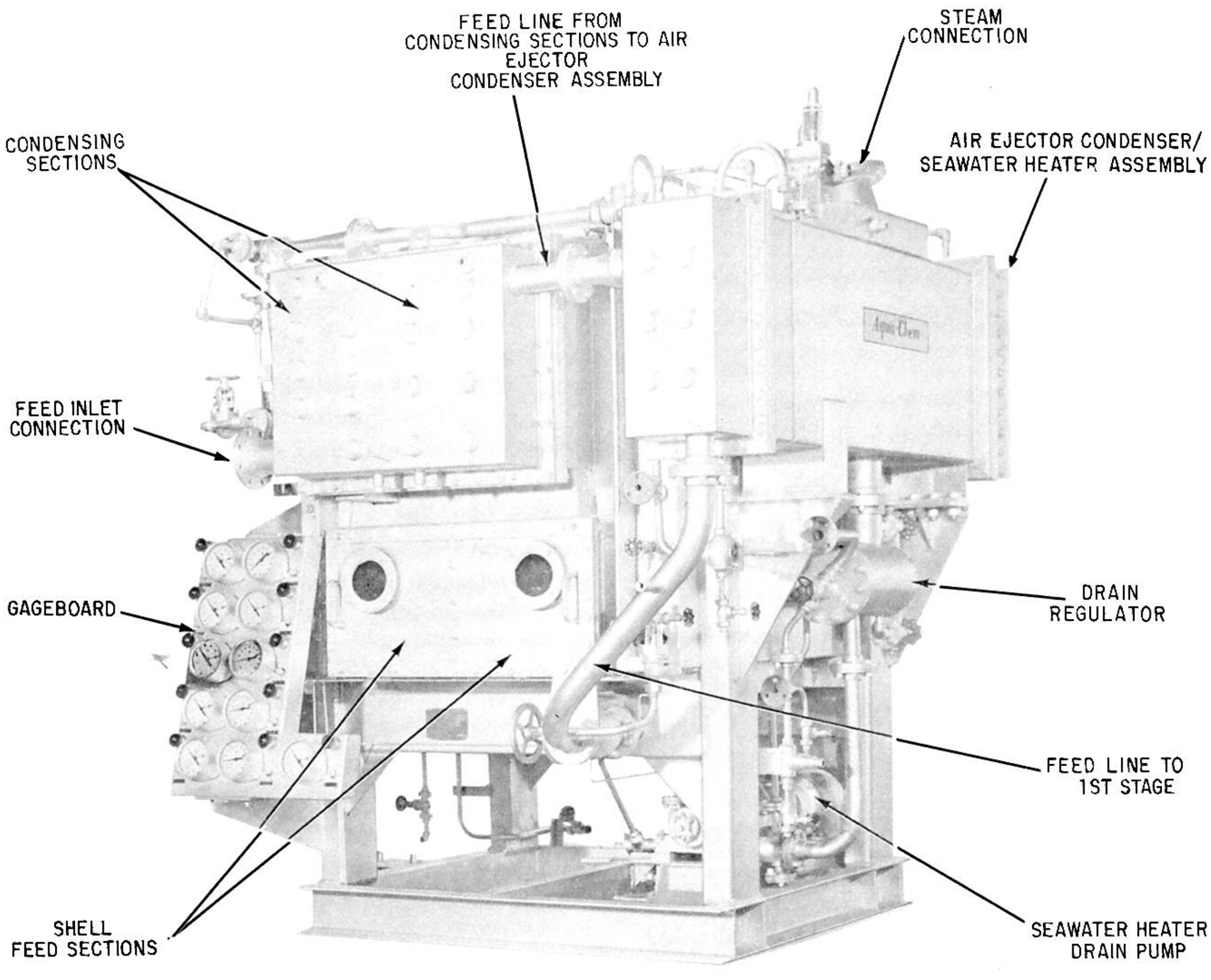


Figure 9-4.—Two-stage, 12,000 gpd flash-type distilling plant.

SEAWATER FEED CIRCUIT.—The seawater feed pump (upper left of fig. 9-5) takes a suction through a sea chest and strainer. It discharges the seawater into the tubes of the condensing section of the second stage of the evaporator. The seawater feed then flows into the tubes of the first-stage condensing section. The condensing section of the evaporator is a shell and tube heat exchanger. It extends the full length of the evaporator shell; that is, through both the first stage and the second stage.

In the condensing sections, the seawater feed condenses the surrounding vapor. As a result of the heat exchanger process, the feed increases in temperature. When the incoming seawater feed has a temperature of 85°F (29°C). the feed leaving the first-stage condensing section of the evaporator should be approximately 138°F (59°C).

Upon leaving the first-stage condensing section, the feed enters the air ejector condenser/seawater heater assembly. In this double-flow shell and tube heat exhanger, the feed picks up heat by condensing steam from the air ejectors and from steam admitted to the seawater heater from the auxiliary exhaust steam system.

The feedwater leaves the air ejector condenser/seawater heater assembly at a temperature of approximately 170°F (77°C). It is then fed to the first stage of the evaporator shell. The feed enters the bottom of the shell through two spray pipes. These pipes partially atomize the water, which aids in flashing the feed into vapor. Feed that does not flash in the first stage goes to the second stage through an internal loop seal located at the bottom of the shell. Water flows to the second stage because it has a higher vacuum than the first stage. The first stage shell pressure is approximately 27 in.Hg, while the second stage is approximately 27 in.Hg. Also assisting is the head due to the higher water level in the first stage which overflows into the second stage. This loop seal method prevents the pressure from equalizing between the stages. The water to the first stage is controlled by a manually operated valve. Feedwater that does not flash in the second stage becomes brine which is pumped overboard.

VAPOR CIRCUIT.—Vapor is formed in the first-stage shell by the hot feedwater (170°F [77°C]) as it enters the shell, which is under a vacuum (23 in.Hg). Saturation temperature for 23 in.Hg is approximately 148°F (64°C). The feed enters the first-stage shell through two spray pipes. These pipes are fitted with deflector plates which cause the feed to spray downward and form a thin, circular curtain of water. This partially atomized curtain of spray results in more complete transformation of the water into vapor steam. The vapor then rises through copper-nickel (Monel) mesh-type demisters (moisture separators) which remove entrained moisture from the vapor. (The moisture removed from the vapor drains back into the bottom [feed] section of the evaporator shell.) The vapor then passes into the condensing section of the evaporator shell where it is condensed into distillate by the cooling action of the incoming feedwater. Vapor produced in the second stage goes through the same process. The shell pressure is lower (27 in.Hg) in the second stage, however, with a subsequent lowered saturation temperature of approximately 115°F (46°C).

DISTILLATE CIRCUIT.—Distillate is formed in the condensing section of both stages of the evaporator. The distillate from the first stage collects in the bottom of the first-stage condensing section in a hotwell-like area (trough). This area is formed by the joint between the evaporator shell division plate and the first-stage collection tray. The distillate passes through a loop seal into a lower trough (or tray) in the second stage. The piping between the two stages contains an orifice plate with a 5/8-inch diameter hole. This orifice controls the flow rate and assists in preventing equalization of pressure between the stage. It also prevents premature flashing of the distillate as it enters the lower pressure area of the second stage.

The distillate is then pumped out of the second-stage distillate trough by the distillate pump. The distillate pump discharges the water through a three-way solenoid-operated trip valve (figure 9-6). This valve, when tripped, will automatically divert the flow of distillate to the bilge if the salinity content reaches a predetermined setpoint (usually 0.065 epm). When the valve is in the reset (normal) position, distillate passing through it goes on through a flowmeter and into an interlock two-valve manifold. This manifold directs the distillate to either the potable water system or the reserve feed system. The manifold is interlocked to prevent opening of both valves at the same time. The potable water system can be contaminated by chloride from a shore water source, which may be suitable for drinking but not for boiler feed. The potable water system and the reserve feed system, therefore, should NEVER be cross-connected in any way.

AIR EJECTOR CIRCUIT.—A two-stage air ejector unit, using auxiliary steam, is located at the top of the distilling plant. It draws vacuum and maintains the vacuum in the evaporator shell. The air ejector second stage discharges into the air ejector condenser seawater heater assembly. The air ejector condenser condenses the steam and vents air and noncondensables (such as CO_2) to the atmosphere. The condensate is formed from the steam. It then drains to either the bilge or the steam drain collecting system through a three-way solenoid-operated trip valve.

BRINE CIRCUIT.—Brine (dark green) is pumped out from the bottom of the second-stage shell. A centrifugal pump is used for this purpose.

HEATING STEAM CIRCUIT.—Auxiliary exhaust steam is used in the seawater heater to provide the heat required to raise the temperature of the seawater feed to approximately 170°F (77°C). The auxiliary exhaust steam entering the seawater heater passes through an orifice which controls the quantity of the steam admitted to the heater. The steam pressure upstream of the orifice is approximately 3 psig.

The seawater heater is vented to the first-stage evaporator through a line with a 1/4-inch orifice. This brings the seawater heater pressure to approximately 9 in.Hg (10 psia). The pressure differential between the auxiliary exhaust steam pressure above the orifice and the seawater heater pressure is critical in providing

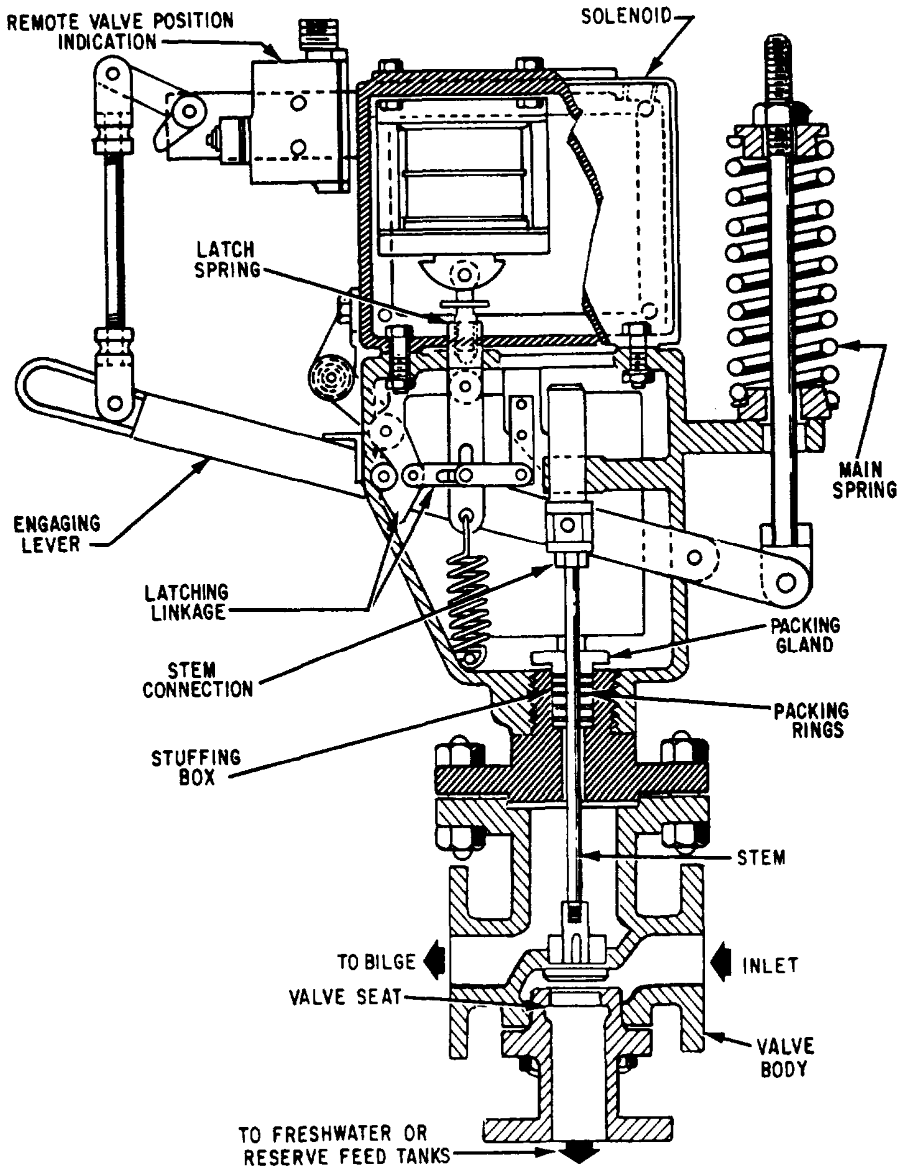


Figure 9-6.—Three-way solenoid trip valve.

proper steam flow to the heater. Improper steam flow will cause the distilling plant output to vary.

Before it enters the seawater heater, the auxiliary exhaust steam is desuperheated by water sprayed into the steam inlet piping. The amount of water is adjusted by an automatic control valve. This valve maintains the steam temperature 5° to 10°F higher than seawater heater shell temperature. This keeps the temperature of the seawater feed relatively constant as it leaves the air ejector condenser/seawater heater assembly.

The water supply for the desuperheating water is a portion of the discharge from the seawater heater drain pump. During plant startup, water from the seawater heater drain pump may not be available. At that time, the ship's condensate system furnishes the water supply. There is a two-valve interlock between the supply from the seawater heater drain pump and the supply from the condensate system. This interlock prevents cross-connecting of these two systems. The interlock is similar to that described for the distillate circuit.

SEAWATER HEATER DRAIN CIRCUIT.—Condensed auxiliary exhaust steam is pumped from the shell of the seawater heater by the seawater drain pump. A drain regulator serves as a hotwell and assures a constant suction head for the pump. The drain regulator is a ball float-operated valve attached below the condensate drain connection of the seawater heater. The ball float in the drain regulator operates the valve. This maintains a relatively constant water level in the housing, which is indicated by a gauge glass. A decrease in water level will tend to close the valve in the drain regulator. Therefore, the amount of condensate discharge by the drain pump will be throttled until the water level in the float housing rises again. The water level in the regulator maintains a suction head for the seawater heater drain pumps. This prevents loss of vacuum in the seawater heater by maintaining a water seal between the heater and the pump.

The drain pump discharges condensate from the seawater heater to the condensate system (startup only), to the steam drain collecting system (normal lineup), or to the bilge.

Other Applications of the Flash-Type Distilling Unit

Flash-type distilling plants may have any number of stages and output capacities. For example, the Navy uses a three-stage, 30,000 gpd plant as well as a five-stage, 50,000 gpd unit. All flash-type plants operate on the same basic principles as those described for the two-stage plant.

Operating Notes for Flash-Type Units

The rate of feed to the first-stage inlet box should be kept constant at all times if the plant is producing its normal capacity or less. Distilling plants operate at a definite number of gallons of feed per minute. The feed rate is indicated by rotameters in the feed line between the distilling condenser circulating water pump and the distillate cooler. All other valves in the feed line should be opened wide. This prevents interference with the proper flow of feed through the plant.

With proper feed flow and a clean plant, the temperature of the feed entering the first-stage feed inlet box will be 175°F (79°C) or less, depending on the temperature of the seawater. Plants operate with a feed temperature of 175°F (79°C) maximum when the temperature of the seawater is 85°F (29°C). When the seawater temperature is lower, the feed temperature will be correspondingly lower.

Do not attempt to control the feedwater temperature after it leaves the feedwater heater and enters the first-stage flash box. The temperature should adjust itself to the varying plant conditions. Full capacity will be realized with proper feed flow, proper vacuums throughout the plant, and proper steam pressure above the orifice.

The feed temperature should never be allowed to exceed 175°F (79°C). Higher operating temperature will greatly increase the amount of scale formation.

The capacity of the flash-type distilling plant depends on (1) the quantity of evaporator feedwater entering the first-stage feed box and (2) the difference in temperature between the feedwater entering the first stage and the vapor in succeeding stages. However, the capacity can be changed only by increasing or decreasing the amount of heat added to the seawater by the feedwater heater.

VERTICAL BASKET DISTILLING PLANT

Single-stage, vertical basket distilling plants have a capacity of approximately 8,000 gpd and are sometimes referred to as the "8K evaporators."

Vertical basket distilling units use 150 psig auxiliary steam, reduced to 20 psi for the heat source. The steam is fed into the basket of the evaporator. The basket is a cylindrical, corrugated shell, located within the bottom of the evaporator shell. The corrugation provides a greater surface area for heat transfer between the basket and the surrounding feedwater. Figure 9-7 shows a top view of the basket. It is completely sealed to prevent the escape of steam into the evaporator shell while operating and to prevent seawater from leaking into the basket when shut down.

Figure 9-8 (two pages at end of this chapter) is a schematic drawing of a single-stage, vertical basket distilling plant, showing the major flowpaths and components. Follow along on the schematic during the discussion of the various flow circuits through the system.

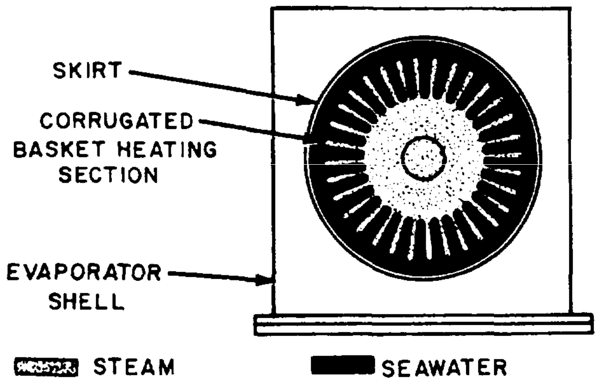


Figure 9-7.—Section view of basket.

Steam Circuit

Steam (yellow) from the 150 psig steam system enters through an isolation valve, a steam strainer, and a solenoid-operated overpressure trip valve. These are located at the lower right corner of figure 9-8. The solenoid-operated trip valve protects the basket from overpressurization. With a steam supply of 150 psig, the basket could be ruptured if pressure downstream of the reducing valve rose unaccountably. The over-pressure trip valve is actuated by a pressure switch located downstream of the reducing valve. The reducing valve reduces the 150 psig steam pressure to 20 psig. The steam then passes through an orifice, which regulates the amount of steam flow into the basket. The steam flows into the corrugated heating section of the basket and gives up its heat to the surrounding feedwater. The condensed steam collects at the bottom of the basket. It then flows back into either the port or starboard main condenser through a float-operated drain regulator, and a three-way, solenoid-operated trip valve.

During normal operation, steam pressure in the evaporator basket should never exceed 15 psig.

Vapor Circuit

Vapors produced by the heating and boiling of the feedwater rise from the corrugated heating section surrounding the basket. This area is enclosed by a skirt (see fig. 9-7). The area between the skirt and the basket is the actual boiling section. Hot water and vapors travel upwards between the skirt and the basket as the feed is heated. The vapor rises above the basket and passes through a corrugated, perforated plate which acts as the first stage of moisture separation. (See fig. 9-8.) The plate traps moisture particles in the vapor and returns them to the brine trough of the plant The trough sends the brine down into the brine gutter via brine downcomers.

The vapor continues to rise and passes through mist eliminators made of copper-nickel mesh. This is the final stage of moisture separation. Any droplets of moisture are screened out of the vapor. They are then returned to the boiling section of the plant. The clean vapor then passes into the distiller condenser where it is condensed into distillate. The mist eliminators and the distiller condenser can be seen better in figure 9-9. Also note the distillate trough section directly below the condenser.

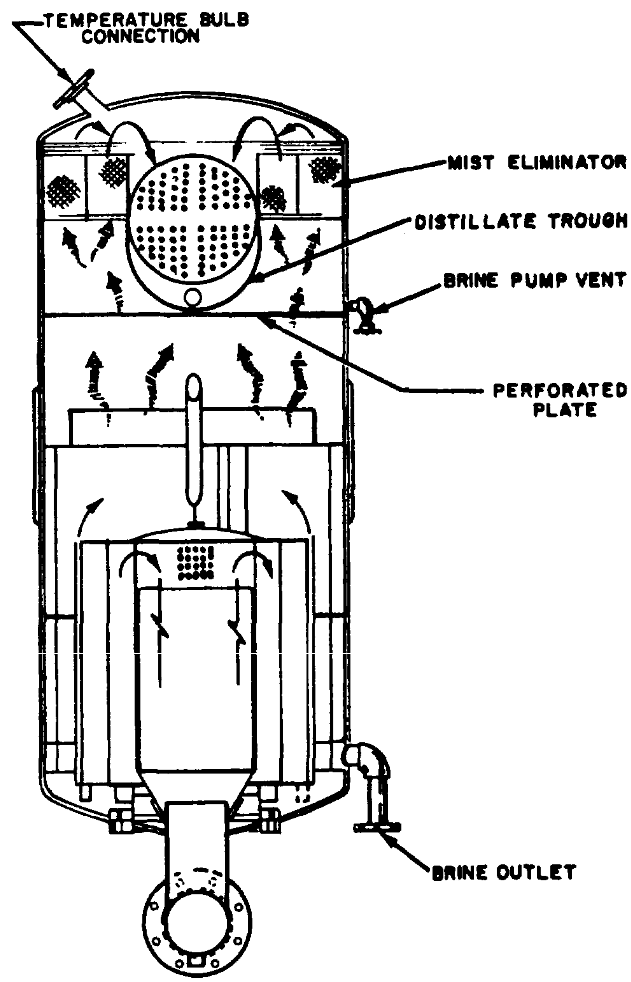


Figure 9-9.—Side view (cutaway) of vertical basket distilling plant.

The shell of the unit is under a vacuum of approximately 18 in.Hg depending on seawater inlet temperature. Boiling will take place at approximately 166°F (74°C) in this vacuum.

Distillate Circuit

Return to figure 9-8. Distillate (dark blue) produced in the distiller condenser collects in the trough. It then flows out of the evaporator shell in the suction of the distillate pump. The distillate pump moves the distillate into the distillate cooler. There a portion of the incoming seawater cools the distillate. Next, the distillate leaves the distillate cooler and passes through a three-way, solenoid-operated trip valve and a flowmeter. After passing the flowmeter, the distillate enters a two-valve interlocked manifold where the distillate can be directed to either the potable water system or the reserve feed and pure water system.

Brine Circuit

Brine (dark green) leaves the bottom of the unit and flows toward the low-pressure (LP) brine pump. When the submarine is on the surface, brine is pumped overboard via the auxiliary seawater (ASW) system by the LP brine pump. When submerged, the brine is first pumped into a brine tank, then pumped overboard via ASW by the high-pressure (HP) brine pump. Additional seawater is added to the brine in the brine tank on a continuous basis to prevent clogging or scaling in downstream piping. This is called brine dilution water. The HP brine pump has a variable speed motor with an automatic level control system. The control system will automatically vary the motor speed as necessary to maintain a constant level in the brine tank. Manual speed control is also provided for the pump for startup, shutdown, or failure of the automatic feature.

Seawater Circulating and Feed Circuit

Seawater (light green) for plant cooling and feed is tapped off the auxiliary seawater system. A portion of the incoming water passes through the tubes of the distillate cooler. The total seawater requirement for the plant is much greater than that required for the distillate cooler. Therefore, a bypass device (shown as an orifice in fig. 9-8) is used to limit the amount of water which flows through the cooler. The bypass device is actually a "backing ring" which changes the inside diameter of the pipe from 2 1/2 inches to 2 inches. This restriction diverts part of the total seawater flow to the distillate cooler which has inlet and outlet connections for 1 1/2-inch pipe.

The seawater flows next into the tubes of the distiller condenser. The amount of seawater flowing through the distiller condenser is controlled by a temperature control valve. This valve opens or closes as necessary to maintain a desired condenser temperature. A temperature monitoring bulb is located at the top of the distiller condenser to control the temperature control valve. The seawater flowing through the temperature control valve goes into the ASW system to overboard.

A portion of the seawater leaving the distiller condenser is tapped off to be used as air ejector condenser cooling water and evaporator feed. The seawater first passes through a reducing valve which reduces and regulates the pressure to approximately 20 psig. Next, the seawater flows through the tubes of the air ejector condenser. There it picks up heat by cooling and condensing air ejector discharge steam. The seawater is now ready for use as evaporator feed. The feed flows out of the air ejector condenser. Then it flows past a manual feed control valve and a feed control orifice, and into the bottom of the evaporator feed section. Flow rate is indicated by a differential gauge connected across the orifice. This two-element gauge contains two Bourdon tubes but has only one pointer. It is connected to sense the pressure difference across the orifice plate, that is, the difference between inlet pressure (7 to 9 psig) and outlet pressure (a vacuum of 18 in.Hg during normal operation of the unit). The gauge is calibrated to indicate pressure that is equivalent to the flow rate of seawater passing through the orifce. The operator can check the differential pressure on the gauge against a flow chart and determine the flow rate of the feed in gallons per minute. In this way, the operator can properly adjust the feed rate into the evaporator.

A bypass in the feed line bypasses some of the feed directly into the brine outlet of the evaporator. This bypass can be used during startup or shutdown and cool down of the evaporator to maintain level in the feed section while still providing adequate cooling water flow through the air ejector condenser.

Air Ejector Circuit

A single-stage air ejector establishes and assists in maintaining a vacuum in the evaporator shell. The air ejector is supplied with 150 psig steam from just upstream of the evaporator basket's steam supply first isolation valve. The air ejector takes a suction from the top of the distiller condenser and discharges into the air ejector condenser. Steam is condensed in the air ejector condenser. The air and noncondensables are vented to the atmosphere. The condensate produced in the air ejector condenser is directed to a drain pan located on top of the brine tank or the bilge. This condensate is not returned to the feed system.

DISTILLING PLANT OPERATION AND MAINTENANCE

You have seen that the distillate must meet specific standards of chloride content. To ensure that those standards are met, the distillate must be monitored continuously by the salinity indicator and chemically tested periodically.

The results of distillate tests for chloride are expressed in terms of either equivalents per million (epm) or parts per million ppm).

Parts per million is a weight-per-weight unit denoting the number of parts of a specified substance in a million parts of water. For example, 58.5 pounds of salt in 1,000,000 pounds of water represents a concentration of 58.5 ppm. Note also that 58.5 ounces of salt dissolved in 1,000,000 ounces of water or 58.5 tons of salt dissolved in 1,000,000 tons of water represents the same concentration—58.5 ppm.

Equivalents per million can be defined as the number of equivalent parts of a substance per million parts of water. (The word "equivalent" refers to the chemical equivalent weight of a substance.) The chemical equivalent weight is different for each element or compound. The chemical equivalent weight of sodium chloride (common table salt) is 58.5. A solution containing 58.5 ppm of this salt is said to contain 1 epm. If a substance has a chemical equivalent weight of 35.5, a solution of that substance containing 35.5 ppm is described as having a concentration of 1 epm.

SALINITY MONITORING

The salinity of distillate is monitored continuously by an electrical salinity monitoring system. A salinity cell (fig. 9-10) is placed in the distillate line in constant contact with the distillate flowing out of the

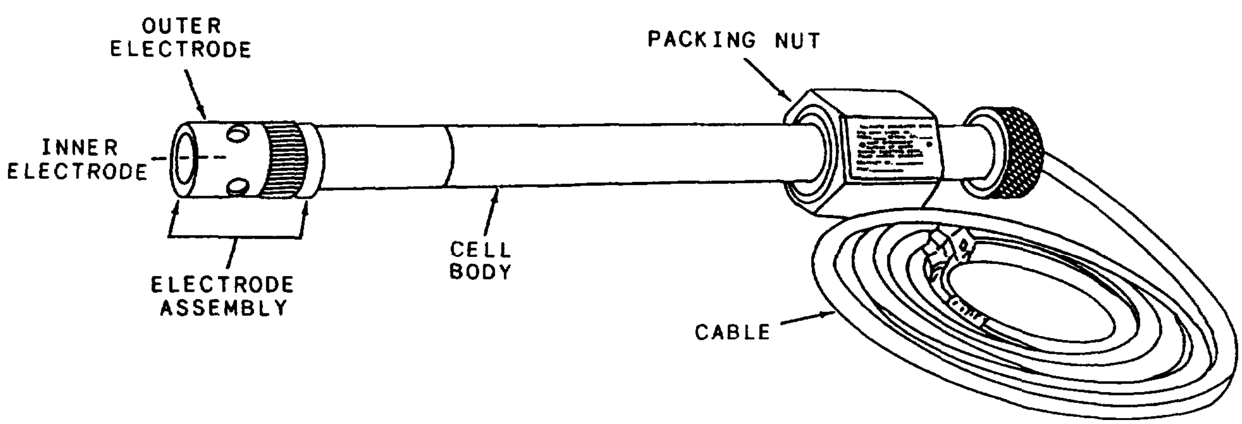


Figure 9-10.—Salinity indicator cell

evaporator. The details of salinity cell installation into the line are shown in figure 9-11.

A salinity cell actually measures the ability of water to conduct electrical current (conductivity). The higher the concentration of chemical impurities in the water, the higher the conductivity of the water. This measurement is read out on a salinity monitoring panel which may be of the type shown in figure 9-12. The electrical reading from the cell is converted to either epm or ppm chloride on the meter face. The chloride reading is based on the assumption that all of the impurities in the distillate are from seawater; however, a salinity cell cannot differentiate between seawater or any other impurity. For this reason, the salinity cell readings are checked frequently by a chemical test for chloride. You must always believe a high salinity cell reading (such as an alarm or tripped valve situation) until it is proven absolutely false. Some older salinity indicator panels have scales calibrated in grains per gallon (gpg) of sea salt. To convert a reading of gpg to epm, multiply the gpg reading by 0.261.

In practically all cases, the measurement made by the distillate salinity cell will also operate the trip function of a three-way, solenoid-operated trip valve (fig. 9-6). If the salinity of the distillate reaches a preset value (0.5 ppm for some ships, 0.065 epm for others), the solenoid in the valve will de-energize. This will allow spring pressure to disengerize the latching linkage from the engaging lever, and the valve stem

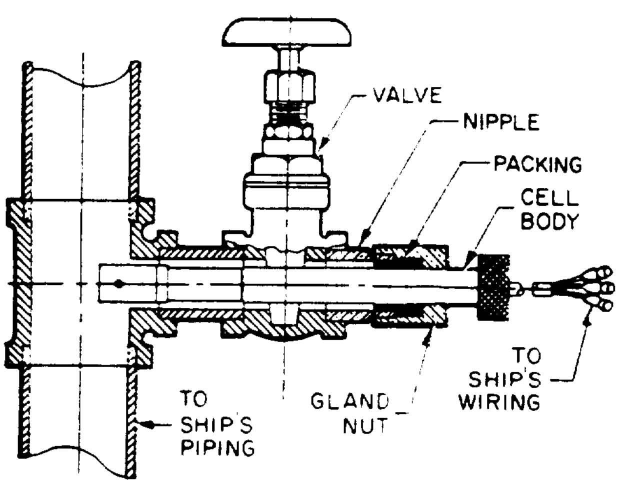


Figure 9-11.—Salinity cell installation.

assembly will drop due to main spring pressure. When the stem assembly drops, the valve seat shuts off the water path of distillate to the freshwater tanks or reserve feed system and opens a path to the bilge or suitable dirty drain system. This type of three-way valve is also used on the air ejector condenser drains of many distilling plants. These valves have locking pins which can be used to lock the main valve engaging lever in the reset position. The locking pins should NEVER be used without the specific permission of the engineering officer. Contaminated water can be put into clean tanks and systems at an excessive rate if these pins are used to prevent the trip valves from tripping.

Salinity cells are normally installed in other places in the evaporator system to monitor the salinity levels. Two examples are (1) the seawater heater drain pump discharge and (2) the loop seal between the first and second stages of the two-stage, flash-type distilling plant described earlier in the chapter. Cells installed in these places have a meter readout and an alarm, but do not actuate trip valves.

The temperature of the water affects the reading of the salinity cell. The higher the temperature of the water, the higher its conductivity. Salinity cells are designed to automatically compensate for changes in water temperature.

CHEMICAL TEST FOR CHLORIDES

The importance of keeping chloride contamination out of the reserve feed tanks cannot be overemphasized. As mentioned earlier in this chapter, serious damage can occur to boilers and steam generators if chlorides are not kept to an absolute minimum in the feed and condensate systems. High chloride concentration in boiler feedwater or condensate indicates that seawater has gotten into the system some place, which means other impurities are present as well. The process of boiling in boilers and steam generators causes large buildups of chlorides, as well as other impurities. This happens even with very small concentrations in the feed system.

One source of chloride contamination may be seawater leaks in the main and auxiliary condensers. Another major source is a faulty or improperly operated distilling plant

In our discussion of salinity and the salinity monitoring system, we described one method of preventing contamination by the evaporators. In that situation, salinity cells were used to continuously monitor the salinity content of water in piping systems

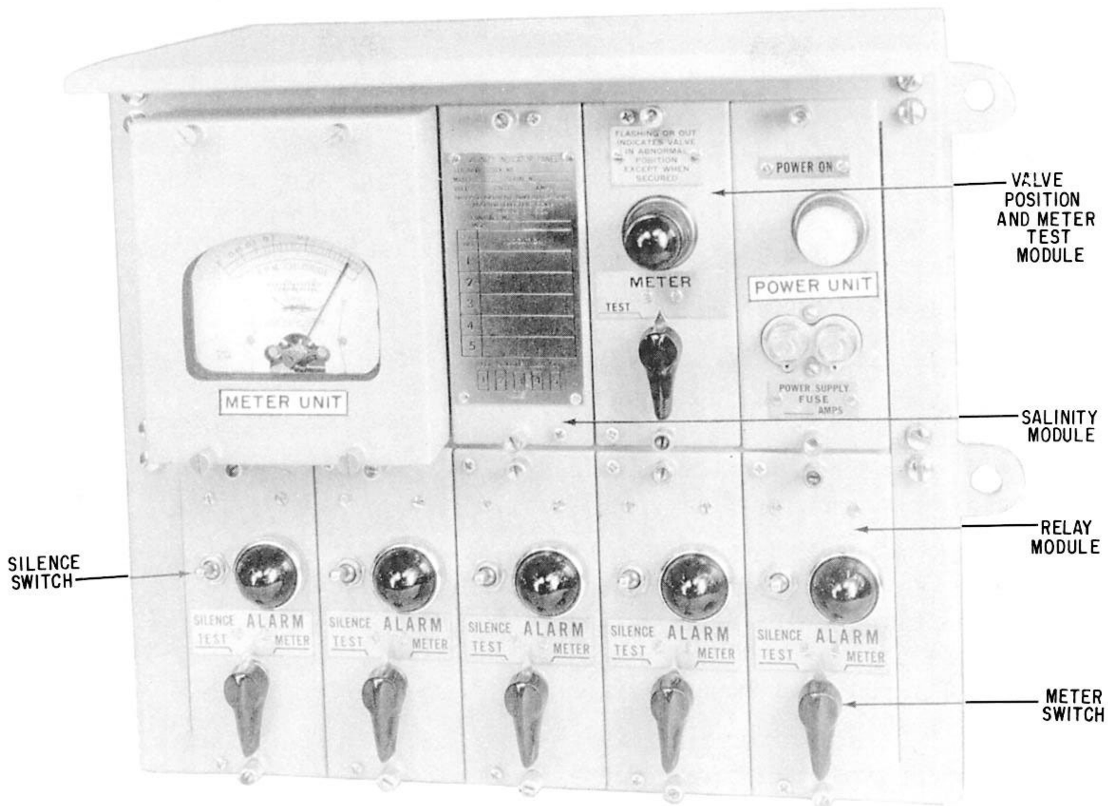


Figure 9-12.—Salinity indicator panel.

connected to the evaporator and to set alarms and tripping valves if the salinity concentration rose above a setpoint. Another method is to chemically test water for chloride concentration. The chemical tests may be performed at some interval dictated by specific operating procedures. One chemical analysis is used to determine the actual chloride concentration in a sample of water by titration. When performed properly, the titration method is extremely accurate. This test can be used on distillate, air ejector drains, main condensate, or any other water that is not greatly discolored. (Even discolored water can be used if it is filtered.)

Additional specific information on water and water testing can be found in chapter 220, volume II, of the *Naval Ships' Technical Manual.*

BRINE DENSITY

Not all of the seawater feed which is fed into an evaporator is changed into distillate. That portion of the feed which does not become distillate is called brine. The concentration of sea salts in this water is called brine density. It has a direct bearing on the quality of the distillate produced by the evaporator. A low brine density indicates that not enough of the feedwater is being converted to distillate. It means poor efficiency in the plant which results in a reduced output capacity.

A high brine density indicates that too much of the feedwater is being converted into distillate. Operation with a high brine density causes excessive scale on heat transfer surfaces. This causes poor quality distillate due to excessive vapor formation. There is possible carryover and reduced efficiency due to the loss of heat energy carried over with the brine.

The ideal value of brine density is just under 1.5 thirty-seconds. The density should never exceed this level. Since the average seawater contains approximately 1 part of dissolved sea salt to 32 parts of water (l/32 by weight), the brine density should be just under 1 1/2 times the density of average seawater, or 1.5/32.

Brine density is measured with a salinometer, which works on the same principle as a hydrometer. The float, or hydrometer, is a hollow metal shell attached to a square stem, weighted with shot at one end. Each side of the stem is graduated in thirty-seconds, from 0/32 to 5/32, and calibrated for four different temperatures: 110°, 115°, 120° and 125°F.

Figure 9-13 shows a salinometer and a brine sampling pot. A brine sample is drained into the pot from a test valve and the temperature is measured. The temperature must be adjusted to correspond with one of the temperature scales on the salinometer to accurately measure the density. The salinometer is then placed in the pot, weighted end down, and allowed to float in the brine. The brine density is read where the brine water level crosses the scale on the side of the graduated stem which corresponds to the brine temperature.

Salinometers should be checked monthly by measuring the density of distilled water. A sample at the proper temperature can be obtained by bypassing the distillate cooler, or a sample of the distillate may be heated. The reading of the pure water should always be zero.

Different evaporator types will have different methods for adjusting the brine density. Follow the instructions and procedures in the EOSS for your plant and ship.

HEAT EXCHANGER SURFACES

Scale deposits on heat transfer surfaces will not appreciably reduce the output of a low-pressure submerged tube distilling plant until the deposits have caused the vacuum in the first-effect tube nest to be reduced to 1 or 2 inches of mercury. When the first-effect tube nest vacuum is lost entirely, the reduction in plant output becomes very great. The reduction in vacuum is due to scale, and is not the result of improper operating conditions. If so, the evaporator tubes must be cleaned when the tube nest vacuum approaches zero.

When the plant is properly operated and the evaporation feed is treated, the interval between cleanings should be 6 months or more.

Salt water flows inside the tubes of the distilling condenser, air ejector condenser, and vapor feed heaters. Under some operating conditions, scale deposits may accumulate inside these tubes. This may happen particularly in the air ejector condenser and the first-effect feed heater. Every 6 months, or whenever the plant is secured to descale the evaporator tubes, the inside surfaces of the heat exchanger tubes should be inspected and cleaned if necessary. Neglect can lead to thick scale deposits which will be difficult to remove.

Scale Formation

Very little hard scale should form in a distilling plant that uses seawater as feed if (1) feedwater distribution is proper, (2) steam pressure above the

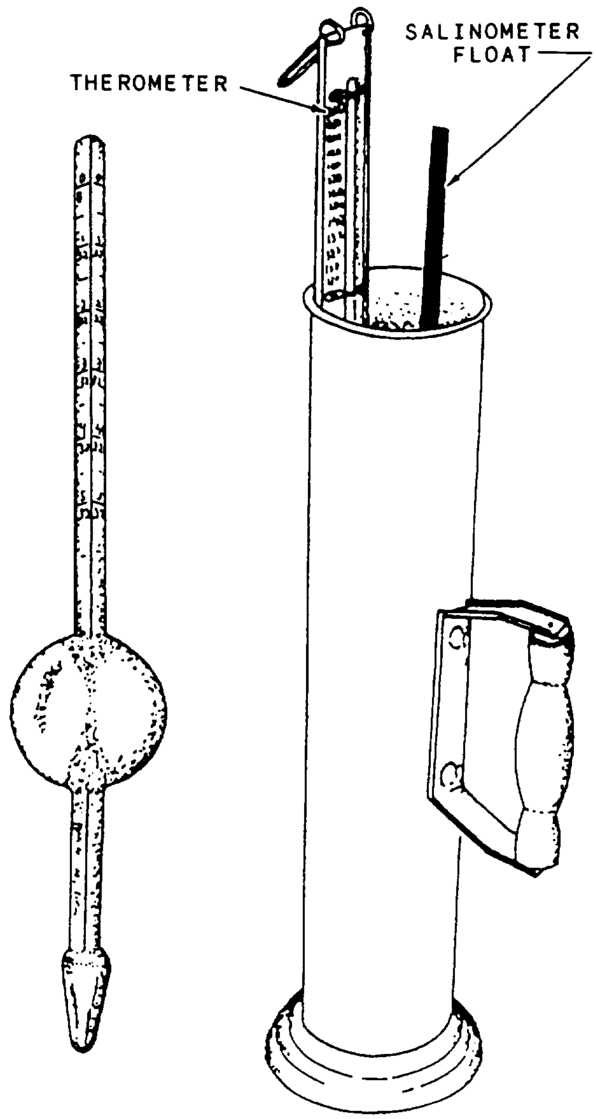


Figure 9-13.—Salinometer and sampling pot.

orifice is not more than 5 psi, (3) a high vacuum is maintained, and (4) the brine density is not over 1.5 thirty-seconds.

During normal operating conditions, scale deposits will form at a certain rate on the distilling plant evaporator tubes. The rate of scaling depends on the concentration of suspended matter and carbonates present in the water used to feed the distilling plant. However, excessive scaling of the evaporator can be used by improper operation of the plant.

Scale deposits increase as the density of the brine in last-effect shell increases. The brine concentration is dependent mainly on the quantity of brine pumped overboard and on the amount of distillate produced. If the brine concentration is too high, there will be an increase in the rate of scaling of the evaporator tubes. The quality of the distillate may be impaired.

To retarded the formation of scale on evaporator tubes and to minimize priming, solutions are continuously injected into the evaporator.

A chemical compound, Ameroyal, is used in all Navy evaporators that are feed-treated. Ameroyal increases the production of distilled water by decreasing downtime of plants for scale removal.

A proportioning pump and tank assembly are used to mix Ameroyal and inject it into the evaporator feed at a controlled rate. The tank has a gauge glass or an internal, fixed measuring plate which is marked off in gallons. The tank usually holds 24 gallons of mixture with room left for expansion.

The proportioning pump is a small, motor-operated reciprocating pump unit and may be either simplex (one pump) or duplex (two pumps) in design. The maximum capacity of the proportioning pump is 2.5 gallons per hour (gph) per pump.

The simplex pump consists of one pump and one motor. The duplex pump consists of two pumps, driven by one motor, served by the same mixing tank. Duplex pumps may serve two distilling plants ONLY when the two plants have the same design distillate capacity and are located in the same compartment. In all other cases, simplex pumps must be installed.

The length of the stroke determines the pump capacity of either the simplex or duplex pump. The stroke can be adjusted, but is never set at less than 20 percent. This assures accuracy of the injection rate and lubrication of the pump plunger. If possible, the pump stroke (or strokes on a duplex pump) should be set to empty the mixing tank, from the top to the bottom of the gage glass, in exactly 24 hours. If this rate of injection requires a stroke of less than 20 percent, the stroke should be set to empty the tank in less than 24 hours.

If the pump stroke must be changed, the setting can be made from the indicator scale mounted on the connecting rod. The stroke can be verified by checking the amount of time required to empty the mixing tank. The indicator scale is calibrated from 0 to 10. If the pump has a maximum capacity of 17 gph, set the indicator pointer at 5 to deliver 3 1/2 gph. To change the stroke, stop the pump and loosen the connecting rod locknut. Watch the pointer on the indicator scale and turn the adjusting screw the required amount. Tighten the connecting rod locknut and restart the pump. Check the time required to empty the tank and reset the pump stroke if necessary.

A vacuum drag injection line, used when the proportioner pump fails, runs from the mixing tank to a point downstream (vacuum side) of the feed control valve. A needle valve is installed in the line. It allows the operator to make relatively fine adjustments in the amount of solution that flows into the evaporator.

Ameroyal comes in concentrated liquid form. Therefore it is not necessary to premix it before putting it in the tank pour the correct amount into the injection tank and stir thoroughly. The injection rate for Ameroyal is 1 pint per 4,000 gpd output.

CAUTION: Ameroyal is an alkaline chemical. (A more familiar form of an alkaline chemical is lye.) Use extreme care when handling and mixing Ameroyal to prevent splashing the liquid into the eyes or on the skin. Rubber gloves and a chemical splash goggles MUST be worn when handling this chemical. DO NOT dump excess Ameroyal in the bilges.

In accordance with the Planned Maintenance System, the mixing tank should be drained to the bilges and flushed out with fresh water weekly, or more often if necessary. This process prevents accumulation of sludge in the tank.

Scale Removal

As previously stated, the evaporator tubes of a submerged tube unit MUST be cleaned when the first-effect tube nest vacuum approaches zero. The vertical basket unit should be cleaned when it becomes necessary to use a basket steam pressure of 8 psig to produce rated capacity. The flash-type unit will require cleaning when it becomes necessary to use a steam pressure of 4 psig in the evaporator feedwater heater. Assuming these reductions in capacity are due to scale and not the result of improper operation, an approved cleaning method should be used to remove the scale.

CHILL SHOCKING.—The temperature in the first-effect nest is near that of the steam supply. This tube nest tends to scale up more quickly than other parts of the plant. Chill shocking (cold shocking) the tubes is generally used to combat this scale. Drain the brine from all shells, then reflood them by means of a hose line connected to a flushing pipe or flooding connection on the shell. This reflooding chills the tube nest bundles. Next, quickly admit steam into the tubes, causing differential expansion and contraction to take place. This process breaks the scale loose from the tubes.

If a feed treatment is not used, the distilling plant should be chill shocked daily. If the Navy standard feed treatment is used, daily chill shocking may be desirable but longer intervals are satisfactory.

MECHANICAL CLEANING.—Mechanical cleaning should be used only as a last resort. Clean with chemicals if possible. The chemical cleaning process is covered later in this chapter. The evaporator tube nest must be withdrawn from the shell for mechanical cleaning. Lifting gear suitable to the type of installation is usually provided to help remove the tube nest.

Submerged Tube Type.—Some evaporators or distilling plants are provided with an overhead trolley from which the tube nest can be suspended for cleaning. Another type is provided with tracks and roller brackets which bolt to the front head of the tube nest. In small installations, chain falls can be used to handle the tube nest.

When you withdraw the tube nest beyond the support plate, bolt the tube nest stop in place. This prevents accidental dropping of the rear head. Clean the tubes with a light scaling tool operated by a light air hammer. Hold the tool against the tube with moderate pressure and move it over the entire length of the tube. Clean every tube in the nest. If you miss one, it will impair the output of the plant and make cleaning more difficult in the future.

NEVER use a torch to descale a tube nest made up of straight tubes. The expansion and contraction caused by the heat may cause the tubes to loosen at their joints.

After cleaning the tubes, apply a hydrostatic test of 50 psi to the bundle before replacing it within the shell.

When you pull the evaporator tubes for cleaning, inspect and clean the distillate condenser, air ejector condenser, the vapor feed heaters, if necessary. Under some operating conditions, scale deposits may accumulate in these tubes. This is particularly true in the air ejector condenser and the first-effect feed heater.

The distillate condenser on end-pull plants must be removed for inspection and cleaning. On other types of plants you can inspect and clean the distillate condenser by removing the heads at both ends. You can clean the air ejector condensers on all plants by removing both heads. You must remove the vapor feed heater tubes on practically all designs for cleaning.

Clean these tube nests by using an extended shank drill, driven by a reversible motor at 250 or 300 rpm. You may also use standard tube-cleaning equipment adapted for use with 5/8-inch outside diameter condenser tubes.

Flash-Type.—In the flash-type distilling plant, scale formation is reduced to a minimum because the feed is heated under pressure. This prevents boiling, and vapor is formed by free flashing under vacuum. The heat exchanger tubes require periodic cleaning. Remove the front and rear water boxes to gain access to the tube sheet outer surfaces and tube interiors of the distilling condensers, air ejector condensers, evaporator feedwater heater, and distillate cooler. Then, push an electric or air-driven cleaning tool through the tubes to remove scale deposits.

CHEMICAL CLEANING.—Chemical cleaning is faster, more economical, more effective, and less damaging to evaporator parts than mechanical cleaning. In chemical cleaning, a heated, diluted acid solution circulates through the saltwater circuits of the system. The three acids used are hydrochloric, sulfamic, and citric.

CAUTION: These acids may be harmful to personnel. Observe the safety precautions and follow the procedures listed in chapter 670(9580-I) of *Naval Ships' Technical Manual.*

Hydrochloric acid comes in liquid form and presents hazards in both handling and storing. Hydrochloric acid is authorized ONLY when properly supervised by qualified naval shipyard personnel; NEVER by ship's force alone.

Sulfamic acid comes in powdered form and is safe for storage aboard ship when stored in the original containers. Sulfamic acid is authorized under the supervision of qualified tender or naval shipyard personnel. At the discretion of type commanders, individual ships may be authorized to carry sulfamic acid and cleaning may be performed by qualified personnel in the ship's crew.

Citric acid comes in powder form. It allows you to acid clean the plant while it is in operation. However, it cannot be used in port because the pH of the effluent exceeds the limits for discharge in port.

Citric acid is injected into the plant through the installed injection system or by vacuum drag. The injection rate is adjusted to obtain a distilling plant feed or brine pH which is monitored by a pH meter or pH paper. Normally, successful cleaning can be accomplished within 8 hours. If the plant is not clean after 20 hours the distilling plant should be opened and inspected at the first opportunity.

Citrus acid may be used on nuclear power plants of surface ships. However, when using it on nuclear power plants, the distillate must be sent to the potable water system or to the bilge. Also, the distilling plant steam drains must be sent to the bilge while cleaning.

When using citric acid you should refer to the *Naval Ships' Technical Manual,* chapter 670 (9580).

CAUTION: Unnecessary use of citric acid may result in tube metal waste.

Testing for Saltwater Leaks

If a leak is detected in a heat exchanger, the defective tube(s) should be located by an air test or a hydrostatic test. This should be done following the recommended procedure in the manufacturer's instructions. Blueprints should also be used to study the construction details of the individual heat exchanger.

As soon as a leaky tube has been located, it should be plugged at both ends.

Plugging the tubes reduces the amount of heating surface. Therefore, the heat exchanger will fail to give satisfactory performance after a number of tubes have been plugged. It will then become necessary to retube the heat exchanger. Under normal conditions, this work should be accomplished by a naval shipyard or tender. However, repair parts and a number of special tools are included in the ship's allowance so that emergency repairs can be made to the heat exchangers and to other parts of the distilling plant.

To find which of the tubes within a removable tube bundle is leaking, test the individual bundles hydrostatically. The leak may be in a removable bundle. These bundles may be in vapor feed heaters within an evaporator shell, evaporator tube nests, or distillate condensers on end-pull plants. If so, the bundle must be withdrawn and a hydrostatic test at full pressure (50 psi) must be applied on the tube side.

The leak may occur in a nonremovable tube bundle. These bundles may be in the distillate cooler, air ejector condenser, or external vapor feed heaters. If so, the tube nest covers must be removed, and the full test pressure (50 psi) applied on the shell side of the unit.

If a nonremovable distillate condenser bundle is within an evaporator shell, the tube nest covers must be removed and a full test pressure of 30 psi should be applied to the evaporator shell.

The proper instructions should be followed at all times when operating and maintaining distilling plants. A properly operated and maintained distilling plant will give many years of satisfactory service.

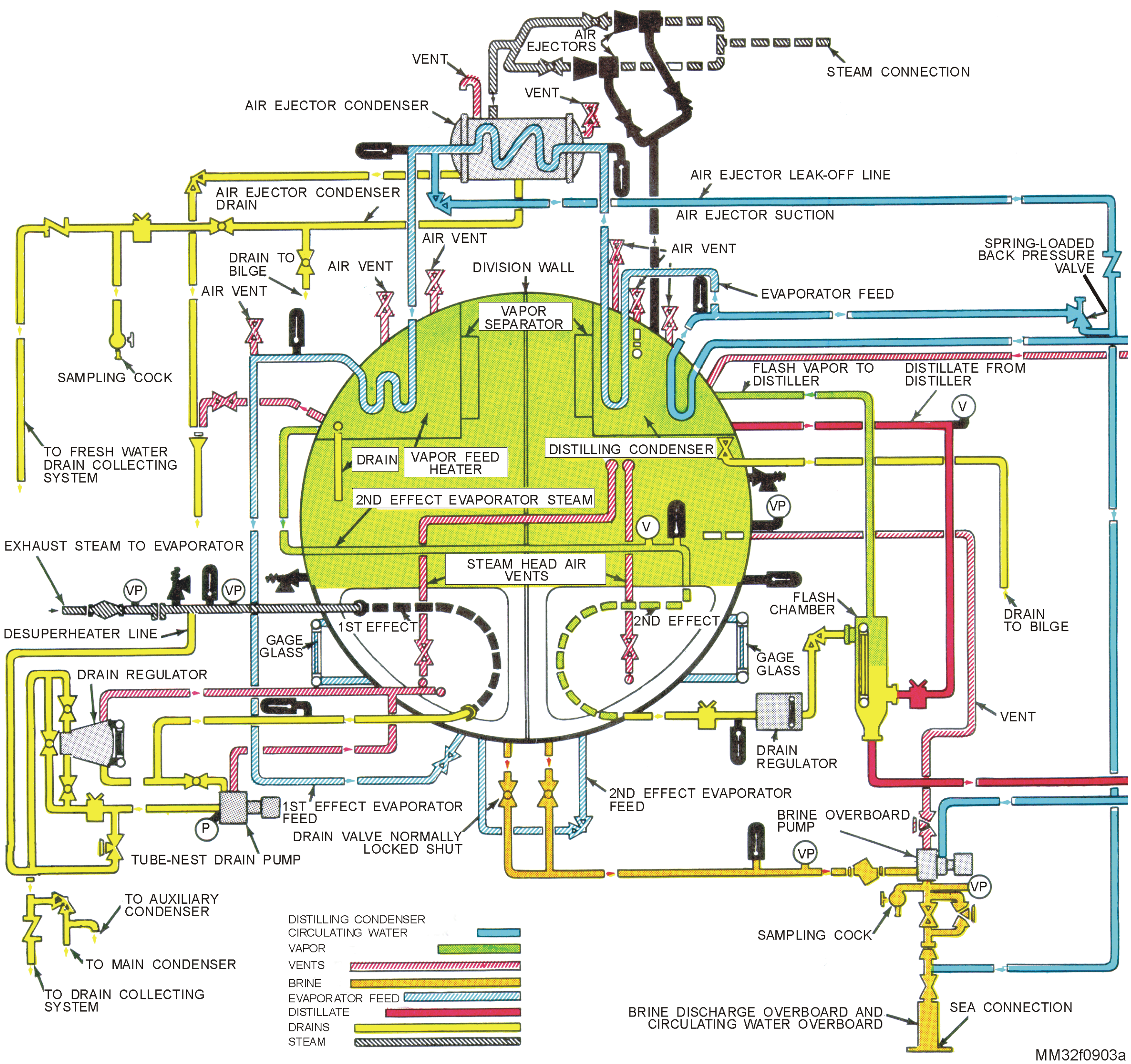


Figure 9-3.—Schematic diagram of a double-effect distilling plant.

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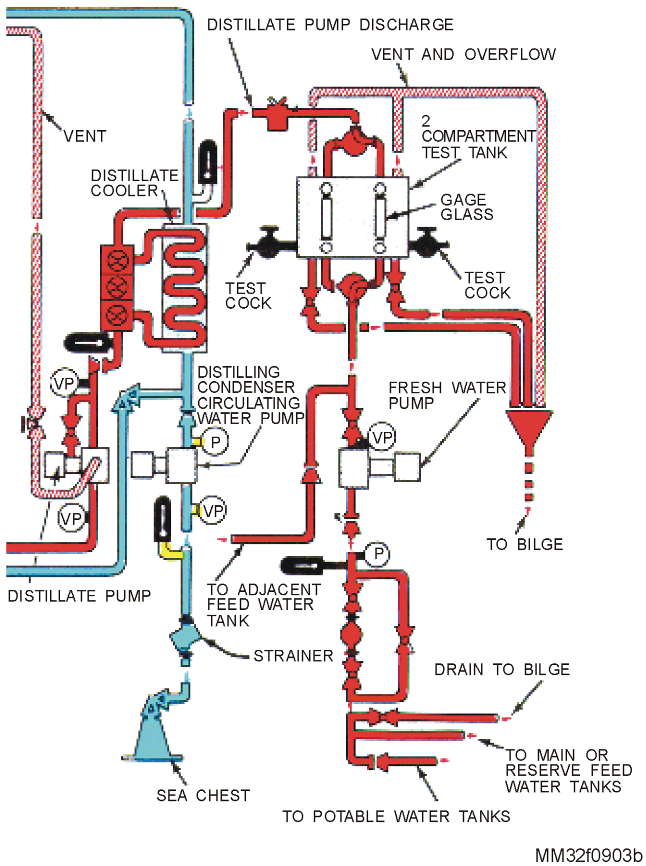

Figure 9-3.—Schematic diagram of a double-effect distilling plant-(cont.)

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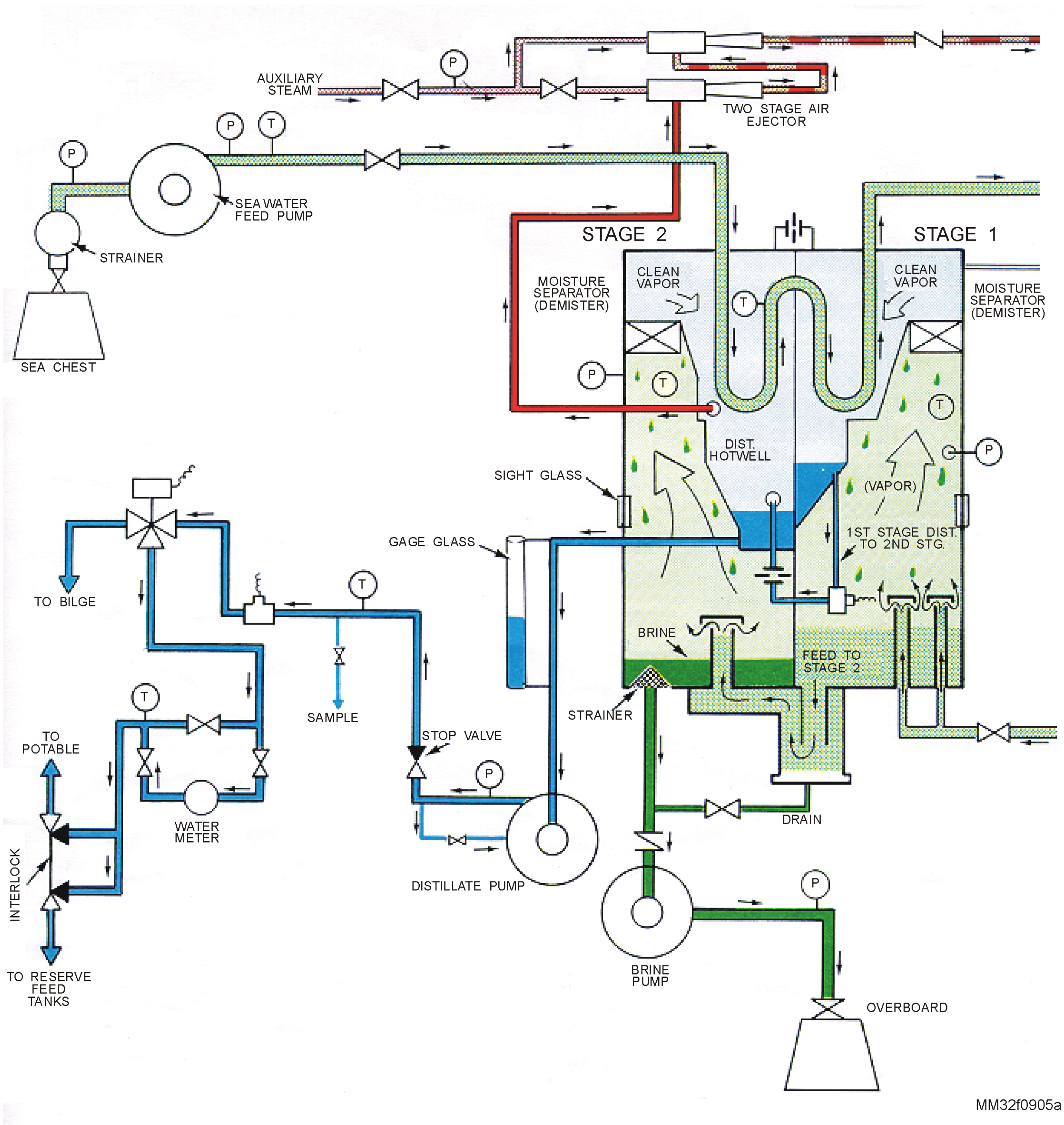

Figure 9-5.—Two-stage, flash-type distilling plant 12,000 gpd capacity.

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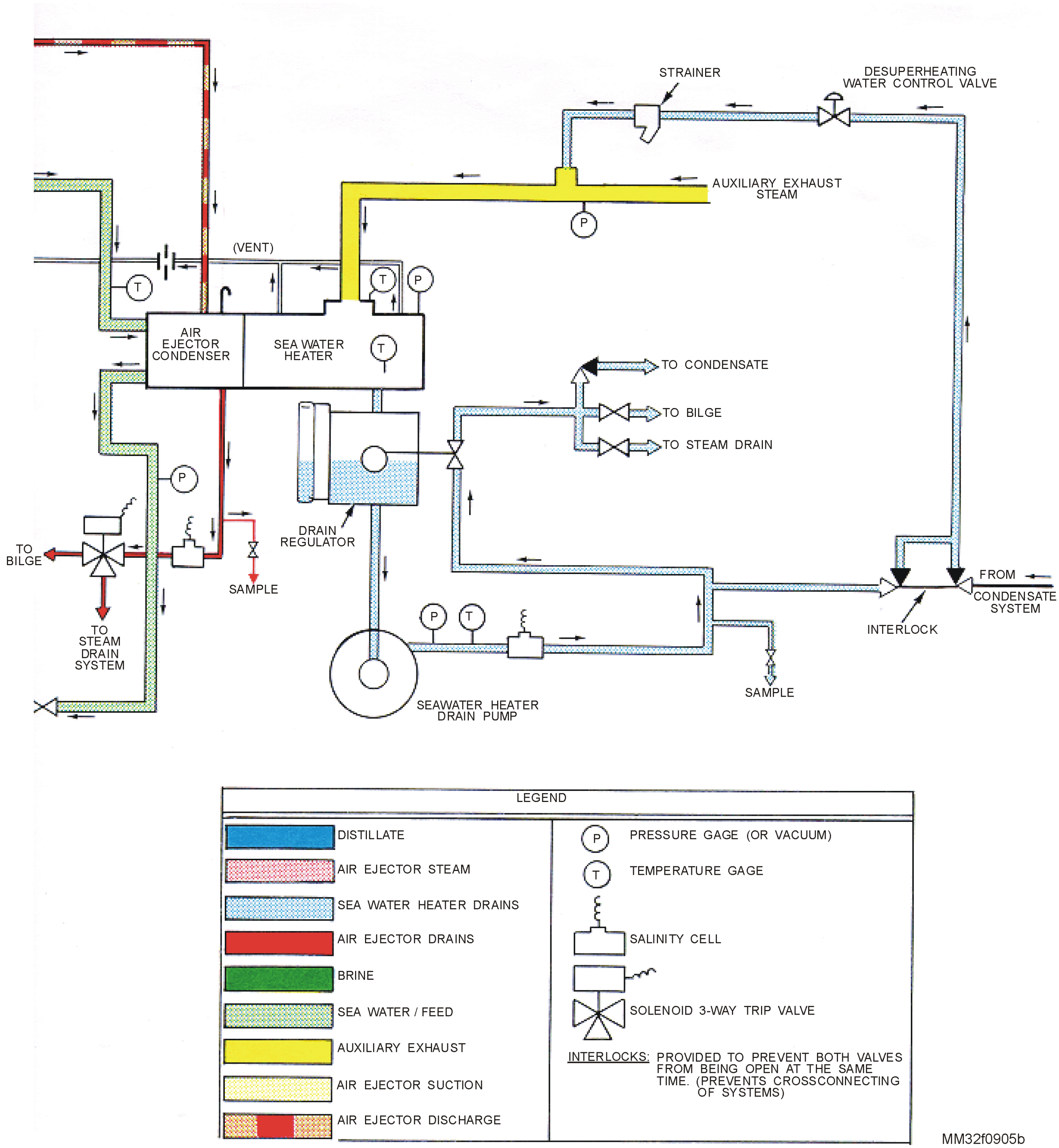

Figure 9-5.—Two-stage, flash-type distilling plant 12,000 gpd capacity-(cont)

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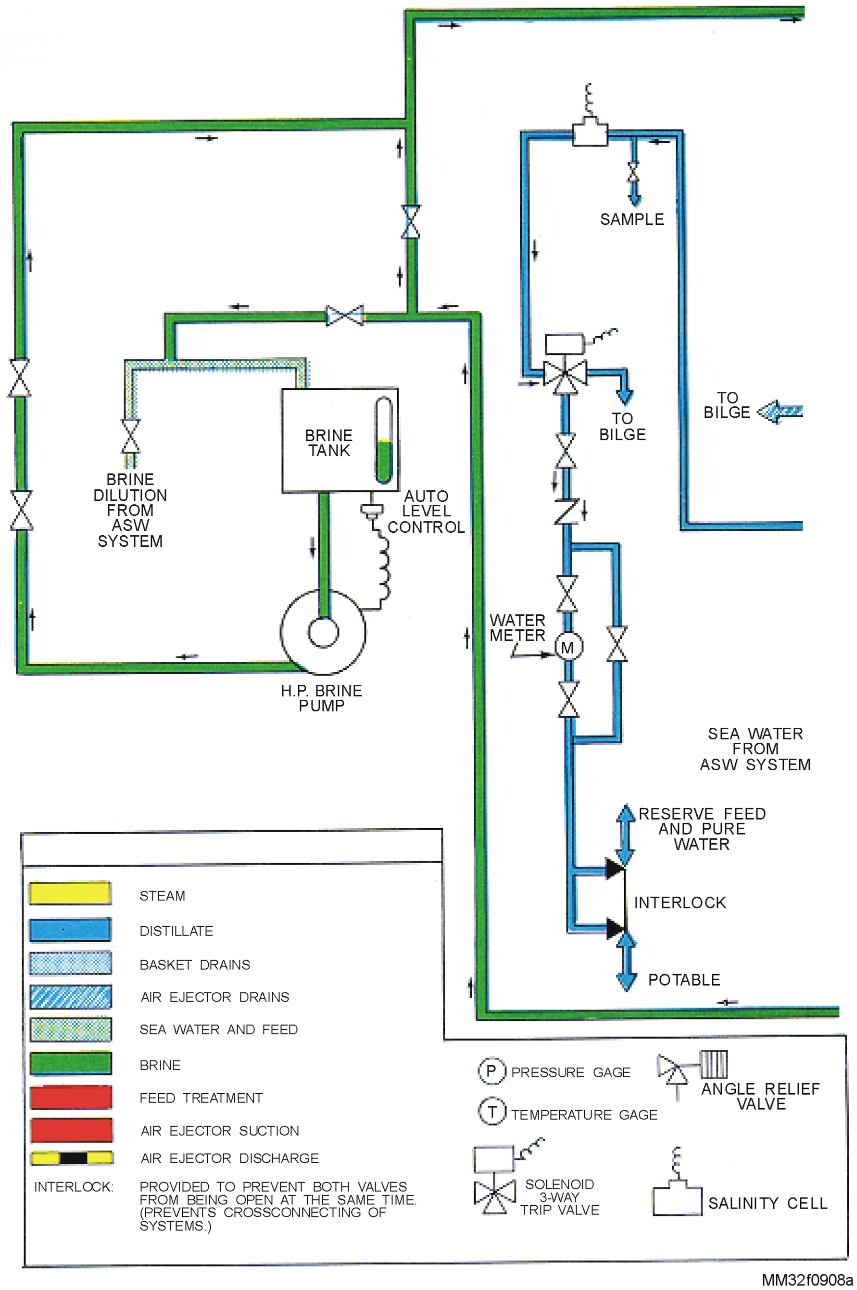

Figure 9-8.—Single-stage, vertical basket distilling plant 8,000 gpd capacity.

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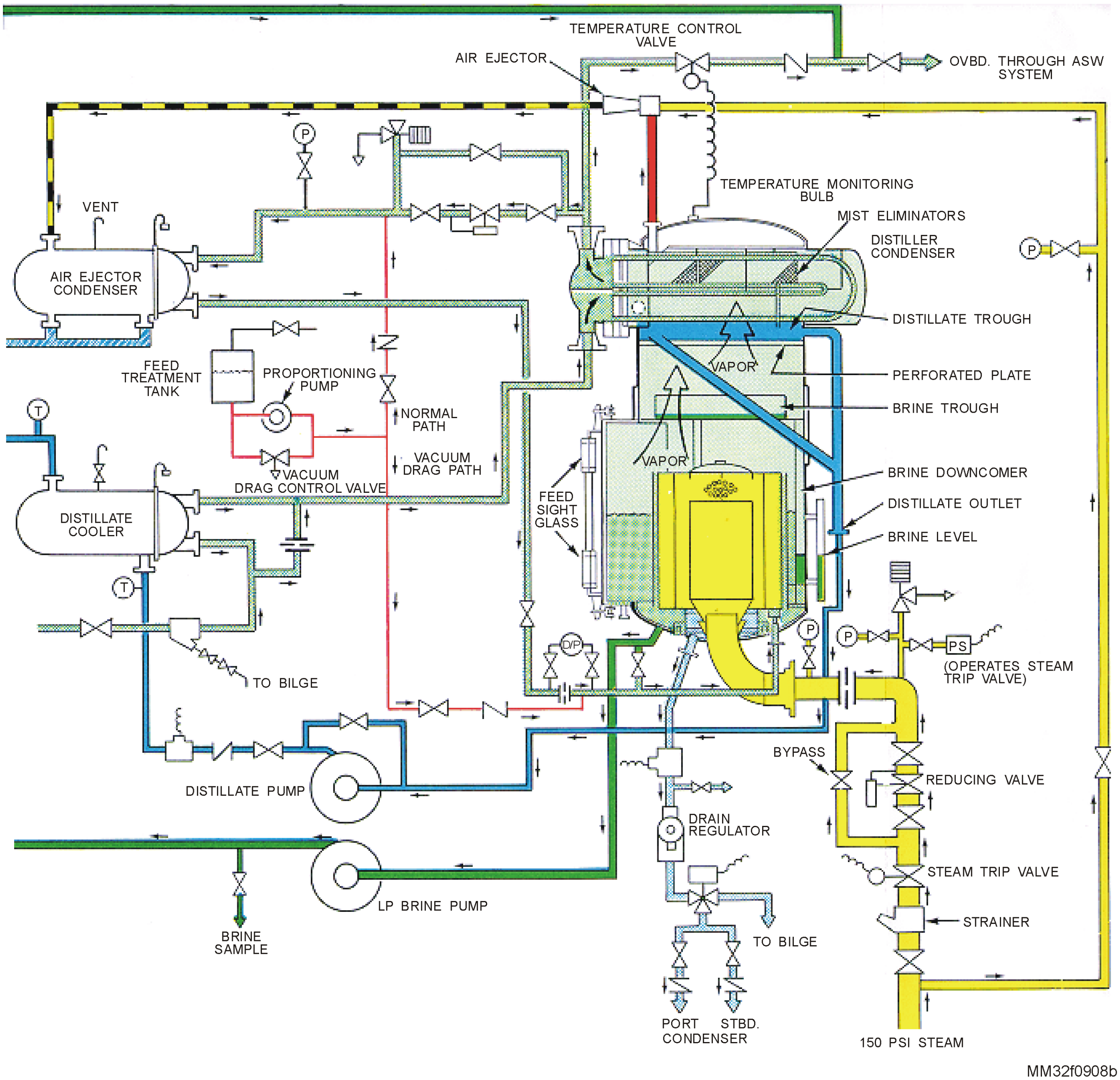


Figure 9-8.—Single-stage, vertical basket distilling plant 8,000 gpd capacity-(cont)

CHAPTER 10

PIPING SYSTEMS

As a Machinist's Mate, you will work with piping, fittings, valves, packing, gaskets, and insulation. You will be responsible for routine maintenance of this equipment in your spaces and possibly throughout the ship. The machinery of a system cannot work properly unless the piping and valves are in good working order.

This chapter contains general information. You should refer to the appropriate manufacturer's technical manuals, ship's plans, information books, and plant or valve manuals for more specific information. *Naval Ships' Technical Manual,* Chapter 505 (9480), "Piping Systems," is one good source of information.

PIPING AND TUBING

The Naval Sea Systems Command defines piping as an assembly of pipe or tubing, valves, fittings, and related components. These form a whole or a part of a system used to transfer fluids (liquids and gases).

IDENTIFICATION

In commercial usage, there is no clear distinction between pipe and tubing; the correct designation for each tubular product is established by the manufacturer. If the manufacturers call a product pipe, it is pipe; if they call it tubing, it is tubing. In the Navy, however, a distinction is made between pipe and tubing based on their dimensions.

There are three important dimensions of any tubular product: outside diameter (OD), inside diameter (ID), and wall thickness. A tubular product is called TUBING if its size is identified by actual measured OD and by actual measured wall thickness. A tubular product is called PIPE if its size is identified by a nominal dimension called nominal pipe size (NPS) and by reference to a wall thickness schedule designation.

The size identification of tubing is simple enough, since it consists of actual measured dimensions. However, the terms used to identify pipe sizes require some explanation. A NOMINAL dimension such as NPS is close to—but not necessarily identical with—an actual measured dimension. For example, a pipe with an NPS of 3 inches has an actual measured OD of 3.50 inches. A pipe with an NPS of 2 inches has an actual measured OD of 2.375 inches. In the larger sizes (about 12 inches) the NPS and the actual measured OD are the same, For example, a pipe with an NPS of 14 inches has an actual measured OD of 14 inches, Nominal dimensions are used to simplify the standardization of pipe fittings, pipe taps, and threading dies.

The wall thickness of pipe is identified by reference to wall thickness schedules (not shown) established by the American Standards Association. For example, a reference to schedule 40 for a steel pipe with an NPS of 3 inches indicates that the wall thickness of the pipe is 0.216 inch. A reference to schedule 80 for a steel pipe of the same NPS (3 inches) indicates that the wall thickness of the pipe is 0.300 inch.

A schedule designation does not identify any one particular wall thickness unless the NPS is also specified. For example, we have said that a schedule 40 steel pipe of NPS 3 inches has an actual wall thickness of 0.216 inch. But if we look up schedule 40 for a steel pipe of NPS 4 inches, we will find that the wall thickness is 0.237 inch. These examples are used merely to illustrate the meaning of wall thickness schedule designations. Many other values can be found in pipe tables given in engineering handbooks.

You have probably seen pipe identified as STANDARD (Std), EXTRA STRONG (XS), and DOUBLE EXTRA STRONG (XXS). These designations, which are still used to some extent, also refer to wall thickness. However, pipe is manufactured in a number of different wall thicknesses; some pipe does not fit into the standard, extra strong, and double extra strong

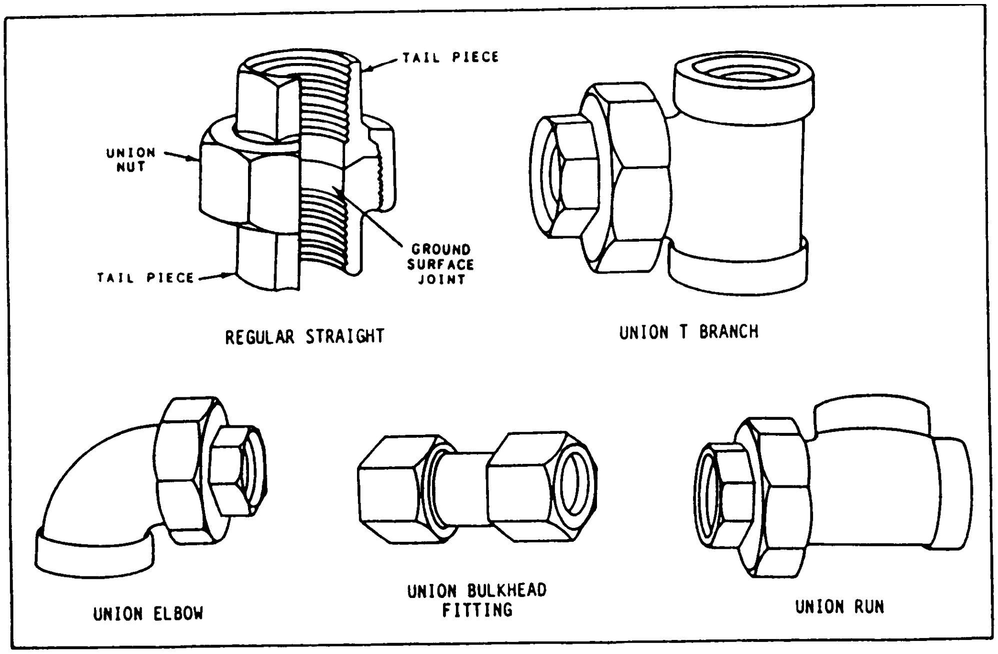


Figure 10-1.—Unions.

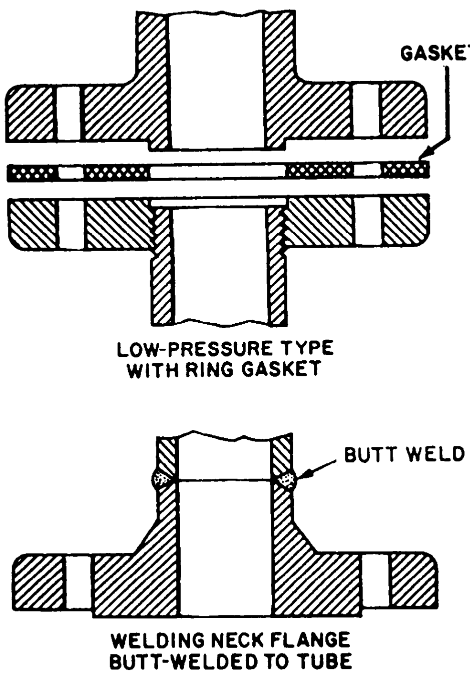


Figure 10-2.—Bolted flange piping joints.

classifications. The wall thickness schedules are being used increasingly to identify the wall thickness of pipe. They provide identification of more wall thicknesses than can be identified under the strong, extra strong, and double extra strong classifications.

We have briefly described the standard ways of identifying the size and wall thickness of pipe and tubing. However, you will sometimes see pipe and tubing identified in other ways. For example, you may see some tubing identified by ID rather than by OD.

PIPING FITTINGS

Piping sections are connected by various standard fittings, including several types of threaded union, bolted, welded, silver-brazed, and expansion joints.

Threaded Union Joints

The threaded union joint is the simplest pipe fitting. Threaded fittings are not widely used aboard modern ships except in low-pressure water piping systems. The union fittings are used in piping systems to allow the piping to be taken down for repairs and alterations. Unions are available in many different materials and designs to withstand a wide range of pressure and temperature. Figure 10-1 shows some commonly used types of unions. The union is used a great deal to join piping up to 2 inches in size. The pipe ends connected to the union are threaded, silver-brazed, or welded into the tail pieces (union halves); then the two ends are joined by setting up (engaging and tightening up on) the union nut. The male and female connecting ends of the tail pieces are carefully ground to make a tight metal-to-metal fit. Welding or silver-brazing the ends to the tail pieces prevents contact of the carried liquid or gas with the union threading.

Bolted Flange Joints

Bolted flange joints are suitable for all pressures now in use. The flanges are attached to the piping by welding, brazing, or rolling and bending into recesses. Screw threads are used for some low-pressure piping. Those illustrated in figure 10-2 are the most common types of flange joints used. They are manufactured for all standard fitting shapes, such as the tee, cross, elbow, and return bend. The welded neck-type flange joints are used extensively where piping is subject to high pressures and heavy expansion strains.

Welded Joints

The majority of joints found in subassemblies of piping systems are welded joints, especially in high-pressure piping. The welding is done according to standard specifications which define the materials and techniques. There are three general classes of welded joints: butt-weld, fillet-weld, and socket-weld (fig. 10-3).

Silver-Brazed Joints

Silver-brazed joints (fig. 10-4) are commonly used to join nonferrous piping when the pressure

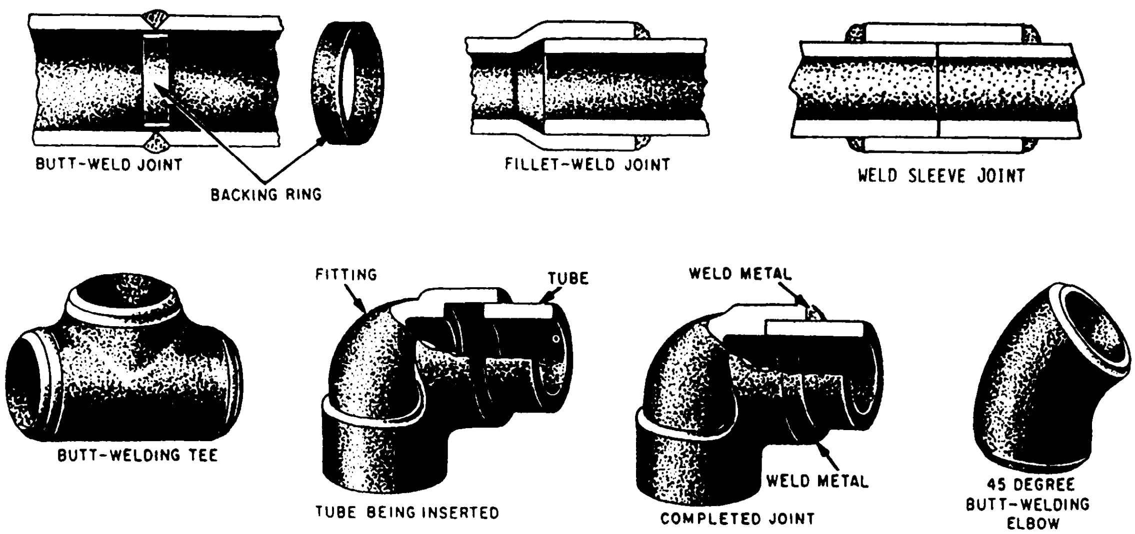


Figure 10-3.—Various types of welded joints.

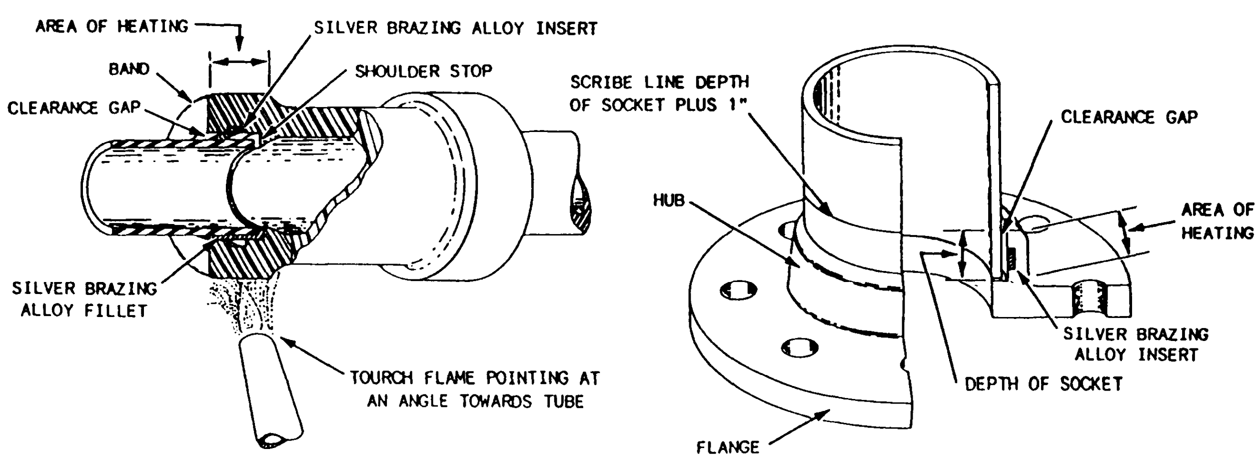


Figure 10-4.—Silver-brazed joints.

and temperature in the lines make their use practicable. The temperature must not exceed 425°F; for cold lines, pressure must not exceed 3000 psi. The alloy is melted by heating the joint with an oxyacetylene torch. This causes the molten metal to fill the few thousandths of an inch annular space between the pipe and the fitting.

Expansion Joints

Expansion joints of various types may be installed at suitable intervals in long steam lines. They are used because metal contracts or expands during changes in temperature. They include corrugated and bellows joints and expansion bends.

CORRUGATED JOINTS AND BELLOWS JOINTS.—The corrugated and bellows types of expansion joints (fig. 10-5) are used for both medium and high pressure and temperature. The principle of these joints is simple; the expansion-contraction movement is absorbed by the changing curvature of the corrugations or bellows

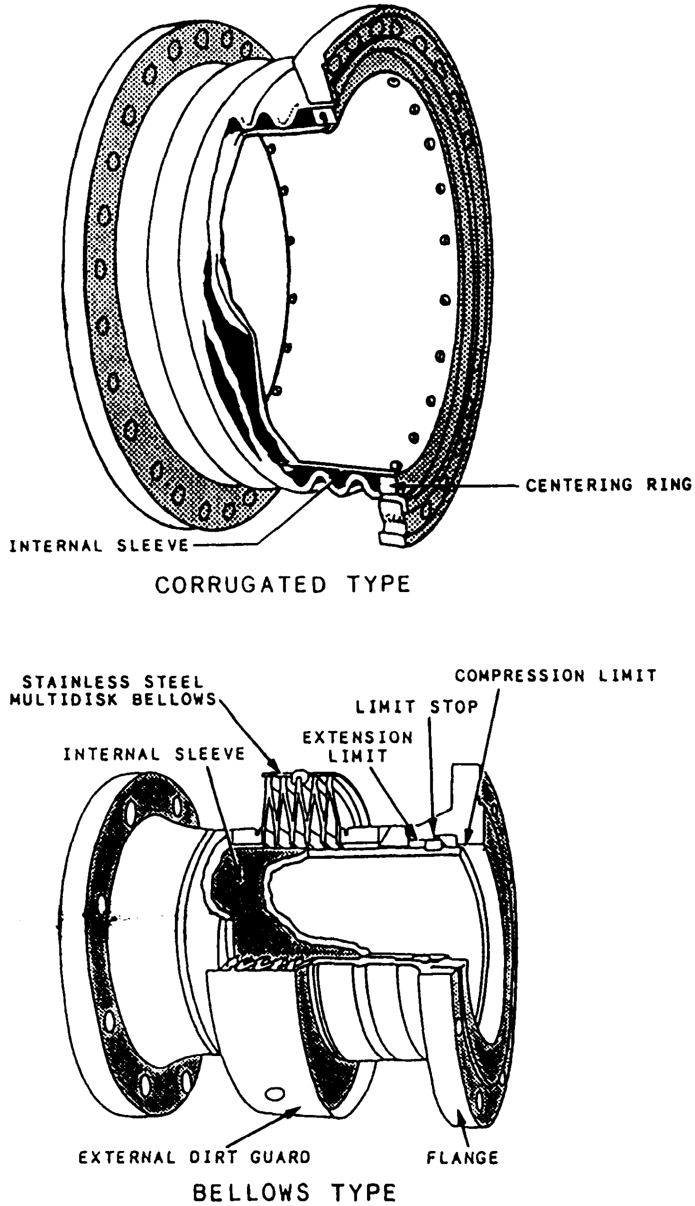


Figure 10-5.—Expansion joints.

(as in an accordion). The internal sleeves, free to slide axially in these joints, prevent excessive turbulence and erosion of the expansion parts. Figure 10-6 illustrates a corrugated bulkhead expansion joint. This joint provides for both radial and axial movement of piping with respect to the bulkhead.

EXPANSION BENDS.—Expansion bends are used for high-pressure and high-temperature steam piping in preference to the corrugated or bellows joint. Expansion bends are merely loops of piping of proper length and configuration; they take up the changes in pipe length caused by temperature changes. The expansion bends take many shapes—most common are the U-bend, Z-bend, and L-bend.

FLANGE SAFETY SHIELDS

A fire in the fireroom or engine room can be caused by a leak at a fuel-oil or lube-oil pipe-flange connection. Even the smallest leak can spray fine droplets of oil on nearby hot surfaces.

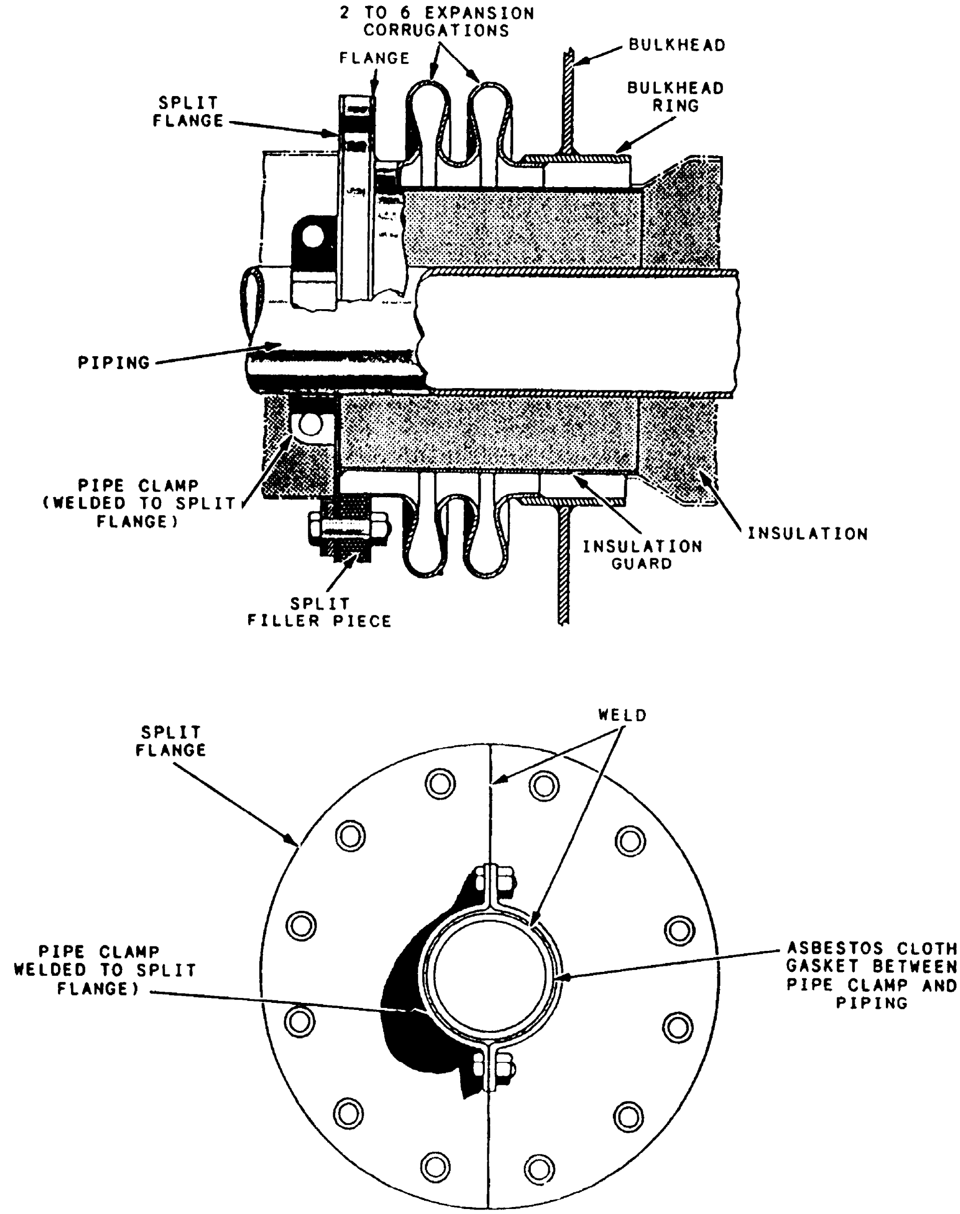


Figure 10-6.—Corrugated bulkhead expansion joints, showing details of installation.

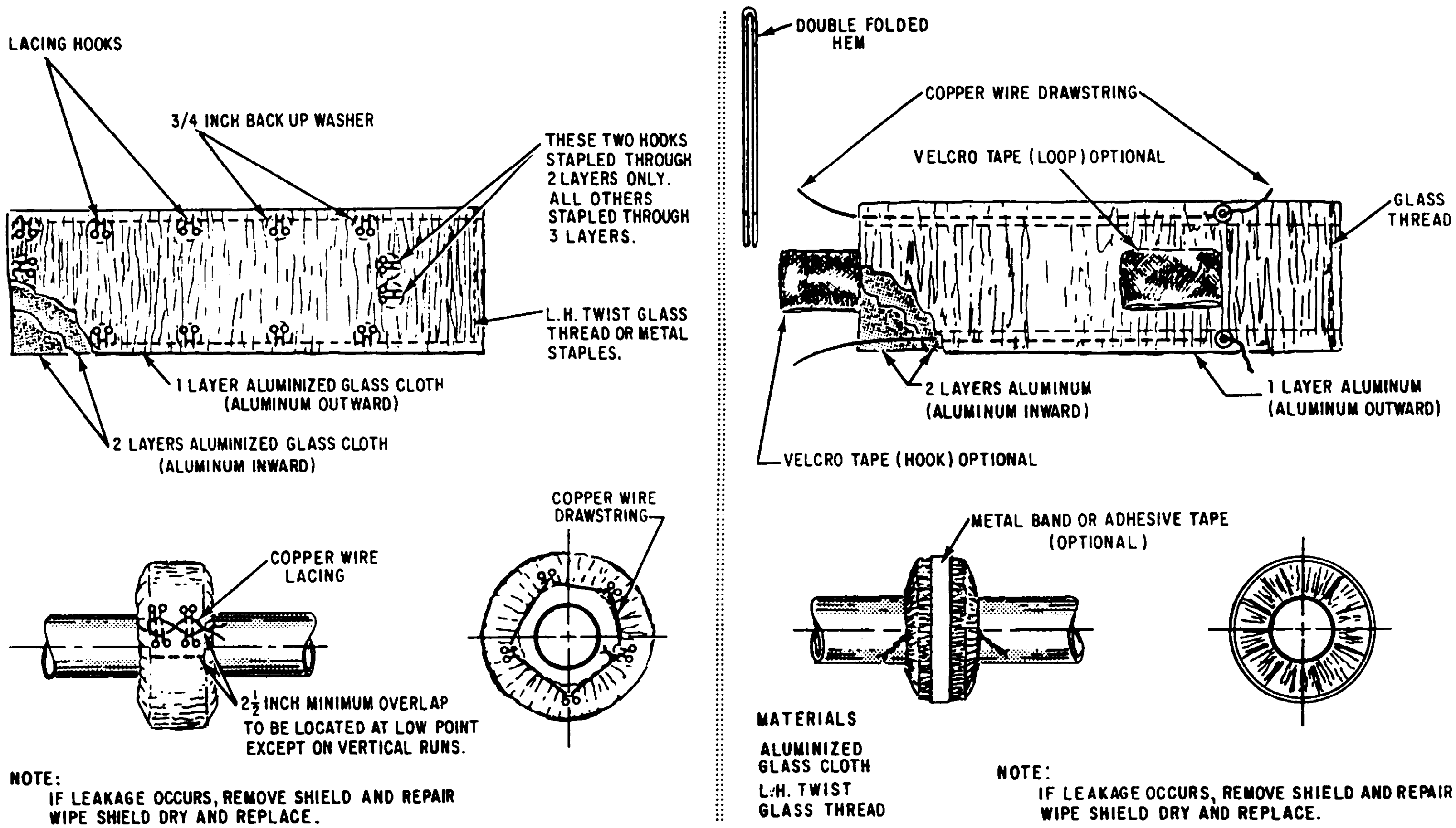


Figure 10-7.—Flange safety shields.

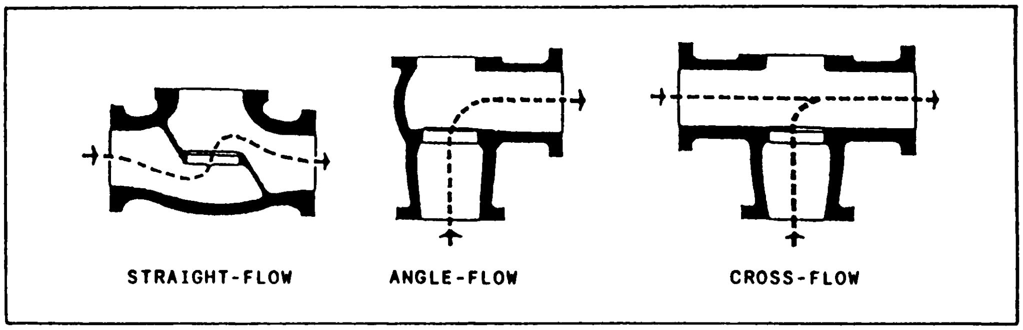


Figure 10-8.—Types of globe valve bodies.

To reduce this possibility, spray shields (flange shields) (fig. 10-7) are provided around piping flanges of flammable liquid systems, especially in areas where the fire hazard is apparent. The spray shields are usually made of aluminized glass cloth and are simply wrapped and wired around the flange.

PIPELINE STRAINERS

Strainers are fitted in many piping lines to prevent the passage of grit, scale, dirt, and other foreign matter. Such matter could obstruct pump or throttle valves, or damage machinery parts. Various types of strainers are used, depending on the service intended.

VALVES

Valves are usually made of bronze or steel. Steel valves are either cast or forged and are made of either plain steel or alloy steel. Alloy steel valves are used in high-pressure, high-temperature systems. The disks and seats (internal sealing surfaces) of these valves are usually surfaced with a chromium-cobalt alloy known as Stellite. Stellite is extremely hard.

Bronze valves are never used in systems where temperatures exceed 550°F. Steel valves are used for all services above 550°F. Bronze valves are used almost exclusively in systems that carry salt water. The seats and disks of these valves are usually made of Monel, a metal that has excellent corrosion- and erosion-resistant qualities. Submarine seawater valves are an exception to the normal use of bronze in seawater valves; most are made of 70-30 copper-nickel alloy.

STOP VALVES

Stop valves are used to shut off or, in some cases, control the flow of fluid. They are controlled by the movement of the valve stem. Stop valves can be divided into four general categories: globe, gate, butterfly, and ball valves. Plug valves and needle valves may also be considered stop valves, but they are covered in *Fireman,* NAVEDTRA 14104.

Globe Valves

Globe valves are probably the most common valves in existence. They are used throughout the engineering plant and other parts of the ship. The globe valve gets its name from the globular shape of the valve body. However, you have to look inside the valve for a positive identification because other valve types may also have globular bodies. Globe valve inlet and outlet openings are arranged in several ways to suit varying requirements of flow. Figure 10-8 shows the common types: straight-flow, angle-flow, and cross-flow. Figure 10-9 shows a pressure-seal bonnet globe

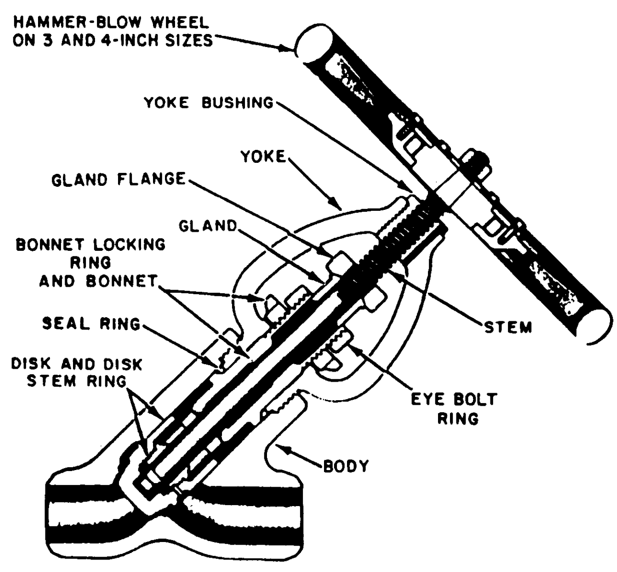


Figure 10-9.—1500-pound pressure seal bonnet globe valve.

valve with an angled straight-flow type of body. The angled valve seat produces lower fluid turbulence and flow restriction than the standard straight-flow globe valve.

Figure 10-10 shows a gear-operated globe stop valve used as an astern throttle valve in a steam plant.

Gate Valves

Gate valves are used when a straight line flow of fluid and minimum flow restriction are needed. Gate valves are so named because the part that either stops or allows flow through the valve acts somewhat like the opening or closing of a gate and is called, appropriately, the gate. The gate is usually wedge shaped. When the valve is wide open, the gate is fully drawn up into the valve bonnet. This leaves an opening for flow through the valve the same size as the pipe in which the valve is installed. Therefore, there is little pressure drop or flow restriction through the valve. Gate valves are not suitable for throttling purposes. The control of flow would be difficult because of valve design, and the flow of fluid slapping against a partially open gate can cause extensive damage to the valve. Except as specifically authorized, gate valves should not be used for throttling.

Gate valves are classified as either rising-stem or nonrising-stem valves. The nonrising-stem valve is shown in figure 10-11. The stem is threaded on the lower end into the gate. As the handwheel on the stem is rotated, the gate travels up or down the stem on the threads while the stem

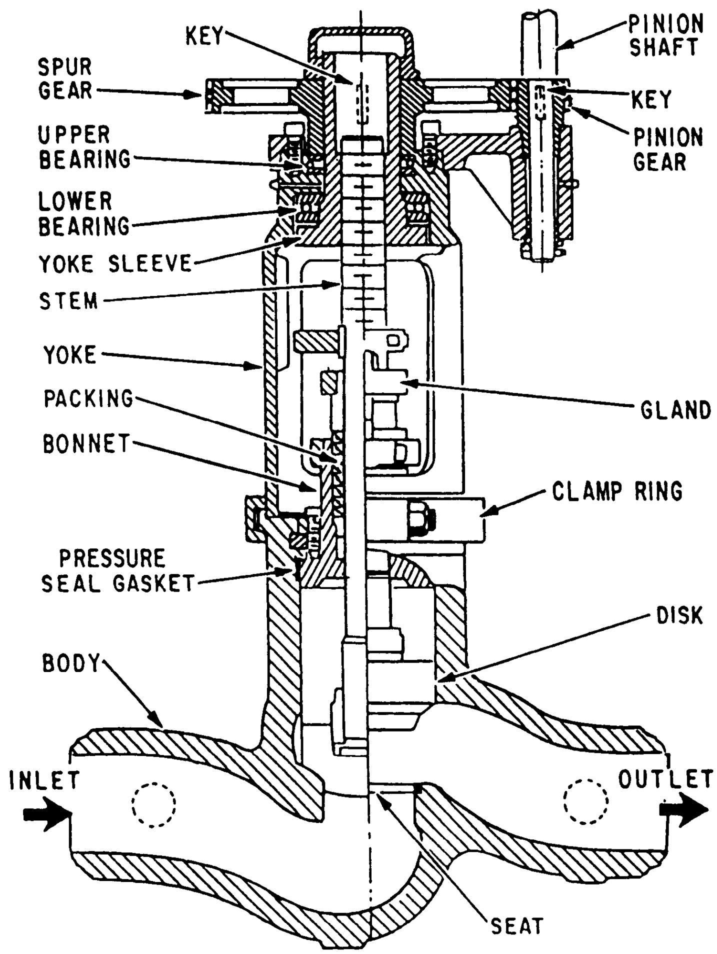
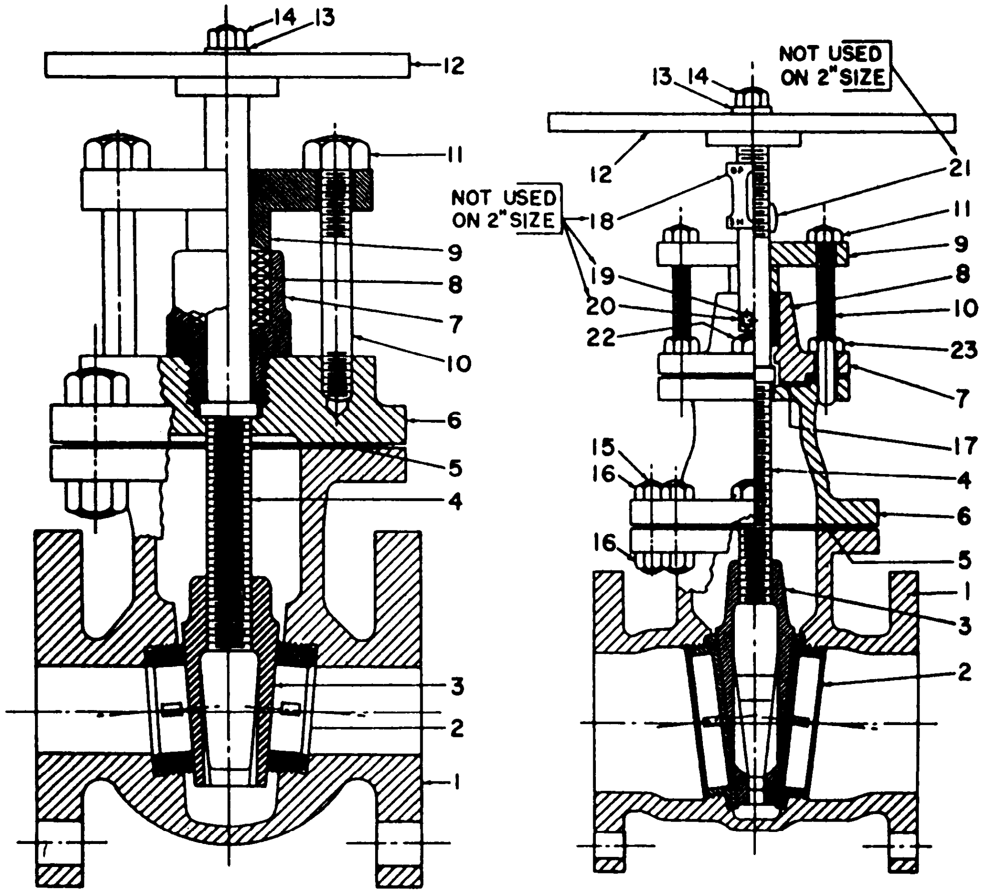


Figure 10-10.—Gear-operated globe stop valve.



LIST OF PARTS			
PART NO.	NAME OF PART	PART NO.	NAME OF PART
1	BODY	13	HANDWHEEL WASHER
2	SEAT RING	14	HANDWHEEL NUT
3	GATE	15	BONNET STUD
4	STEM	16	BONNET STUD NUT
5	BONNET GASKET	17	STUFFING BOX GASKET
6	BONNET	18	INDICATOR PLATE
7	STUFFING BOX	19	LOCK WASHER
8	PACKING	20	INDICATOR PLATE SCREW
9	GLAND	21	INDICATOR NUT
10	GLAND STUD	22	STUFFING BOX STUD
11	GLAND STUD NUT	23	STUFFING BOX STUD NUT
12	HANDWHEEL		

Figure 10-11.—Cross-sectional views of gate stop valves (nonrising stem).

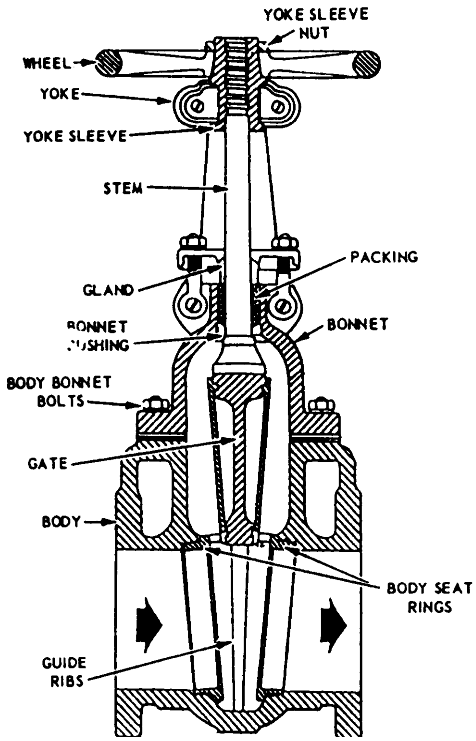


Figure 10-12.—Cutaway view of a gate stop valve (rising stem).

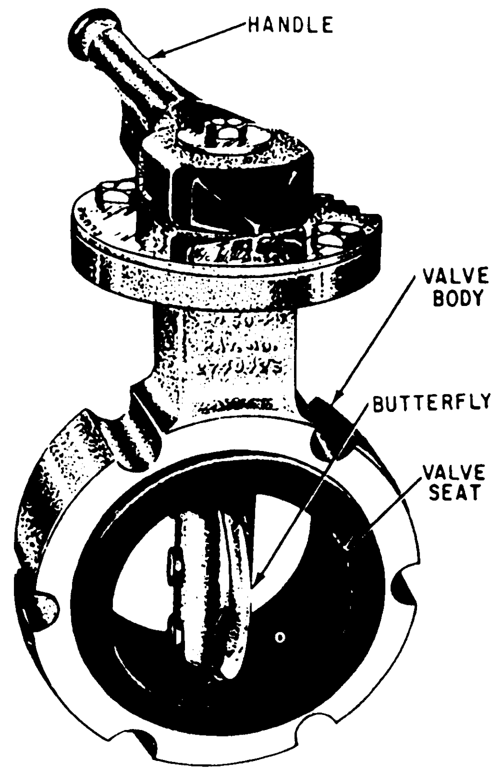


Figure 10-13.—Butterfly valve.

remains vertically stationary. This type of valve will almost always have a pointer type of indicator threaded onto the upper end of the stem to indicate valve position.

The rising-stem gate valve is shown in figure 10-12. It has the stem attached to the gate. The gate and stem rise and lower together as the valve is operated.

Gate valves used in steam systems have flexible gates. This type of gate prevents binding of the gate within the valve when the valve is in the closed position. When steam lines are heated, they will expand, causing some distortion of valve bodies. A solid gate fits snugly between the seat of a valve in a cold steam system. When the system is heated and pipes elongate, the seats will compress against the gate. The gate will be wedged between the seats and clamps the valve shut. This problem is overcome by using a flexible gate. This type of gate is best described as two circular plates that are flexible around the hub. These two plates are attached to each other. The gate can then flex as the valve seat compresses it. This prevents clamping.

The major problem with flexible gates (if installed with the stem below the horizontal) is that water tends to collect in the body neck. Then, under certain conditions, the admission of steam may cause the valve body neck to rupture, the bonnet to lift off, or the seat ring to collapse. To prevent this, you must follow correct warming-up procedures. Also, some very large gate valves have a three-position vent and bypass valve. This valve allows venting of the bonnet either upstream or downstream of the valve and has a position for bypassing the valve.

Butterfly Valves

One type of butterfly valve is shown in figure 10-13. It may be used in a variety of systems aboard ship. These valves can be used effectively in fresh water; seawater; JP-5; Diesel Fuel, Marine (DFM) lube oil; and chill water systems aboard ship. The butterfly valve is light in weight, relatively small, and relatively quick-acting. It provides positive shutoff, and can be used for throttling. However, throttling is not recommended.

This type of butterfly valve consists of a body, a resilient seat, a butterfly-type disk, a stem, packing, a notched positioning plate, and a handle. The resilient seat is under compression when it is mounted in the valve body. This makes a seal around the periphery of the disk and both upper and lower points where the stem passes through the seat. Packing forms a positive seal around the stem for added protection in case the seal formed by the seat is damaged.

To close or open a butterfly valve, turn the handle only one quarter turn to rotate the disk 90°. Some larger butterfly valves may have a handwheel that operates through a gearing arrangement. This method is used especially where space limitation precludes the use of a long handle.

Butterfly valves are relatively easy to maintain. The resilient seat is held in place by mechanical means, and neither bonding nor cementing is necessary. Because the seat is replaceable, the valve seat does not require lapping, grinding, or machine work.

Ball Valves

Ball valves, as the name implies, are stop valves that use a ball to stop or start the flow of fluid. The ball, shown in figure 10-14, performs the same function as the disk in the globe valve. When the valve handle is operated to open the valve, the ball rotates to a point where the hole through the ball is in line with the valve body inlet and outlet. The valve is shut by a 90-degree rotation of the handwheel for most valves. The ball is rotated so that the hole is perpendicular to the flow openings of the valve body, and flow is stopped.

Most ball valves are of the quick-acting type. They require only a 90-degree turn to operate the valve either completely open or closed. However, many are planetary gear operated. This type of gearing allows the use of a relatively small handwheel and operating force to operate a fairly large valve. The gearing does, however, increase the operating time for the valve. Some ball valves

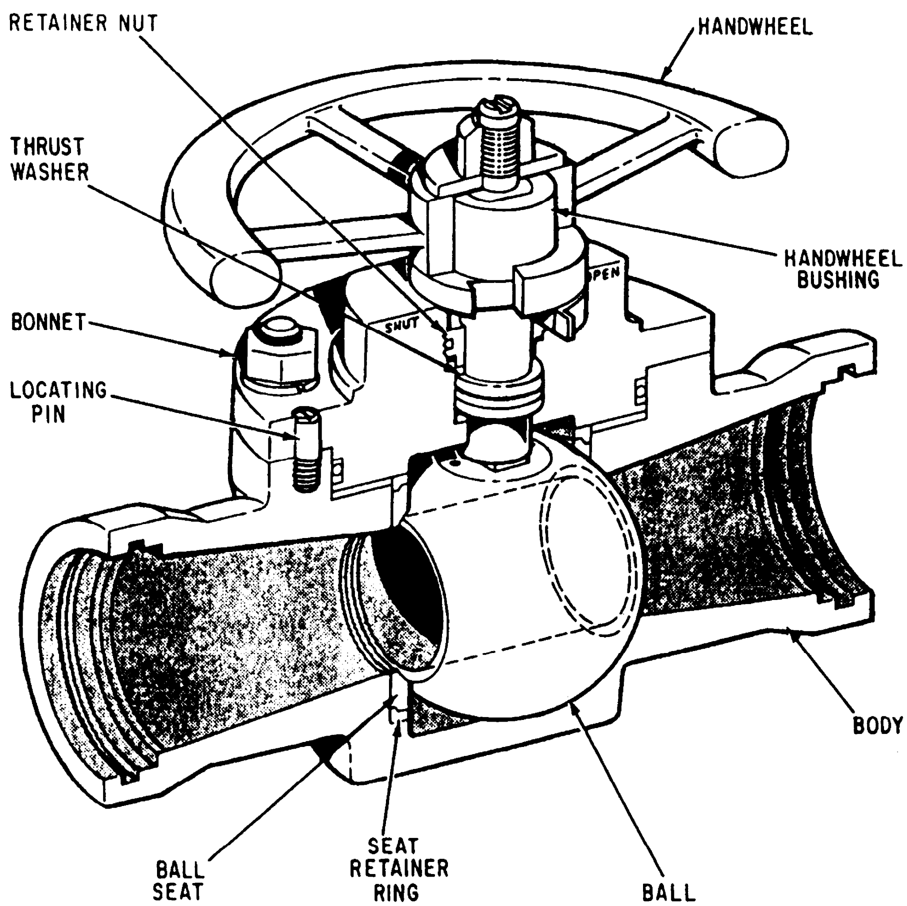


Figure 10-14.—Typical seawater ball valve.

contain a swing check located within the ball to give the valve a check valve feature. Figure 10-15 shows a ball-stop swing-check valve with planetary gear operation. Ball valves are normally found in the following systems aboard ship: seawater, sanitary, trim and drain, air, hydraulic, and oil transfer.

CHECK VALVES

Check valves allow fluid to flow in a system in only one direction. They are operated by the flow of fluid in the piping. A check valve may be of the swing type, lift type, or ball type.

AUTOMATIC PRESSURE CONTROL VALVES

There are many types of automatic pressure control valves. Some of them merely provide an escape for excessive pressures; others reduce or regulate pressure.

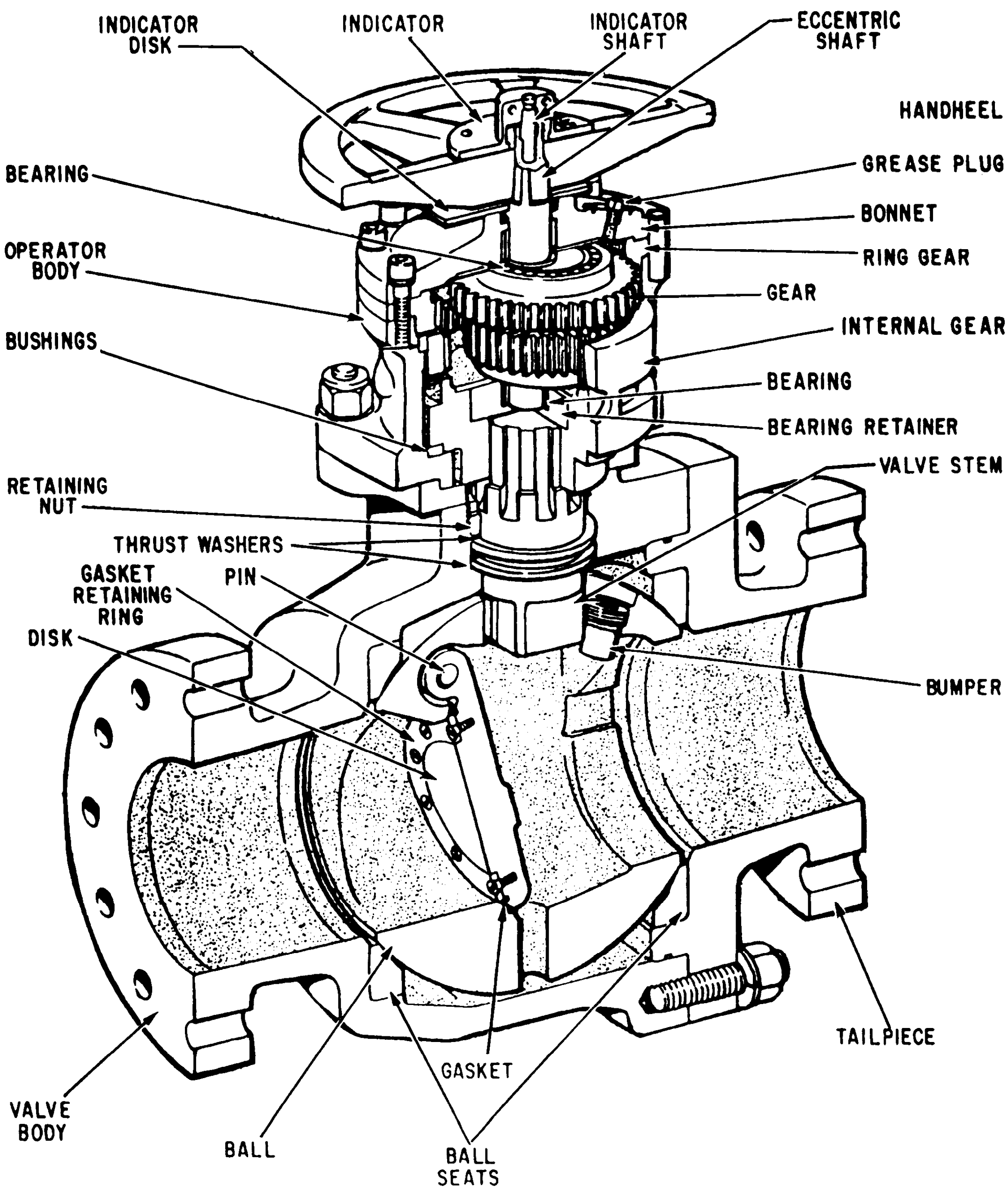


Figure 10-15.—Typical ball stop swing-check valve for seawater service.

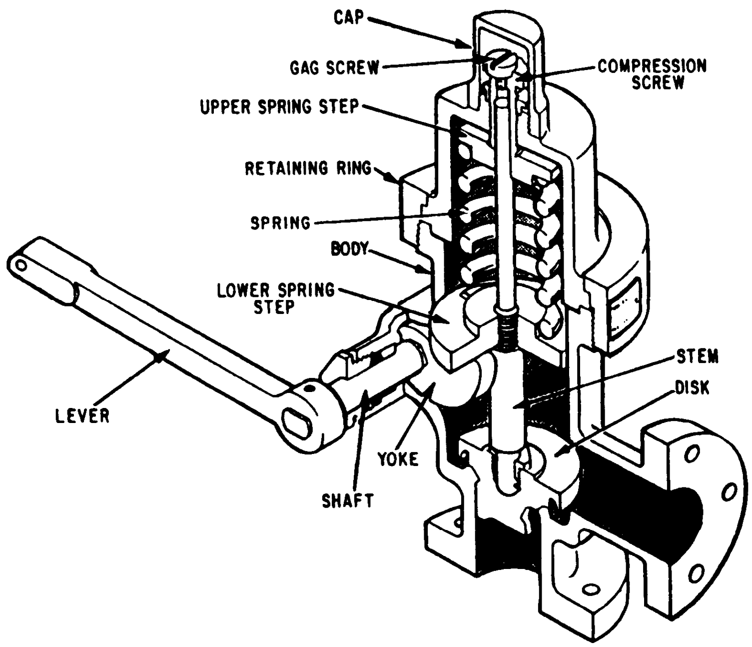


Figure 10-16.—Relief valve.

Relief Valves

Relief valves are installed in most systems to protect them from excessive pressure. These valves have an adjusting screw, a spring, and a disk. The force exerted on the disk by the spring sets the relieving pressure. Most relief valves simply open when the preset pressure is reached and close when the pressure drops slightly below the lifting pressure. Many relief valves will also have a lever so the valve can be opened by hand for test purposes. Figure 10-16 shows a relief valve of this type.

Sentinel Valves

Sentinel valves are simply small relief valves installed in some systems to warn of impending overpressure. Sentinel valves do not relieve the pressure of the system. If the situation causing the sentinel valve to lift is not corrected, a relief valve (if installed) will lift to protect the system or component. If a relief valve is not installed, action must be taken quickly to secure the piece of equipment or system to reduce the pressure.

Pressure-Reducing Valves

Reducing valves are automatic valves that provide a steady pressure into a system that is at a lower pressure than the supply system. Reducing valves of one type or another are found in steam, air, lube-oil, seawater, and other systems. A reducing valve can normally be set for any desired downstream pressure within the design limits of the valve. Once the valve is set, the reduced pressure will be maintained. This is true regardless of changes in the supply pressure as long as the supply pressure is at least as high as the reduced pressure desired. It is also true regardless of the amount of reduced pressure fluid that is used.

There are three basic designs of pressure-reducing valves in use. They are spring-loaded reducing valves, pneumatic-pressure-controlled (gas-loaded) reducing valves, and air-pilot operated diaphragm-type reducing valves. There are many different styles within these three types.

SPRING-LOADED REDUCING VALVES.— One type of spring-loaded reducing valve is

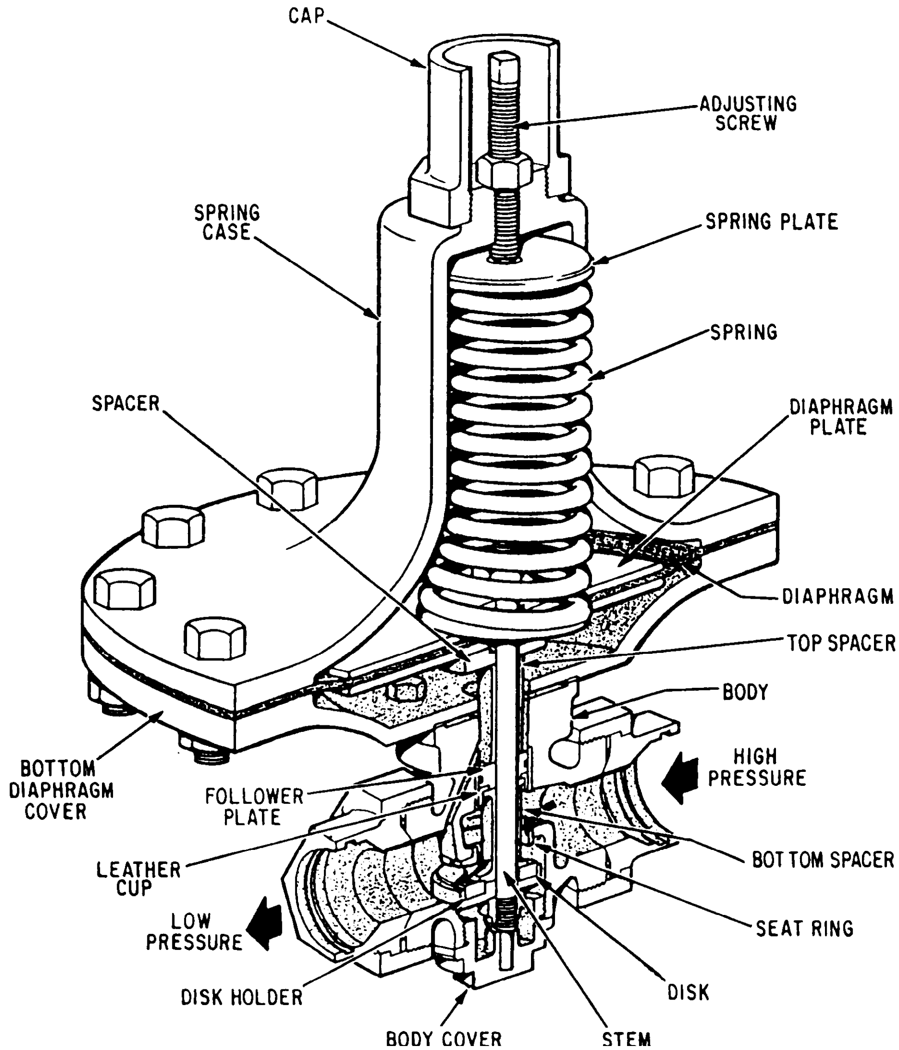


Figure 10-17.—Pressure-reducing (spring-loaded) valve.

shown in figure 10-17. These valves are used in a wide variety of applications. Low-pressure air reducers, distilling plant seawater reducers, some reduced-steam system reducers, and others are of this type. The valve simply uses spring pressure against a diaphragm to open the valve. On the bottom of the diaphragm, outlet pressure (the pressure in the reduced pressure system) of the valve forces the disk upward to shut the valve. When outlet pressure drops below the set point of the valve, spring pressure overcomes outlet pressure and forces the valve stem downward, opening the valve. As outlet pressure increases, approaching the desired value, the pressure under the diaphragm begins to overcome spring pressure. This forces the valve stem upwards, shutting the valve. Downstream pressure can be adjusted by removing the valve cap and turning the adjusting screw, which varies the spring pressure against the diaphragm. This particular spring-loaded valve will fail in the open position in the case of a diaphragm rupture.

Another, more complex, spring-loaded reducing valve is shown in figure 10-18. The principal parts of this spring-loaded reducing valve are (1) the main valve, an upward-seating valve which has a piston on top of its stem; (2) an upward-seating auxiliary (or controlling) valve; (3) a controlling diaphragm; and (4) an adjusting spring.

High-pressure steam (or other gas or fluid) enters the valve on the inlet side and acts against

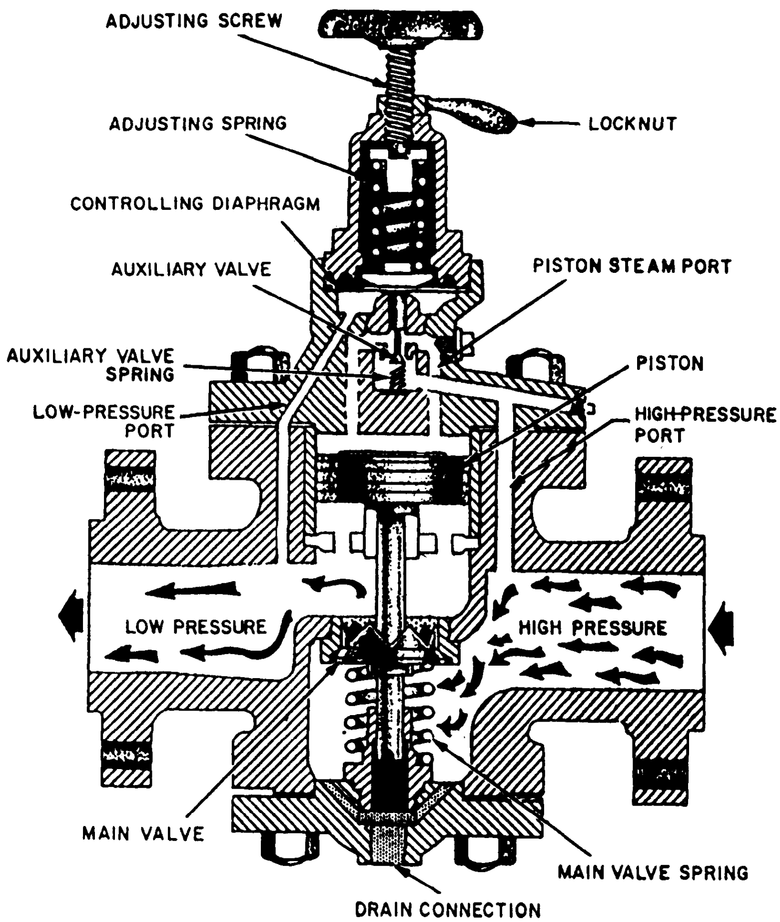


Figure 10-18.—Spring-loaded reducing valve.

the main valve disk, tending to close the main valve. However, high-pressure steam is also led through ports to the auxiliary valve. This valve controls the admission of high-pressure steam to the top of the main valve piston. The piston has a larger surface area than the main valve disk. Therefore, high-pressure steam acting on the top of the main valve piston will tend to open the main valve. This allows steam at reduced pressure to flow out the discharge side.

But what makes the auxiliary valve open to allow high-pressure steam to get to the top of the main valve piston? The controlling diaphragm exerts a downward pressure upon the auxiliary valve stem. This tends to open the valve. However, reduced-pressure steam is led back to the chamber beneath the diaphragm. The steam then exerts a pressure upward on the diaphragm. This tends to close the auxiliary valve. The position of the auxiliary valve, therefore, is determined by the position of the controlling diaphragm.

The position of the diaphragm at any given moment is determined by the relative strength of two opposing forces, The first is the downward force exerted by the adjusting spring. The second is the upward force that is exerted on the underside of the diaphragm by the reduced-pressure steam. These two forces are continually seeking a state of balance. Because of this, the discharge pressure of steam is kept constant as long as the amount of steam used is kept within the capacity of the valve.

INTERNAL PILOT-ACUATED PRESSURE REDUCING VALVE.—This valve, shown in

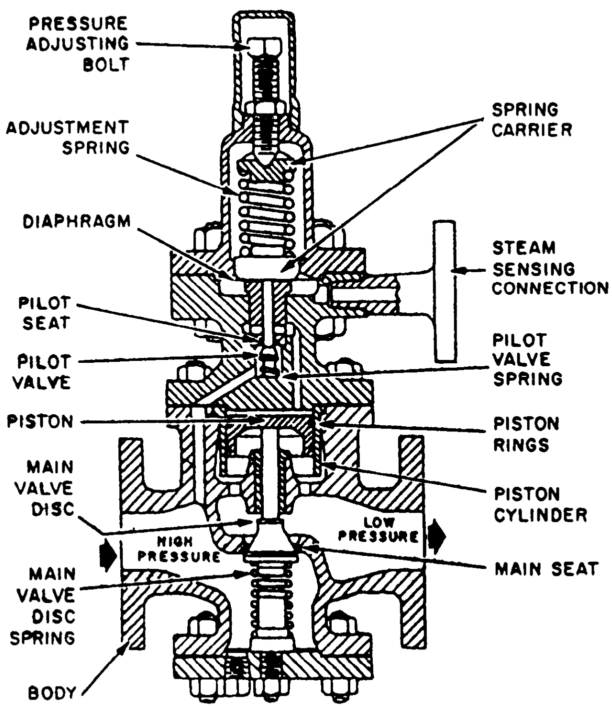


Figure 10-19.—Reducing valve (Atlas Valve Company).

figure 10-19, uses a pilot valve to control the main valve. The pilot valve controls the flow of upstream fluid, which is ported to the pilot valve, to the operating piston that operates the main valve. The main valve is opened by the operating piston and closed by the main valve spring. The pilot valve opens when the adjusting spring pushes downward on the pilot diaphragm. It closes when downstream pressure exerts a force that exceeds the force of the adjusting spring. When the pilot valve shuts off or throttles the flow of upstream fluid to the operating piston, the main valve then pushes the valve and stem upward, to throttle or close the main valve. When downstream pressure drops off, the adjusting spring force acts downward on the diaphragm. This action overcomes the force of the downstream system pressure, which is acting upward on the diaphragm. This opens the pilot valve, allowing upstream pressure to the top of the operating piston to open the main valve.

PNEUMATIC-PRESSURE CONTROLLED REDUCING VALVES.—There are two types of the pneumatic-pressure-controlled (or gas-loaded) reducing valve. One type regulates low-temperature fluids, such as air, water, or oil (fig. 10-20). The other type (not shown) regulates high-temperature fluids, such as steam or hot water. The high-temperature fluid reducer is found only in older ships.

Air-controlled regulators operate on the principle that the pressure of an enclosed gas varies inversely to its volume. A reduction in volume results in an immediate increase in pressure. Conversely, an increase in volume results in an immediate decrease in pressure. A relatively small change in the large volume within the dome loading chamber produces only a slight pressure variation, while the slightest variation in the small volume within the actuating chamber creates an enormous change in pressure. The restricting orifice connecting these two chambers governs the rate of pressure equalization by retarding the flow of gas from one chamber to the other.

The dome loading chamber is charged with air or other compressible gases (such as nitrogen) at a pressure equal to the desired reduced pressure. When the chamber is loaded and when the loading valve is closed, the dome will retain its charge almost indefinitely. When the regulator is in operation, the trapped pressure within the dome passes into the actuating chamber through the small separation plate orifice. This pressure moves the large flexible diaphragm, which forces the reverse acting valve off its seat. The pressure entering the regulator is then permitted to flow through the open valve into the reduced pressure line. A large pressure equalizing orifice transmits this pressure directly to the underside of the diaphragm. When the delivered pressure approximates the loading pressure in the dome and the unbalanced forces equalize, the valve will close. With the slightest drop in delivered pressure, the pressure charge in the dome instantly forces the valve open. This allows system fluid to pass through and thereby maintains the outlet pressure relatively constant.

To charge the loading chamber, back off slightly on the dome needle valve. Connect the specially furnished hand pump (either 300 or 600 psi), and fill the dome to the desired

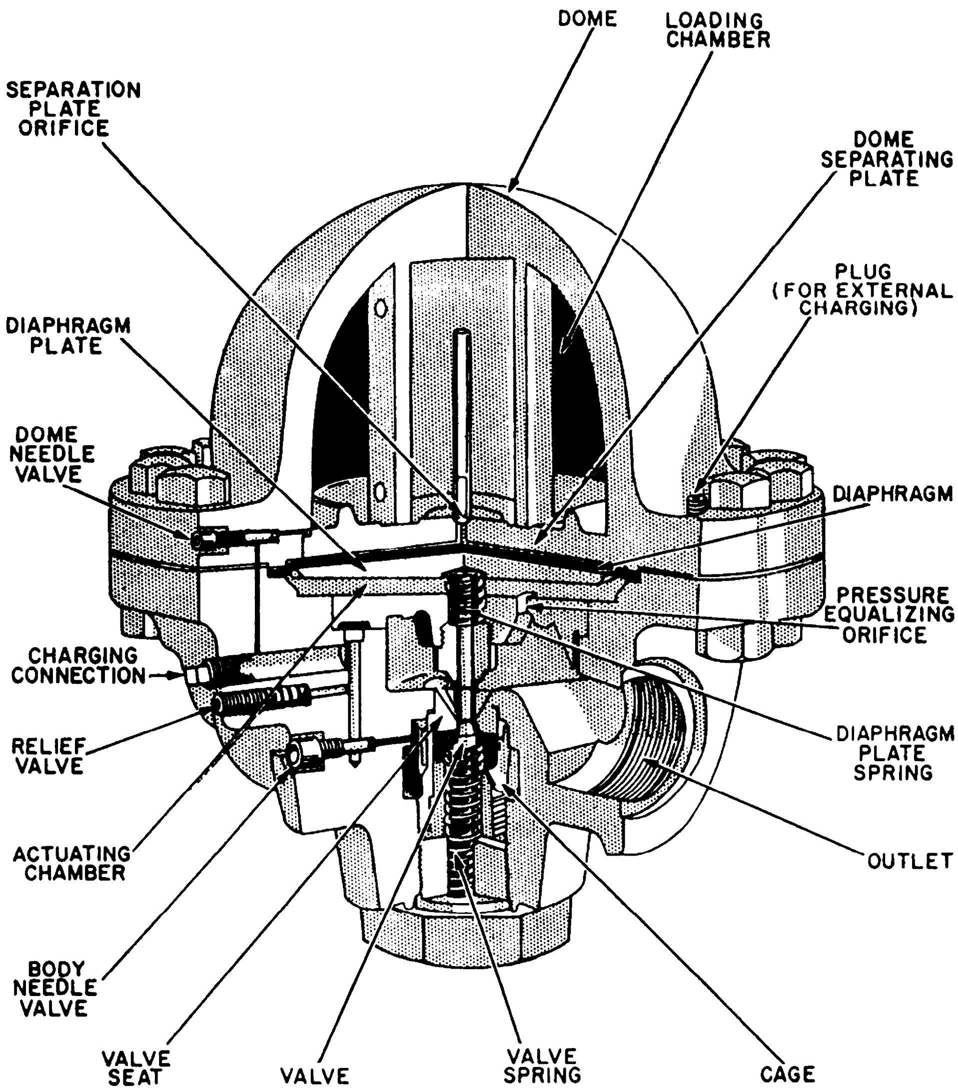


Figure 10-20.—Pneumatic-pressure-controlled reducing valve for low-temperature service.

outlet pressure. If the regulator is to handle a gas, charge the dome loading chamber with this gas via the dome needle valve and the body needle valve (fig. 10-20). If the regulator is to handle a liquid, charge the dome from an external source. Remove the plug on the dome loading chamber and connect the external source. This may be an air bottle or an air pump. Keep the body needle valve closed while you use the dome needle valve to adjust the dome pressure to obtain the desired outlet pressure.

Air-Pilot-Operated Diaphragm Control Valves.—These valves are used extensively on naval ships. The valves and pilots are available in several designs to meet different requirements. They may be used to reduce pressure, to augment pressure, as unloading valves, or to provide continuous regulation of pressure. Valves and pilots of very similar design can also be used for other services. Examples are liquid-level control and temperature control.

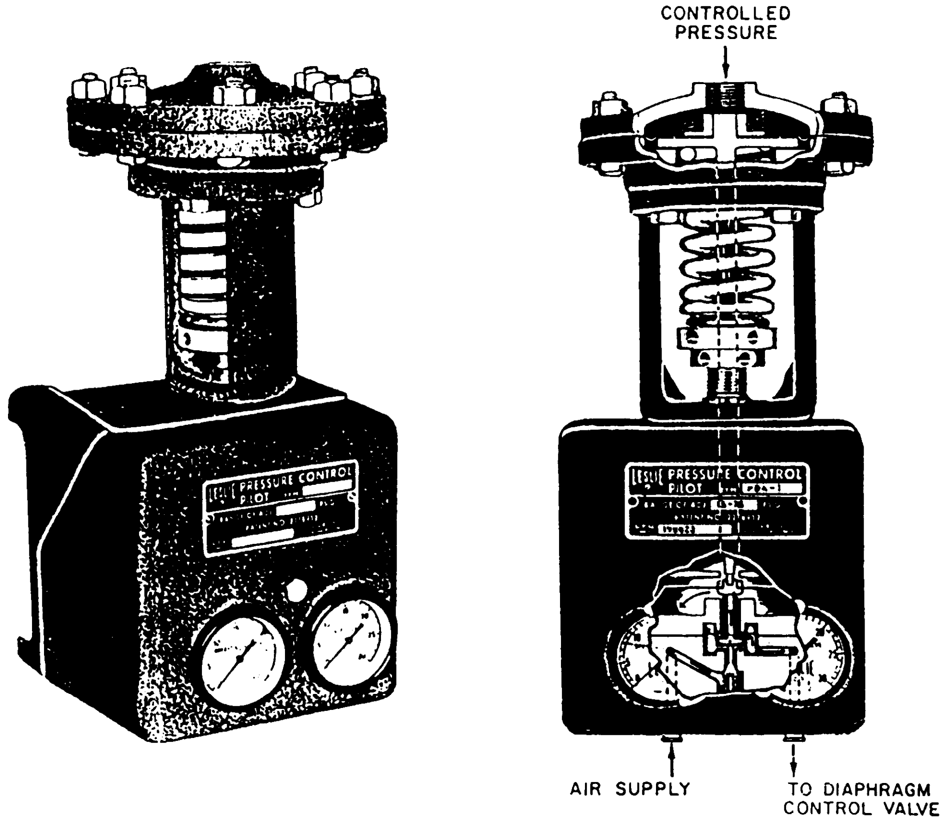


Figure 10-21.—Air-operated control pilot.

The air-operated control pilot may be either direct acting or reverse acting. A direct-acting pilot is shown in figure 10-21. In this type of pilot, the controlled pressure—that is, the pressure from the discharge side of the diaphragm control valve—acts on top of a diaphragm in the control pilot. This pressure is balanced by the pressure exerted by the pilot adjusting spring. If the controlled pressure increases and overcomes the pressure exerted by the pilot adjusting spring, the pilot valve stem is forced downward. This action opens the pilot valve. This action increases the amount of operating air pressure going from the pilot to the diaphragm control valve. A reverse-acting pilot has a lever that reverses the pilot action. In a reverse-acting pilot, therefore, an increase in controlled pressure produces a decrease in operating air pressure.

In the diaphragm control valve, operating air from the pilot acts on the valve diaphragm. The superstructure contains the diaphragm. It is direct acting in some valves and reverse acting in others. If the superstructure is direct acting, the operating air pressure from the control pilot is applied to the TOP of the valve diaphragm. If the superstructure is reverse acting, the operating air pressure from the pilot is applied to the UNDERSIDE of the valve diaphragm.

Figure 10-22 shows a very simple type of direct-acting diaphragm control valve. The operating air pressure from the control pilot is applied to the top of the valve diaphragm. The valve in the figure is a downward-seating valve. Therefore, any increase in operating air pressure pushes the valve stem downward. This tends to close the valve.

Now look at figure 10-23. This is also a direct-acting valve. The operating air pressure from the control pilot is applied to the top of the valve diaphragm. But the valve shown in figure 10-23 is more complicated than the one shown in figure 10-22. The valve shown in figure 10-23 is an upward-seating valve rather than a downward-seating valve. Therefore, any increase in operating air pressure from the control pilot tends to OPEN this valve rather than to close it.

As we have seen, the air-operated control pilot may be either direct acting or reverse acting. The

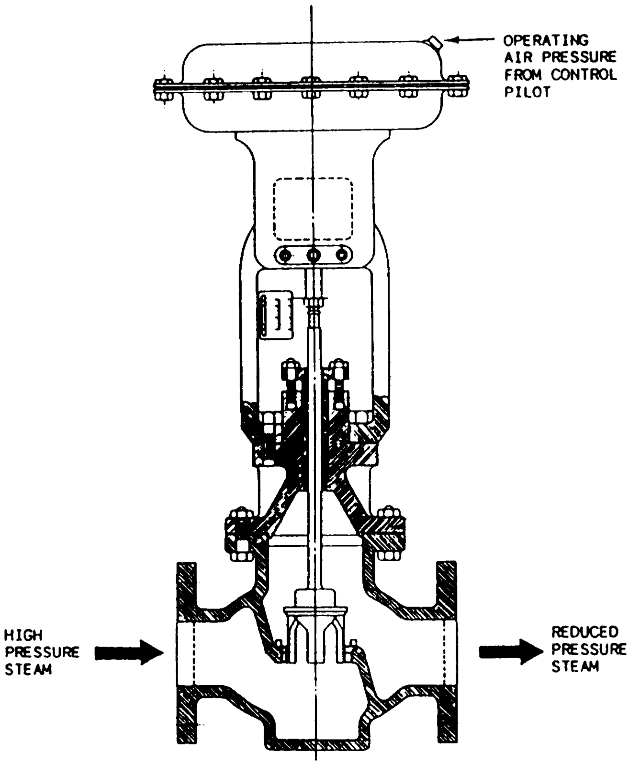


Figure 10-22.—Diaphragm control valve (downward seating).

superstructure of the diaphragm control valve may be either direct acting or reverse acting. And, the diaphragm control valve may be either upward seating or downward seating. These three factors, as well as the purpose of the installation, determine how the diaphragm control valve and its air-operated control pilot are installed in relation to each other.

To see how these factors are related, let's consider an installation; a diaphragm control valve and its air-operated control pilot are used to supply reduced steam pressure. Figure 10-24 shows one arrangement that we might use. We will assume that the service requirements indicate the need for a direct-acting, upward-seating, diaphragm control valve. Can you figure out which kind of control pilot—direct acting or reverse acting—should be used in this installation?

Let's try it first with a direct-acting control pilot. The controlled pressure (discharge pressure from the diaphragm control valve) increases. When that happens, increased pressure is applied to the diaphragm of the direct-acting control pilot. The valve stem is pushed downward and the valve in the control pilot is opened. This sends an increased amount of operating air pressure from

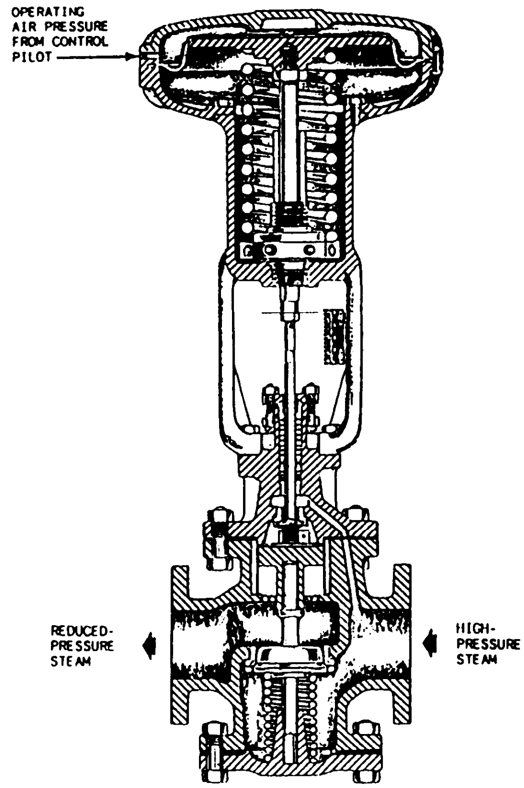


Figure 10-23.—Diaphragm control valve (upward seating).

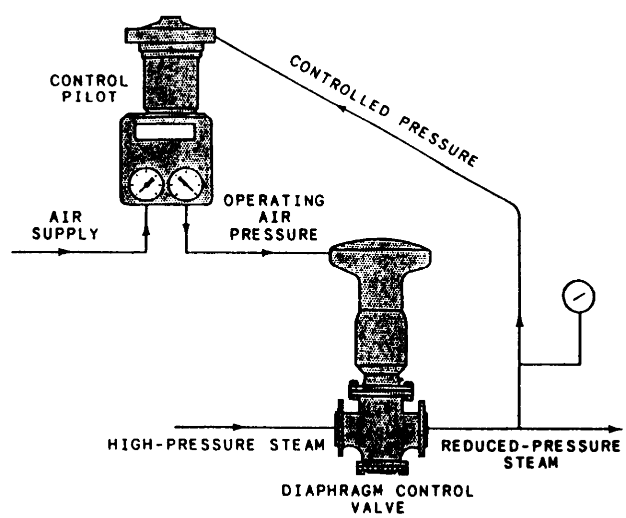


Figure 10-24.—Arrangement of control pilot and diaphragm control valve for supplying reduced steam pressure.

the control pilot to the top of the diaphragm control valve. The increased operating air pressure acting on the diaphragm of the valve pushes the stem downward. Since this is an upward-seating valve, this action OPENS the diaphragm control valve still wider. Obviously, this won't work—for this application, an INCREASE in controlled pressure must result in a DECREASE in operating air pressure. Therefore, we made a mistake in choosing the direct-acting control pilot. For this particular pressure-reducing application, we should choose a REVERSE-ACTING control pilot.

You will probably not need to decide which type of control pilot and diaphragm control valve are needed in any particular installation. But you must know how and why they are selected so that you will not make mistakes in repairing or replacing these units.

Thermostatically Controlled Recirculating Valves

When the ship is at fractional power, or cruising power, recirculating condensate must move from the discharge side of the main air ejector condenser to the main condenser. Recirculation prevents excessive loss of feedwater as vapor discharged from the air ejector after-condenser vent. This ensures proper operation of the air ejectors at fractional power. We need to make recirculation automatic. This will avoid excessive recirculation with attendant excessive loss of heat. To ensure this, most air ejector recirculating lines are fitted with thermostatically controlled valves.

We can avoid excessive heat loss by recirculating condensate from the discharge side of the main air ejector condenser to the main condenser. The air ejector condensers must be supplied with cooling water (condensate) during their operation. A hand-controlled valve allows us to bypass the thermostatic recirculating valve during the warming-up period. We will also use this bypass valve when the thermostatic valve is inoperative.

Under normal operating conditions, recirculation to the main condenser at light loads is automatically controlled by the thermostatic recirculating valves. These valves are actuated by the temperature of the condensate discharged from the air ejector aftercondenser. A rise in the water temperature, above the temperature at which the valve is set, results in automatic opening of the valve. This allows recirculation of the heated water back to the condenser and through the air ejector again. The thermostatically controlled recirculating valves are adjusted through a range of approximately 40°F. They should be individually set to open at the highest temperature at which the air ejectors will operate without loss of condenser vacuum or excessive vapor from the air ejector aftercondenser vent.

In the interest of economy, be sure the thermostatically controlled valve is in good condition and properly set. Keep the manual bypasses closed under all normal operating conditions. The control bulbs of the valves should be located in the condensate line as close as possible to the aftercondenser discharge. Preferably, when space is available, they should be located within the last pass of the air ejector aftercondenser water chest.

Hydraulically Operated Gland Seal Regulator

Figure 10-25 shows a gland seal regulator of the type used on some ships for main engine and/or turbine generator gland seal steam control. The regulator is actually a type of special valve.

During low load, when the pressure in the sealing system drops below the desired value, pressure on the BELLOWS ASSEMBLY is reduced and the PIVOT RODS move downward. Spring-loaded action on the LEVER tends to keep the PIVOT BLOCK hard against the pivot rod. The lever then moves with the pivot rod, raising the links and the PILOT VALVE. This action drains oil from beneath the PISTON, causing the piston to move downward and shut the exhaust valve. After the exhaust valve has been shut, the makeup steam valve opens and admits supply steam into the seal system to increase pressure.

When the gland seal pressure rises to the desired value, the reverse of these events takes place. The increased pressure on the bellows raises the pivot rods and causes the pilot valve to admit oil to the piston. The piston moves upward to shut the makeup steam valve, after which the exhaust valve opens.

In case of a failure of the bellows, the pivot rods move downward to their furthest travel, and the pilot valve is raised to dump oil pressure from under the piston. The piston moves downward to shut the exhaust valve and to open the makeup steam valve. This action provides a supply of gland seal to the shaft packing. The position of the valves can then be controlled manually by the control knob.

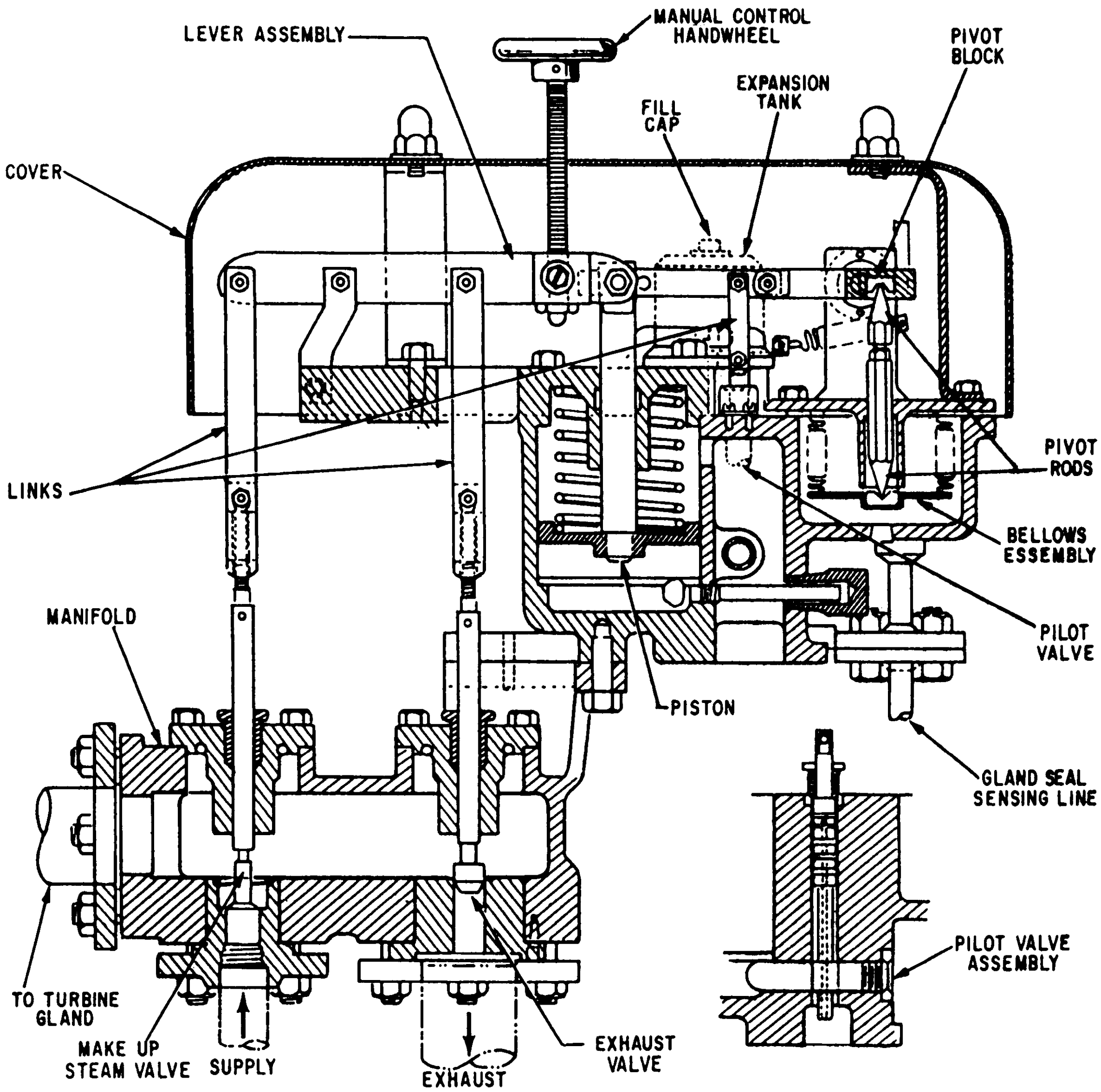


Figure 10-25.—Hydraulic steam seal regulator.

REMOTE-OPERATED VALVES

Remote-operating gear provides a means of operating certain valves from distant stations. Remote-operating gear may be mechanical, hydraulic, pneumatic, or electric.

Some remote-operating gear for valves is used in normal operation of valves. For example, the main engine throttle valves are opened and closed by a reach rod or a series of reach rods and gears. Reach rods may be used to operate engine-room valves in instances where the valves are difficult to reach from operating stations.

Other remote-operating gear is installed as emergency equipment. Some split-plant valves, main drainage valves, and main condenser injection and overboard valves are equipped with remote-operating gear. These valves can be operated normally or, in an emergency, they may be operated from remote stations. Remote-operating gear also includes a valve position indicator to show whether the valve is open or closed.

STEAM TRAPS

Steam traps in steam lines drain condensate from the lines without allowing steam to escape. There are many different kinds of steam traps.

They all consist essentially of a valve and some device or arrangement that will cause the valve to open and close as necessary to drain the condensate without allowing the escape of steam. Some designs are suitable for low pressures and low temperatures, others for high pressures and high temperatures. A few common types of steam traps are the mechanical, thermostatic, and orifice.

MECHANICAL STEAM TRAPS

Mechanical steam traps may be of the ball-float type or the bucket type.

Ball-Float Trap

In a ball-float steam trap, figure 10-26, the valve of the trap is connected to the float in such a way that the valve opens when the float rises. When the trap is in operation, the steam and any water that may be mixed with it flow into the float chamber. As the water level rises, the float lifts, thereby lifting the valve plug and opening the valve. The condensate drains out and the float moves down to a lower position, closing the valve. The condensate that passes out of the trap returns to the feed system.

Bucket-Type Trap

In a bucket-type steam trap, figure 10-27, the bucket floats when condensate enters the trap body. The valve is connected to the bucket in such a way that the valve closes as the bucket rises. As condensate continues to flow into the trap body, the valve remains closed until the bucket is full. When the bucket is full, it sinks, thus opening the valve. The valve remains open until enough condensate has passed out to allow the bucket to float, thus closing the valve.

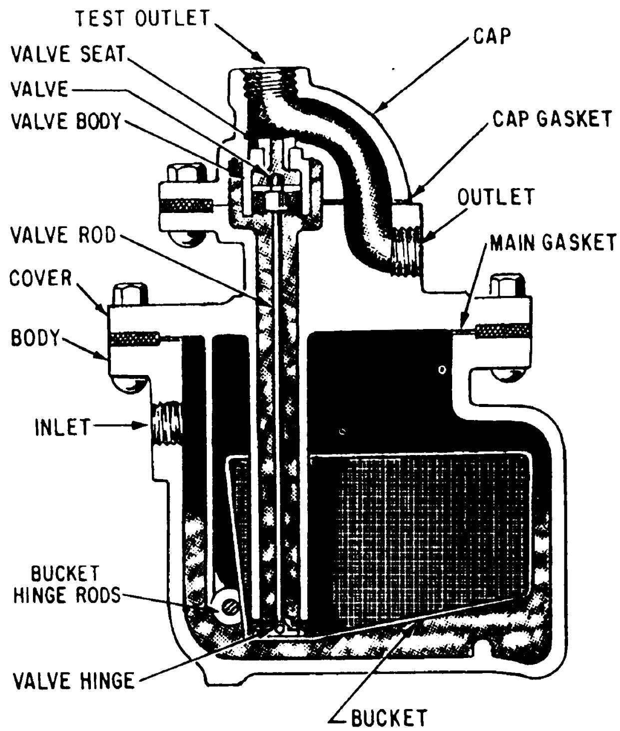


Figure 10-27.—Bucket-type steam trap.

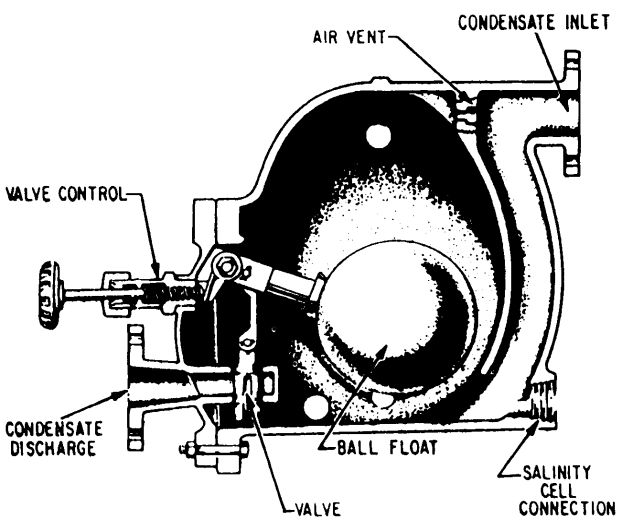


Figure 10-26.—A ball-float steam trap.

THERMOSTATIC STEAM TRAPS

There are several types of thermostatic steam traps. In general, these traps are more compact and have fewer moving parts than most mechanical steam traps. The operation of a bellows-type thermostatic trap is controlled by expansion of the vapor of a volatile liquid enclosed in a bellows-type element. Steam enters the trap body and heats the volatile liquid in the sealed bellows, thus causing expansion of the bellows. The valve is attached to the bellows in such a way that the valve closes when the bellows expands. The valve remains closed, trapping steam in the trap body. As the steam cools and condenses, the bellows cools and contracts, thereby opening the valve and allowing the condensate to drain.

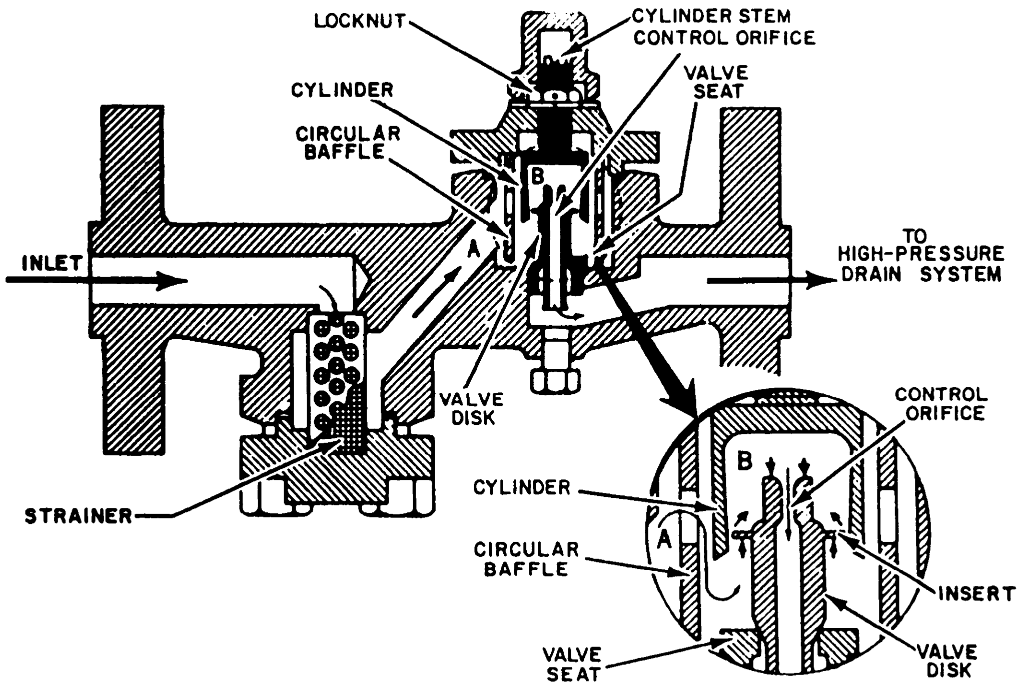


Figure 10-28.—Impulse steam trap.

The impulse and bimetallic steam traps are two examples of those that use the thermostatic principle.

Impulse Steam Traps

Impulse steam traps of the type shown in figure 10-28 are commonly used in steam drain collecting systems aboard ship. Steam and condensate pass through a strainer before entering the trap. A circular baffle keeps the entering steam and condensate from impinging on the cylinder or on the disk.

The impulse trap operates on the principle that hot water under pressure tends to flash into steam when the pressure is reduced. So that you understand how this principle is used, let's consider the arrangement of the parts shown in figure 10-28 and see what happens to the flow of condensate under various conditions.

The only moving part in the steam trap is the disk, which is rather unusual in design. Near the top of the disk is an insert that acts as a piston. As you can see in the inset, the working surface above the insert is larger than the working surface below the insert. The importance of having this larger effective area above the insert is brought out later in this discussion.

A control orifice runs through the disk from top to bottom and is considerably smaller at the top than at the bottom. The bottom part of the disk extends through and beyond the orifice in the seat. The upper part of the disk (including the insert) is inside a cylinder. The cylinder tapers inward, so the amount of clearance between the insert and the cylinder varies according to the position of the valve. When the valve is open, the clearance is greater than when the valve is closed.

When the trap is first cut in (put in service), pressure from the inlet (chamber A) acts against the underside of the insert and lifts the disk off the valve seat. Condensate is thus allowed to pass out through the orifice in the seat. At the same time, a small amount of condensate (CONTROL FLOW) flows up past the insert and into chamber B, The control flow discharges through the control orifice, into the outlet side of the trap. The pressure in chamber B remains lower than the pressure in chamber A.

As the line warms up, the temperature of the condensate flowing through the trap increases. The reverse taper of the cylinder varies the amount of flow around the insert. This continues until a balanced position is reached in which the total force exerted above the insert is equal to the total force exerted below the insert. It is important to note that there is still a PRESSURE DIFFERENCE between chamber A and chamber B. The FORCE is equalized because the effective area above the insert is larger than the effective area below the insert. The difference in working area is such that the valve maintains an open, balanced position when the pressure in chamber B is 86 percent of the pressure in chamber A.

As the temperature of the condensate approaches its boiling point, some of the control flow going to chamber B flashes into steam as it enters the low-pressure area. The steam has a much larger volume than the water from which it is generated. Therefore, pressure is built up in the space above the insert (chamber B). The pressure in this space becomes greater than 86 percent of the inlet pressure. At that time, the force exerted on the top of the insert pushes the entire disk downward and closes the valve.

With the valve closed, the only flow through the trap is past the insert and through the control orifice. When the temperature of the condensate entering the trap drops slightly, condensate enters chamber B without flashing into steam. Pressure in chamber B is thus reduced to the point that the valve opens and allows condensate to flow through the orifice in the valve seat. Thus the entire cycle is repeated.

With a normal condensate load, the valve opens and closes at frequent intervals. A small amount of condensate discharges at each opening. With a heavy condensate load, the valve remains wide open and allows a heavy, continuous discharge of condensate.

Bimetallic Steam Traps

These traps are used in many ships to drain condensate from main steam lines, auxiliary steam lines, and other steam components. The main working parts of this steam trap are a segmented bimetallic element and a ball-type check valve (fig. 10-29).

The bimetallic element consists of several bimetallic strips fastened together in a segmented fashion. One end of the bimetallic element is fastened rigidly to a part of the valve body. The other end, which is free to move, is fastened to the top of the stem of the ball-type check valve.

Line pressure acting on the check valve tends to keep the valve open. When steam enters the trap body, the bimetallic element expands unequally because of the different response to temperature of the two metals. The bimetallic element deflects upward at its free end. This moves the valve stem upward and closes the valve. As the steam cools and condenses, the bimetallic element moves downward toward the horizontal position. This opens the valve and allows some condensate to flow out through the valve. As the flow of condensate begins, an unbalance of line pressure across the valve is created. Since the line pressure is greater on the upper side of the ball of the check valve, the valve now opens wide and allows a full capacity flow of condensate.

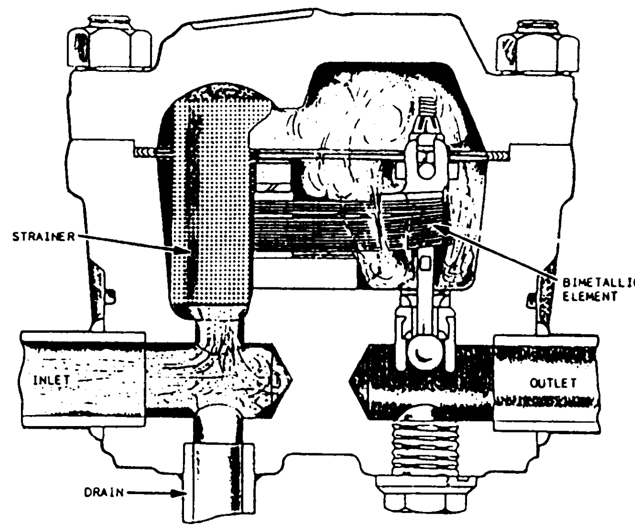


Figure 10-29.—Bimetallic steam trap.

ORIFICE-TYPE STEAM TRAPS

Figure 10-30 shows the assembly of an orifice-type steam trap. Constant-flow drain orifices may be used in systems of 150 psi and above where condensate load and pressure remain near constant.

The constant-flow drain orifice operates on a thermodynamic principle; the variable density of condensate helps its operation. Density changes with temperature. As the temperature of the condensate decreases, the density of the condensate increases, as well as the flow of the condensate through the orifice. The reverse is also true. As the temperature of the condensate increases, the density of the condensate decreases, as well as the flow of the condensate through the orifice.

Because of the difference in densities between the steam and the condensate, the condensate will flow through the orifice at a faster rate.

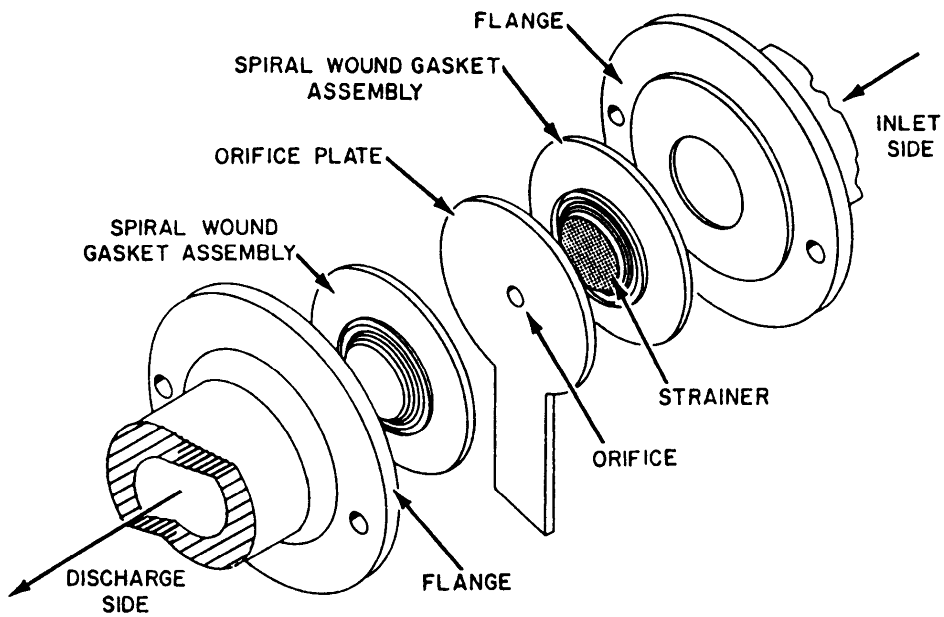


Figure 10-30.—Orifice-type steam trap assembly.

Other operating aspects of the orifice are size, pressure, and condensate load.

By calculating the condensate flow based on the condensing rate of the equipment and by knowing the pressure of the system, you can select an orifice of the proper size. Flow rate through the orifice is expressed in pounds per hour (lb/hr).

The advantages of the orifice-type trap over other types warrant their use in all systems of 150 psi and above.

MAINTENANCE AND REPAIR OF VALVES

Preventive maintenance is the best way to extend the service life of valves and fittings. Alway refer to the applicable PMS procedures and the *Navy Standard Valve Technical Manual.* When making valve repairs on more sophisticated valve types, use the manufacturer's technical manual. As soon as you observe a leak, determine the cause, then apply the proper corrective maintenance. Maintenence may be as simple as tightening a packing nut or gland. A leaking flange joint may need only to have the bolts tightened or to have a new gasket or O-ring inserted. Dirt and scale, if allowed to collect, can ultimately cause leakage. Loose hangers permit sections of a line to sag, and the weight of the pipe and these sagging sections may strain joints to the point of leakage.

Whenever you install a valve, be sure you know the function the valve is to perform, that is, whether it must prevent back flow, begin flow, stop flow, regulate flow, or regulate pressure. Inspect the valve body for information that is stamped on it by the manufacturer: type of system (oil, water, or gas), operating pressure, direction of flow, and other information.

You should also know the operating characteristics of the valve, the metal from which it is made, and the type of end connection with which it is fitted. Operating characteristics and the type of material are factors that affect the length and kind of service that a valve will give. End connections indicate whether or not a particular valve is suited to the installation.

Valves should be installed in accessible places and with enough headroom to allow for full operation. Install valves with the stem pointing upward, if possible. A stem position between straight up and horizontal is acceptable, but avoid the inverted position (stem pointing downward). If the valve is installed with the stem pointed downward, sediments will collect in the bonnet and score the stem. Also, in a line that is subject to freezing temperatures, liquid trapped in the valve bonnet may freeze and rupture it.

Globe valves may be installed with pressure either above or below the disk, depending on which method will be best for the operation, protection, maintenance, and repair of the machinery served by the system. The question of what would happen if the disk became detached from the stem is a major consideration in determining whether pressure should be above or below the disk. If you are required to install a globe valve, be sure to check the blueprints for the system to see which way the valve must be installed. Very serious casualties can result if a valve is installed with pressure above the disk when it should be below the disk, or below the disk when it should be above.

Valves that have been in constant service over a long period of time will eventually require gland tightening, repacking, or a complete overhaul of all parts. If a valve is not doing the job for which it is intended, the valve should be dismantled and all parts inspected. All defective parts must be replaced.

The repair of globe valves (other than routine renewal of packing) is generally limited to refinishing the seat and disk surfaces. When this work is being done, there are certain precautions that should be observed.

When refinishing the valve seat, do not remove any more material than is necessary. Valves that do not have replaceable valve seats can be refinished only a limited number of times.

Before you repair the seat and disk of a globe valve, check the valve disk to make certain it is secured rigidly to and is square on the valve stem. Also, check to be sure the stem is straight. If the stem is not straight, the valve disk cannot seat properly. Carefully inspect the valve seat and valve disk for evidence of wear, for cuts on the seating area, and for improper fit of the disk to the seat. Even though the disk and the seat appear to be in good condition, they should be spotted-in to find out whether they actually are.

SPOTTING-IN VALVES

The method used to visually determine whether the seat and the disk of a valve make good contact with each other is called spotting-in. To spot-in a valve seat, first apply a thin coating of prussian blue evenly over the entire machined face surface of the disk. Then insert the disk into the valve and rotate it one-quarter turn, using light downward pressure. The prussian blue will adhere to the valve seat at those points where the disk makes contact. Figure 10-31 shows the appearance of a correct seat when it is spotted-in. It also shows the appearance of various kinds of imperfect seats.

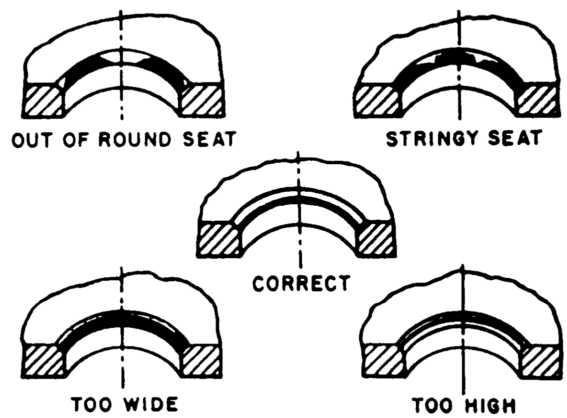


Figure 10-31.—Examples of spotted-in valve seats.

After you have noted the condition of the seat surface, wipe all the prussian blue off the disk face surface. Apply a thin, even coat of prussian blue to the contact face of the seat and place the disk on the valve seat again and rotate the disk one-quarter turn. Examine the resulting blue ring on the valve disk. The ring should be unbroken and of uniform width. If the blue ring is broken in any way, the disk is not a proper fit.

GRINDING-IN VALVES

The manual process used to remove small irregularities by grinding together the contact surfaces of the seat and disk is called grinding-in. Grinding should not be confused with refacing processes in which lathes, valve reseating machines, or power grinders are used to recondition the seating surfaces.

To grind-in a valve, first apply a small amount of grinding compound to the face of the disk. Then insert the disk into the valve and rotate the disk back and forth about one-quarter turn; shift the disk-seat relationship from time to time so that the disk will be moved gradually, in increments, through several rotations. During the grinding process, the grinding compound will gradually be displaced from between the seat and disk surfaces; therefore, you must stop every minute or so to replenish the compound. When you do this, wipe both the seat and the disk clean before applying the new compound to the disk face.

When it appears that the irregularities have been removed, spot-in the disk to the seat in the manner previously described.

Grinding-in is also used to follow up all machining work on the valve seats of disks. When the valve seat and disk are first spotted-in after they have been machined, the seat contact will be very narrow and will be located close to the bore. Grinding-in, using finer and finer compounds as the work progresses, causes the seat contact to become broader. The contact area should be a perfect ring covering approximately one-third of the seating surface.

Do not overgrind a valve seat or disk. Overgrinding tends to produce a groove in the seating surface of the disk; it also tends to round off the straight, angular surface of the disk. Machining is the only process by which overgrinding can be corrected.

LAPPING VALVES

When a valve seat contains irregularities that are slightly larger than can be satisfactorily removed by grinding-in, the irregularities can be removed by lapping. A cast-iron tool of exactly the same size and shape as the valve disk is used to true the valve seat surface. Two lapping tools are shown in figure 10-32.

Observe the following operating instructions when you use a lapping tool:

1. Do not bear down heavily on the handle of the lapping tool.
2. Do not bear sideways on the handle of the lapping tool.
3. Rotate the lapping tool so that the lap will gradually and uniformly cover the entire seat.
4. Keep a check on the working surface of the lapping tool. If a groove develops, have the tool refaced.

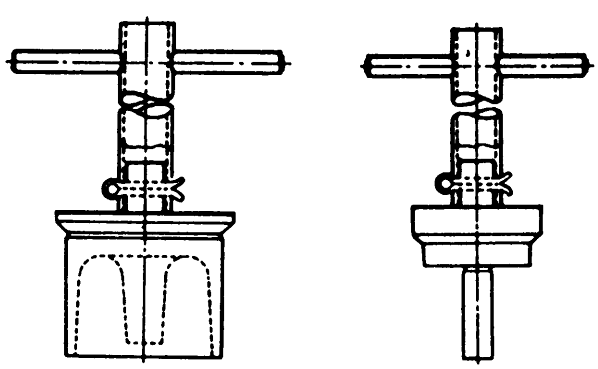


Figure 10-32.—Lapping tools.

5. Always use clean compound for lapping.
6. Replace the compound frequently.
7. Spread the compound evenly and lightly.
8. Do not lap more than is necessary to produce a smooth, even seat.
9. Always use a fine grinding compound to finish the lapping job.
10. Upon completion of the lapping job, spot-in and grind-in the disk to the seat.

Use only approved abrasive compounds to recondition valve seats and disks. Compounds for lapping and grinding valve disks and seats are supplied in various grades. A course grade compound is used when extensive corrosion or deep cuts are found on the disks and seats. A compound of medium grade is used to follow up the coarse grade; it may also be used to start the reconditioning process on valves that are not too severely damaged. A fine grade compound should be used when the reconditioning process nears completion. A microscopic-fine grade should be used for finish lapping and for all grinding-in.

REFACING VALVES

Badly scored valve seats must be refaced in a lathe, with a power grinder, or with a valve reseating machine. However, the lathe rather than the reseating machine should be used to reface all valve disks and all hard-surfaced valve seats.

Work that must be done on a lathe or with a power grinder should be turned over to machine shop personnel.

REPACKING VALVES

If the stem and packing of a valve are in good condition, you can normally stop packing gland leaks by tightening up on the packing gland or nut. You must be careful, however, to avoid excessive thread engagement of the packing gland studs (if used) and to avoid tightening old, hardened packing which will cause the valve to seize. Subsequent operation of such a valve may score or bend the stem.

Coils, rings, and corrugated ribbon are common forms of packing used on valves. The form of packing to be used to repack a particular valve will depend on the valve size, application, and type.

Basically, valve repacking involves removal of the old packing (this must be done carefully to avoid scoring of the gland or stem), inspecting and cleaning the valve stem and gland, and installing new packing. Adding the packing is not difficult, but it must be done properly or the valve will leak or bind.

When using ring packing, cut the packing so the ends fit flush and stagger the splits from each other to prevent leakage.

Some special-purpose valves are provided with precut packing available through the supply system, which must be soaked in pure (distilled) water for several hours before installation. Many valves require the use of packing pushers (either wooden or brass bushings) to ensure that the bottom rings of packing are compressed properly. These packing pushers fit into the packing gland stuffing box and the gland is tightened up with the pusher inside. After compression of the packing, the gland and pushers are removed and more packing is added. Different lengths of packing pushers are required to provide for the decreasing depths of the gland stuffing box as packing is added.

PACKING AND GASKET MATERIALS

Packing and gasket materials are required to seal joints in steam, water, gas, air, oil, and other lines. They are also used to seal connections that slide or rotate under operating conditions. There are many commercial types and forms of packing and gasket material. The Navy has simplified the selection of packing and gasket materials commonly used in naval service. The Naval Sea Systems Command has prepared a packing and gasket chart (Mechanical Standard Drawing B0153, Rev 9). This chart shows the symbol numbers and the recommended applications of all types and kinds of packing and gasket materials. A copy of the chart should be located in all engineering spaces.

A four-digit symbol number identifies each type of packing and gasket. The first digit indicates the class of service with respect to fixed and moving joints. For example, if the first digit is 1, it indicates a moving joint (moving rods, shafts, valve stems, and so forth). If the first digit is 2, it indicates a fixed joint (such as a flange or a bonnet). The second digit indicates the material of which the packing or gasket is primarily composed. This may be asbestos, vegetable fiber, rubber, metal, and so on. The third and fourth digits indicate the different styles or forms of the packing or gaskets made from the material.

Practically all shipboard packing and gasket problems can be solved if the correct material is selected from the listings on the packing and gasket chart.

CAUTION

NEVER use low-pressure packing in place of high-pressure packing; however, some high-pressure packing may be used to repack low-pressure steam valves.

The following examples show the kind of information you can get from the packing and gasket chart.

Suppose you are required to repack and install a valve in a 300-psi saturated steam line. By referring to the packing and gasket chart, you will find several materials that are suitable for repacking the valve:

Symbol 1103 Asbestos rod, braided, plain
Symbol 1104 Asbestos rod, braided, wire insertion
Symbol 1430 Metallic, flexible

Notice that the first digit is 1 in each case, to indicate that the packing is suitable for a moving joint.

To install a valve, you will need suitable gaskets. In this case, the first digit will be 2, indicating that the gasket material is suitable for fixed joints. By referring to the packing and gasket chart, you will find that you can use any of the following gasket materials:

Symbol 2150 Asbestos, sheet, compressed
Symbol 2151 Asbestos, metallic, cloth sheet
Symbol 2410 Gasket, metallic, asbestos, spiral wound

In addition to the standard packing and gasket chart, most ships have a packing and gasket chart made up specifically for that ship. The shipboard chart shows the symbol numbers and the sizes of packing and gaskets required in the ship's piping systems, machinery, and hull fittings.

PACKING

Corrugated ribbon packing (CRP) is a relatively new packing material; it is a 100 percent graphite material expressly suited for installation in steam, feed, and condensate valves. CRP (fig. 10-33)

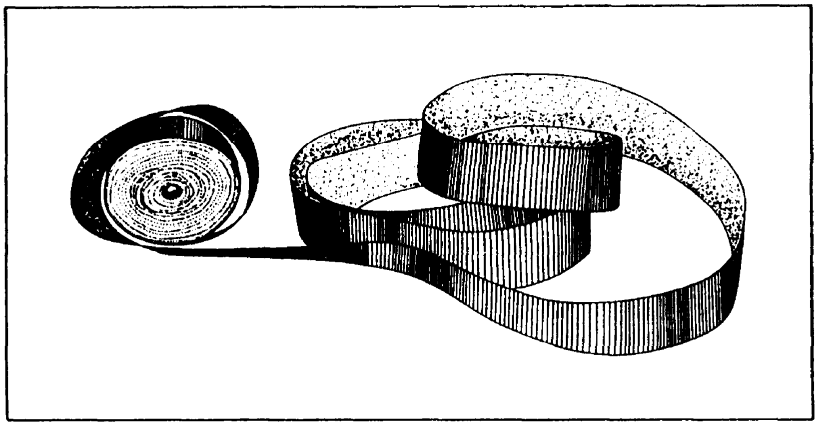


Figure 10-33.—Corrugated ribbon packing.

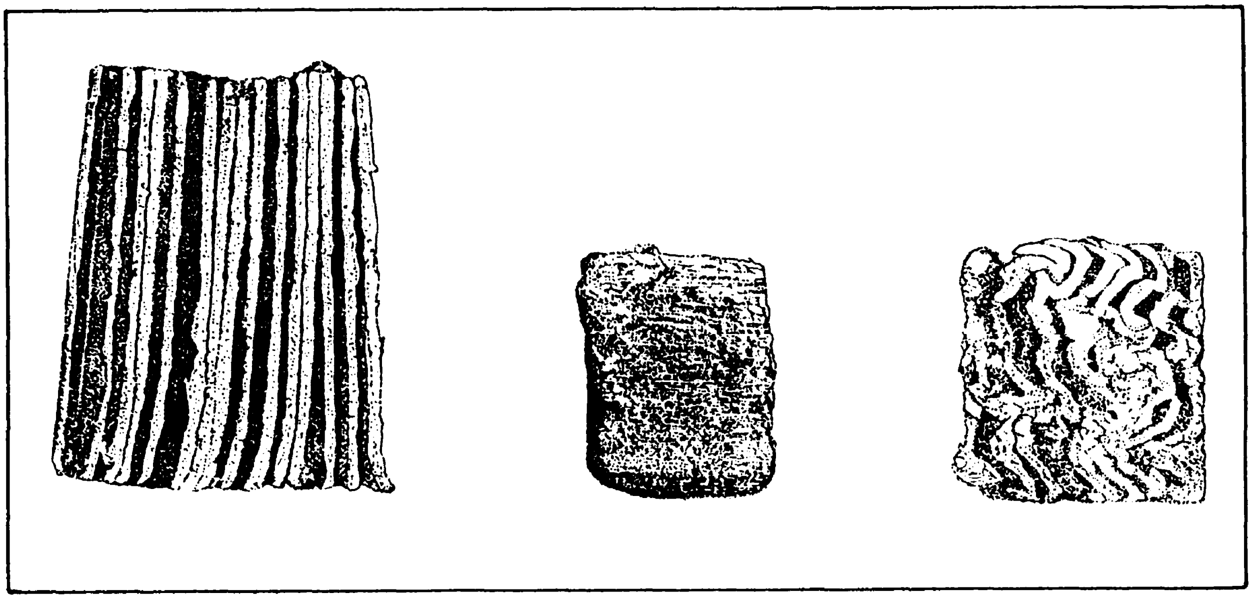


Figure 10-34.—Sectional views of corrugated ribbon packing after restructuring.

contains no binders, resins, fillers, lubricants, or other additives. It has the lubricating quality typical of pure graphite with the capability for rapid heat dissipation, thus reducing wear. Unlike conventional graphite, which is brittle, CRP is flexible and highly resilient. When CRP is formed in a valve stuffing box, it restructures as illustrated in figure 10-34,

This restructuring capability allows CRP to be wrapped around the valve stem in any size valve stuffing box and to be formed into a ring by compression. It forms a solid endless packing ring when it is compressed.

CRP is easily cut to a predetermined length. It does not turn rock hard or shrink at any temperature. Once installed and after run-in, it normally needs no further adjustment. This means greatly reduced maintenance. The resiliency and no-lint structure of CRP remain unchanged at any temperature. There is no lubricant or additive to be squeezed out, vaporized, or carbonized. Also, it has a long shelf and service life.

WARNING

CRP conducts electricity. Identification and warning stickers must be clearly visible on all containers to assure prevention of its use for electrical insulation.

Use CRP with anti-extrusion rings made of graphite filament yarn (GFY) packing. Install the rings at the bottom (first ring) and at the top (last ring) of every stuffing box. Set the GFY to prevent the CRP from being forced out of the stuffing box (extruded) through stem-stuffing, stem-gland, and gland-stuffing box clearances.

If GFY is not available, you can install a ring of conventional packing as anti-extrusion rings. However, the use must be temporary. At the earliest opportunity, disassemble, inspect, and repack the valve using GFY anti-extrusion rings with CRP.

GFY packing, figure 10-35, is a severe service packing ideal for use in difficult fluid-handling applications. It is unaffected by the most destructive corrosive fluid substances. It will withstand extreme temperatures of over 1000°F encountered in valve stuffing boxes. GFY packing is self-lubricating. It has exceptional heat dissipation characteristics. This allows tight packing adjustment to make leakage almost non-existent. It also provides maximum protection against stem scoring. This packing greatly reduces system fluid loss, maintenance, and downtime to provide longer, trouble-free valve life. GFY is available in sizes from 1/8 inch to 1 inch square on spools.

NOTE: Regardless of how good the packing material may be, if the surface of the shaft passing through the stuffing box is scored or damaged in any way, the packing will not last long. When replacing packing, carefully inspect the shaft in the area where it passes through the stuffing box. Inspect the interior of the stuffing box itself. Take whatever steps you can to ensure that the packing will make contact with the straightest, smoothest possible surface. (You may have to have the shaft repaired and refinished, or replaced.)

GASKETS

At one time, fixed steam joints could be satisfactorily sealed with gaskets of compressed asbestos sheet packing (fig. 10-36, view A). However, the 15 percent rubber content of the gasket makes it unsatisfactory for modern high-temperature steam equipment. Gaskets of corrugated copper or of asbestos and copper are sometimes used on low- and medium-pressure lines. The serrated-face metal gasket (view B) and the spiral-wound metallic-asbestos gasket (view C) are used in present-day high-temperature, high-pressure installations.

Plain Full-Faced Gaskets

When cutting a plain full-faced gasket from compressed asbestos sheet, lay an appropriate size piece of the asbestos sheet on the flange. Scribe in the bolt holes and flange circle lines with light

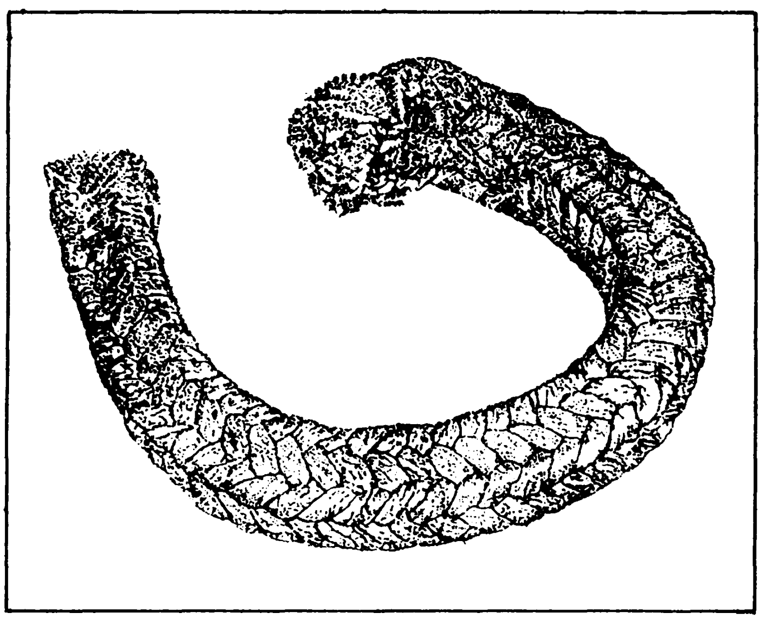


Figure 10-35.—Graphite filament yarn.

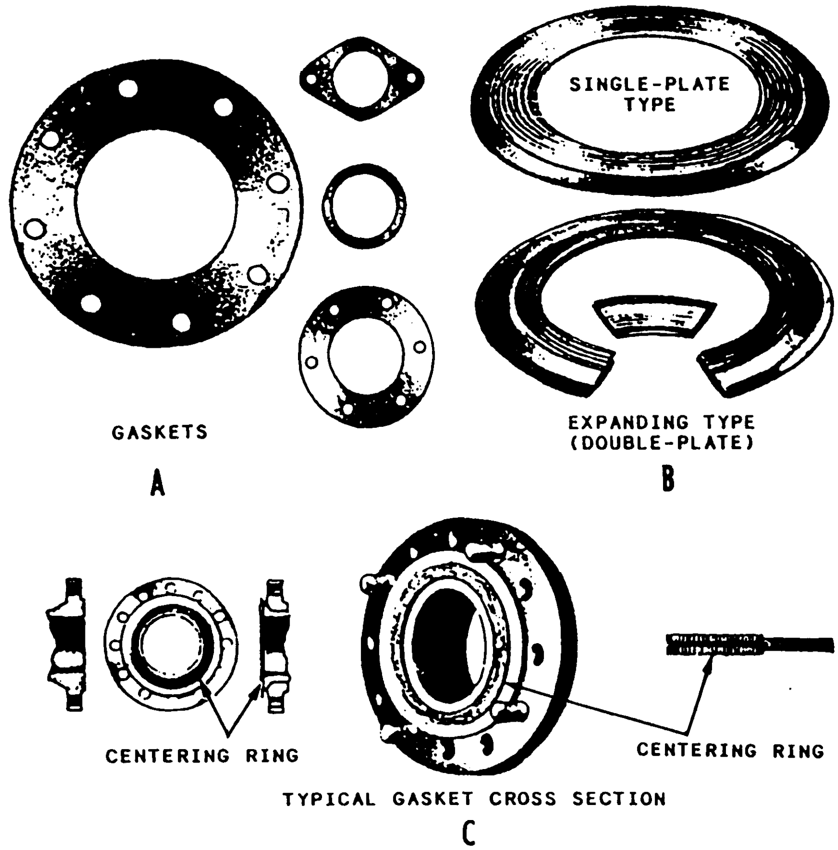


Figure 10-36.—Fixed joint gaskets. A. Sheet asbestos gaskets. B. Serrated-face metal gasket. C. Spiral-wound metallic asbestos gasket.

blows of a ball peen hammer. Using a gasket punch, about 1/16 inch larger in diameter than the bolts, cut the bolt holes into the gasket material. Use a piece of hardwood as the supporting and backing surface for the material while punching it to prevent damage to the lips of the punch. After the holes have been punched, use shears or a sharp knife to cut the center and outside circles to form the ring.

Serrated-Face Metal Gasket

Serrated-face metal gaskets (fig. 10-36, view B) are made of steel, Monel, or soft iron. They have raised serrations to make a better seal at the piping flange joints. These gaskets have resiliency; line pressure tends to force the serrated faces tighter against the adjoining flange. Two variations of serrated-face metal gaskets are shown: the single-plate type and the expanding type (double-plate).

Spiral Wound Metallic Asbestos Gaskets

Spiral-wound metallic-asbestos gaskets (fig. 10-36, view C) are made of two parts. The first is interlocked piles of preformed corrugated metal and asbestos strips, spirally wound, called a FILLER. The second is a solid metal outer or centering ring, sometimes called a RETAINING RING. The filler piece is replaceable. When renewing a gasket, remove the filler piece from the retaining metal ring and replace it with a new refill. Do not discard the solid metal retaining outer ring unless it is damaged. Then place the gasket into a retainer or centering ring. The solid steel centering also acts as reinforcement to prevent blowouts. The gaskets can be compressed to the thickness of the centering ring.

Precautions

When renewing a gasket in a flanged joint, use special precautions. When breaking the joint, particularly in steam and hot water lines, or in saltwater lines that have a possibility of direct connection with the sea, be sure of the following conditions:

1. There is no pressure on the line.
2. The line pressure valves, including the bypass valves, are firmly secured, wired closed, and tagged.
3. The line is completely drained.
4. At least two flange-securing bolts and nuts diametrically opposite remain in place until the others are removed. These bolts are then slackened to allow breaking of the joint. They are removed after the line is clear.
5. Precautions are taken to prevent explosions or fire when breaking joints of flammable liquid lines.
6. Proper ventilation is ensured before joints are broken in closed compartments.

These precautions may prevent serious explosions, severe scalding of personnel, or flooding of compartments. Thoroughly clean all sealing and bearing surfaces for the gasket replacement. Then check the gasket seats with a surface plate. Scrape as necessary to ensure uniform contact. Replace all damaged bolt studs and nuts. In flanged joints that have raised faces, the edges of gaskets may extend beyond the edge of the raised face.

WARNING

Asbestos materials are health hazardous and require special storage, handling and disposal according to Chapter 635 of *Naval Ships' Technical Manual* and OPNAVINST 5100.19B, NAVOSH Program Manual for Forces Afloat.

PACKING PRECAUTIONS

Observe the following general precautions with regard to the use of packing:

1. Do NOT use metallic or semimetallic packing on bronze or brass shafts, rods, plungers, or sleeves. If these materials are used, scoring may result. Use a braided packing that is lubricated throughout. Or, use a nonmetallic plastic packing in the center of the box with an end ring of the braided packing at each end of the box.
2. Do NOT use a packing frictioned with rubber or synthetic rubber of any kind on rotary or centrifugal shafts. Such packing will overheat.
3. Do NOT use braid-over-braid packing on rotary or centrifugal shafts. The outer layer will wear through quickly and eventually the packing will become rags.
4. Do NOT use packing with a rubber binder on rotary-type compressors. It will swell and bind, thereby developing excessive frictional heat. The use of flexible metallic packing is recommended. Or, you may use a lead-base plastic packing alternated with the flexible metallic packing.
5. On hydraulic lifts, rams, and accumulators, use a V-type packing or O-ring. For water, this packing should be frictioned with crude, reclaimed, or synthetic rubber. For oils, the packing should be frictioned with oil-resistant synthetic rubber.
6. Do NOT use a plastic packing, such as symbol 1433 or 1439, alone on worn equip ment or out-of-line rods; it will not hold. Use a combination of 1433 with end rings of plain braided asbestos (1103) or flexible metallic packing (1430). These will be satisfactory for temporary service until defective parts can be repaired or replaced.
7. Do NOT use a soft packing against thick or sticky liquids or against liquids having solid particles. This packing is too soft to hold back liquids, such as cold boiler fuel oil, and it usually gets torn. Some of the solid particles may be suspended in these liquids. They will embed themselves in the soft packing. These particles then act as an abrasive on the rod or shaft. Flexible metallic packing is best for these conditions.

INSULATION

The purpose of insulation is to retard the transfer of heat FROM piping that is hotter than the surrounding atmosphere or TO piping that is cooler than the surrounding atmosphere. Insulation helps to maintain the desired temperatures in all systems. In addition, it prevents sweating of piping that carries cool or cold fluids. Insulation also protects personnel from being burned by hot surfaces. Piping insulation is the composite piping covering that consists of the insulating material, lagging, and fastening. The INSULATING MATERIAL offers resistance to the flow of heat. The LAGGING, usually of painted canvas, is the protective and confining covering placed over the insulating material. The FASTENING attaches the insulating material to the piping and to the lagging.

Insulation covers a wide range of temperatures. They range from the extremely low temperatures of the refrigerating plants to the very high temperatures of the ship's boilers. No one material could possibly be used to meet all the conditions with the same efficiency.

The following QUALITY REQUIREMENTS for the various insulating materials are taken into consideration by the Navy in the standardization of these materials:

1. Low heat conductivity
2. Noncombustibility
3. Lightweight material
4. Easy molding and installation capability
5. Moisture repellent
6. Noncorrosive, insoluble, and chemically inactive
7. Composition, structure, and insulating properties unchanged by the temperatures at which it is to be used
8. Once installed, it should not cluster, become lumpy, disintegrate or build up in masses from vibration
9. Verminproof
10. Hygienically safe to handle

Insulating material is available in preformed pipe coverings, blocks, batts, blankets, and felts. Chapter 635 of the *Naval Ships' Technical Manual* contains all of the insulating materials, along with their application and precautions.

INSULATION AND CEMENTS

The insulating cements are composed of a variety of materials. They differ widely among themselves as to the conductivity, weight, and other physical characteristics. Typical variations are the asbestos cements, diatomaceous cements, and mineral and slag wool cements. These cements are less efficient than other high-temperature insulating materials. However, they are valuable for patchwork emergency repairs and for covering small irregular surfaces, such as valves, flanges, and joints. The cements are also used as a surface finish over block or sheet forms of insulation, to seal joints between the blocks, and to provide a smooth finish over which asbestos or glass cloth lagging may be applied (fig. 10-37).

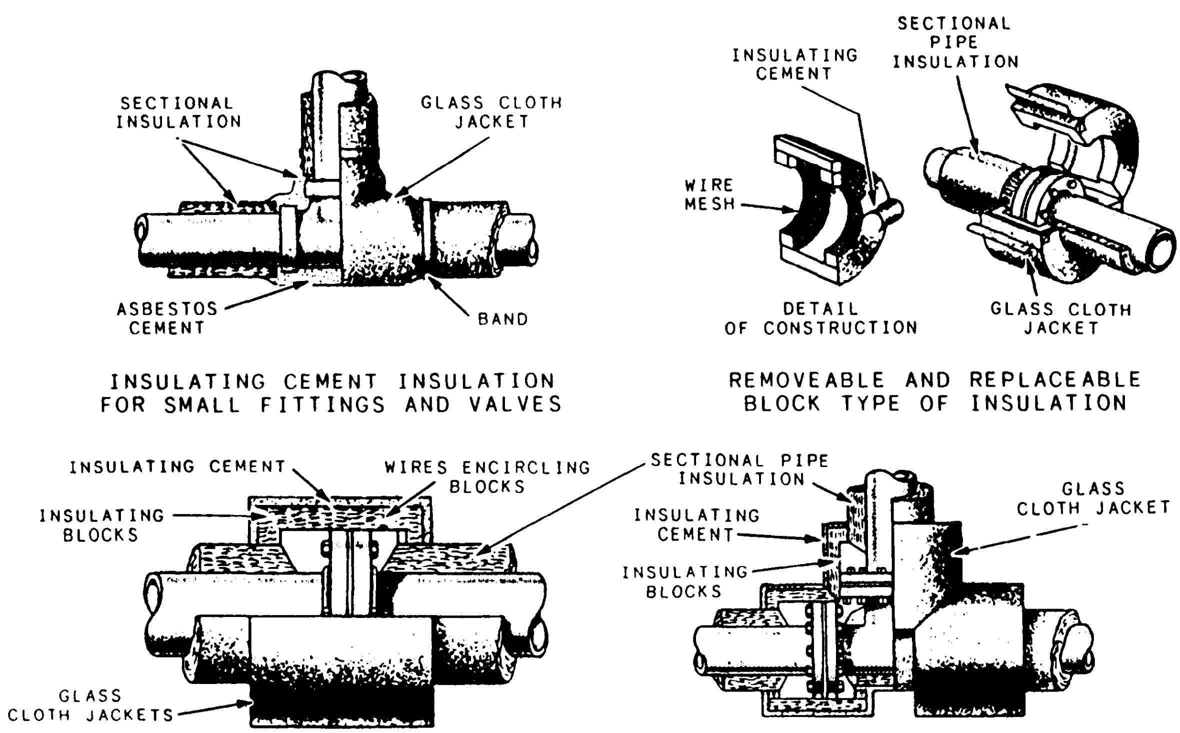


Figure 10-37.—Permanent-type insulation of pipe fittings, flanges, and valves.

Removable insulation is usually installed in the following locations:

1. Manhole covers, inspection openings, turbine casing flanges, drain plugs, strainer cleanouts, and spectacle flanges
2. Flanged pipe joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul
3. Valve bonnets of valves larger than 2 inches NPS that operate at 300 psi and above, or at 240°F and above
4. All pressure-reducing and pressure-regulating valves, pump pressure governors, and strainer bonnets

A small unit of machinery or equipment, such as an auxiliary turbine, requires a different approach. It would be difficult to install both permanent insulation over the casing and removable and replaceable covers over the casing flanges. Therefore, the entire insulation may be made removable and replaceable. Covers should fit accurately and should project over adjacent permanent insulation.

Observe the following general precautions in the application and maintenance of insulation:

1. Fill and seal all air pockets and cracks. Failure to do this will cause large losses in the effectiveness of the insulation.
2. Seal the ends of the insulation and taper off to a smooth, airtight joint. At joint ends or other points where insulation is liable to damage, use sheet metal lagging. Cuff flanges and joints with 6-inch lagging.
3. Keep moisture out of all insulation work. Moisture is an enemy of heat insulation fully as much as it is of electrical insulation. Any dampness increases the conductivity of all heat-insulating materials.
4. Insulate all hangers and other supports at their point of contact from the pipe or other unit they are supporting. Otherwise, a considerable quantity of heat will be lost via conduction through the support.
5. Keep sheet metal covering bright and unpainted unless the protecting surface has been damaged or has worn off. The radiation from bright-bodied and light-colored objects is considerably less than from rough and dark-colored objects.
6. Carefully inspect, provide upkeep, and repair heat insulation once it is installed. Replace lagging and insulation removed to make repairs just as carefully as when it was originally installed. When replacing insulation, make certain that the replacement material is the same type that had been used originally.
7. Insulate all flanges with easily removable forms. These can be made up as pads of insulating material, wired or bound in place. The whole can be covered with sheet metal casings that are in halves and easily removed.

The main steam, auxiliary steam, auxiliary exhaust, feedwater, and steam heating piping systems are lagged to hold in the heat. The circulating drainage, fire, and sanitary piping systems are lagged to prevent condensation of moisture on the outside of the piping.

CAUTION

Inhaled asbestos filler can cause severe lung damage in the form of disabling or fatal fibrosis of the lungs. Asbestos has also been found to be a causal factor in the development of cancer of the membrane lining the chest and abdomen. Lung damage and disease usually develop slowly and often do not become apparent until years after the initial exposure. Ripping out or handling asbestos is restricted to the trained emergency asbestos removal team or an Intermediate Maintenance Activity (IMA). Chapter 635 of *Naval Ships' Technical Manual* (NSTM) and Chapter **B1 of OPNAVINST 5100.19, NAVOSH** Program Manual for Forces Afloat, include asbestos removal precautions and procedures.

CHAPTER 11

REFRIGERATION

As a Machinist's Mate (MM), you must have a knowledge of refrigeration and air-conditioning systems. When you are assigned to a ship, you will learn how to start, operate, and stand watch on, and secure these systems. Before you can do that, you must have a thorough understanding of the operating principles. You can learn these principles if you study this chapter thoroughly and carefully.

Most refrigeration systems used by the Navy use R-12, R-114, and R-134 as a refrigerant. Chemically, R-12 is dichlorodifluoromethane (CCl_2F_2). R-12 has such a low boiling point that it cannot exist as a liquid unless it is confined in a container under pressure. This chapter is primarily concerned with R-12 systems. However, the cycle of operation and the main components of R-12 systems are basically the same as those in other refrigeration and air-conditioning plants. For more detailed information on refrigeration, refer to *NSTM* 516.

FUNDAMENTALS OF REFRIGERATION

Refrigeration is a general term. It describes the process of removing heat from spaces, objects, or materials and maintaining them at a temperature below that of the surrounding atmosphere. To produce a refrigeration effect, the material to be cooled needs only to be exposed to a colder object or environment. The heat will flow in its NATURAL direction—that is, from the warmer material to the colder material. Refrigeration, then, usually means an artificial way of lowering the temperature. Mechanical refrigeration is a mechanical system or apparatus that transfers heat from one substance to another.

You will find it easier to understand refrigeration if you know the relationships among temperature, pressure, and volume, and how pressure affects liquids and gases.

HEAT

The purpose of refrigeration is to maintain spaces at low temperatures. Remember, you cannot cool anything by adding coolness to it; you have to REMOVE HEAT from it. Therefore, refrigeration cools by removing heat.

Heat and Temperature

It is important to know the difference between heat and temperature. HEAT is a form of energy. TEMPERATURE is the intensity of heat. The quantity or amount of heat energy in a substance is measured in BRITISH THERMAL UNITS (Btu). The Btu is the amount of heat required to raise the temperature of 1 pound of pure water 1°F. Temperature, as you know, is measured in degrees, which indicate the intensity of the heat in a given substance. It does not indicate the number of Btu in the substance. For example, let's consider a spoonful of very hot water and a bucketful of warm water. Which has the higher temperature? Which has more heat? The heat in the spoonful of hot water is more intense; therefore, its temperature is higher. The bucketful of warm water has more Btu (more heat energy), but its heat is less intense.

Sensible Heat and Latent Heat

In the study of refrigeration, you must distinguish between sensible heat and latent heat. Sensible heat is the heat absorbed or given off by a substance that is NOT in the process of changing its physical state. The addition or removed of heat always causes a change in the temperature of the substance. Sensible heat can be sensed, or measured, with a thermometer.

Latent heat is the heat absorbed or given off by a substance while it is changing its physical state. The heat absorbed or given off does NOT cause a temperature change in the substance—the heat is latent or hidden. In other words, sensible heat is the heat that affects the temperature of things; latent heat is the heat that affects they physical state of things. You will find more information on sensible heat and latent heat in *Fireman NAVEDTRA 14104.*

Specific Heat

Substances vary with respect to their ability to absorb or lose heat. The ability of a substance to absorb heat or to lose it is known as the specific heat of the substance. The specific heat of water is 1.0 (1 Btu/lb/°F), and the specific heat of every other substance is measured by comparison with this standard. Thus, if it takes only l/2 Btu to raise the temperature of 1 pound of a substance l°F, the specific heat of that substance is 0.5 or one-half the specific heat of water. If you look up the specific heat of ice in a table, you will find it to be approximately 0.5.

Heat Flow

Heat flows only from objects of higher temperature to objects of lower temperature. This was described earlier as the natural flow of heat. When two objects at different temperatures are placed near each other, heat will flow from the warmer object to the cooler one until both objects are at the same temperature. Heat flows at a greater rate when there is a large temperature difference. As the temperature difference approaches zero, the rate of heat flow also approaches zero. Heat flow may take place by radiation, by conduction, by convection, or by some combination of these methods.

Refrigeration Ton

The unit of measure for the amount of heat removed is known as the refrigeration ton. The capacity of a refrigeration unit is usually stated in refrigeration tons. The refrigeration ton is based on the cooling effect of 1 ton (2,000 pounds) of ice at 32°F melting in 24 hours. The latent heat of fusion of ice (or water) is 144 Btu. Therefore, the number of Btu required to melt 1 ton of ice is 144 × 2,000 = 288,000. The standard refrigeration ton is defined as the transfer of 288,000 Btu in 24 hours. On an hourly basis, the refrigeration ton is 12,000 Btu per hour (288,000 is divided by 24).

The refrigeration ton is the standard unit of measure used to designate the heat-removal capacity of a refrigeration unit. It is not a measure of the ice-making capacity of a machine, since the amount of ice that can be made depends on the initial temperature of the water and other factors.

PRESSURE, TEMPERATURE, AND VOLUME

We said earlier, that it is important that you understand some of the ways pressure affects liquids and gases and some of the relationships between pressure, temperature, and volume in gases.

The boiling point of any liquid varies according to the pressure on the liquid—the higher the pressure, the higher the boiling point. It is well to remember that condensing a gas to a liquid is just the reverse process of boiling a liquid until it vaporizes. The same pressure and temperature relationship is required to produce either change of state.

Water boils at 80°F under a vacuum of 29 inches of mercury and at 489°F at a pressure of 600 psig. Refrigerants used in vapor compressor cycle equipment usually have much lower boiling points than water under any given pressure. However, these boiling points also vary according to pressure. R-12, for example, boils at -21.6°F at atmospheric pressure and at 0°F at 9.17 psig. You can see that R-12 cannot exist as a liquid at ordinary temperatures unless it is confined in a container to maintain its own pressure.

If the temperature of a liquid is raised to the boiling point corresponding to its pressure and if application of heat is continued, the liquid begins to boil and vaporize. The vapor that is formed remains at the same temperature as the boiling liquid as long as it is in contact with the liquid. A vapor CANNOT be superheated as long as it is in contact with the liquid from which it is being generated.

The pressure-temperature-volume relationships of gases are expressed by Boyle's law, Charles' law, and the general gas law or equation.

BOYLE'S LAW states that the volume of any dry gas varies inversely with its absolute pressure, provided the temperature remains constant. This law may also be expressed as

$$V_1P_1 = V_2P_2$$

where V_1 is the original volume of the gas, P_1 its orignal absolute pressure, V_2 with its new volume, P_2 its new absolute pressure.

CHARLES' LAW states that the volume of a gas is directly proportional to its absolute temperature, provided the pressure is kept constant. The equation for this law is

$$V_1T_2 = V_2T_1$$

The GENERAL GAS EQUATION combines Boyle's law and Charles' law. It expresses the interrelationship of the volume, the absolute pressure, and the absolute temperature of gases. The general gas law is expressed by

$$\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$$

These equations indicate the nature of the interrelationship of the pressure, the volume, and the temperature of any gas. You probably will not find it necessary to use the equations themselves, but you should have a thorough understanding of the principles which they express. Let's summarize them:

1. When temperature is held constant, increasing the pressure on a gas causes a proportional decrease in volume. Decreasing the pressure causes a proportional increase in volume.

2. When pressure is held constant, increasing the temperature of a gas causes a proportional increase in volume. Decreasing the temperature causes a proportional decrease in volume.

3. When the volume is held constant, increasing the temperature of a gas causes a proportional increase in pressure. Decreasing the temperature causes a proportional decrease in pressure.

In this discussion of the effects of pressure on a gas, we have pointed out that the volume and the temperature of gas are different AFTER the pressure has been changed. It is important to note, however, that a temperature change normally occurs in a gas WHILE the pressure is being changed. Compressing a gas raises its temperature; allowing a gas to expand lowers its temperature. As you will see, this fact is important in the refrigeration cycle.

MECHANICAL REFRIGERATION SYSTEMS

Various types of refrigerating systems are used for naval shipboard refrigeration and air conditioning. The one used most for refrigeration purposes is the vapor compression cycle with reciprocating compressors.

Figure 11-1 shows a general idea of this type of refrigeration cycle. As you study this system, try to understand what happens to the refrigerant as it passes through each part of the cycle. In particular, be sure that you understand why the refrigerant changes from liquid to vapor and from vapor to liquid and what happens it terms of heat because of these changes of state. We will trace the refrigerant through its entire cycle, beginning with the thermostatic expansion valve (TXV).

Liquid refrigerant enters the expansion valve which separates the high side of the system and the low side of the system. This valve regulates the amount of refrigerant which enters the cooling coil. Because of the pressure differential, as the refrigerant passes through the TXV, some of it flashes to a vapor.

From the TXV, the refrigerant passes into the cooling coil (or evaporator). The boiling point of the refrigerant under the low pressure in the evaporator is about 20°F lower than the temperature of space in which the cooling coil is installed. As the liquid boils and vaporizes, it picks up its latent heat of vaporization from the space being cooled. The refrigerant continues to absorb latent heat of vaporization until all the liquid has been vaporized. By the time the refrigerant leaves the cooling coil, it has not only absorbed this latent heat of vaporization but has also picked up some additional heat-that is, the vapor has become superheated. As a rule, the amount of superheat is 4° to 12°F.

The refrigerant leaves the evaporator as low-pressure superheated vapor. The remainder of the cycle is used to dispose of this heat and convert the refrigerant back into a liquid state so that it can again vaporize in the evaporator and absorb the heat again.

The low-pressure superheated vapor is drawn out the evaporator by the compressor, which also keeps the refrigerant circulating through the system. In the compressor cylinders, the refrigerant is compressed from a low-pressure, low-temperature vapor to a high-pressure vapor, and its temperature rises accordingly.

The high-pressure R-12 vapor is discharged from the compressor into the condenser. Here the refrigerant condenses, giving up its superheat (sensible heat) and its latent heat of condensation. The condenser may be air or water cooled. The refrigerant, still at high pressure, is now a liquid again.

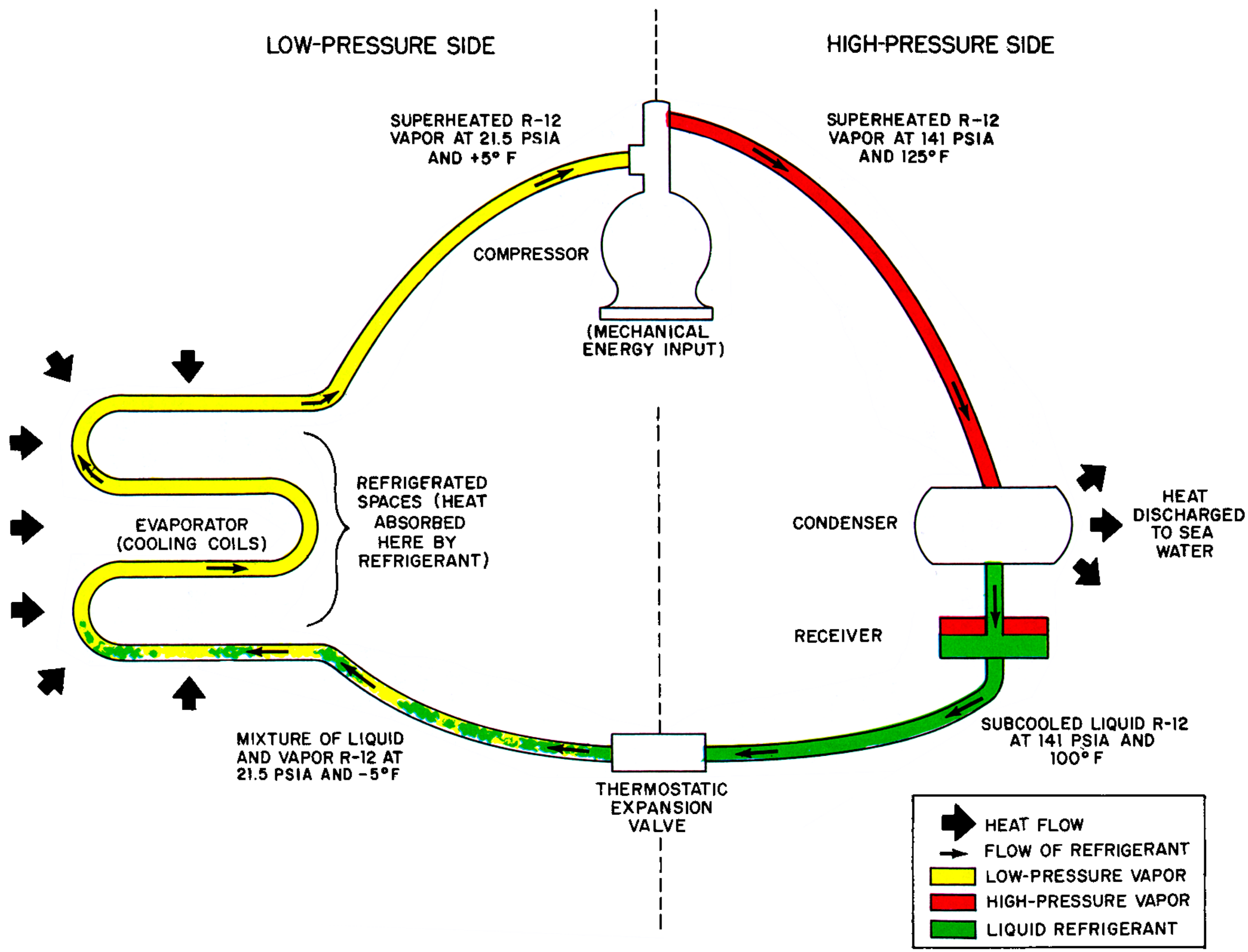


Figure 11-1.—Schematic representation of refrigeration cycle.

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From the condenser, the refrigerant flows into a reciever which serves as a storage place for the liquid refrigerant in the system. From the receiver, the refrigerant goes to the TXV and the cycle begins again.

This type of refrigerant system has two pressure sides. The LOW-PRESSURE SIDE extends from the TXV up to and including the intake side of the compressor cylinders. The HIGH-PRESSURE SIDE extends from the discharge valve of the compressor to the TXV. Figure 11-2 shows most of the components on the high-pressure side of an R-12 system as it is installed aboard ship.

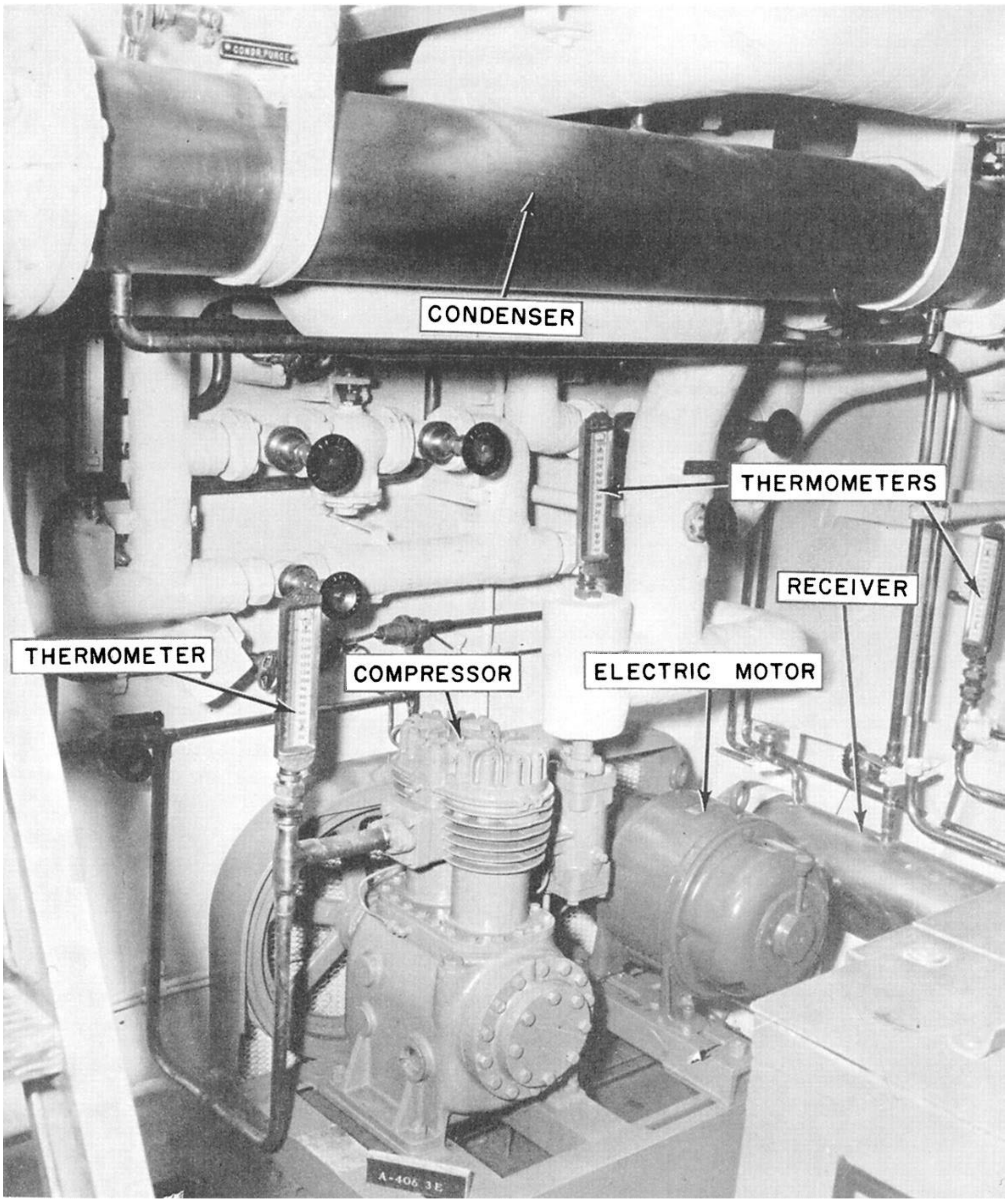

Figure 11-2.—High-pressure side of R-12 installation aboard ship.

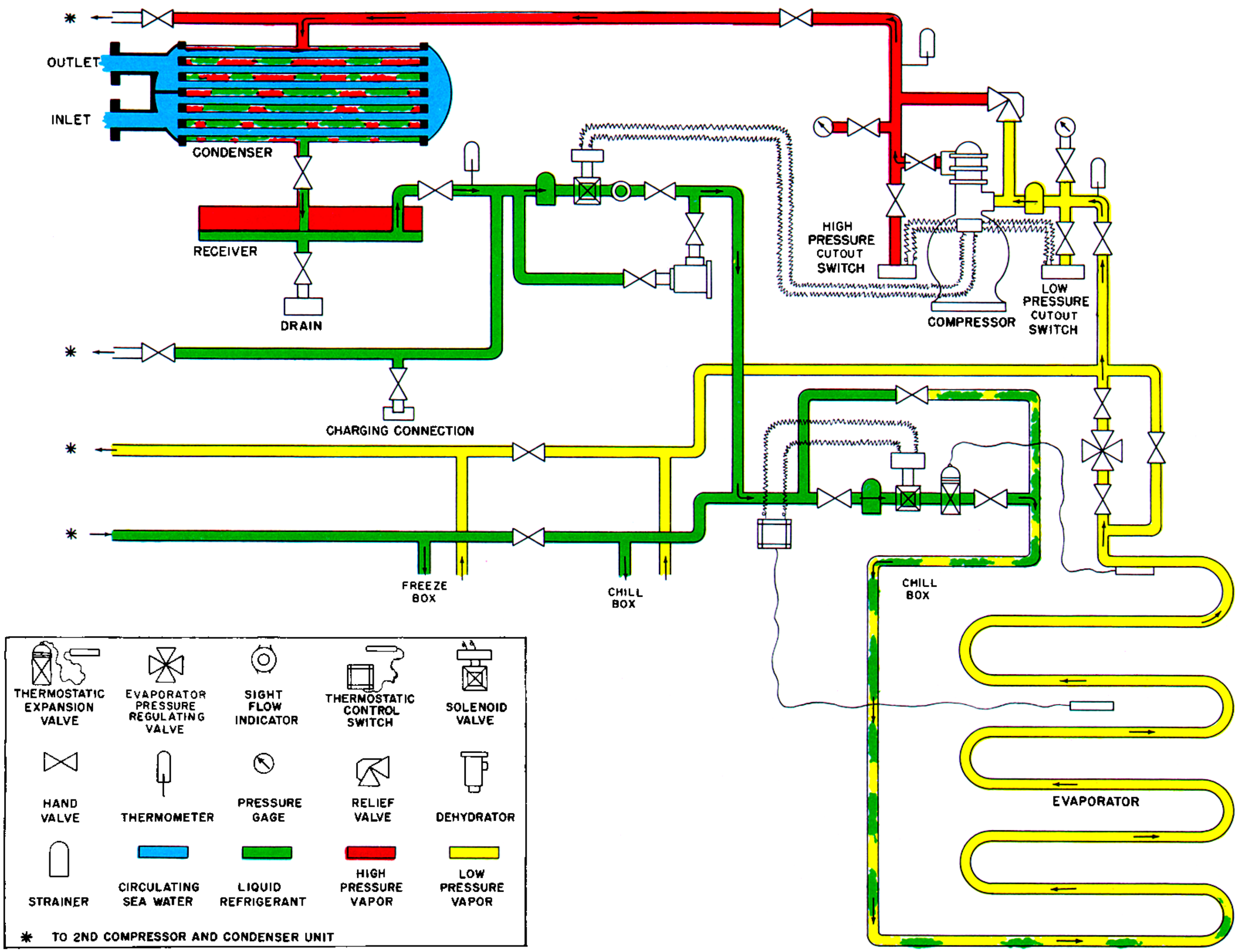

Figure 11-3.—Diagram of an R-12 refrigeration system.

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MAIN PARTS OF THE R-12 SYSTEM

The main parts of an R-12 refrigeration system are shown diagrammatically in figure 11-3. The primary components of the system are the TXV, the evaporator, the compressor, the condenser, and the receiver. Additional equipment required to complete the plant includes piping, pressure gauges, thermometers, various types of control switches and control valves, strainer, relief valves, sight-flow indicators, dehydrators, and charging connections.

In this chapter, we will deal with the R-12 system as though it had only one evaporator, one compressor, and one condenser. As you can see from figure 11-3, however, a refrigeration system may (and usually does) include more than one evaporator, and it may include an additional compressor and condenser units.

Thermostatic Expansion Valve (TXV)

We mentioned earlier that the TXV regulates the amount of refrigerant to the cooling coil. The amount of refrigerant needed in the coil depends, of course, on the temperature of the space being cooled.

The thermal control bulb, which controls the opening and closing of the TXV, is clamped to the cooling coil near the outlet. The substance in the thermal bulb will vary depending on the refrigerant used. The expansion and contraction (because of temperature change) transmit a pressure to the diaphragm. This causes the diaphragm to be moved downward, opening the valve and allowing more refrigerant to enter the cooling coil. When the temperature at the control bulb falls, the pressure above the diaphragm decreases and the valve tends to close. Thus, the temperature near the evaporator outlet controls the operation of the TXV.

Evaporator

The evaporator consists of a coil of copper, aluminum, or aluminum alloy tubing installed in the space to be refrigerated. Figure 11-4 shows some of this tubing. As mentioned before, the liquid R-12 enters the tubing at a reduced pressure and, therefore, with a lower boiling point. As the refrigerant passes through the evaporator, the heat flowing to the coil from the surrounding air causes the rest of the liquid refrigerant to boil and vaporize. After the refrigerant has absorbed its latent heat of vaporization (that is, after it is entirely vaporized), the refrigerant continues to absorb heat until it becomes superheated by approximately 10°F. The amount of superheat is determined by the amount of liquid refrigerant admitted to the evaporator. This, in turn, is controlled by the spring adjustment of the TXV. A temperature range of 4° to 12°F of superheat is considered desirable. It increases the efficiency of the plant and evaporates all of the liquid. This prevents liquid carryover into the compressor.

Compressor

The compressor in a refrigeration system is essentially a pump. It is used to pump heat "uphill" from the cold side to the hot side of the system.

The heat absorbed by the refrigerant in the evaporator must be removed before the refrigerant can again absorb latent heat. The only way the vaporized refrigerant can be made to give up the latent heat of vaporization that is absorbed in the evaporator is by cooling and condensing it. Because of the relatively high temperature of the available cooling medium, the only way to make the vapor condense is by first compressing it.

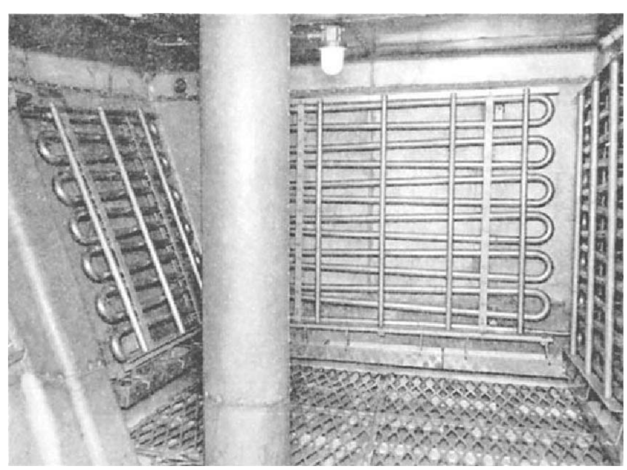


Figure 11-4.—Evaporator tubing.

When we raised the pressure, we also raise the temperature. Therefore, we have raised its condensing temperature, which allows us to use seawater as a cooling medium in the condenser.

In addition to this primary function, the compressor also keeps the refrigerant circulating and maintains the required pressure difference between the high-pressure and low-pressure sides of the system.

Many different types of compressors are used in refrigeration systems. The designs of compressors vary depending on the application of the refrigerants used in the system. Figure 11-5 shows a motor-driven, single -acting, two-cylinder, reciprocating compressor, such as those commonly used in naval refrigeration plants.

Compressors used in R-12 systems may be lubricated either by splash lubrication or by pressure lubrication. Splash lubrication, which depends on maintaining a fairly high oil level in the compressor crankcase, is uaually satisfactory for smaller compressors. High speed or large capacity compressors use pressure lubrication systems.

SHAFT SEALS.—Where the crankshaft extends through the crankcase, a seal is used to prevent the refrigerant from escaping and also to prevent air from entering the crankcase when the pressure in the

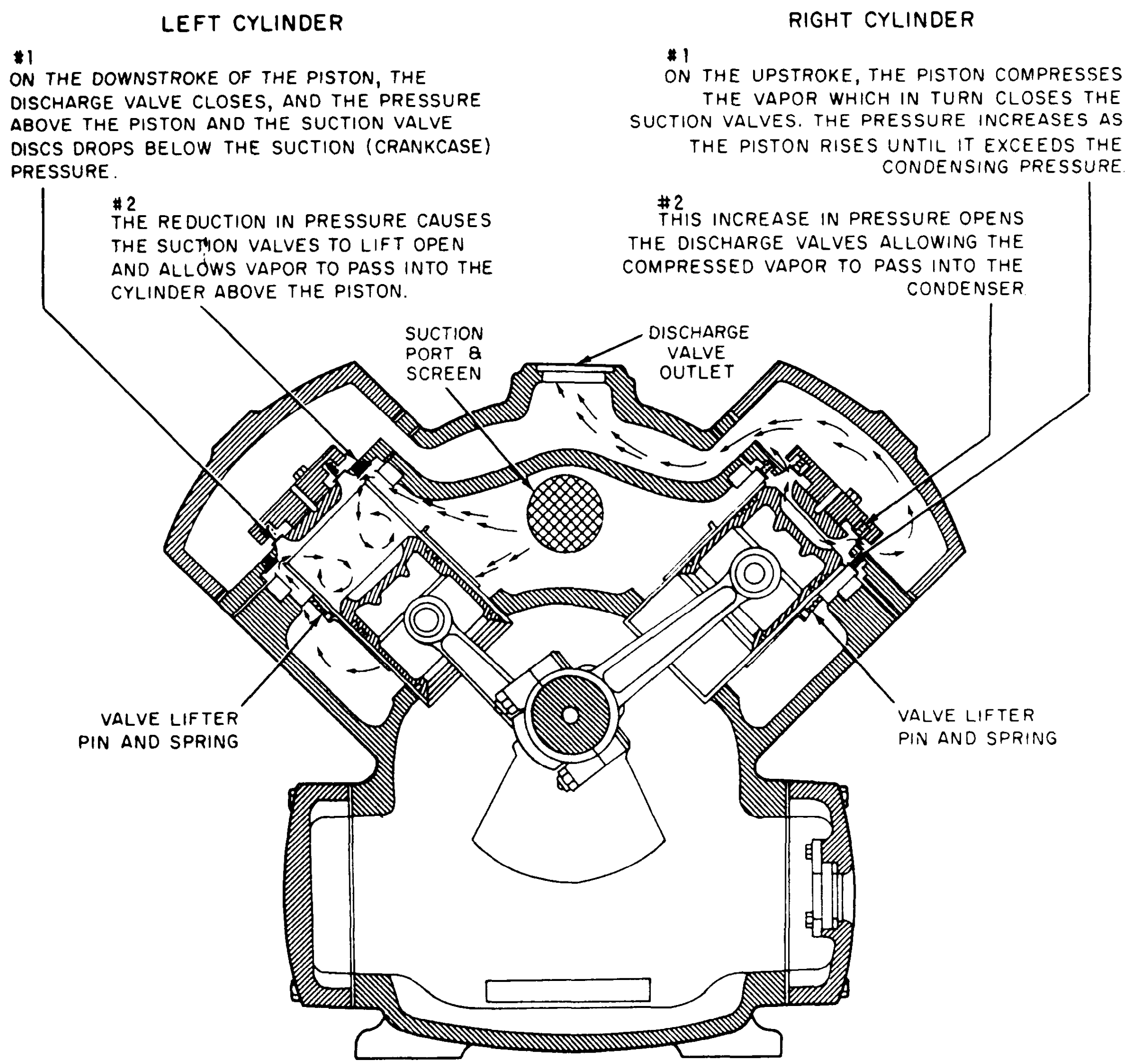


Figure 11-5.—Reciprocating compressor.

crankcase is lower than the surrounding atmospheric pressure. This is accomplished by crankshaft seal assemblies. There are several types of seals such as the rotary seal, the stationary bellows, the rotating bellows, and the diaphragm.

The rotary seal, shown in figure 11-6, consists of a stationary cover plate and gasket, a rotating assembly which includes a carbon ring, a neoprene seal, a compression spring, and compression washers. The sealing points are (1) between the crankshaft and the rotating carbon rings and sealed by a neoprene ring, (2) between the rotating carbon ring and the cover plate and sealed by lapped surfaces, and (3) between the cover plate and the crankcase and sealed by a metallic gasket. The seal is adjusted by adding or removing metal washers between the crankshaft shoulder and the shaft seal compression spring.

A stationary bellows seal is illustrated in figure 11-7. It consists of a bellows clamped to the compressor housing at one end to form a seal against a rotating shaft seal collar on the other. The sealing points are (1) between the crankcase and the bellows and sealed by the cover plate gasket, (2) between the crankshaft and the shaft seal collar and sealed by a neoprene gasket, and (3) between the surface of the bellows nose and the surface of the seal collar and sealed by lapped surfaces. The stationary bellows seal is factory set for proper tension and should not be altered.

The rotating bellows seal, figure 11-8, consists of a bellows clamped to the crankshaft at one end to form a seal against a stationary, removable shaft seal shoulder on the other end. The sealing points are located (1) between the crankshaft and bellows and sealed by a shaft seal clamping nut, (2) between the removable shaft seal shoulder and the crankcase and sealed by a neoprene gasket, and (3) between the bellows nosepiece and the shaft seal collar and sealed by lapped surfaces. This seal is also factory set.

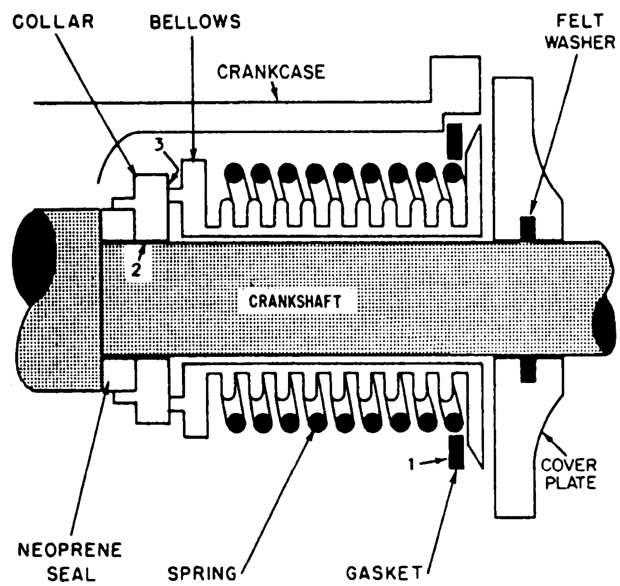


Figure 11-7.—Station bellows seal.

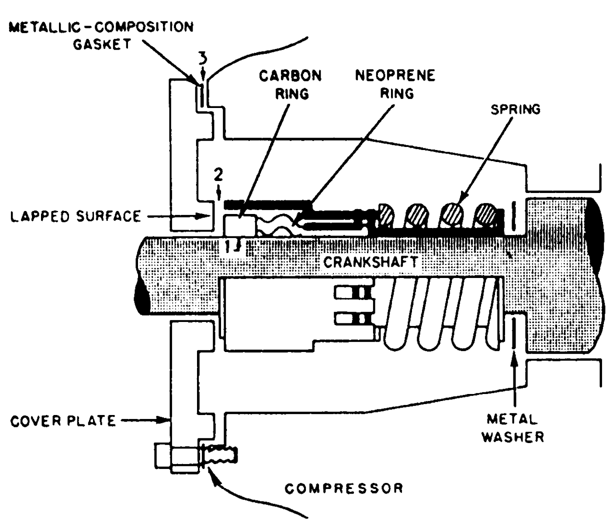


Figure 11-6.—Rotary seal.

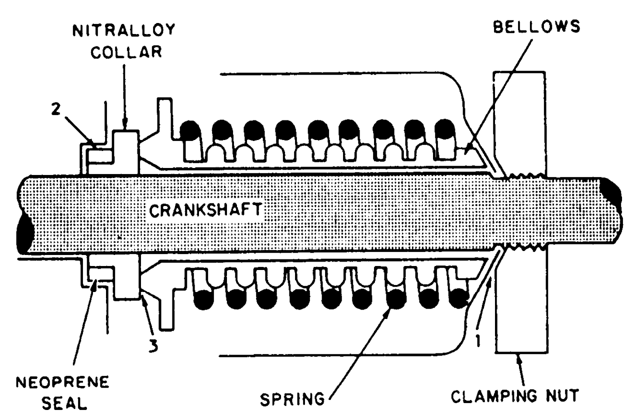


Figure 11-8.—Rotating bellows seal.

The diaphragm seal, figure 11-9, consists of a diaphragm clamped to the crankcase at its outer circumference and to a fulcrum ring at its center. The fulcrum ring forms a seal collar which is locked to the diaphragm. The sealing points are located (1) between the outer circumference of the diaphragm and the crankcase and sealed by a copper ring gasket, (2) between the fulcrum ring and the diaphragm-sealed at the factory and not to be broken, (3) between the fulcrum ring and the rotating shaft seal collar and sealed by lapped surfaces, and (4) between the shaft seal collar and the crankshaft shoulder and also sealed by lapped surfaces.

The tension in a diaphragm seal is adjusted by adding or removing diaphragm-to-crankcase gaskets to obtain the specified deflection. For information on handling, cleaning, and replacing shaft seal assemblies, consult the manufacturer's technical manual or the directions enclosed with the new seal.

CAPACITY CONTROL SYSTEM.—Most compressors are equipped with an oil pressure operated automatic capacity control system. This system unloads or cuts cylinders out of operation following decreases in the refrigerant load requirements of the plant. A cylinder is unloaded by a mechanism that holds the suction valve open so that no gas can be compressed.

Since oil pressure is required to load or put cylinders into operation, the compressor will start with all controlled cylinders unloaded. But as soon as the compressor comes up to speed and full oil pressure is developed, all cylinders will become operative. After the temperature pulldown period, the refrigeration load imposed on the compressor will decrease, and the capacity control system will unload cylinders accordingly. The unloading will result in reduced power comsumption. On those applications where numerous cooling coils are supplied by one compressor, the capacity control system will prevent the suction pressure from dropping to the low-pressure cutout setting. This will prevent stopping the compressor before all solenoid valves are closed.

Several designs of capacity control systems are in use. One of the most common is shown in figure 11-10. The capacity control system consists of a power element and its linkage for each controlled cylinder, a step control hydraulic relay, and a capacity control valve.

The system's components are all integrally attached to the compressor. The suction or crankcase pressure of the refrigeration plant is sensed by the capacity control valve to control the system. In other words, a change in the refrigeration load on the plant will cause a change in suction pressure. This change in suction pressure will then cause the capacity control system to react according to whether the suction pressure increased or decreased. The working fluid of the system is compressor oil pump pressure. Compressor oil pump pressure is metered into the system through an orifice. Once the oil passes the orifice, it becomes the system control oil and does work.

Locate the following components on figure 11-10, and use them to read the next two paragraphs.

(1) Compressor oil pump pressure tap-off

(2) Control oil strainer

(3) Hydraulic relay

(4) Hydraulic relay piston

(5) Unloader power element

(6) Unloader power element piston

(7) Lifting fork

(8) Unloader sleeve

(9) Suction valve

(10) Capacity control valve

(11) Crankcase (suction) pressure sensing point

The following functions take place when the compressor is started with a warm load on the refrigeration system.

Compressor oil (1) is pumped through the control oil strainer (2) into the hydraulic relay (3). There the

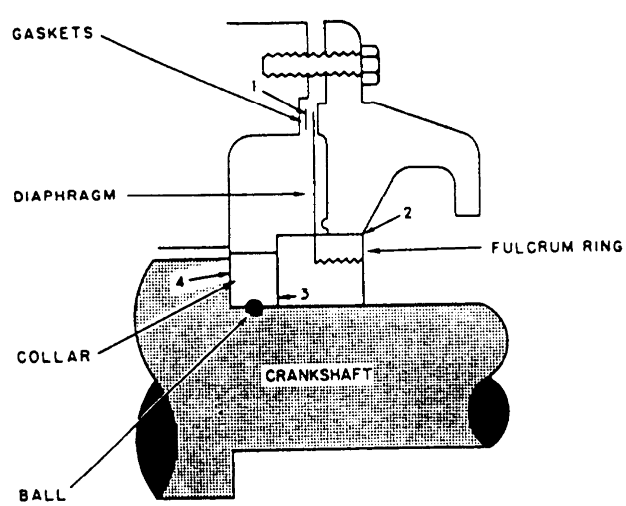


Figure 11-9.—Diaphragm-type seal.

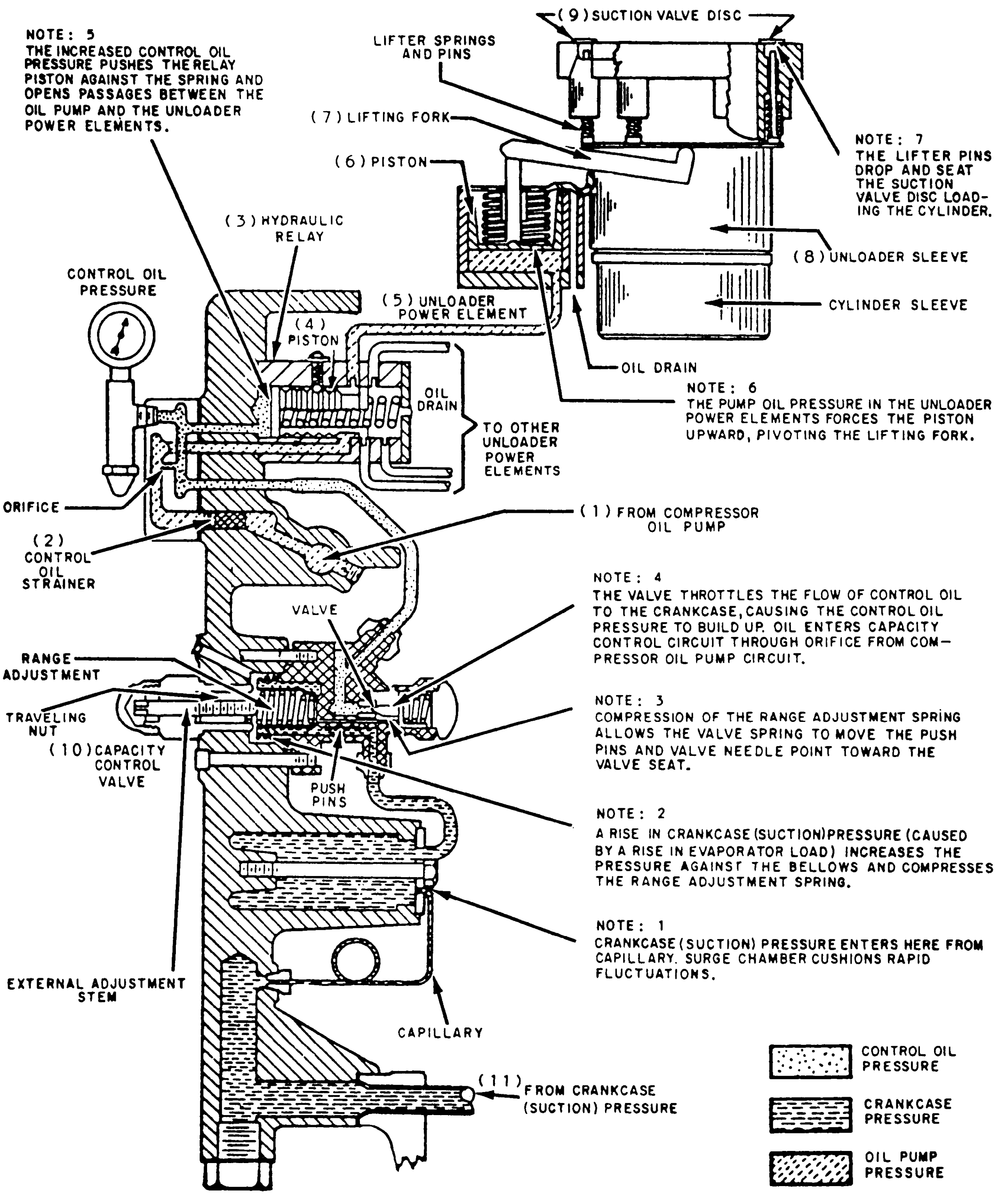
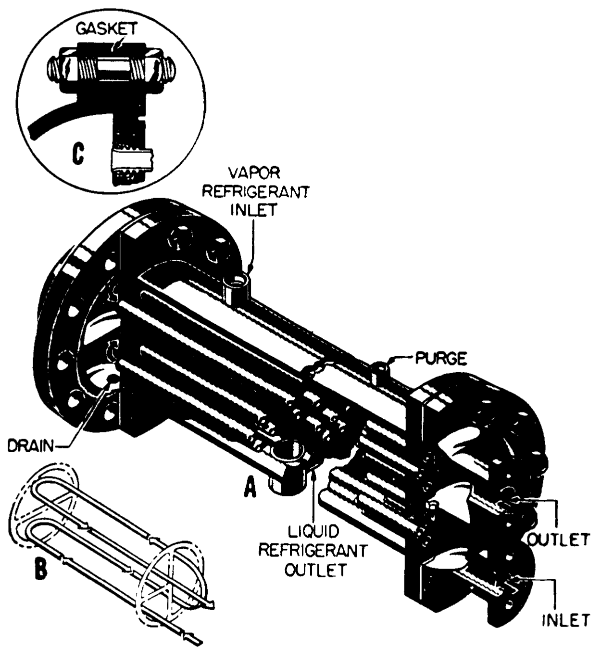


Figure 11-10.—Capacity control system.

oil flow to the unloader power elements is controlled in steps by the movement of the hydraulic relay piston (4). As soon as pump oil pressure reaches a power element (5), the piston (6) rises, the lifting fork (7) pivots, and the unloader sleeve (8) lowers, permitting the suction valve (9) to seat. The system is governed by suction pressure which actuates the capacity control valve (10). This valve controls the movement of the hydraulic relay piston by metering the oil bleed from the control oil side of the hydraulic relay back to the crankcase.

Suction pressure increases or decreases according to increases or decreases in the refrigeration load requirements of the plant. After the temperature pulldown period with a subsequent decrease in suction pressure, the capacity control valve moves to increase the control oil bleed to the crankcase from the hydraulic relay. There is a resulting decrease in control oil pressure within the hydraulic relay. This decrease allows the piston to be moved by spring action. This action successively closes oil ports and prevents compressor oil pump pressure from reaching the unloader power elements. As oil pressure leaves a power element, the suction valve rises and that cylinder unloads. With an increase in suction pressure, the above process is reversed, and the controlled cylinders will load in succession. The loading process is detailed in steps 1 through 7 in figure 11-10.



A. Cutaway view.
B. Water-flow diagram.
C. Arrangement of heat joint.
Figure 11-11.—Watercooled condenser for R-12 refrigeration system.

Condenser

The compressor discharges the high-pressure, high-temperature refrigerant vapor to the condenser, where it flows around the tubes through which seawater is being pumped. As the vapor gives up its superheat (sensible heat) to the seawater, the temperature of the vapor drops to the condensing point. The refrigerant, now in liquid form, it subcooled slightly below its condensing point. This is done at the existing pressure to ensure that it will not flash into vapor.

A watercooled condenser for an R-12 refrigeration system is shown in figure 11-11. Circulating water is obtained through a branch connection from the fire main or by means of an individual pump taking suction from the sea. The purge connection, shown in figure 11-11, is on the refrigerant side. It is used to remove air and other noncondensable gases that are lighter than the R-12 vapor.

Most condensers used for naval refrigeration plants are of the watercooled type. However, some small units have air-cooled condensers. These consist of tubing with external fins to increase the heat transfer surface. Most air-cooled condensers have fans to ensure positive circulation of air around the condenser tubes.

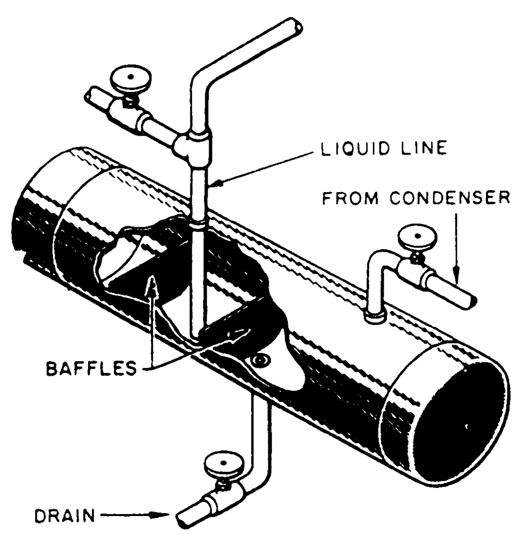


Figure 11-12.—Receiver.

Receiver

The receiver, shown in figure 11-12, acts as a temporary storage space and surge tank for the liquid refrigerant. The receiver also serves as a vapor seal to keep vapor out of the liquid line to the expansion valve. Receivers may be constructed for either horizontal or vertical installation.

ACCESSORIES

In addition to the five main components just described, a refrigeration system requires a number of controls and accessories. The most important of these will be described briefly in the following paragraphs.

Dehydrator

A dehydrator, or dryer, containing silica-gel or activated alumina, is placed in the liquid refrigerant line between the receiver and TXV. In older installations, bypass valves allow the dehydrator to be cut in or out of the system. In newer installations, the dehydrator is installed in the liquid refrigerant line without any bypass arrangement. A dehydrator is shown in figure 11-13.

Moisture Indicator

A moisture indicator is either located in the liquid refrigerant line or built into the dehydrator. The moisture indicator contains a chemically treated element which changes color when there is an increase of moisture in the refrigerant. The color change is reversible and will change back to a DRY reading when the moisture is removed from the refrigerant. Excessive moisture or water will damage the moisture indicator element and turn it pink, which indicates it must be replaced.

Solenoid Valve and Thermostatic Control Switch

A solenoid valve is installed in the liquid line leading to each evaporator. Figure 11-14 shows a

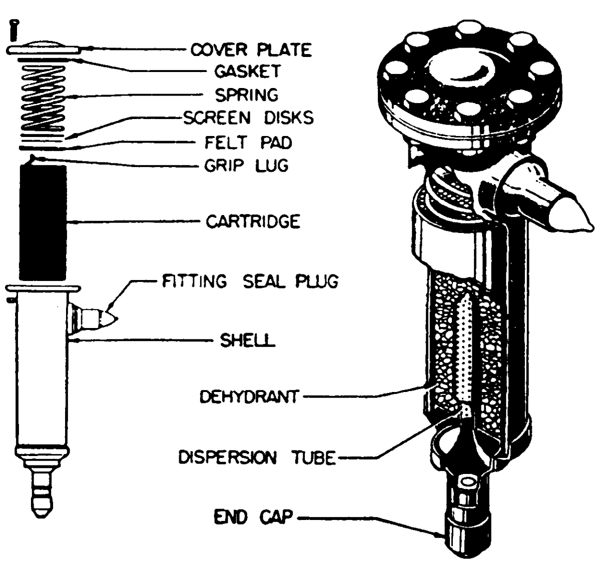


Figure 11-13.—Refrigeration dehydrator.

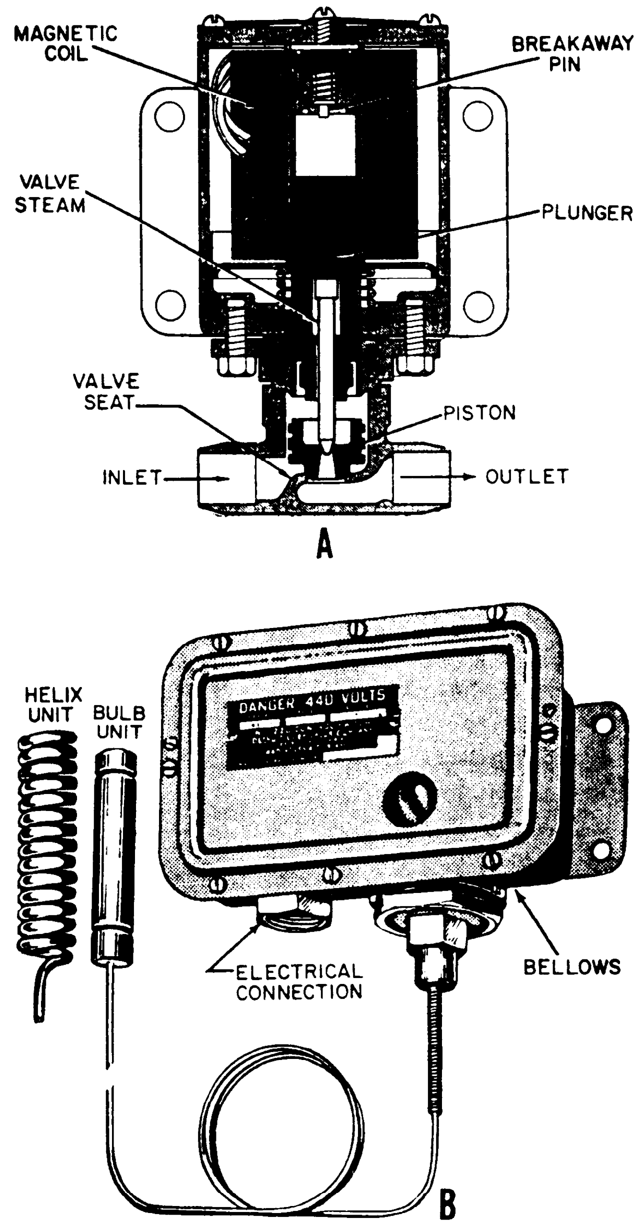


Figure 11-14.—Solenoid valve and thermostatic control switch.

solenoid valve and the thermostatic control switch that operates it. The thermostatic control switch is connected by long flexible tubing to a thermal control bulb which is located in the refrigerated space. When the temperature in the refrigerated space drops to the desired point, the thermal control bulb causes the thermostatic control switch to open. This action closes the solenoid valve and shuts off all flow of liquid refrigerant to the TXV. When the temperature in the refrigerated space rises above the desired point, the thermostatic control switch closes, the solenoid valve opens, and liquid refrigerant once again flows to the TXV.

The solenoid valve and its related thermostatic control switch maintain the proper temperature in the refrigerated space. You may wonder why the solenoid valve is necessary if the TXV controls the amount of refrigerant admitted to the evaporator. Actually, the solenoid valve is not necessary on units that have only one evaporator. In systems that have more than one evaporator, where there is wide variation in load, the solenoid valve provides additional control to prevent the spaces from becoming too cold at light loads.

In addition to the solenoid valve installed in the line to each evaporator, a large refrigeration plant usually has a main liquid line solenoid valve installed just after the receiver. If the compressor stops for any reason except normal suction pressure control, the main liquid solenoid valve closes. This prevents liquid refrigerant from flooding the evaporator and flowing to the compressor suction. Extensive damage to the compressor can result if liquid is allowed to enter the compressor suction.

Evaporator Pressure Regulating Valve

In some ships, several refrigerated spaces of varying temperatures are maintained by one compressor. In these cases, an evaporator pressure regulating valve is installed at the outlet of each evaporator EXCEPT the evaporator in the space in which the lowest temperature is to be maintained. The evaporator pressure regulating valve is set to keep the pressure in the coil from falling below the pressure corresponding to the lowest evaporator temperature desired in that space.

The evaporator pressure regulating valve is used mostly on water coolers, on units where high humidity is required (such as fruit and vegetable stowage spaces), and in installations where two or more rooms are maintained at different temperatures by the use of the same refrigeration unit.

A cross section of a common evaporator pressure regulating valve (commonly called EPR valve) is shown in figure 11-15. The tension of the spring above the diaphragm is adjusted so that when the evaporator

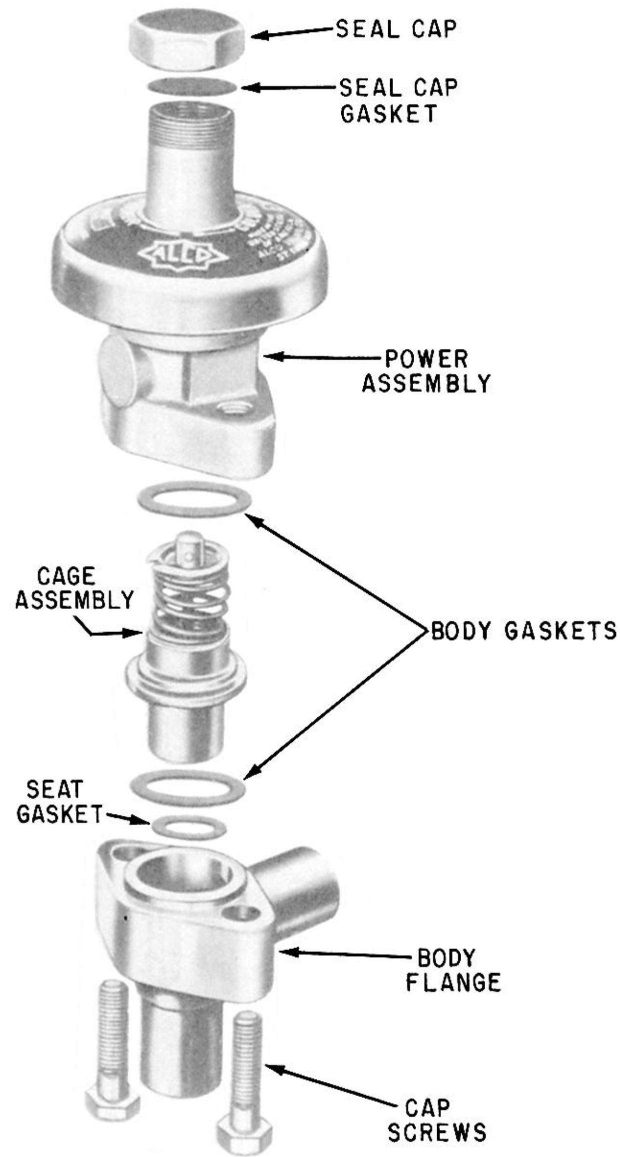


Figure 11-15.—Exploded view of a typical evaporator pressure regulating valve (EPR).

coil pressure drops below the desired minimum, the spring will shut the valve.

The EPR valve is not really a temperature control—that is, it does not regulate the temperature in the space. It is only a device to prevent the temperature from becoming too low.

Low-Pressure Cutout Switch

The low-pressure cutout switch is also known as a suction pressure control switch. It is the control that causes the compressor to go on or off as required for normal operation of the refrigeration plant. This switch is located on the suction side of the compressor and is actuated by pressure changes in the suction line. When the solenoid valves in the lines to the various evaporators are closed so that the flow of refrigerant to the evaporators is stopped, the pressure of the vapor in the compressor suction line drops quickly. When the suction pressure has dropped to the desired pressure, the low-pressure cutout switch causes the compressor motor to stop. When the temperature in the refrigerated spaces has risen enough to operate one or more of the solenoid valves, refrigerant is again admitted to the cooling coils, and the compressor suction pressure builds up again. At the desired pressure, the low-pressure cutout switch closes, starting the compressor again and repeating the cycle.

High-Pressure Cutout Switch

A high-pressure outout switch is connected to the compressor discharge line to protect the high-pressure side of the system against excessive pressures. The design of this switch is essentially the same as that of the low-pressure cutout switch. However, the low-pressure cutout switch is made to CLOSE when the suction pressure reaches its upper normal limit. The high-pressure cutout switch is made to OPEN when the discharge pressure is too high. As mentioned before, the low-pressure cutout switch is the compressor control for normal operation of the plant. The high-pressure cutout switch, on the other hand, is a safety device only and does not have control of compressor operation under normal conditions.

Oil Failure Switch

An oil failure switch is provided with high-speed compressors. The switch is designed to prevent operation of the compressor in the event of low oil pressure. The switch has one bellows connected to the oil pressure on the discharge of the compressor oil pump and the other connected to the compressor suction refrigeration pressure. The switch is set to open the electrical circuit and stop the compressor when the oil pressure drops to a low-pressure set point.. It closes the electrical circuit and starts the compressor when the oil pressure reaches the reset set point.

To start the compressor after it has been stopped and the contacts of the oil failure switch have opened, a time delay mechanism is used with the compressor motor starter. The time delay switch will open 10 to 30 seconds after the compressor motor has been started. The oil pressure normally will be built up in this time interval. The oil pressure switch will have made contact to keep the compressor motor electrical circuit energized after the time delay switch opens. If the oil pressure has not built up within about 30 seconds after the compressor is started, the contacts of the oil pressure differential switch will not have closed. The compressor will stop because the time delay relay switch is open.

Water Failure Switch

A water failure switch stops the compressor in the event of failure of the circulating water supply. This is a pressure-actuated switch. It is generally similar to the low-pressure cutout switch and the high-pressure cutout switch previously described. If the water failure cutout switch fails to function, the refrigerant pressure in the condenser will quickly build up to the point that the high-pressure switch stops the compressor.

Strainer

Because of the solvent action of R-12, any particles of grit, scale, dirt, or metal that the system may contain are readily circulated through the refrigerant lines. To avoid damage to the compressor from such foreign matter, a strainer is installed in the compressor suction connection.

Spring-Loaded Relief Valve

A spring-loaded relief valve is installed in the compressor discharge line as an additional precaution against excessive pressures. The relief valve is set to open at approximately 225 psig. Therefore, it functions only in case of failure or improper setting of the high-pressure cutout switch. If the relief valve opens, it discharges high-pressure vapor to the suction side of the compressor.

The type of pressure-actuated control switch used in all of the above installations is the general type shown in figure 11-16 with its cover removed. (The oil pressure failure switch has two bellows instead of the one shown in the illustration.) These switches operate at various pressure ranges. Some switches have manual reset buttons to prevent the automatic restoration of power after a pressure failure, such as a high discharge pressure.

Water Regulating Valve

A water regulating valve controls the quantity of circulating water flowing through the refrigerant condenser. The water regulating valve is actuated by the refrigerant pressure in the compressor discharge line. This pressure acts upon a diaphragm (or, in some valves, a bellows arrangement) which transmits motion to the valve stem.

The primary function of the water regulating valve is to maintain a constant refrigerant condensing pressure. Basically, two variable conditions exist: (1) the amount of refrigerant to be condensed and (2) changing water temperatures. The valve maintains a constant refrigerant condensing pressure by controlling the water flow through the condenser. By sensing the refrigerant pressure, the valve permits only enough water through the condenser to condense the amount of refrigerant vapor coming from the compressor. The quantity of water required to condense a given amount of refrigerant varies with the water temperature. Thus, the flow of cooling water through the condenser is automatically maintained at the rate actually required to condense the refrigerant under varying conditions of load and temperature.

Liquid Strainer

A liquid strainer of the type shown in figure 11-17 is also installed in the liquid line leading to each evaporator. These strainers protect the solenoid valves and the TXV.

Pressure Gages and Thermometers

A number of pressure gages and thermometers are used in refrigeration systems. Figure 11-18 shows a compound R-12 gage. The temperature markings on this gage show the boiling point (or condensing point) of the refrigerant at each pressure; the gage cannot measure temperature directly. The red pointer is a

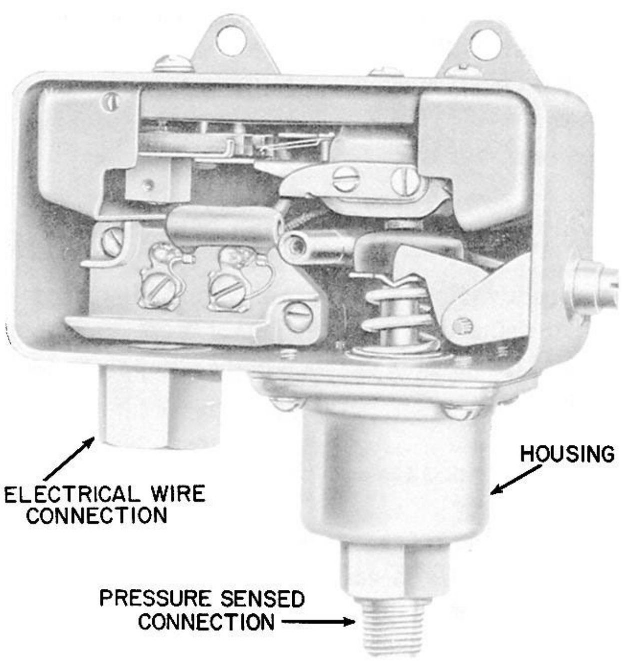


Figure 11-16.—Pressure-actuated control switch.

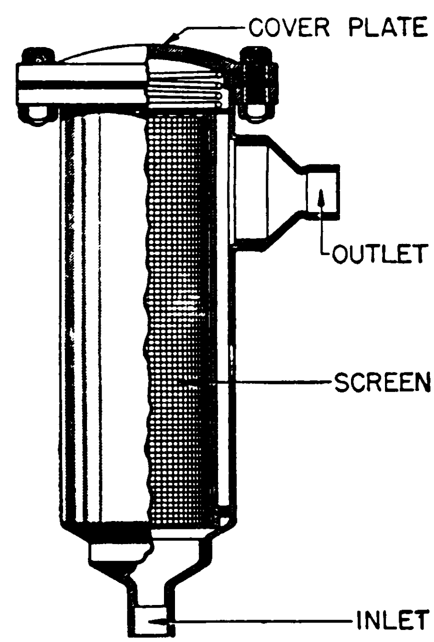


Figure 11-17.—Strainer of liquid refrigerant.

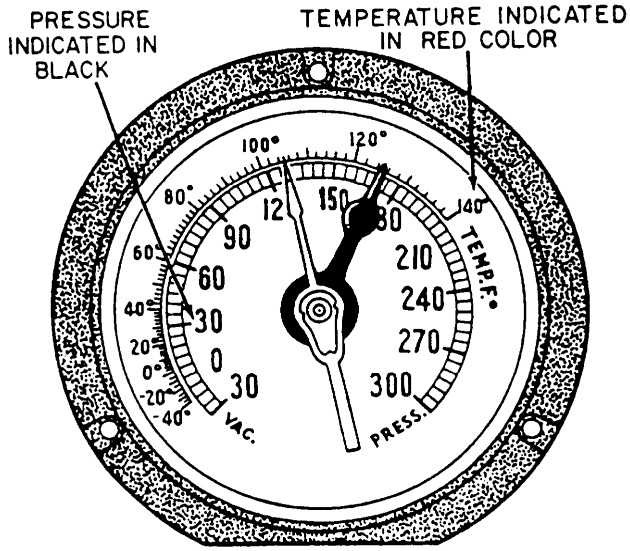


Figure 11-18.—Compound R-12 pressure gauge.

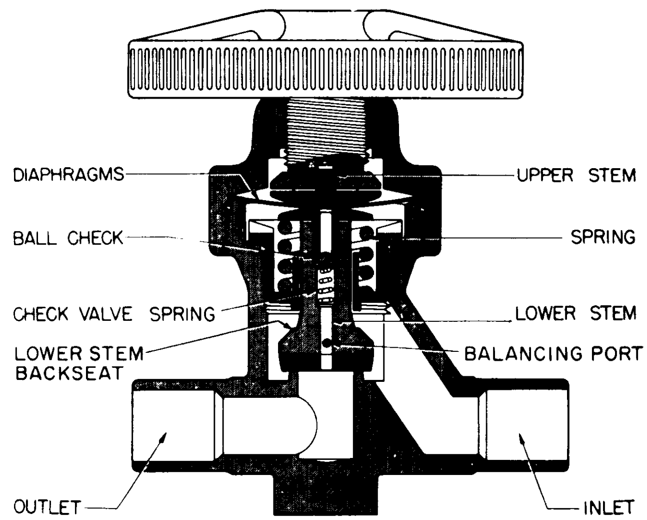


Figure 11-19.—Packless valve for refrigeration system.

stationary marker that can be set manually to indicate the maximum working pressure.

A water pressure gauge is installed in the circulating water line to the condenser to indicate failure of the circulating water supply.

Standard thermometers of appropriate range are provided for the refrigerant system.

Refrigerant Piping

Refrigerant piping in modern naval installations is made of ACR seamless copper. Copper is good for this purpose because (1) it does not become corroded by refrigerants; (2) the internal surface of the tubing is smooth enough to minimize friction; and (3) copper tubing is easily shaped to meet installation requirements.

Packless Valves

Nearly all hand-operated valves in large refrigeration systems are packless valves of the type shown in figure 11-19. In this type of valve, the upper part is sealed off from the lower part by a diaphragm. An upward-seating ball check in the lower valve stem makes it possible for the spring to lift the lower stem regardless of pressure differences developed while the valve was closed. Thus, the valve will operate properly regardless of direction of flow. By backseating the valve, the diaphragm can be changed without placing the system or unit out of operation.

OPERATING PROCEDURES FOR AN R-12 SYSTEM

You will need some very specific training before you become a good refrigeration system operator. First, you need a lot of practical experience on the systems. Second, you need to pay close attention to the procedures followed by qualified personnel.

Your first responsibility with an R-12 system will probably require you to check temperatures and pressures, maintain the plant operating log, detect symptoms of faulty operation, and check conditions in the spaces or units being cooled.

The intervals of time between plant inspections will vary depending on the purpose of the plant. The temperatures and pressures throughout the system and the oil level in the compressor crankcase are checked every hour. The results are recorded unless watch standing instructions specify otherwise. These checks are used to determine whether the plant is operating properly. One of the best methods for checking is to compare the existing temperatures and pressures with those recorded when the plant was known to be operating properly, under conditions similar to the present conditions.

OPERATING AN R-12 PLANT IN AUTOMATIC

After the prescribed operating pressures and temperatures have been established with the compressor running in MANUAL, place the selector switch in the AUTOMATIC position.

NOTE: A refrigeration compressor should NEVER be left unattended when in the MANUAL mode of operation.

The suction-pressure control (low-pressure cutout switch) is connected electrically to start and stop the compressor automatically on the basis of load conditions. If the automatic control valves and switches are in proper adjustment, the operation of the plant, after proper starting, will be entirely automatic.

When the selector switch is set for automatic operation, the water failure switch, the high-pressure switch, or the low-pressure switch will close and energize their respective circuits.

In some installations, the supply of condenser cooling water comes directly from a centrifugal pump or from the fire and flushing main. If cooling water is obtained from the fire and flushing main, the pump controller switch is opened manually. The water failure switch remains closed regardless of the source of condenser cooling water.

In systems not equipped with water regulating valves, normal operating conditions generally produce condensing pressures of less than 125 psi. This happens because the condensing water temperature is usually less than 85°F. Where the system does have these valves, they should be adjusted to maintain the condensing pressure at 125 psi. When the valves are so adjusted, the quantity of cooling water required decreases rapidly with decreasing circulating water temperatures. In systems equipped with air-cooled condensers, condensing pressures may exceed 125 psi when the temperature of the surrounding air is higher than normal.

NOTES ON COMPRESSOR OPERATION

An R-12 compressor should not remain idle for an extended period of time. When a plant has two or more compressors, they should be operated alternately. The total operating time on each of the compressors should be approximately the same. An idle compressor should be operated at least once a week.

Only one compressor should serve a cooling coil circuit. When compressors are operated in parallel on a common cooling circuit, lubricating oil may be transferred from one compressor to another. This may cause serious damage to all compressors on the circuit.

MAINTENANCE OF R-12 SYSTEMS

You will be expected to do some of the maintenance that keeps a refrigeration plant operating efficiently. You will need to understand and use the procedures listed below and described in the following paragraphs:

1. Defrosting cooling coils
2. Pumping down refrigeration systems
3. Testing for refrigeration leaks
4. Testing for air and noncondensable gases
5. Checking compressor oil
6. Caring for V-belts
7. Setting control and safety devices
8. Testing and renewing compressor valves
9. Caring for shaft seals

DEFROSTING COOLING COILS

The cooling coils should be defrosted as often as necessary to maintain the effectiveness of the cooling surface. Too much frost on the coils results in reduced cooling capacity, low compressor-suction pressure, and a tendency for the compressor to short cycle. The maximum permissible time interval between defrosting operations depends on many factors. Some of these are refrigerant evaporating temperature, free-moisture content of supplies placed in the refrigerated space, temperature of refrigerated spaces, frequency of opening of cold-storage compartment doors, and atmospheric humidity.

The most common method of defrosting a cooling coil in the average refrigeration installation requires two steps: (l)shut off the supply of R-12 to the coil to be defrosted by closing the liquid-line stop valve ahead of the expansion valve and (2) leave the entrance door open to permit the temperature in the compartment to rise above 32°F. The frost will melt off the coils or may be easily brushed off. Since the cooling coils are made of tinned copper or galvanized steel tubing, take care not to damage the evaporator coil.

Most refrigeration systems now in use are provided with HOT-GAS DEFROSTING lines. These lines facilitate defrosting where compartment temperatures are maintaned at 32°F or less. The principal advantage of hot-gas defrosting is that the freeze-room coils can be defrosting while the rest of the plant operates normally.

In the following paragraphs, defrosting procedures will refer only to freeze-room coils.

A hot-gas defrosting line leads from the compressor discharge piping to the tail coil of the freeze-room cooling coil. The hot-gas line joins the suction line between the freeze room and the suction valve. Therefore, hot gas admitted to the freeze-room cooling coil flows "backwards" through the coil. In other words, the hot gas flows in the direction opposite the flow of refrigerant under normal operating conditions.

To defrost the coils of the freeze room, follow these steps. Close the normal refrigerant-liquid supply and the suction return-line valves of the freeze-room cooling coil. Then, open the valve in the hot-gas supply line to admit compressed refrigerant gas to the coil. As the frost melts on the exterior coil surfaces, the gas is condensed in the coils and becomes a liquid. The liquid is led from the inlet end of the freeze-room cooling coil to the main liquid supply line. It is used in the other compartments.

When the defrosting has been completed, return the system to its normal operating condition. Do this by (1) closing the defrosting valves and (2) opening the valves in the refrigerant-liquid supply line to the freeze-room coil and the suction return valve from the freeze-room coil. Take care that all liquid refrigerant has been discharged from the freeze-room coil before the suction line valve from the compartment is opened. If all the liquid has not been discharged, liquid slugs may be returned to compressor.

PUMPING DOWN A REFRIGERANT SYSTEM

The pumping-down procedure will depend on the maintenance to be done. In some cases, maintenance can be performed on the charged system after a part to be repaired or replaced has been isolated. Generally, it is possible to pump down any part of a charged system (except the condenser, the liquid receiver, and the compressor discharge line) by the use of cutout valves. When repairs are to be made to a major portion of the system, the system must be pumped down to return all refrigerant to the receiver.

If repairs are to be made to the receiver, the condenser, or the compressor discharge line, the entire system must be drained into spare refrigerant drums. However, the procedure is different when a system has valves to isolate the compressor discharge line and condenser and when it is not objectionable to release refrigerant to the atmosphere. (This refers to refrigerant which may be trapped in the condenser after the system has been pumped down to the receiver.) In this case, repairs to the compressor discharge line and condenser may be made with this section isolated.

It is sometimes necessary to open a charged system to make repairs or replacements or to clean strainers. In this case, the refrigerant pressure within the part of the system to be opened should be pumped down to a pressure slightly above atmospheric (l/2 psig to 2 psig) before any connections are broken. As a part of the system that contains liquid R-12 is pumped down, the system's temperature will decrease as a result of the evaporation of the liquid refrigerant. When the temperature of such a part of the system begins to rise to normal again, while the low pressure in the part is maintained, it is reasonably certain that all R-12 liquid within the part has evaporated.

During the final evacuation of the system, you may reach a pressure of less than 0 psig. If so, you should immediately bleed enough refrigerant into the evacuated part of the system to raise the pressure to between l/2 psig and 2 psig. Connections may be then be opened, and repairs, replacements of parts, or other necessary service operations may be accomplished.

When a refrigerant system is opened, you should temporarily plug the free ends of the refrigerant lines to keep out air and dirt When remaking the connections, make one tight and leave the other loose temporarily. This will help sweep air and other foreign matter out of the free end as the system is slowly purged with refrigerant gas bled from the charge in the system. Then, quickly tighten the remaining loose connection(s). Refrigerant lines, oil-charging lines, gage lines, and control lines are generally of small size and short length. Still, they should be purged with refrigerant gas immediately before they are connected to the system. You may remove some connecting lines that you plan to use again. If so, cap the ends to protect the threads and keep the inside of the lines clean.

When major repairs are to be made to a major portion of the system or when the system is to be secured for an extended period, the refrigerant system must be pumped down to return all refrigerant to the reciever. Keep enough refrigerant gas within the system to create a positive pressure of approximately 2 psig throughout the circuit. The exception is the areas within the compressor discharge line and the condenser and between the receiver and the main liquid-line shutoff valve. To pump down the system, close to main liquid-line shutoff valve and the dehydrator-bypass valve (if installed), and open the cooling-coil solenoid valves. Allow the compressor to operate on manual control until the suction pressure reaches approximately l/2 psig to 2 psig; then stop the compressor. Repeat the operation until the liquid refrigerant in the circuit has evaporated, and the suction pressure remains relatively constant at l/2 psig to 2 psig.

During the pump-down period, you can trace the evaporation of liquid refrigerant in the liquid line back to the main liquid-line shutoff valve. You can see frost forming and then melting as the liquid refrigerant is evaporated and super-heated. Open the power-supply switch to the compressor; close the compressor suction and discharge shutoff valves. Shut off the water supply to the condenser and drain the condenser water. When the amount of liquid refrigerant contained in the system is in excess of the capacity of the receiver, the surplus liquid refrigerant must be drawn off into separate refrigerant drums.

You will need to drain the refrigerant charge from the system when it is necessary to make repairs. These repairs may be to the condenser, the liquid receiver, or the compressor discharge line, or for any other reason. Use the following procedures:

1. Close the liquid-line valve at the reciever outlet. Start the compressor and pump down the cooling coil and suction-line pressure to the point at which the low-pressure control switch stops the unit.

2. The compressor will be stopped by the low-pressure cutout switch. Restart the unit manually and continue the pumping-down procedure until the suction pressure reaches approximately 2 psig and stops the compressor. Repeat the operation in periodic cycles until the liquid refrigerant in the circuit has evaporated and the suction pressure remains relatively constant between l/2 psig and 5 psig.

3. Close the compressor discharge line valve, and close all liquid valves at the cooling coils.

4. Connect an empty R-12 service drum to the refrigerant drain valve. (Before connecting the drum to the R-12 system, cool the drum thorougly so the refrigerant will drain rapidly into the drum.) Always use a clean R-12 service drum, containing no air or water, so that the drained R-12 is kept in suitable condition for future use.

5. Purge the air out of the line connecting the drain valve and the drum. Do this by leaving the connection at the drum valve open as you slowly flush refrigerant through the line and out at the connection. Close the connection. Drain the R-12 into the cooled drum by opening the drain valve and the service drum valve.

6. When the service drum is full, close the drain valve and permit the R-12 liquid in the drain line to evaporate. Close the service drum valve and disconnect the drum from the system.

7. Weigh the drum while filling to be certain that it is not overcharged. The net and gross weights are stamped on the drum. (These weights include that of the cast iron protector cap which fits over the cylinder valve.)

CAUTION: NEVER fill a service drum beyond its rated capacity. Drum rupture may result from hydraulic pressure caused by a rise in temperature.

TESTING FOR REFRIGERANT LEAKS

Refrigerant leaks mean the loss of refrigeration and refrigerant. Various tests are used to determine the existence of leaks in refrigerant systems. Pressure tests are used after a system has been installed and after extensive repairs or replacement of parts has been made. Pressure tests are made BEFORE the system is charged with refrigerant. Charged systems are tested for leakage with either an electronic refrigerant gas detector or with soapsuds. The method to be used depends largely upon the size of the leak and upon the type of space in which the test is to be performed.

You will be required to use the detectors and soapsuds to check for the refrigerant leakage.

In addition to tests for leaks that are made at periodic intervals, tests should be made before the compressors are started and at any other time that a shortage of refrigerant in the system is suspected. Here are some unusual operating conditions which indicate a shortage of refrigerant in the system.

1. High suction-line temperatures

2. Relatively high crankcase and cylinder temperatures

3. Excessively high refrigerant temperature in the liquid line

4. Bubbles in the refrigerant sight-flow indicator

5. Liquid refrigerant carrying parially through the coil with considerable superheat at the thermal element

6. A short cycle or a compressor running continuously

7. Excessive oil seepage at the shaft seal connection

8. Oil seepage at the refrigerant-system piping and compressor connections

A shortage of refrigerant in the system nearly always indicates leaks. When a shortage is found, the entire system should be tested for leaks by one of the following methods.

Electronic Leak Detector

The electronic leak detector (not shown) is battery operated and has an exploring tube similar to the halide detector. It has an on-and-off switch and a sensitivity switch. When you put it into operation, the detector will make a clicking sound. When it picks up a concentration of refrigerant, it produces a high pitch squeal. For further information on the electronic leak detector, refer to the manufacturer's technical manual.

CAUTION: Do NOT use a halide or electronic leak detector in any ammunition spaces. Soapsuds is the ONLY method of leak detection to be used in these spaces.

A halide torch or an electronic refrigerant gas detector is so sensitive that it is useless if the atmosphere is contaminated by excessive leakage of R-12. This is most likely to happen in a small or poorly ventilated compartment. If a compartment is contaminated by R-12 and cannot be ventilated, or if in an ammunition space, the soapsuds test must be used.

Soapsuds Test

When using the soapsuds test, prepare the soap-and-water solution so that it has the consistency of liquid hand soap and will work up a lather on a brush. (The lather will remain wet for a longer period if a few drops of glycerine are added to the solution.)

Apply the lather all the way around the joint; then look carefully for bubbles. If a joint is so located that a part of it is not visible, use a small mirror to inspect that part.

Remember that it sometimes takes a minute or more for bubbles to appear if the leak is small. Doubtful spots should be lathered and examined a second time.

Always follow a definite procedure in testing for refrigerant leaks so that you do not miss any joints. If available, use a ship's plan or authorized drawing of the system to map out your search. The extra time spent in testing all joints will be justified. The smallest leak is important. However, insignificant the leak may seem, it eventually empties the system of its charge to the point of faulty plant operation. Because R-12 is practically odorless, the first indication of a leak is the loss of refrigerating effect. A refrigerant system should never be recharged until all leaks are discovered and repaired.

NEVER use oil to test for R-12 leaks. Oil is not reliable because of its capacity to absorb R-12. If a small leak should exist where oil has been applied, the R-12 will be absorbed by the oil and will show no indication (bubbles) of the leak until the oil is saturated with R-12. However, the presence of oil on a line or joint is a good indication of a leak.

TESTING FOR AIR AND NONCONDENSABLE GASES

You MUST take precautions to keep air and noncondensable gases out of a refrigerant system. When air enters the system, you must purge the condenser and that means a loss of refrigerant. Atmospheric air always contains some moisture which will enter the system when air does. A refrigerant system must be kept as moisture free as possible. This will eliminate such troubles as water freezing at the expansion valves, internal oxidation or corrosion of parts, and emulsification or sludging of lubricating oils.

Air and noncondensable gases in a refrigerant system are pumped through the system and are discharged by the compressor into the condenser. These gases are trapped in the condenser by the liquid seal maintained over the receiver outlet. Generally, these gases are lighter than the relatively dense R-12 vapor. Therefore, they tend to collect in the upper part of the condenser when the compressor is stopped. The purge valve for discharging these gases to the atmosphere is located either in the upper part of the condenser shell or in the compressor discharge line above the condenser. While the compressor is in operation, any noncondensable gases in the system are thoroughly mixed with the R-12 vapor. This mixing is caused by the turbulence produced by the rapidly pulsating discharge of refrigerant into the condenser. Therefore, you should not try to purge noncondensable gases from the system while the compressor is in operation. Noncondensable gases in a condenser cause excessive condensing pressures and a loss in plant efficiency.

The best time to check an R-12 system for noncondensable gases is immediately before the compressor starts after a shutdown period. When a condenser is to be checked for noncondensable gases, the gauges and thermometers used must be in calibration. The system must have sufficient refrigerant charge so that the liquid refrigerant present in the receiver will seal the liquid-line connection.

The following procedure should be followed to check a refrigerant system for noncondensable gases:

1. Close the liquid-line valve.

2. Shut off the compressor and close the suction-line valves.

3. Determine the actual condensing temperature of the refrigerant. Install a service gauge in the compressor discharge connection if a discharge-pressure gauge is not already provided. An approximation of the actual condensing temperature of the refrigerant has been reached when there is no further decrease in the discharge pressure. (On watercooled condensers, you can speed up on the reduction in pressure by circulating the condenser water until the discharge pressure is reduced.) In most ships the thermometer in the liquid line at the receiver indicates the actual condensing temperature. If a thermometer is not installed in an air-cooled condenser application, one should be placed near the condenser to record the ambient temperature at that location. When the temperature of an air-cooled condenser has dropped to the ambient temperature, the reading of the thermometer will approximate the actual condensing temperature.

4. On the compound-pressure gauge, read the condensing temperature which corresponds to the condensing pressure registered by the high-pressure gauge. The temperature indicated on the temperature scale is the condensing temperature of pure R-12 at the pressure indicated by the gauge.

5. Subtract the existing condensing temperature from the condensing temperature of pure R-12 at the existing condenser pressure. If the difference between these two temperatures is more than 5°F, it will be necessary to purge the condenser of noncondensable gases.

If the above test indicates the need for purging, slowly release the noncondensable gases. When a purge valve is not provided, purge the gases by opening the discharge-pressure gauge connection.

Some of the R-12 gas will mix with the condensable gases and escape while the condenser is being purged. The amount will depend on the rate or purging and upon the concentration of the noncondensable gases in the condenser. There is no practical test aboard ship to determine definitely when an excessively high proportion of R-12 gas is being purged with the noncondensable gases. To keep the R-12 loss to a minimum when the condenser is being purged, purge slowly and frequently check the condenser for noncondensable gases. R-12 is odorless in concentrations of less than 20 percent by volume in air. In heavier concentrations, however, it resembles carbon tetrachloride in odor.

CHECKING COMPRESSOR OIL

If the apparent oil level is lower than normal after a prolonged shutdown, it is almost certain that the actual working oil level is far too low. After you have added enough oil to raise the apparent oil level to the center of the bull's eye sight glass, check the actual oil level as follows:

1. Operate the compressor on MANUAL control for at least 1 hour. If the compressor is operating on a water cooler or other coil that is apt to freeze, observe the temperature and interrupt compressor operation as necessary to prevent freezing. Repeat cycling until the total running time (1 hour) is obtained. Then slowly close the suction line stop valve.

2. Stop the compressor. If the compressor is force lubricated, immediately observe the oil level in the sight glass. If the compressor is splash lubricated, turn the flywheel until the crankshaft and connecting rod ends are immersed in the lubricating oil, then check the oil level.

To check the oil level when the compressor has been running on its normal cycle with no abnormal shutdown period, proceed as follows:

1. Wait until the end of a period of operation to stop the compressor. If the operation is continuous, wait until the compressor has been in operation at least one-half hour.

2. As soon as the compressor stops, observe the oil level in the sight glass on force-lubricated compressors. If the compressor is splash lubricated, turn the flywheel until the crankshaft and connecting rod ends are satisfactorily immersed in the lubricating oil; then check the oil level.

Do NOT remove oil from the crankcase because of an apparent high level unless too much oil has been previously added or unless it is apparent that oil from the crankcase of one compressor of the plant has been inadvertently deposited in the crankcase of another.

However, if the oil level is lower than its recommended height on the glass, add enough oil to obtain the desired level. Do NOT add more oil than is necessary. Too much oil can cause excessive oil transfer to the cooling coils.

Adding Oil

There are two common methods of adding oil to a compressor. In one type of installation, a small oil-charging pump is used for adding oil to the compressor crankcase. In another type, a clean, well-dried funnel is used. In either installation, you must be careful to prevent air or foreign matter from entering the compressor.

When performing hourly checks of the compressors, you may observe either no oil in the crankcase or a very low oil level on the sight glass. This indicates that the oil has left the compressor and is circulating in the system. It will be necessary to add oil and operate the system. After the compressor has reclaimed the excessive oil in the system, the excess oil should be drained.

Removing Oil

To remove oil from the compressor crankcase, reduce the pressure in the crankcase to approximately 1 psi by gradually closing the suction line stop valve. Then stop the compressor and close the suction and discharge line valves. Loosen the lubricating oil drain plug near the bottom of the compressor crankcase and allow the required amount of oil to drain out. Since the compressor crankcase is under a slight pressure, do NOT fully remove the drain plug from the compressor. Allow the oil to seep out around the threads of the loosened plug. When the desired amount of oil has been removed, tighten the drain plug, open the suction and discharge line valves, and start the compressor. If an oil drain valve is provided instead of a plug, you can drain the required amount of oil without pumping down the compressor.

Renewing the Oil

Clean copper tubing should be used for R-12 systems, and reasonable care should be taken to prevent the entrance of foreign matter and moisture during installation. If this was done, the oil in the compressor crankcase will probably not become so contaminated that it requires renewal more than once a year. When iron or steel pipe and fittings are used in the R-12 system, a sample of oil from the compressor crankcase should be withdrawn into a clean glass container every 3 months. If the sample shows contamination, all the lubricating oil should be renewed. It is good practice to check the cleanliness of the lubricating oil after each cleaning of the compressor suction scale trap.

CARE OF V-BELTS

Excessive looseness will cause slippage, rapid wear, and deterioration of V-belts. On the other hand, a belt that is too tight will cause excessive wear of both the belt and the main bearing of the compressor. In extreme cases it may cause a bad seal leak. When properly tightened, a belt can be depressed 1/2 to 3/4 inch by the pressure of one finger at a point midway between the flywheel and the motor pulleys.

When you need to replace one belt of a multiple V-belt drive, install a complete new set of matched belts. Belts stretch considerably during the first few hours of operation. Replacement of a single belt will upset the load balance between the new and old belts and will be a potential source of trouble. It is better to run the unit temporarily with a defective belt removed than to operate a new belt with two or more seasoned belts.

V-belts, motor pulleys, and compressor flywheels should be kept dry and free of oil. Belt dressing should NEVER be used.

NOTE: Other units use flexible couplings to connect the motor to the compressor. The maintenance on these couplings should be done following the Planned Maintenance System (PMS).

SETTING CONTROL AND SAFETY DEVICES

A refrigeration plant cannot operate efficiency and safely unless the control and safety devices are in good working order and set properly. When a new control or safety device is installed, it must be adjusted or set to function at pressures or temperatures following the plant design. Periodic tests and inspections may indicate faulty plant operation that is caused by improperly adjusted control or safety devices. You must know how these devices operate and how to adjust them.

This section contains information on these common types of control and safety devices used by the Navy.

1. High-pressure switch
2. Low-pressure switch
3. Water failure switch
4. Thermostatic expansion valve
5. Water regulating valve
6. Thermostatic switch
7. Automatic reducing valve

The methods of setting the low-pressure switch, the water failure switch, and the thermostatic switch are similar. However, these switches differ as to operating range, purpose, and setting. Also, the high-pressure switch and the water failure switch are safety devices while the low-pressure switch and the thermostatic switches are control devices. For detailed information, consult *Naval Ships' Technical Manual* and the manufacturer's technical manuals.

High-Pressure Switch

The high-pressure switch has an operating range of 60 psig to 350 psig and an adjustable differential (difference between the cut-in point and cutout point). Turn the range adjusting screw clockwise to raise both the cut-in point and cutout point. Turn it counterclockwise to lower these points. The differential adjustment affects only the cutout point. Turn it clockwise to raise the cutout point and counterclockwise to lower the cutout point.

To set the switch, first remove the cover plate. Then the two adjusting screws labeled DIFFERENTIAL and RANGE are easily accessible.

1. Start the compressor and control the discharge pressure by throttling the circulating water through the condenser.

2. Turn the differential screw to its limit counterclockwise and turn the range screw to its limit clockwise.

3. Raise the compressor discharge to about 10 psig above the desired cut-in pressure.

4. Turn the range screw counterclockwise until the contactor in the switch opens, thereby stopping the compressor.

5. When the discharge pressure drops to the desired cut-in pressure, turn the range screw clockwise until the contacts close, starting the compressor. The cut-in point is now set.

6. With the compressor running, turn the differential screw to its limit clockwise.

7. Raise the discharge pressure to the desired cutout pressure.

8. Turn the differential screw counterclockwise until the contacts open, stopping the compressor. The cutout point is now set.

Low-Pressure Switch

The low-pressure switch has an operating range of 20 inches of vacuum to 80 psig and an operating differential of 9 psig to 30 psig.

To set the low-pressure switch, start the compressor and control the suction pressure by throttling the compressor suction valve.

1. Turn the range and differential adjustment screws counterclockwise.

2. Lower the suction pressure to about 10 psig below the desired cut-in pressure.

3. Turn the range screw clockwise until the switch contacts open, stopping the compressor.

4. Allow the suction pressure to rise to the desired cut-in pressure.

5. Turn the range screw counterclockwise until the switch contacts close, starting the compressor. The cut-in point is now set.

6. Turn the differential screw to its limit clockwise.

7. Throttle the suction valve to lower the suction pressure to the desired cutout pressure.

8. Turn the differential screw counterclockwise until the switch contacts open, stopping the compressor. The cutout point is now set.

Water Failure Switch

The water failure switch should be set to cut in at 15 psig and to cut out at 5 psig. To set the water failure switch, turn the differential screw to its limit counterclockwise for minimum differential since the required differential (difference between cut-in and cutout points) is 10 psig.

1. Throttle the water overboard valve until a pressure of 15 psig is maintained at the condenser inlet.

2. Turn the range screw clockwise until the switch contacts open.

3. Turn the screw counterclockwise slowly until the contacts close.

4. Slowly shut off the water supply, decreasing the pressure. The contacts should open at 5 psig.

Thermostatic Expansion Valve

The TXV is generally factory set and seldom needs adjustment. The design and construction of expansion valves vary greatly. Figure 11-20 shows a cross-sectional assembly view of a type that is generally used aboard ship. Other designs may have different arrangements for adjustment, sealing, and control.

When the TXV is operating properly, the temperature at the outlet side of the valve is much lower than that at the inlet side. If this temperature difference does not exist when the system is in operation, the valve seat is probably dirty and clogged with foreign matter.

The major trouble encountered can usually be traced to a collection of moisture or dirt at the valve seat and orifice. Carefully analyze the symptoms of improper valve operation before you conclude that the valve is out of adjustment. Once a valve is properly adjusted, additional adjustment should not be necessary unless changes are made to the cooling-coil arrangement or thermal element location.

The TXV is adjusted to maintain a superheat ranging from approximately 4° to 12°F at the cooling-coil outlet. This is done by means of a gear and screw arrangement. The proper superheat adjustment varies with the design and service-operating conditions of the valve anad the design of the particular plant. Increased spring pressure increases the degree of superheat at the coil outlet, and decreased pressure has the opposite effect. Many TXVs are initially adjusted by the manufacturer to maintain a predetermined degree of superheat. In these cases, there is provision for further adjustments in service.

If expansion valves are adjusted to give a high degree of superheat at the coil outlet or if the valve is stuck shut, the amount of refrigerant admitted to the cooling coil will be reduced. When there is not enough refrigerant, the coil will be "starved" and will operate at a reduced capacity. Compressor lubricating oil carried with the refrigerant may collect at the bottom of the

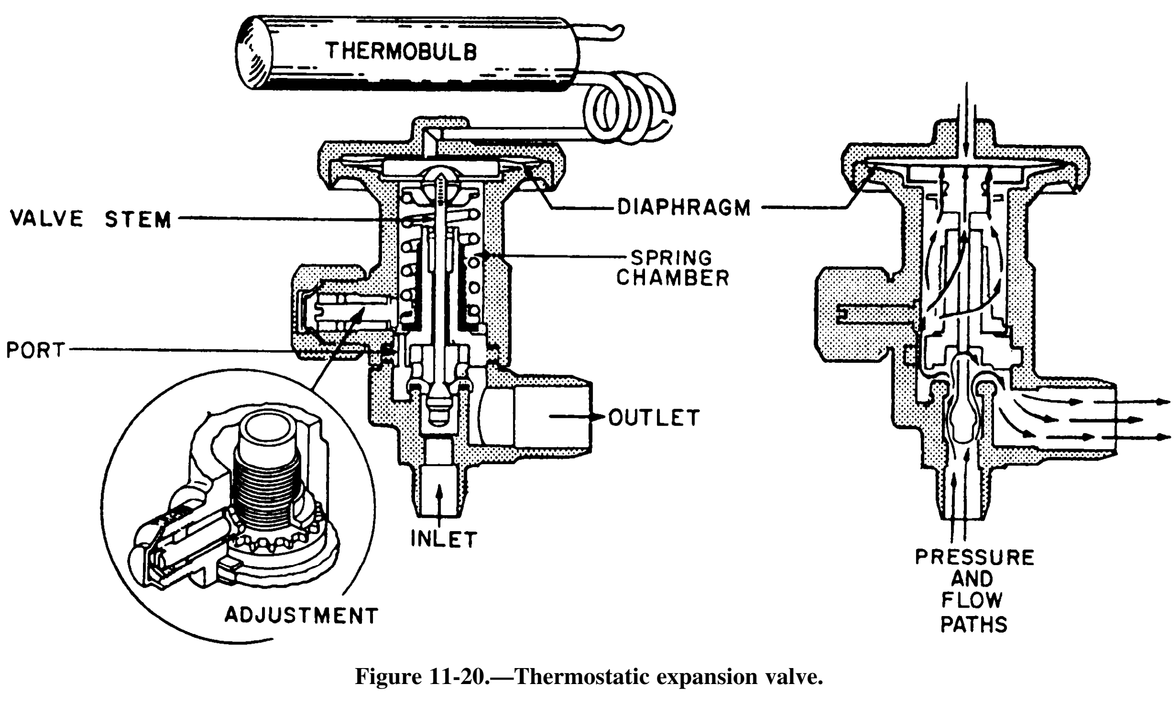


Figure 11-20.—Thermostatic expansion valve.

cooling coils. This robs the compressor crankcase and provides a condition whereby slugs of lubricating oil may be drawn back to the compressor. If the expansion valve is adjusted for a too-low degree of superheat or it the valve is stuck open, liquid refrigerant may flood from the cooling coils back to the compressor. If the liquid collects at **a** low point in the suction line or coil and is drawn back to the compressor intermittenly in slugs, there is danger of injury to the moving parts of the compressor.

In general, the expansion valves for air-conditioning and water cooling plants (high-temperature installations) must be adjusted for higher superheat than those for cold storage refrigeration and ship's service store equipment (low-temperature installations).

Water Regulating Valve

The water regulating valve should be adjusted to maintain a compressor discharge pressure of approximately 125 psig. An increase in the tension on the main spring increases the amount of pressure required to open the valve; a decrease in tension decreases the required amount of pressure. Turn the adjusting nuts clockwise to increase tension and counterclockwise to decrease it. If the ambient temperature is high, pressure (gas) in the compressor discharge line and the condenser may remain high. This may cause the water regulating valve to partly open when the compressor is idle. In such instances, the point of the valve opening should be raised just enough to cause the valve to close during compressor shutdown.

The valve can be flushed by opening it with an outside force. A screwdriver or similar tool may be used to force the spring yoke.

Thermostatic Switch

The thermostatic switch which operates the solenoid valve is similar to the low-pressure switch. Tubing connects a bellows in the thermostatic switch to a thermobulb in the compartment being cooled. The thermobulb and tubing are charged with R-12 or some other volatile liquid. Temperature changes in the refrigerated compartment cause corresponding pressure changes of the actuating medium in the thermobulb. These pressure changes are transmitted to the thermostatic switch through the connecting tubing. Set or adjust the cut-in and cutout points of the thermostatic switch the same way you did with the low-pressure switch.

Automatic Reducing Valve

When condenser circulating water comes from a fire main, the pressure must be reduced. The branch line leading from the fire main to the condenser has an automatic reducing valve for this purpose. It is installed just ahead of the regulating valve. The outlet pressure can be varied by turning the adjusting screw, which is located under the cap. Turn it clockwise to increase the pressure applied by the spring to the top of the diaphragm. This opens the valve wider and increases the outlet pressure. Turn the screw counterclockwise to decrease the spring pressure on the top of the diaphragm. This tends to decrease the discharge pressure.

TESTING AND RENEWING COMPRESSOR DISCHARGE AND SUCTION VALVES

An R-12 compressor SHOULD NOT BE OPENED for valve inspection or replacement until it has been determined that the faulty operation of the system is caused by improper functioning of the valves. Faulty compressor valves may be indicated by either an increase in discharge temperature or decrease in the normal compressor capacity. Either the compressor will fail to pump at all or the suction pressure cannot be pumped down to the designed value; the compressor will run for abnormally long intervals (or even continuously). If the compressor shuts down for short periods (short cycles), the compressor valves may be leaking.

If the refrigeration plant is not operating satisfactorily, you should first shift the compressor and then check the operation of the plant. If the operation of the plant is satisfactory when the compressors have been shifted, the trouble is probably with the compressor.

To test the compressor discharge valves, pump down the compressor to 2 psig. Then stop the compressor and quickly close the suction and discharge line valves. If the discharge pressure drops at a rate in excess of 3 psi per minute and the crankcase suction pressure rises, you probably have compressor discharge valve leakage. If it is necessary to remove the discharge valves with the compressor pumped down, break the connection to the discharge pressure gauge to release discharge pressure on the head. Then remove the compressor top head and discharge valve plate, being careful not to damage the gaskets.

If the discharge valves are defective, the entire discharge valve assembly should be replaced. Any attempt to repair the valve would probably involve relapping and would require highly specialized equipment. Except in an emergency, do not attempt such repair aboard ship.

You can check the compressor internal suction valves for leakage by performing these steps:

1. Start the compressor by using the MANUAL control switch on the motor controller.

2. Close the suction line stop valve gradually to prevent violent foaming of the compressor crankcase lubricating oil.

3. Rump a vacuum of approximately 20 inches of mercury. If this vacuum can be readily obtained, the compressor suction valves are satisfactory.

Do not expect the vacuum to be maintained after the compressor stops because R-12 being released from the crankcase oil will cause the pressure to rise. Do NOT attempt to check compressor suction valve efficiency of new R-12 units until after the compressor has been in operation for at least 3 days. It may be necessary for the valves to wear in.

However, if any of the compressor valves are defective, the compressor should be pumped down, opened, and the valves inspected. Defective valves or pistons should be replaced with spare assemblies.

CARING FOR SHAFT SEALS

The first indication of shaft seal failure is excessive oil leaking at the shaft. When the seal requires replacement or when there are signs of abnormal wear or damage to the running surfaces, then there is a definite reason for the abnormal conditions. An inspection should be made to locate and correct the trouble, or the failure will recur.

Seal faiure is very often due to the condition of the crankcase oil. Dirty or acidic oil is generally caused by one or both of the following conditions:

1. Dirt or foreign material is in the system or system piping. Dirt frequently enters the system at the time of installation. After a period of operation, any foreign material present in the system accumulates in the compressor crankcase. It tends to concentrate in the oil chamber surrounding the shaft seal. When the oil contains grit, it is only a matter of time until the highly finished running faces become damaged, causing failure of the shaft seal. Whenever foreign material is found in the lubricating oil, the entire system (piping, valves, and strainers) should be cleaned thoroughly.

2. Moisture frequently causes an acid condition of the lubricating oil. Oil in this condition will not promote failure of the compressor parts. If moisture is suspected, use a dryer when the compressor is put into operation.

Removing the Shaft Seal

Use the following procedure to repair or renew a shaft seal.

If the seal is broken to the extent that it permits excessive oil leakage, do not attempt to pump the refrigerant out the compressor. If you do, air containing moisture will be drawn into the system through the damaged seal. This moisture may cause expansion valves to freeze. If oil is leaking excessively, close the compressor suction and discharge valves. Relieve the pressure to the atmosphere by loosening a connection on the compressor discharge gauge line. If the condition of the seal permits, pump down the compressor as explained earlier in this chapter.

Next, drain and measure the oil from the compressor crankcase so that an equal amount can he replaced. Since the oil contains refrigerant, it will foam while being drained. The oil drain valve or plug should be left open while you are working on the seal. In this way, the refrigerant escaping from the oil remaining in the crankcase will not build up pressure and unexpectedly blow out the seal while it is being removed.

Remove the compressor flywheel (or coupling) and carefully remove the shaft seal assembly. If the assembly cannot be readily removed, build up a slight pressure in the compressor crankcase. Slightly open the compressor suction valve, taking the necessary precautions to support the seal to prevent it from being blown from the compressor and damaged.

Installing the Shaft Seal

When you have to replace a seal, replace the entire seal assembly. Clean the parts and replace them following the manufacturer's instructions.

Wipe the shaft clean with a cloth. Do NOT use a dirty or lint-bearing cloth. Unwrap the seal, being careful not to touch the bearing surfaces with your hands. (This can be done by using surgical gloves.) Rinse the seal in an approved solvent and allow it to air-dry. (Do NOT wipe the seal dry.) Dip the seal in clean refrigerant oil Insert the assembly following the manufacturer's instructions and bolt the seal cover in place, tightening the bolts evenly. Replace the fly-wheel and or coupling belts and all the amount of oil removed. Then test the unit for leaks by opening the suction and discharge valves and using an electronic leak detector.

CHARACTERISTICS OF REFRIGERANTS

Pure R-l 2 ($CC1_2F_2$) is colorless. It is odorless in concentrations of less then 20 percent by volume in air. In higer concentrations, its odor resembles that of carbon tetrachloride. It has a boiling point of -21.6°F at atmospheric pressure. At ordinary temperatures R-l 2 is a liquid when under a pressure of approximately 70 psig to 75 psig.

Mixtures of R-12 vapor and air, in all proportions, are nonirritating to the eyes, nose, throat, and lungs. The refrigerant will not contaminate or poison foods or other supplies with which it may come in contact. The vapor is nonpoisonous. However, if R-12 concentration becomes excessive, unconsciousness or even death may result because of lack of oxygen to the brain. In view of R-l2's low boiling point at atmospheric pressure, you must always protect your eyes from contact with liquid R-12; the liquid will freeze the tissues of the eyes. Always wear goggles if you are to be exposed to R-12.

R-12 in either a liquid or vapor state is nonflammable and nonexplosive. R-12 will not corrode the metals commonly used in refrigerating systems.

R-l 2 is a stable compound capable of undergoing (without decomposition) the physical changes required of it in refrigeration service. It is an excellent solvent and has the ability to loosen and remove all particles of dirt, scale, and oil with which it comes in contact within a refrigerating system.

R-22 ($CHC1F_2$) and R- 11 ($CC1_3F$) are colorless, nonexplosive, nonpoisonous refrigerants with many properties similar to those of R-12.

SAFETY PRECAUTIONS

Personnel working with refrigerants may be injured or killed if proper precautions are not taken. REFRIGERANTS ARE HALOCARBONS.

HALOCARBONS

Halocarbons are organic chemical compounds containing hydrogen and one or more atoms of carbon, fluorine, bromine, chlorine, or iodine which may be present in various combinations in the compound.

You may be more familiar with their brand names, such as Freon(s) (refrigerants), Gentron, Gension D., Frigen, AFFF, or Carbon Tetrachloride. You will work with these compounds regularly aboard ship. Because you use these frequently, you may gain a false sense of security which lets you forget the dangerous potential of halocarbons. They are especially dangerous when used in high concentration in confined or poorly ventilated spaces.

HANDLING OF REFRIGERANT CYLINDERS (BOTTLES)

Refrigerants are furnished in cylinders for use in shipboard refrigeration systems. The following precautions MUST BE OBSERVED in the handling, use, and storage of these cylinders:

NOTE: Before handling refrigerant bottles, read OPNAVINST 5100.19 and chapters 516 and 670 of *Naval Ships' Technical Manual (NSTM).*

1. NEVER drop cylinders nor permit them to strike each other violently.

2. NEVER use a lifting magnet or a sling (rope or chain) when you are handling cylinders. A crane may be used if a safe cradle or platform is provided to hold the cylinders.

3. Caps provided for valve protection must be kept on cylinders except when the cylinders are being used.

4. Whenever refrigerant is discharged from a cylinder, the cylinder should be weighed immediately, and the weight of the refrigerant remaining in the cylinder should be recorded.

5. NEVER attempt to mix gases in a cylinder.

6. NEVER put the wrong refrigerant into a refrigeration system! NO REFRIGERANT EXCEPT THE ONE FOR WHICH A SYSTEM WAS DESIGNED SHOULD EVER BE INTRODUCED INTO THE SYSTEM. Check the equipment nameplate or the manufacturer's technical manual to determine the proper refrigerant type and charge. Putting the wrong refrigerant into a system may cause a violent explosion.

7. When a cylinder has been emptied, close the cylinder valve immediately to prevent the entrance of air, moisture, or dirt. Also, be sure to replace the valve protection cap.

8. NEVER use cylinders for any purpose other than their intended purpose. Do NOT use them as rollers and supports.

9. Do NOT tamper with the safety devices in the valves or cylinders.

10. Open cylinder valves slowly. NEVER use wrenches or other tools except those provided by the manufacturer.

11. Be sure that the threads on regulators or other connections are the same as those on the cylinder valve outlets. NEVER force connections that do not fit.

12. Regulators and pressure gauges provided for use with a particular gas must NOT be used on cylinders containing other gases.

13. NEVER attempt to repair or alter cylinders or valves.

14. NEVER fill R-12 cylinders beyond 85 percent capacity.

15. Store cylinders in a cool, dry place, in an UPRIGHT position. If the cylinders are exposed to excessive heat, a dangerous increase in pressure will occur. If cylinders must be stored in the open, ensure that they are protected against extremes of weather. NEVER allow a cylinder to be subjected to a temperature above 130°F.

16. NEVER allow R-12 to come in contact with a flame or red-hot metal! When exposed to excessively high temperatures, R-12 breaks down into PHOSGENE gas, an extremely POISONOUS substance.

R-12 is such a powerful freezing agent that even a very small amount can freeze the delicate tissues of the eye, causing permanent damage. It is essential that goggles be worn by all personnel who may be exposed to a refrigerant, particularly in its liquid form. If refrigerant does get into the eyes, the person suffering the injury should receive IMMEDIATE medical treatment to avoid permanent damage. MAKE SURE that the person does NOT rub his eyes.

CAUTION: Do NOT use anything except clean water at room temperature for this type of eye injury.

If R-12 comes in contact with the skin, it may cause frostbite. This injury should be treated as any other cause of frostbite. Immerse the affected part in a warm bath for about 10 minutes, then dry carefully. Do NOT rub or massage the affected area.

Know, understand, and use these safety precautions, and you can safely operate and maintain refrigeration plants.

CHAPTER 12

AIR CONDITIONING

Air conditioning is a field of engineering that deals with the design, construction, and operation of equipment used to establish and maintain desirable indoor air conditions. It is used to maintain the environment of an enclosure at any required temperature, humidity, and purity. Simply stated, air conditioning involves the cooling, heating, dehumidifying, ventilating, and purifying of air. This chapter deals with that process.

THE PURPOSES OF AIR CONDITIONING AND RELATED FACTORS

One of the chief purposes of air conditioning aboard ship is to keep the crew comfortable, alert, and physically fit. None of us can long maintain a high level of efficiency under adverse environmental conditions. We have to maintain a variety of compartments at a prescribed temperature with proper circulation. They must have proper moisture content, the correct proportion of oxygen and an acceptable level of air contamination (dust, airborne dirt, etc.). We also have to provide mechanical cooling or ventilation in ammunition spaces to prevent deterioration of ammunition components. We have to provide them in gas storage spaces to prevent excessive pressure buildup in containers and contamination in the space caused by gas leakage. Finally, we must provide cooling and ventilation in electrical/electronic equipment spaces. This is done to maintain the ambient temperature and humidity as specified for the equipment.

Proper air conditioning must consider humidity, heat of the air, temperature, body heat balance, the effect of air motion, and the sensation of comfort.

HUMIDITY

Humidity is the vapor content of the atmosphere; it has a great influence on human comfort. The common expression, "It isn't the heat, it's the humidity," indicates discomfort produced by moisture-laden air in hot weather. Extremely low moisture content also has undesirable effects on the human body. The measurement and control of moisture in the air is an important phase of air conditioning. To understand this phase, you should become familiar with the meaning of saturated air, absolute and specific humidity, and relative humidity.

Saturated Air

Air can hold varying amounts of water vapor. It depends on the air's temperature at a given atmospheric pressure. As the temperature rises, the amount of moisture that the air can hold increases (assuming no change in atmospheric pressure). But for every temperature there is a definite limit to the amount of moisture that the air can hold. When air contains the maximum amount of moisture that it can hold at a specific temperature and pressure, it is said to be saturated.

The saturation point is usually called the DEWPOINT. If the temperature of saturated air falls below its dewpoint, some of the vapor in the air must condense to water. An example is the dew that appears on decks and bulkheads in the early morning. This happens when there is a drop in temperature. Another is the "sweating" of cold water pipes as water vapor from the relatively warm air condenses on the cold surface of the pipes.

Absolute and Specific Humidity

The amount of water vapor in the air is expressed in terms of the weight of the moisture. The weight is usually given in grains (7,000 grains = 1 pound). ABSOLUTE humidity is the weight in grains of water vapor per cubic foot of air. SPECIFIC humidity is the weight in grains of water vapor per pound of air. (The weight of water vapor refers only to moisture that may be present in the liquid state, such as rain or dew.)

Relative Humidity

Relative humidity is the ratio of the weight of water vapor in a sample of air to the weight of water vapor the same sample of air would contain if saturated at the existing temperature. This ratio is usually stated as a percentage. For example, when air is fully saturated, the relative humidity is 100%. When air contains no moisture at all, its relative humidity is 0%. If air is half-saturated, the relative humidity is 50%. The normal comfort range of relative humidity for humans is between 30% and 70%.

The deciding factor in human comfort is the relative humidity-not the absolute or specific humidity.

Just as heat flows from a higher temperature to a lower temperature, moisture always travels from areas of greater wetness to areas of lesser wetness. If the air above a liquid is saturated, the two are in balance and no moisture can travel from the liquid to the air; that is, the liquid cannot evaporate. If the air is only partially saturated, some moisture can travel to the air; that is, some evaporation can take place.

When the temperature of the air is 76°F and the relative humidity is nearly 90%, the air is nearly saturated. At such a relative humidity, the body may perspire freely but the perspiration does not evaporate rapidly; thus a general feeling of discomfort results.

However, when the temperature of the same air is 86°F, the relative humidity would then be only 64%. Although the absolute amount of moisture in the air is the same, the relative humidity is lower, because at 86°F the air is capable of holding more water vapor than it can hold at 76°F. The body is now able to evaporate its excess moisture and the general feeling is much more agreeable, even though the temperature of the air is 10° higher. (The cooling effect on the body is brought about by the absorption of latent heat during the evaporating process.)

In both examples, the specific humidity is the same, but the ability of the air to evaporate liquid is quite different at the two temperatures. The ability to evaporate moisture is directly indicated by the relative humidity. This is the reason that the control of relative humidity is of extreme importance in air conditioning.

HEAT OF AIR

The heat of air is considered from three standpoints—sensible, latent, and total heat.

SENSIBLE HEAT is the amount of heat which, when added to or removed from air, changes the temperature of the air. Sensible heat changes can be measured by the common (dry-bulb) thermometer.

Air always contains some water vapor. Any water vapor in the air contains the LATENT HEAT OF VAPORIZATION. (The amount of latent heat present has no effect on temperature and it cannot be measured with a dry-bulb thermometer.)

Any mixture of dry air and water vapor contains both sensible and latent heat. The sum of the sensible heat and the latent heat in any sample of air is called the TOTAL HEAT of the air.

TEMPERATURES

To test the effectiveness of air-conditioning equipment and to check the humidity of a space, two different temperatures are considered. These are the dry-bulb and wet-bulb temperatures.

Measurement of Temperatures

The DRY-BULB TEMPERATURE is the temperature of sensible heat of the air, as measured by an ordinary thermometer. Such a thermometer in air conditioning is referred to as a dry-bulb thermometer because its sensing bulb is dry, in contrast with the wet-bulb type described next.

The WET-BULB TEMPERATURE is best explained by a description of a wet-bulb thermometer. It is an ordinary thermometer with a loosely woven cloth sleeve or wick placed around its bulb which is then wet with distilled water. The water in the sleeve or wick is caused to evaporate by a current of air (see next paragraph) at high velocity. This evaporation withdraws heat from the thermometer bulb, lowering the temperature by several degrees. The difference between the dry-bulb and the wet-bulb temperatures is called the wet-bulb depression. When the wet-bulb temperature is the same as the dry-bulb, the air is saturated (that is, evaporation cannot take place). The condition of saturation is unusual, however, and a wet-bulb depression is normally expected.

The wet-bulb and dry-bulb thermometers are usually mounted side by side on a frame that has a handle and a short chain attached. This allows the thermometers to be whirled in the air, thus providing a high-velocity air current to promote evaporation. Such a device is known as a SLING PSYCHROMETER. When using the sling psychrometer, whirl it rapidly—at least four times per second. Observe the wet-bulb temperature at intervals. The point at which there is no further drop in temperature is the wet-bulb temperature for that space.

MOTORIZED PSYCHROMETERS are provided with a small motor-driven fan and dry cell batteries. Motorized psychrometers are generally preferred and are gradually replacing sling psychrometers.

Relationships Between Temperatures

You should clearly understand the definite relationships of the three temperatures—dry-bulb, wet-bulb, and dewpoint.

1. When air contains some moisture but is not saturated, the dewpoint temperature is lower than the dry-bulb temperature; the wet-bulb temperature lies between them.
2. As the amount of moisture in the air increases, the difference between the dry-bulb temperature and the wet-bulb temperature becomes less.
3. When the air is saturated, all three temperatures are the same.
4. By using both the wet-bulb and the dry-bulb temperature readings, the relative humidity and the dewpoint temperature can be found on a psychrometric chart (see fig. 12-1). The wet-bulb temperature lines are angled across the chart. The dewpoint temperature lines are straight across the chart. This is indicated by the arrows for wet-bulb and dewpoint. Find where the wet-bulb and dry-bulb lines cross, interpolate the relative humidity from the nearest humidity lines to the temperature-line crossing point. Then to find the dewpoint, follow the straight dewpoint line closest to the intersection across to the left of the chart and read the dewpoint temperature. For instance, find the wet-bulb temperature of 70°F and trace the line angling down to the right to the dry-bulb temperature of 95°F. Next, to find the dewpoint temperature, follow the dewpoint temperature lines nearest the intersection straight across to the left of the chart. The dewpoint line falls about G-third of the way between the 55° mark and the 60° mark. By interpolation, you can determine the dewpoint temperature to be about 57°F. To find the relative humidity, first find the dry-bulb temperature. Read across the bottom, find 95°F and follow straight up to the intersection of the wet- and dry-bulb readings. The relative humidity arc nearest the intersection is 30%. However, the intersecting line is below 30% and higher than 20%. By interpolation, we determine the relative humidity to be 28%.

BODY HEAT BALANCE

Ordinarily the body remains at a fairly constant temperature of 98.6°F. It is very important that this body temperature be maintained and, since there is a continuous heat gain

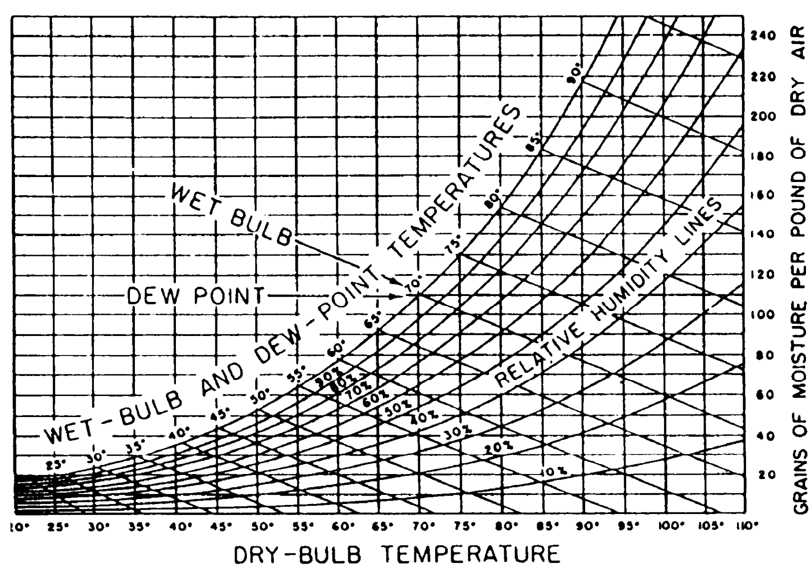


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Figure 12-1.—Simplified psychometric chart.

from internal body processes, there must also be a continuous loss to maintain body heat in balance. Excess heat must be absorbed by the surrounding air or lost by radiation. As the temperature and humidity of the environment vary, the body automatically regulates the amount of heat that it gives off. However, the body's ability to adjust to varying environmental conditions is limited. Furthermore, although the body may adjust to a certain (limited) range of atmospheric conditions, it does so with a distinct feeling of discomfort. The discussion which follows will help you understand how atmospheric conditions affect the body's ability to maintain a heat balance.

Body Heat Gains

The body gains heat (1) by radiation, (2) by convection, (3) by conduction, and (4) as a by-product of physiological processes that take place within the body.

The heat gain by radiation comes from our surroundings. However, heat always travels from areas of higher temperature to areas of lower temperature. Therefore, the body receives heat from those surroundings that have a temperature higher than body' surface temperature. The greatest source of heat radiation is the sun. Some sources of indoor heat radiation are heating devices, operating machinery, and hot steam piping.

The heat gain by convection comes only from currents of heated air. Such currents of air may come from a galley stove or an engine.

The heat gain by conduction comes from objects with which the body comes in contact.

Most body heat comes from within the body itself. Heat is produced continuously inside the body by the oxidation of foodstuffs and by other chemical processes, by friction and tension within the muscle tissues, and by other causes as yet not completely identified.

Body Heat Losses

There are two types of body heat losses: loss of sensible heat and loss of latent heat. Sensible heat is given off by (1) radiation, (2) convection, and (3) conduction. Latent heat is given off in the breath and by evaporation of perspiration.

EFFECT OF AIR MOTION

In perfectly still air, the layer of air around a body absorbs the sensible heat given off by the body and increases in temperature. The layer of air also absorbs some of the water vapor given off by the body, thus increasing in relative humidity. This means the body is surrounded by an envelope of moist air which is at a higher temperature and relative humidity than the ambient air. Therefore, the amount of heat that the body can lose to this envelope is less than the amount it can lose to the ambient air. When the air is set in motion past the body, the envelope is continually being removed and replaced by the ambient air, thereby increasing the rate of heat loss from the body. When the increased heat loss improves the heat balance, the sensation of a "breeze" is felt; when the increase is excessive, the rate of heat loss makes the body feel cool and the sensation of a "draft" is felt.

SENSATION OF COMFORT

From the foregoing discussion, it is evident that the three factors-temperature, humidity, and air motion-are closely interrelated in their effects upon the comfort and health of personnel aboard ship. In fact, a given combination of temperature, humidity, and air motion will produce the same feeling of warmth or coolness as a higher or lower temperature in conjunction with a compensating humidity and air motion. The term given to the net effect of these three factors is known as the EFFECTIVE TEMPERATURE. Effective temperature cannot be measured by an instrument, but can be found on a special psychrometric chart when the dry-bulb temperatures and air velocity are known.

The combinations of temperature, relative humidity, and air motion of a particularly effective temperature may produce the same feeling of warmth or coolness. However, they are NOT all equally comfortable. Relative humidity below 15% produces a parched condition of the mucous membranes of the mouth, nose, and lungs, and increases susceptibility to disease germs. Relative humidity above 70% causes an accumulation of moisture in clothing. For best health conditions, you need a relative humidity ranging from 40% to 50% for cold weather and from 50% to 60% for warm weather. An overall range from 30% to 70% is acceptable.

VENTILATION EQUIPMENT

Proper circulation is the basis for all ventilating and air-conditioning systems and related processes. Therefore, we shall first consider methods used aboard ship to circulate air. In the following sections, you will find information on shipboard equipment used to supply, circulate, and distribute fresh air, and to remove used, polluted, and overheated air.

Fans used in Navy ships in conjunction with supply and exhaust systems are divided into two general classes—axial flow and centrifugal.

Most fans in duct systems are of the axial-flow type because they generally require less space for installation.

Centrifugal fans are generally preferred for exhaust systems that handle explosive or hot gases. The motors of these fans, being outside the air stream, cannot ignite the explosive gases. The drive motors for centrifugal fans are subject to overheating to a lesser degree than are motors of vane-axial fans.

VANE-AXIAL FANS

Vane-axial fans (fig. 12-2) are high-pressure fans, generally installed in duct systems. They have vanes at the discharge end to straighten out

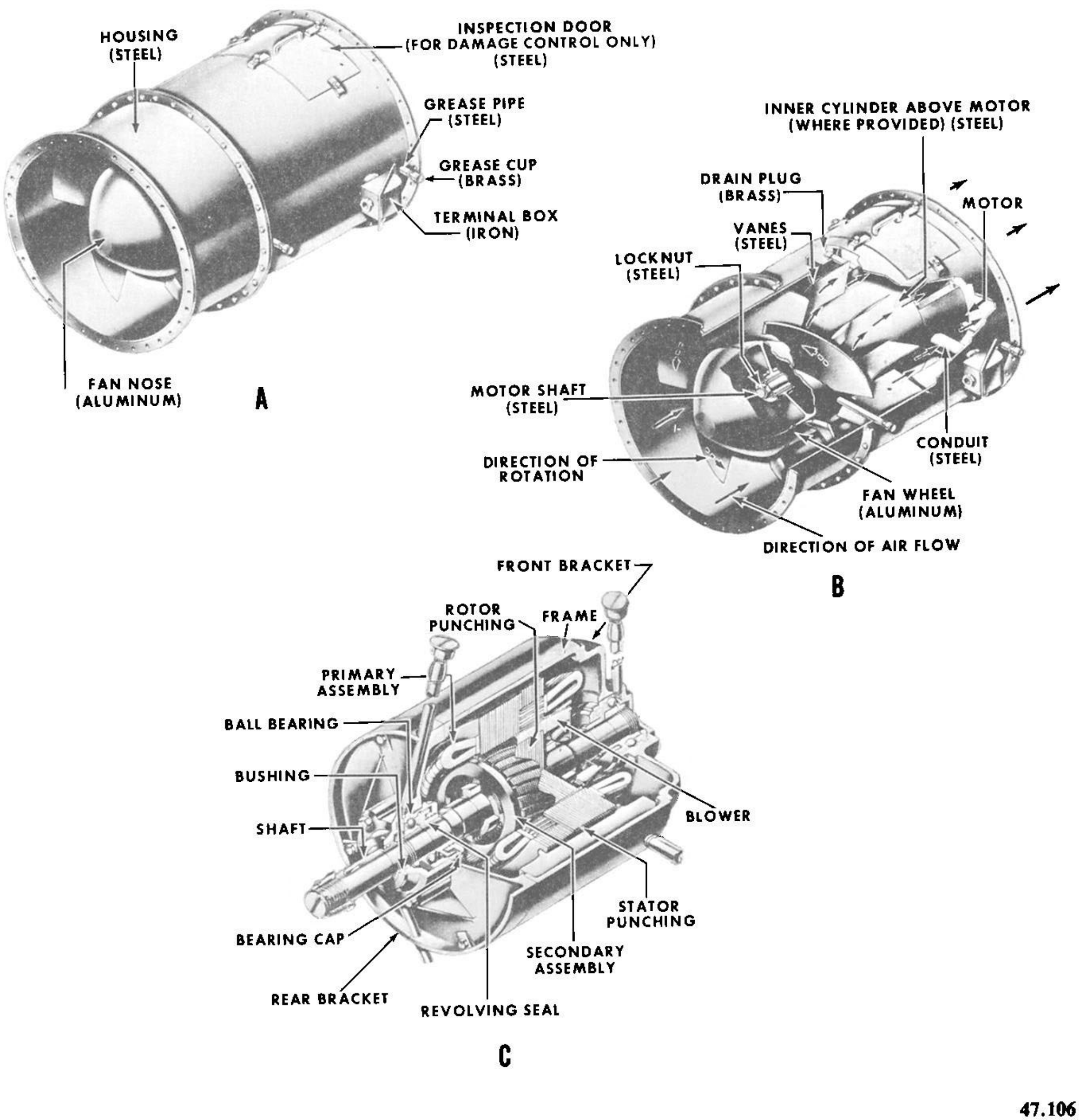

Figure 12-2.—Vane-axial ventilating fan: A. Exterior view. B. Cutaway view. C. Cutaway view of the fan motor.

rotational air motion caused by the impeller. The motors for these fans are cooled by the air in the duct and will overheat if operated with all air over the fan shut off.

TUBE-AXIAL FANS

Tube-axial fans are low-pressure fans, usually installed without duct work. However, they do have sufficient pressure for a short length of duct.

CENTRIFUGAL FANS

Centrifugal fans (part A of fig. 12-3) are used primarily to exhaust explosive or hot gases. However, they may be used in lieu of axial-flow fans if they work better with the arrangement or if their pressure-volume characteristics suit the installation better than an axial-flow fan. Centrifugal fans are also used in some fan-coil assemblies, which are discussed later in this chapter.

PORTABLE FANS

Portable-axial fans (part B of fig. 12-3) with flexible air hoses are used aboard ship for ventilating holds and cofferdams. They are also used in unventilated spaces to clear out stale

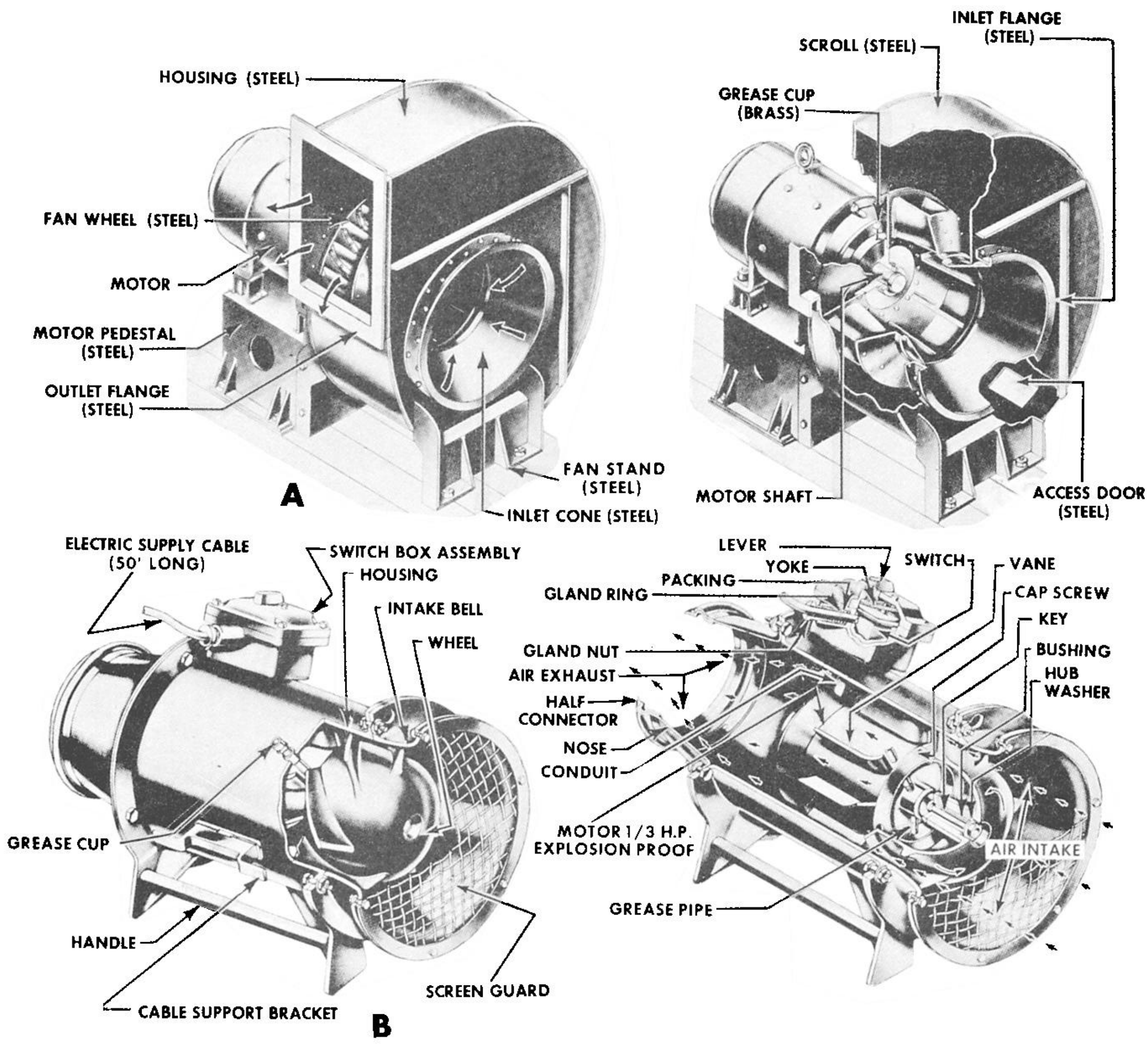

Figure 12-3.—Miscellaneous ventilating fans: A. Centrifugal fan. B. Portable axial fan.

air or gases before personnel enter, and for emergency cooling of machinery.

Most portable fans are of the axial-flow type, driven by electric, "explosion-proof" motors. On ships carrying gasoline, a few air turbine-driven centrifugal fans are normally provided. You can place greater confidence in the explosion-proof characteristics of these fans. (**CAUTION:** Never use a dc-driven fan to exhaust air that contains explosive vapor.)

WATERPROOF VENTILATOR

The waterproof ventilator, shown in figure 12-4, consists of an outer housing, an inner ventilator shaft extending up to the other housing, and a bucket-type closure supported over the ventilator shaft by a compression spring. The bucket has drain tubes which extend into a sump between the ventilator shaft and the outer housing. The sump has scupper valves which drain onto the weather deck.

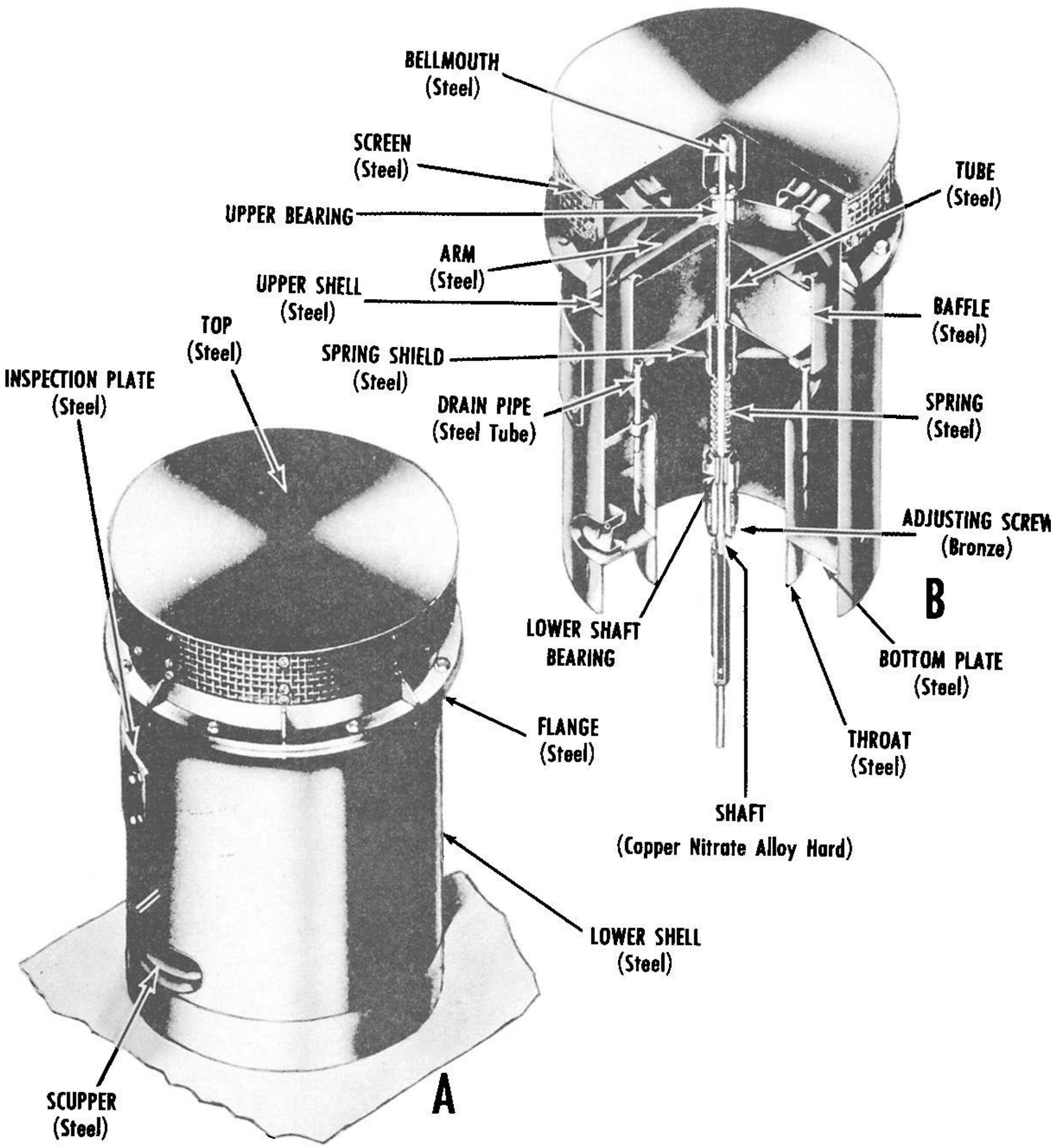

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Figure 12-4.—Waterproff ventilators: A. Exterior view. B. Cutaway view.

The ventilator operates automatically and is normally open. Small amounts of water, which enter the ventilator, fall into the bucket and drain out through the drain tubes and scuppers. In heavy seas, when water enters the bucket faster than it drains out, the weight of water forces the bucket down against the top of the ventilator shaft. Thus, a watertight seal is formed and maintained until sufficient water drains out to permit the force of the spring to raise the bucket to the open position. Normally, some provision is made so that the ventilator can also be closed manually. With slight variations in construction, ventilation of this type may be used for both the supply and exhaust of air.

BRACKET FANS

Bracket fans are used in hot weather to provide local circulation. These fans are normally installed in living, hospital, office, commissary, supply, and berthing spaces. Where air-conditioning systems are used, bracket fans are sometimes used to facilitate proper circulation and direction of cold air.

EXHAUSTS

Many local exhausts are used to remove heat and odors. Machinery spaces, laundries, and galleys are but a few of the spaces aboard ship where local exhausts are used.

Most exhausts used on Navy ships are mechanical (contain an exhaust fan), although natural exhausts are sometimes used in ship's structures and on small craft.

MECHANICAL COOLING EQUIPMENT

Almost all working and living spaces on newer ships are air conditioned. The equipment used on these ships was carefully tested to see which types would best dehumidify and cool ship compartments. Two basic types of equipment have been found most effective and are now in general use. They are chilled water circulating systems and self-contained air conditioners.

CHILLED WATER CIRCULATING SYSTEMS

Two basic types of chilled water air-conditioning systems are now in use. They are a vapor compression unit and a lithium bromide absorption unit. In the vapor compression unit, the primary refrigerant cools the secondary refrigerant (chilled water) that is used to cool the spaces. This type uses the vapor compression cycle and R-11 or R-114 as the primary refrigerant. The type of primary refrigerant depends on the size and type of compressor. The lithium bromide unit operates on the absorption cycle and uses water as the primary refrigerant. Lithium bromide is used as an absorbent.

Vapor compression plants are used in most ships. However, lithium bromide plants are used in submarines because they require no compression, which means a quieter operation.

Vapor Compression Units

The vapor compression chilled water circulating system differs from a refrigerant circulating (direct expansion) air-conditioning system in this way: The air is conditioned by using a secondary refrigerant (chilled water) which is circulated to the various cooling coils. Heat from the air-conditioned space is absorbed by the circulating chilled water. Heat is then removed from the water by the primary refrigerant system in the water chiller. In large tonnage vapor compression systems, the compressor is a centrifugal type that uses R-11 or R-114 as the primary refrigerant.

The operating cycle of the centrifugal refrigeration plant (fig. 12-5) is basically the same as other refrigeration plants except for the method of compression. The refrigerant gas is pressurized in the centrifugal turbocompressor. This then is discharged into the condenser where it is condensed by circulating seawater flowing through the condenser tubes. The condensed liquid refrigerant drains to the bottom of the condenser into a float chamber. When the refrigerant level is high enough, a float-operated valve opens. (**NOTE:** In some R-l 1 units an orifice is installed instead of a float valve.) This allows the liquid high-pressure refrigerant to spray out into the water chiller (evaporator). Water to be

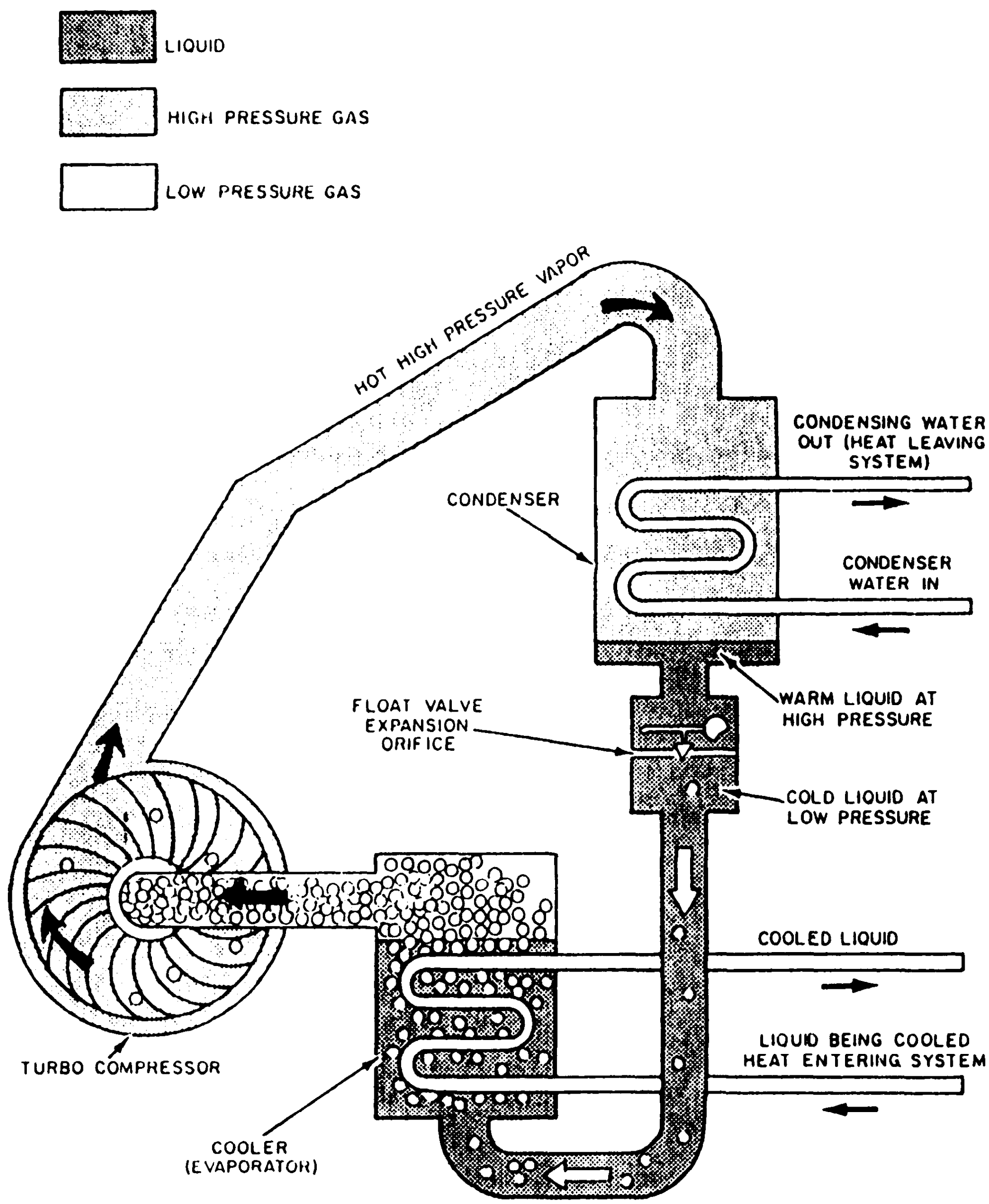

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Figure 12-5.—Vapor compressor (centrifugal) unit.

chilled flows through the tubes of the water chiller. As the refrigerant from the condenser sprays out over the tubes, the water within the tubes is chilled or cooled due to the vaporization of the liquid refrigerant. The vaporized refrigerant then reenters the suction side of the compressor to start the cycle again.

The load on the air-conditioning plant is determined by the desired chilled water temperature. The compressor load is changed by either an increased or decreased demand of the chilled water temperature. Upon demand the load is changed by the use of adjustable prerotation vanes. The vanes are located on the suction side of the compressor. The vanes act as dampers to increase or decrease the flow of refrigerant vapor into the suction of the compressor. This throttling action at the compressor suction allows an increase or decrease of the capacity of the compressor without changing the compressor speed.

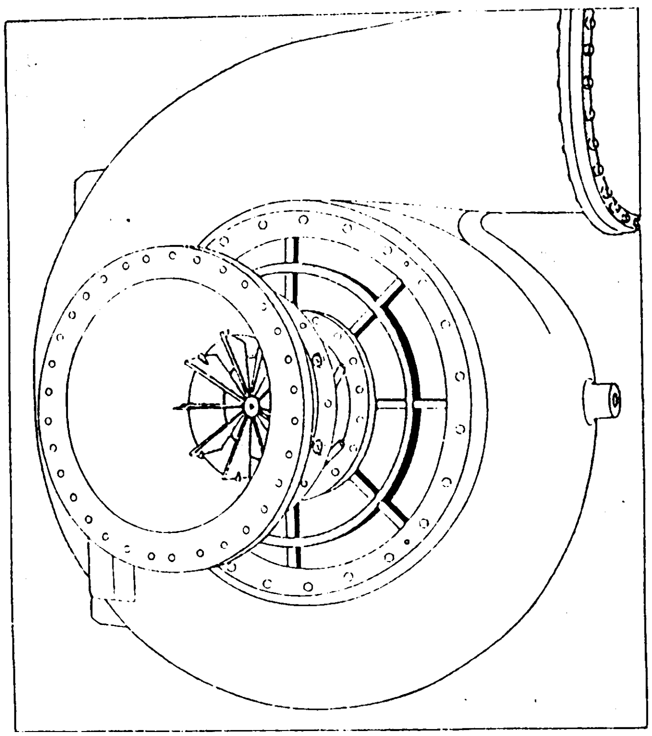

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Figure 12-6.—Suction end of a centrifugal compressor showing prerotation vanes.

Figure 12-6 shows a centrifugal compressor with the inlet piping removed. Note that the prerotation vanes are in the fully open position. The vane position is normally controlled automatically through an electropneumatic control system. The control system senses and maintains the chilled water outlet temperature of the chiller at a preset value by varying the position of the vanes.

In some plants, the electric motor used to drive the compressor is hermetically sealed and is cooled by a flow of refrigerant through it. The compressor is lubricated by a forced feed lubrication system. This system normally consists of an auxiliary oil pump, an attached oil pump (integral with compressor), an oil cooler, and a set of oil filters. The auxiliary oil pump is used for starting and securing the plant.

Several automatic controls are built into the centrifugal compressor control system. These devices increase the self-operating ability of the plant by automatically shutting down the compressor if a hazardous situation develops. Some of these conditions are high condenser pressure, low compressor lube oil pressure, seawater loss to the condenser, loss of chilled water, low refrigerant temperature, low chilled water temperature, and high discharge temperature.

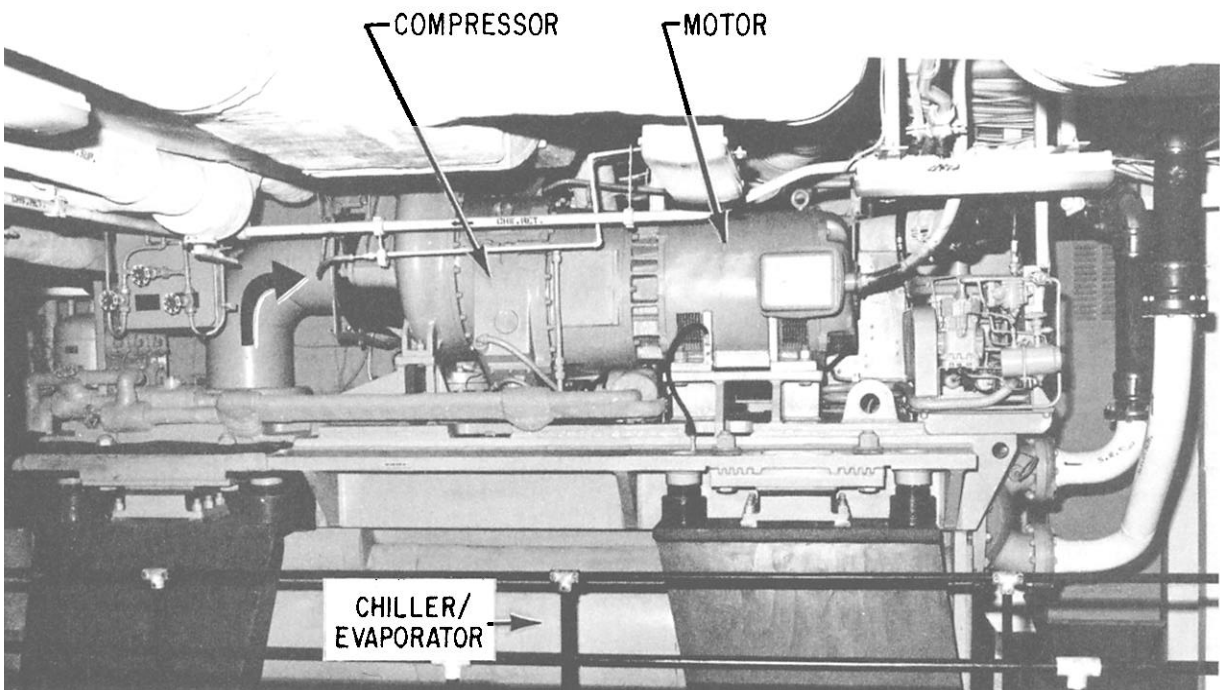

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Figure 12-7.—R-114 centrifugal air-conditioning plant.

An oil heater keeps the oil warm in the oil sump of the compressor during plant shutdown. If the oil is not kept heated, it absorbs large amounts of refrigerant. This results in excessive oil foaming when the unit is started. The heaters in most plants are connected so that they are automatically turned on when the compressor is off, and off when the compressor is on.

Figure 12-7 shows a centrifugal compressor air-conditioning unit. This particular plant has a 150-ton capacity and uses R-114 as the refrigerant. The gauges and controls for the plant are on the other side of the unit.

Lithium Bromide Absorption Unit

Water is used as a refrigerant in the lithium bromide absorption cycle. The absorption system differs from the compression-type refrigeration machines in this way: The absorption cycle uses heat energy instead of mechanical energy to cause the change in conditions necessary for a complete refrigeration cycle. In other words, the compressor is replaced by steam heat.

These two principles are the basis for the lithium bromide absorption refrigeration cycle:

1. Lithium bromide has the ability to absorb large quantities of water vapor.
2. When under a high vacuum, water boils (vaporizes) at a low temperature and, in doing so, absorbs heat.

To understand the lithium bromide absorption cycle, follow along on figure 12-8 during the following explanation. Notice that the

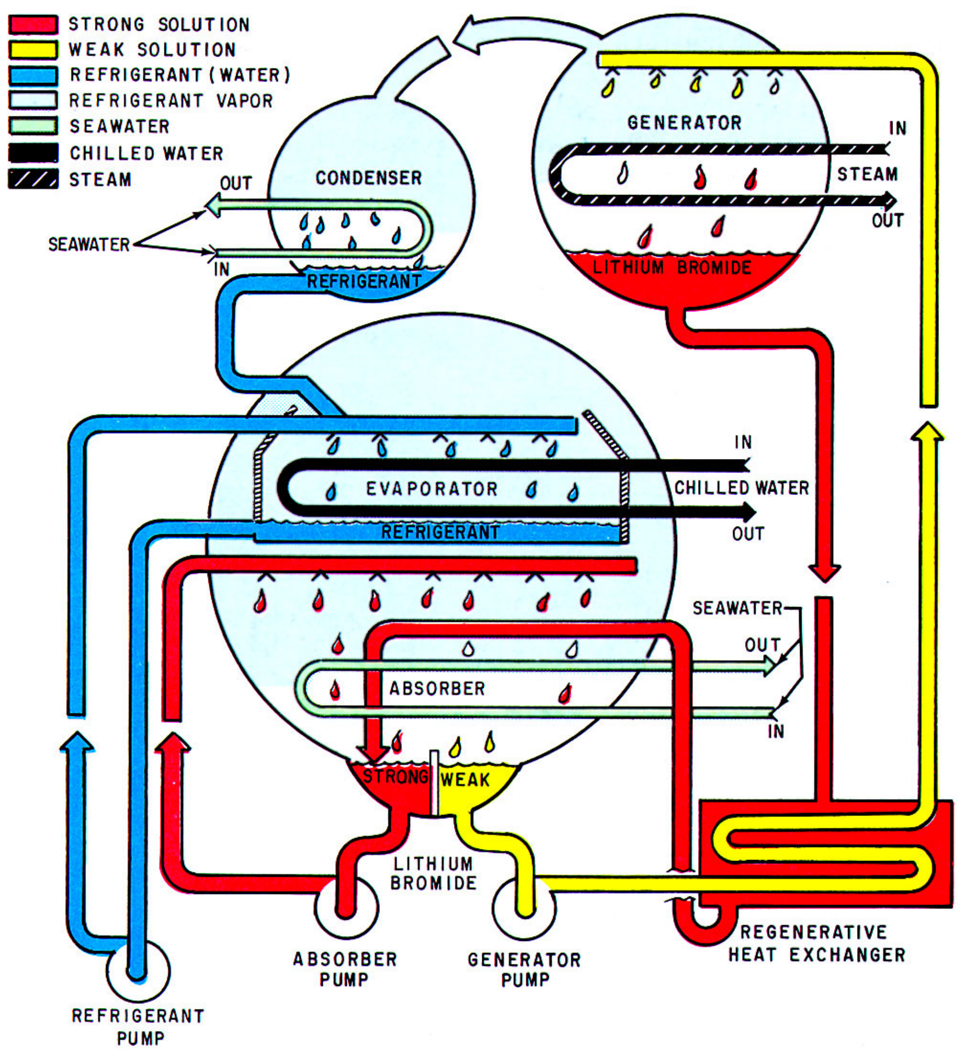

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Figure 12-8.—Basic absorption cycle.

sections labeled EVAPORATOR and ABSORBER are in a common shell. The sections are separated by the refrigerant tray and baffles. This shell is under a high vacuum of about 29.8 in. Hg. Water boils at 35°F (1.7°C) at this pressure. (Note that this is only 3°F above the freezing point of water.) The refrigerant pump circulates the refrigerant (water) through the evaporator. The water is sprayed out over the chilled water tubes through a spray header. This causes the water to vaporize (or flash) more readily. As the water vaporizes around the chilled water tubes, it removes heat from the circulating chilled water. The water vapor is now floating about in the evaporator/absorber shell. Now, the absorber comes into play.

Lithium bromide solution is sprayed out from a spray header in the absorber. The absorber pump provides the driving head for the spray. As the lithium bromide solution is sprayed out, it absorbs the water vapor which is in the shell from the evaporation process. As the lithium bromide absorbs more and more water vapor, its ability to absorb decreases. This is known as a WEAK solution. Here, in the generator section of the plant, the weak solution is rejuvenated for reuse as a STRONG solution. The generator pump pumps the weak solution from the weak solution section of the absorber up to the generator.

In the generator, the weak lithium bromide solution is sprayed out over steam tubes which heat the solution and drive the water vapor out of solution. The strong solution thus produced flows back into the absorber for reuse. The water vapor driven out of the solution flows from the generator into the condenser where it is condensed by circulating seawater for reuse as a refrigerant. The condensed vapor flows into the evaporator and down to the refrigerant tray.

A regenerative heat exchanger is provided in the system for the lithium bromide solution. The weak solution must be heated to drive out the water vapor; the strong solution must be cooled to absorb water vapor. The regenerative heat exchanger aids in this process by cooling the strong solution and preheating the weak solution in the cycle.

Seawater (condensing) flow is provided through the absorber section. It cools the strong solution returning from the generator and removes the heat produced as the lithium bromide solution absorbs the water vapor. The outlet seawater from the absorber is the inlet water for the condenser.

The absorber pump and the generator pump are driven by a common electric motor.

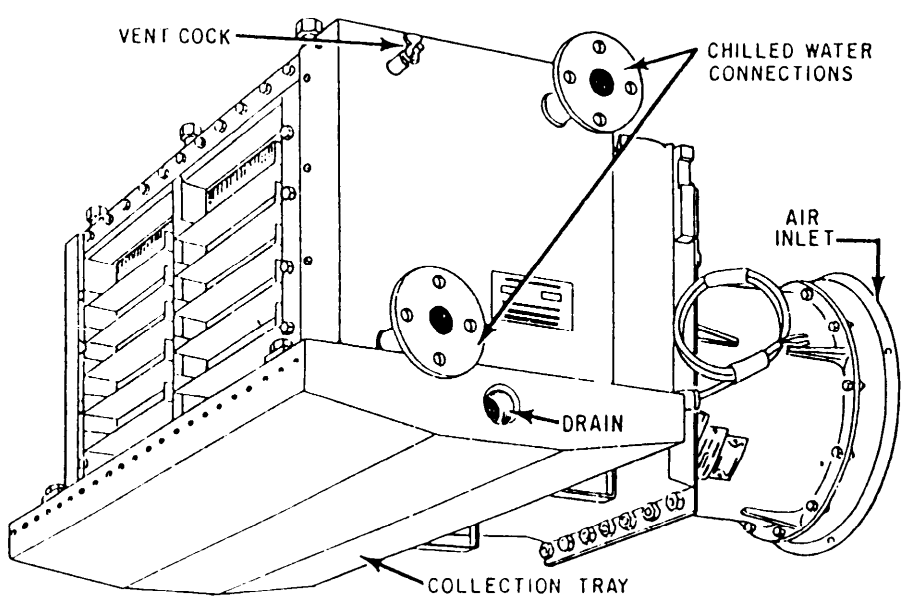

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Figure 12-9.—Fan-coil assembly.

Therefore, the two pumps are referred to cumulatively as the absorber/generator pump.

A purge system (not shown) consists of a pump, an eductor, and a purge tank. The system is provided with the lithium bromide absorption system to keep air and noncondensables out of the evaporator/absorber shell. The maintenance of the high vacuum within the shell is of utmost importance to the proper operation of the plant.

Fan-Coil Assemblies

Fan-coil assemblies use chilled water for the air conditioning of spaces. These assemblies are known as "spot coolers." The chilled water is piped through the cooling coils of the units and a fan forces air over the coils. One type of fan-coil assembly is shown in figure 12-9. Note the chilled water connections, the vent cock at the top, and the condensate collection tray at the bottom of the unit.

The condensate collection tray collects the moisture condensed out of the air. The condensate is generally piped to the bilge or a waste water drain system. It is important that the drain for the collection tray be kept clear. If the condensate cannot drain out of the tray, it collects and evaporates, leaving impurities which rapidly lead to the corrosion of the tray.

SELF-CONTAINED AIR CONDITIONERS

Ships without central-type air conditioning may use self-contained air-conditioning units. NAVSEA approval is required.

A self-contained air-conditioning unit is simply the type of air conditioner you see installed in the windows of many homes. All that is required for installation is to mount the proper brackets for the unit case and provide electrical power.

These units use nonaccessible hermetically sealed compressors (motor and compressor are contained in a welded steel shell). For this reason, shipboard maintenance of the motor-compressor unit is impractical. The thermal expansion valve used in these units is preset and nonadjustable. However, a thermostat and fan speed control are normally provided for comfort adjustment.

HEATING EQUIPMENT

Ventilation heaters are installed in ventilation ducting to heat spaces in cold weather and to control humidity. The two types of heat in current use are steam and electrical heat.

There are three types of steam heaters in current use—the S-type, the T-type, and the convection type. The S- and T-types are shown in figure 12-10. The S-type is used in small

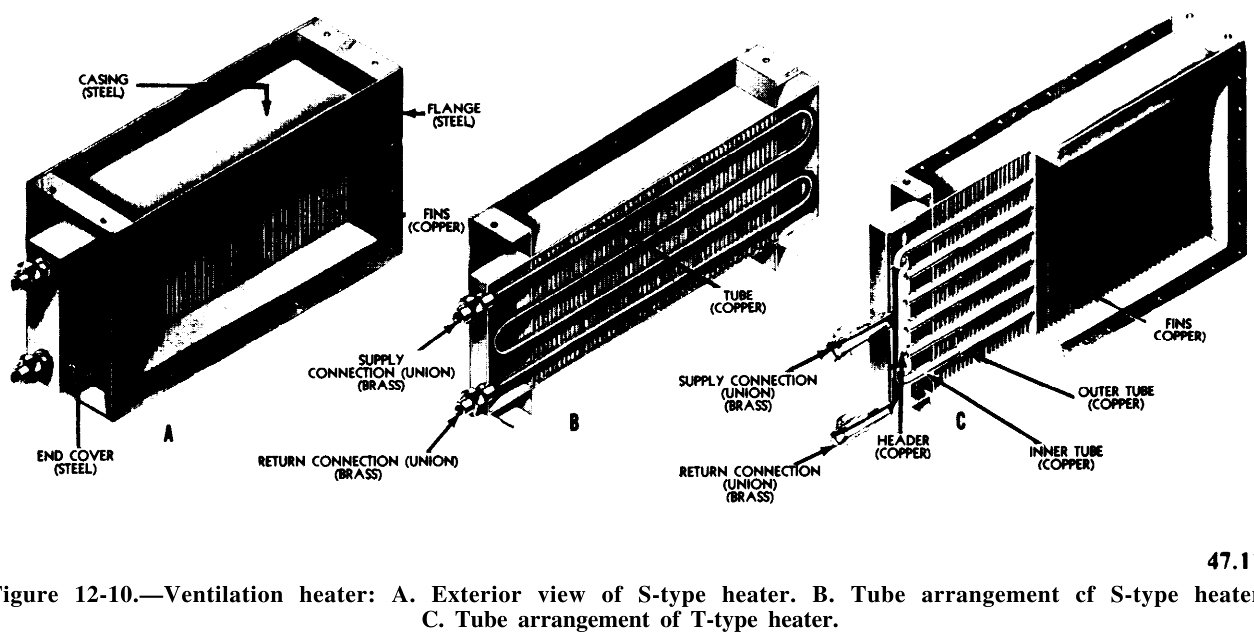

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Figure 12-10.—Ventilation heater: A. Exterior view of S-type heater. B. Tube arrangement cf S-type heater. C. Tube arrangement of T-type heater.

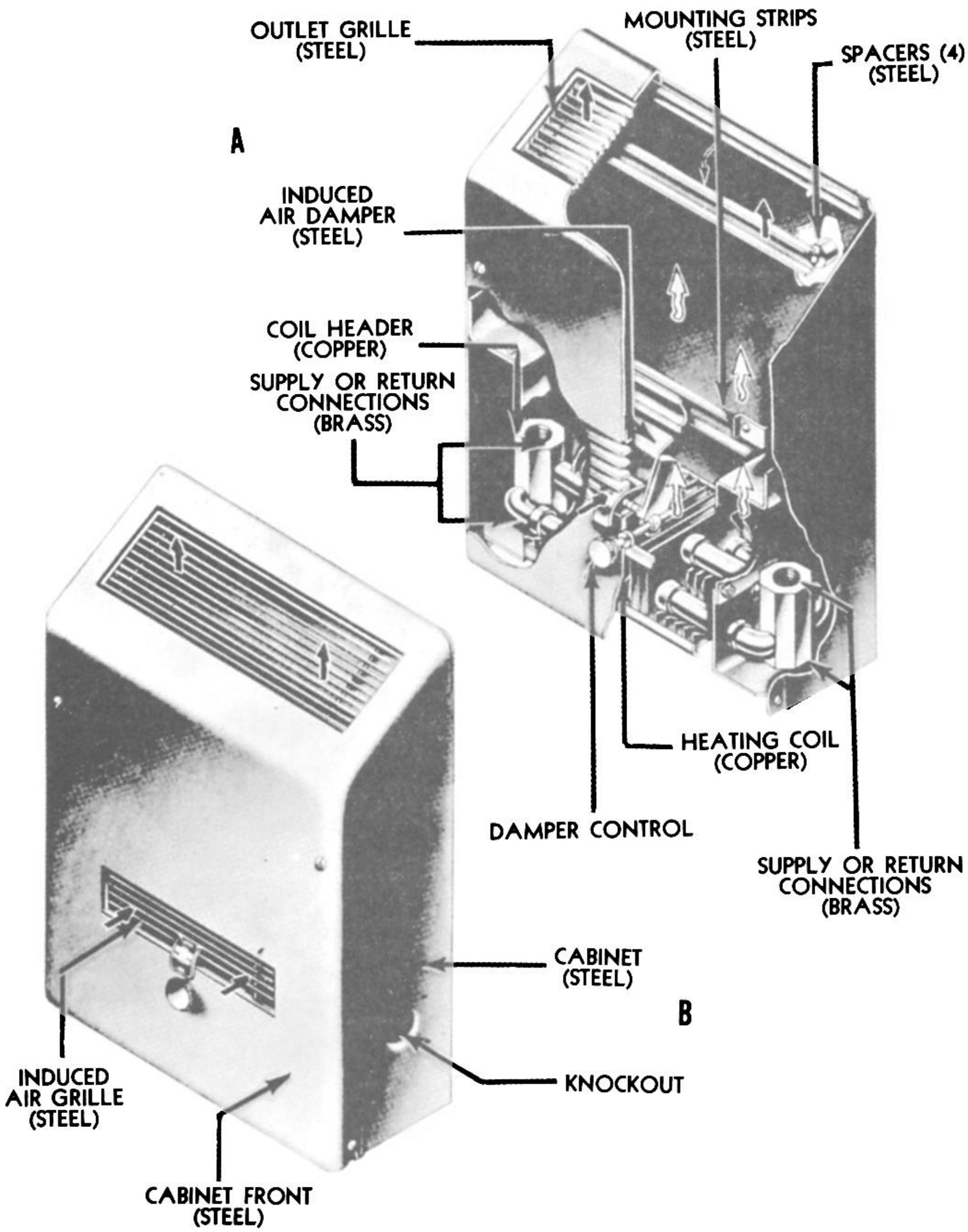

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Figure 12-11.—Convection heater: A. Cutaway view. B. Exterior view.

installations while the T-type is used where larger heaters are needed. Figure 12-11 shows a convection heater which is used in small spaces and in spaces where mechanical ventilation is not used. All three of these heaters can be used with steam pressures of up to 150 psi.

Electric heaters are simply banks of heating elements installed in the airflow of a ventilation system.

MAINTENANCE OF VENTILATION EQUIPMENT

Ventilation equipment that fails to perform properly may jeopardize the health or life of crew members. Therefore, the individuals responsible for inspection and maintenance must be thoroughly familiar with the ventilation equipment.

GUARDING AGAINST OBSTRUCTIONS TO VENTILATION

Items such as swabs, deck gear, and trash stowed in fan rooms or ventilation trunks restrict airflow and increase dirt and odors taken inboard. Ventilation terminals must NEVER be used for stowage. Wet clothing secured to ventilation terminals increases the moisture content of the compartment air and restricts the airflow. Stowage arrangements should be such that ventilation weather openings are NEVER restricted.

KEEPING THE SYSTEM CLEAN

Dirt accumulation in a ventilation system restricts the flow of air and creates a serious fire hazard. In a clean duct, the cooling effect of the metal tends to act as a flame arrester, but an accumulation of foreign matter within a duct is a potential source of combustion. One method of reducing the amount of dirt and combustible matter, which may be carried into a ventilation system, is to wet down the areas near the air intakes before sweeping.

Since a great volume of air passes through or over the elements of a ventilation system, dirt collects in the various units in spite of all precautionary measures. The greatest accumulation of dirt is found within trunks and ducts where it is not readily noticeable. Therefore, periodic inspections and a definite service procedure are necessary to keep the system clean.

Filters help to keep ventilation systems free of dust and dirt. Navy standard air filters have pressure taps on each side of the filter bank. By using a portable differential pressure gauge, you can quickly read the pressure drop across the filter. When the pressure drop increases to three times that of a clean filter, the filter must be cleaned. Ships carry spare filters so that a clean one may be substituted for the dirty one. A systematic procedure should be set up for cleaning all filters in the ship.

Special cleaning sinks are installed in ships with enough filters to justify the space, expense, and weight. These sinks are probably one of two types—steam or ultrasonic. In the steam type, steam is used to heat and agitate the water. In the ultrasonic type, cleaning is done by vibration caused by sound waves passing through the cleaning fluid.

Navy standard air filters have a thin film of oil applied to the wires. The oil film retains fine particles of dust and lint. After washing, the filters should be reoiled by spraying with filter oil. Sprayers furnished for oiling air filters must NOT be used for any other purpose. This is to avoid the possibility of contaminating the filters with toxic, flammable, or smelly materials.

FLAME ARRESTERS AND GREASE FILTERS <u>SHOULD NEVER BE OILED</u>.

MAINTENANCE OF COOLING EQUIPMENT

Since air-conditioning systems are similar in many ways to refrigeration plants, much of the information in this manual concerning refrigeration is equally applicable to air-conditioning equipment.

To ensure proper maintenance of any air-conditioning plant, you should strictly follow the requirements of the 3-M Systems.

CHAPTER 13

COMPRESSED AIR SYSTEMS

As a Machinist's Mate, you should have a thorough knowledge of air compressors. Compressed air serves many purposes aboard ship. These purposes include, but are not limited to, the operation of pneumatic tools and equipment, prairie-masker systems, diesel engine starting and/or speed control, air deballasting, torpedo charging and ejecting, aircraft starting and cooling, and the operation of pneumatic boiler and propulsion control systems. Compressed air is supplied to the various systems by high-, medium-, or low-pressure air compressors, depending on the needs of the ship. Reducing valves may be used to reduce high-pressure air to a lower pressure for a specific use.

AIR COMPRESSORS

The compressor is the heart of any compressed air system. It takes in atmospheric air, compresses it to the pressure desired, and pumps the air into supply lines or into storage for later use.

Air compressors come in different designs, construction, and methods of compression. Some of the most common types used in Navy ships will be discussed in this chapter.

COMPRESSOR CLASSIFICATION

An air compressor is generally classified according to capacity (high, medium, or low), the type of compressing element, the type of driving unit, how it is connected to the driving unit, the pressure developed, and whether the discharged air is oil free. Because of our increasing need for oil-free air aboard ship, the oil-free air compressor is replacing most of the standard low-pressure air compressors. For this reason we will discuss it in some detail further along in this chapter.

Types of Compressing Elements

Shipboard air compressors may be centrifugal, rotary, or reciprocating. The reciprocating type is generally selected for capacities from 200 to 800 cubic feet per minute (cfm) and for pressures of 100 to 5,000 psi. The rotary lobe type is selected for capacities up to 8,800 cfm and for pressures of no more than 20 psi. The centrifugal type is selected for 800 cfm or greater capacities (up to 2,100 cfm in a single unit) and for pressures up to 125 psi.

Most general-service-use air compressors aboard ship are reciprocators (figure 13-1). In this type of compressor the air is compressed in one or more cylinders. This is very much like the compression that takes place in an internal-combustion engine.

Sources of Power

Compressors may be driven by electric motors or steam turbines. Aboard ship, most low- and high-pressure air compressors are driven by electric motors.

Drive Connections

The driving unit may be connected to the compressor by one of several methods. When the compressor and the driving unit are mounted on the same shaft, they are close coupled. This method is usually restricted to small capacity compressors driven by electric motors. However, the high-speed, single-stage, centrifugal, turbine-driven units serving prairie-masker systems in FF 1052 and similar ships are close coupled. Flexible couplings join the driving unit to the compressor when the speed of the compressor and the speed of the driving unit are the same. This is called a direct-coupled drive.

V-belt drives are commonly used with small, low-pressure, motor-driven compressors, and with some medium-pressure compressors. In a few

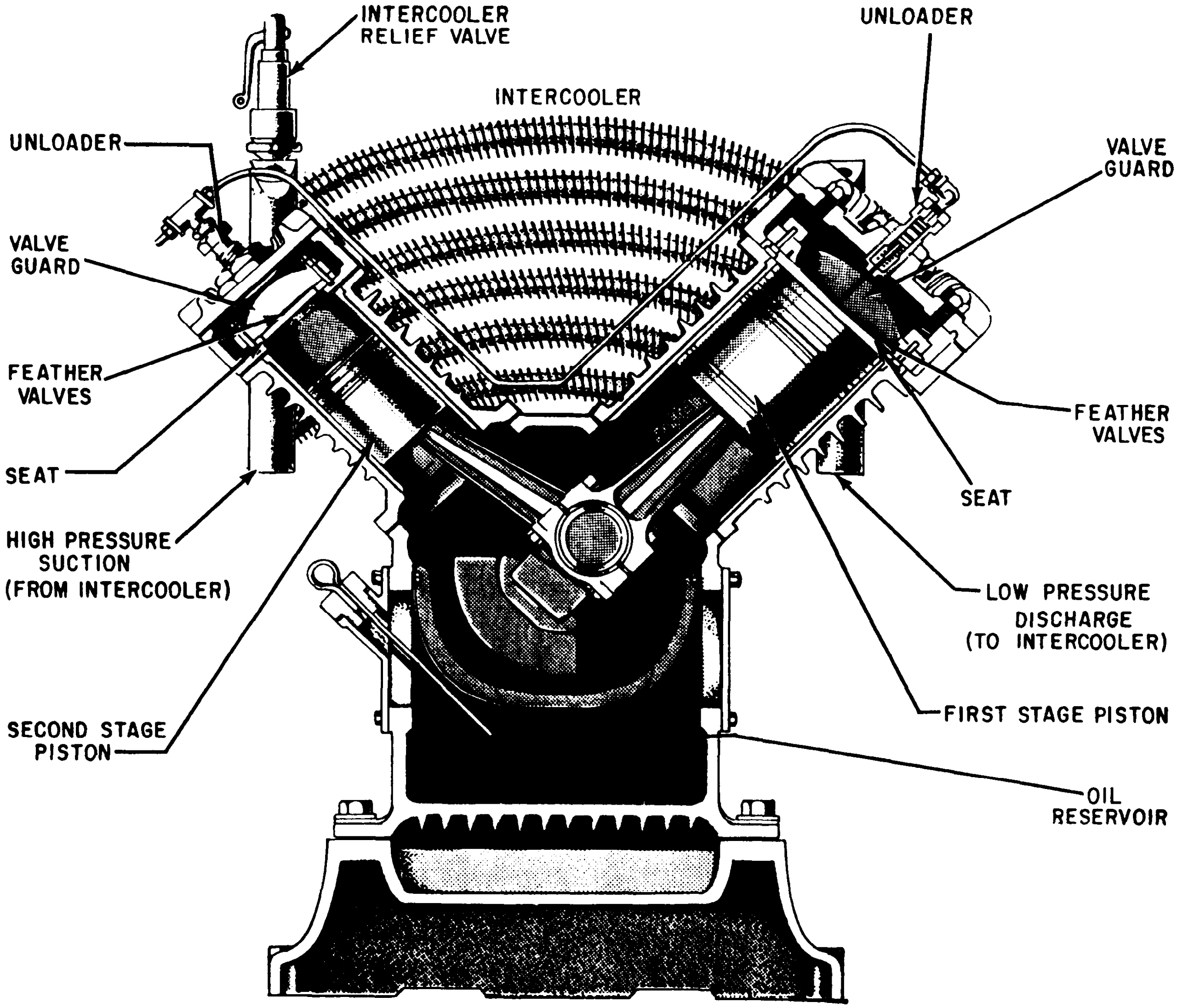

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Figure 13-1.—A simple two-stage reciprocating low-pressure air compressor.

installations, a rigid coupling is used between the compressor and the electric motor of a motor-driven compressor. In a steam-turbine drive, compressors are usually (not always) driven through reduction gears. In centrifugal (high speed) compressors they are usually driven through speed increasing gears.

Pressure Classification

According to *Naval Ships' Technical Manual,* compressors are classified as low, medium, or high pressure. Low-pressure compressors have a discharge pressure of 150 psi or less. Medium-pressure compressors have a discharge pressure of 151 psi to 1,000 psi. Compressors that have a discharge pressure above 1,000 psi are classified as high pressure.

Most low-pressure reciprocating air compressors are of the two-stage type. They have either a vertical V (fig. 13-1) or a vertical W (fig. 13-2) arrangement of cylinders. The V-type compressors have one cylinder for the first (lower pressure) stage of compression and one cylinder for the second (higher pressure) stage of compression. The W-type compressors have two cylinders for the first stage of compression and one cylinder for the second stage. This arrangement is also shown in part A of figure 13-3. Notice that the

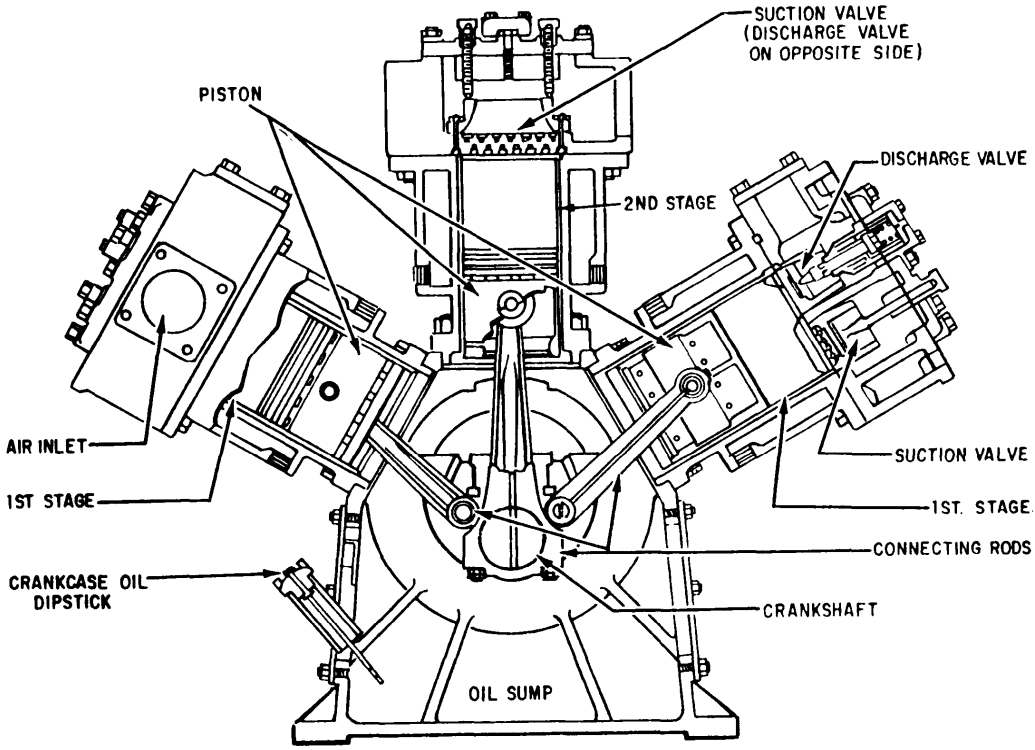

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Figure 13-2.—Low-pressure reciprocating air compressor, vertical W configuration.

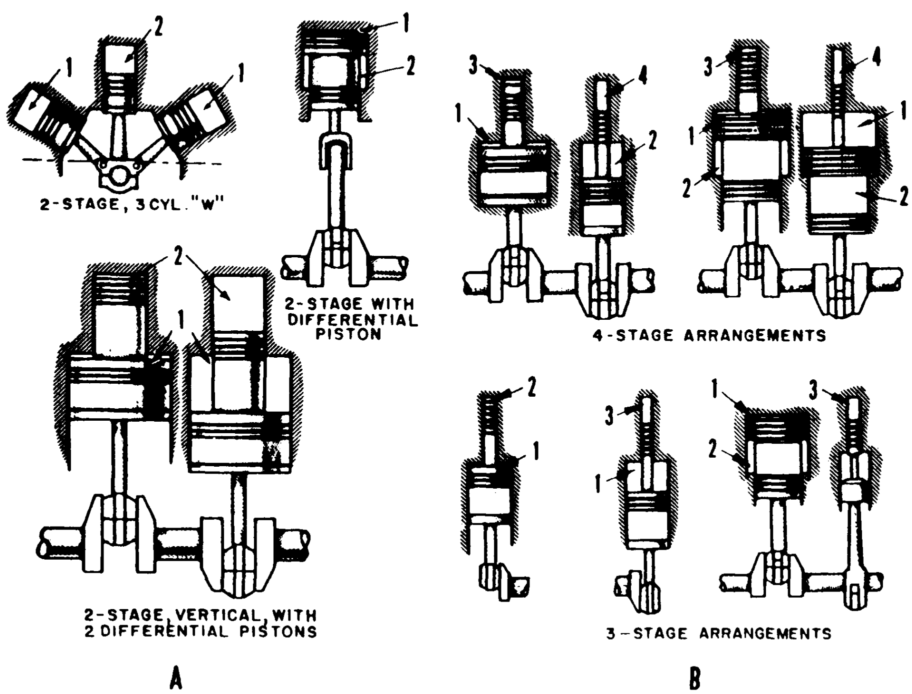

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Figure 13-3.—Air compressor cylinder arrangements: (A) Low- and medium-pressure compressors; (B) High-pressure compressor.

pistons in the lower pressure stage (1) have a larger diameter than the pistons in the higher pressure stage (2).

Medium-pressure air compressors are of the two-stage, vertical, duplex, single-acting type. Many medium-pressure compressors have differential pistons. This type of piston has more than one stage of compression during each stroke of the piston. (See fig. 13-3A.)

Most high-pressure compressors are motor-driven, liquid-cooled, four-stage, single-acting units with vertical cylinders. Figure 13-3B shows the cylinder arrangements for high-pressure air compressors installed in Navy ships. Small capacity, high-pressure air systems may have three-stage compressors. Large capacity, high-pressure air systems may be equipped with four-, five-, or six-stage compressors.

OPERATING CYCLE OF RECIPROCATING AIR COMPRESSORS

Reciprocating air compressors are similar in design and operation. The following discussion describes the operating cycle during one stage of compression in a single-stage, single-acting compressor.

The cycle of operation, or compression cycle, within an air compressor cylinder (shown in figure 13-4) includes two strokes of the piston: a suction stroke and a compression stroke. The suction stroke begins when the piston moves away from top dead center (TDC). The air under pressure in the clearance space (above the piston) expands rapidly until the pressure falls below the pressure on the opposite side of the inlet valve. At this point, the difference in pressure causes the inlet valve to open, and air is admitted to the cylinder. Air continues to flow into the cylinder until the piston reaches bottom dead center (BDC).

The compression stroke starts as the piston moves away from BDC and continues until the piston reaches TDC again. When the pressure in the cylinder equals the pressure on the opposite side of the air inlet valve, the inlet valve closes. Air continues to be compressed as the piston moves toward TDC. The pressure in the cylinder becomes great enough to force the discharge valve open against the discharge line pressure and the pressure of the valve springs. (The discharge valve opens shortly before the piston reaches TDC.) During the remainder of the compression stroke, the air which has been compressed in the cylinder

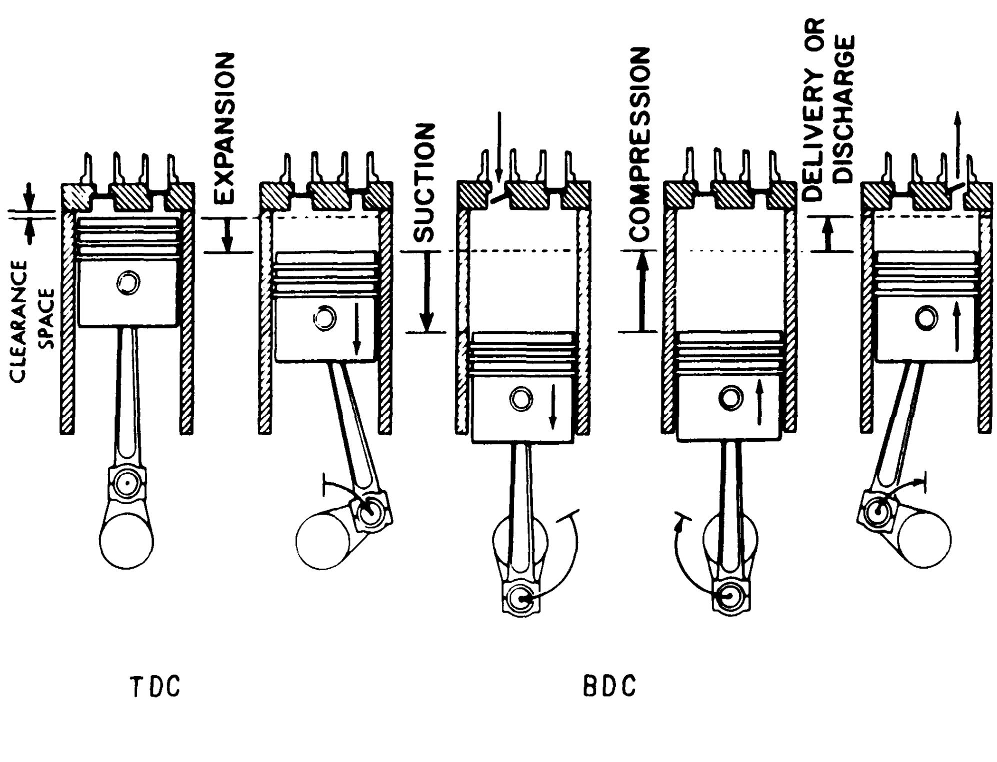

Figure 13-4.—The compression cycle.

is discharged at almost constant pressure through the open discharge valve.

The basic operating cycle just described is completed twice for each revolution of the crankshaft in double-acting compressors, once on the down stroke and once on the up stroke.

COMPONENT PARTS OF RECIPROCATING AIR COMPRESSORS

Reciprocating air compressors consist of a system of connecting rods, a crankshaft, and a flywheel. These parts transmit power developed by the driving unit to the pistons as well as lubrication systems, cooling systems, control systems, and unloading systems.

Compressing Element

The compressing element of a reciprocating compressor consists of the air valves, cylinders, and pistons.

VALVES.—The valves are made of special steel and come in a number of different types. The opening and closing of the valves is caused by the difference between (1) the pressure of the air in the cylinder and (2) the pressure of the external air on the intake valve or the pressure of the discharged air on the discharge valve.

Two types of valves commonly used in high-pressure air compressors are shown in figure 13-5. The strip, or feather, type valve is shown in part A. It is used for the suction and discharge valves of the lower pressure stages, that is, 1 and 2. The valve shown in the figure is a suction valve; the discharge valve assembly (not shown) is identical except that the positions of the valve seat and the guard are reversed. At rest, the thin strips lie flat against the seat. They cover the slots and seal any pressure applied to the guard side of the valve. The following action works in either a suction or discharge operation (depending on the valve service). As soon as pressure on the seat side of the valve exceeds the pressure on the guard side, the strips flex against the contoured recesses in the guard. As soon as the pressure equalizes or reverses, the strips unflex and return to their original position, flat against the seat.

The disk-type valve in figure 13-5B is used for the suction and discharge valves of the higher pressure stages, that is, 3 and 4. The fourth stage assembly is shown. These valves are of the spring-loaded, dished-disk type. At rest, the disk is held against the seat by the spring. It is sealed by pressure applied to the keeper side of the valve. The following action works in either a suction or discharge operation (depending on the valve service). As soon as the pressure on the seat side of the valve exceeds the pressure on the keeper side, the disk lifts against the stop in the keeper. This compresses the spring, and permits air to pass through the seat, around the disk and through the openings in the sides of the keeper. As soon as the pressure equalizes or reverses, the spring returns the disk to the seat.

CYLINDERS.—The designs of cylinders depend mostly upon the number of stages of compression required to produce the maximum discharge pressure. Several common cylinder arrangements for low- and medium-pressure air compressors are shown in figure 13-3A. Several arrangements for cylinders and pistons of high-pressure compressors are shown in figure 13-3B. The stages are numbered 1 through 4, and a three- and a four-stage arrangement are shown. In five- and six-stage compressors, the same basic stage arrangement is followed.

PISTONS.—The pistons may be of two types: trunk pistons or differential pistons. TRUNK PISTONS (fig. 13-6A) are driven directly by the connecting rods. The upper end of a connecting rod is fitted directly to the piston by a wrist pin. This causes a tendency for the piston to develop a side pressure against the cylinder walls. To distribute the side pressure over a wide area of the cylinder walls or liners, pistons with long skirts are used. This type of piston minimizes cylinder wall wear. DIFFERENTIAL PISTONS (fig. 13-6B) are modified trunk pistons with two or more different diameters. These pistons are fitted into special cylinders. They are arranged so that more than one stage of compression is achieved by one piston. The compression for one stage takes place over the piston crown; compression for the other stage(s) takes place in the annular space between the large and small diameters of the piston.

Lubrication System

There are generally three types of lubrication systems in reciprocating compressors. They are for high-pressure, low-pressure, and nonlubricated systems. High-pressure air compressor cylinders are generally lubricated by an adjustable mechanical force-feed lubricator (except for

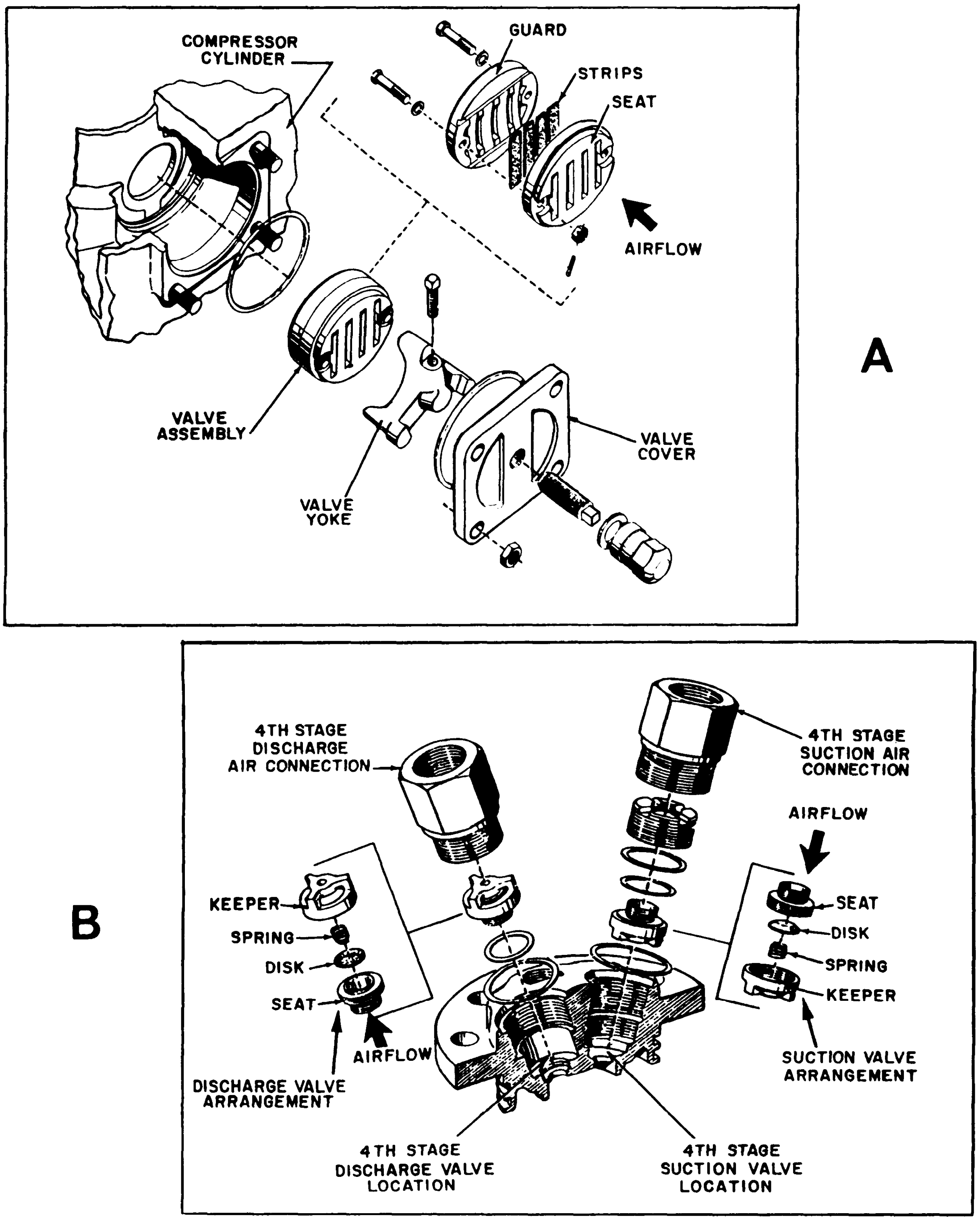

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Figure 13-5.—High-pressure air compressor valves: (A) Valve arrangement for lower pressure stages (suction shown); (B) Valve arrangement for higher pressure stages (both suction and discharge shown).

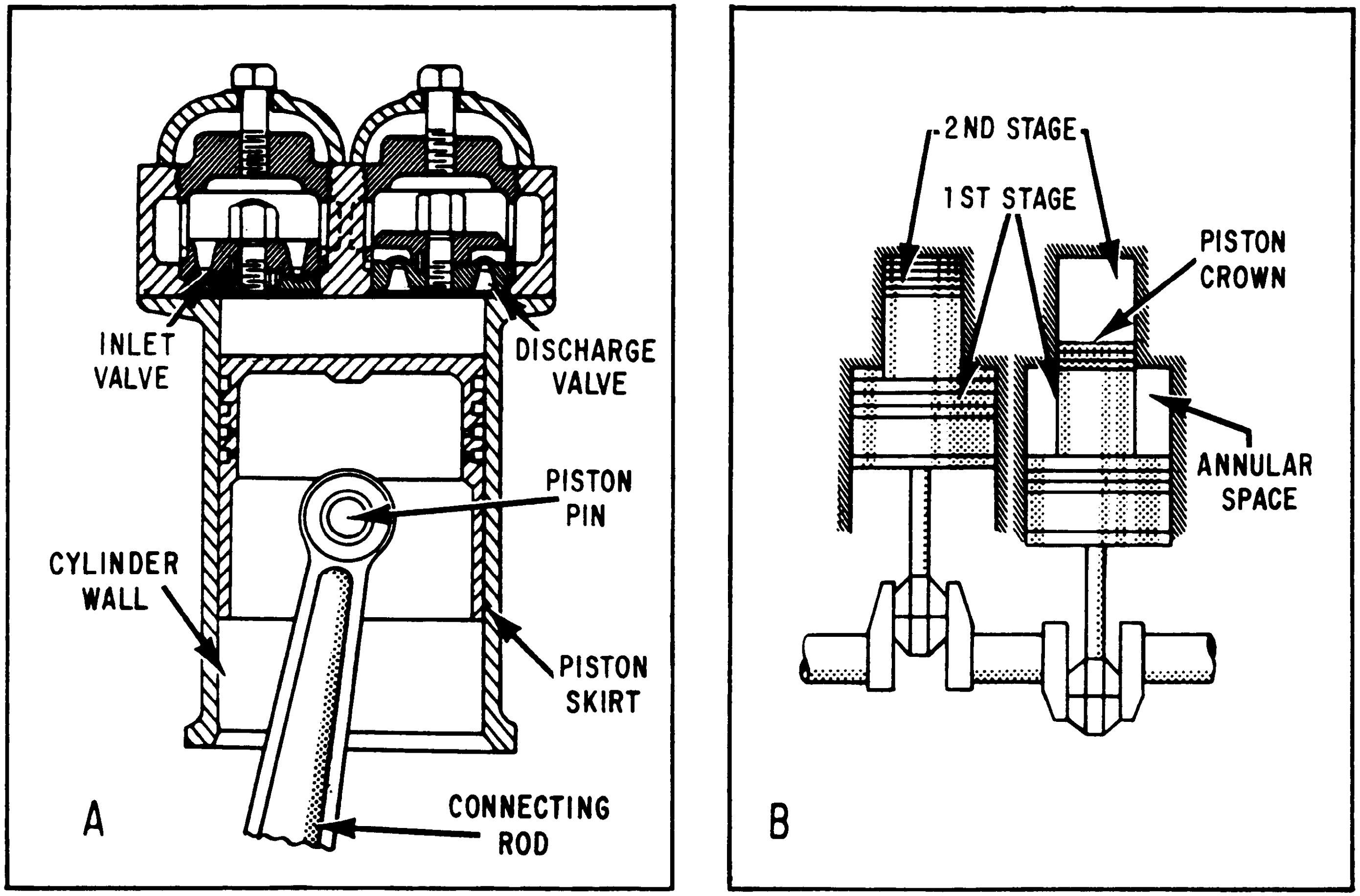

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Figure 13-6.—Air compressor pistons: (A) Trunk type; (B) Differential type.

nonlubricated compressors). This unit is driven from a reciprocating or rotary part of the compressor. Oil is fed from the cylinder lubricator by separate lines to each cylinder. A check valve at the end of each feed line keeps the compressed air from forcing the oil back into the lubricator. Each feed line has a sight-glass oil flow indicator. Lubrication begins automatically as the compressor starts up. The amount of oil that must be fed to the cylinder depends on the cylinder diameter, the cylinder wall temperature, and the viscosity of the oil. Figure 13-7 shows the lubrication connections for the cylinders. The type and grade of oil used in compressors is specified in the equipment technical manual. The correct type is vital to the operation and reliability of the compressor.

The running gear is lubricated by an oil pump which is attached to the compressor and driven from the compressor shaft. This pump is usually a gear type. It draws oil from the reservoir (oil sump) in the compressor base and delivers it

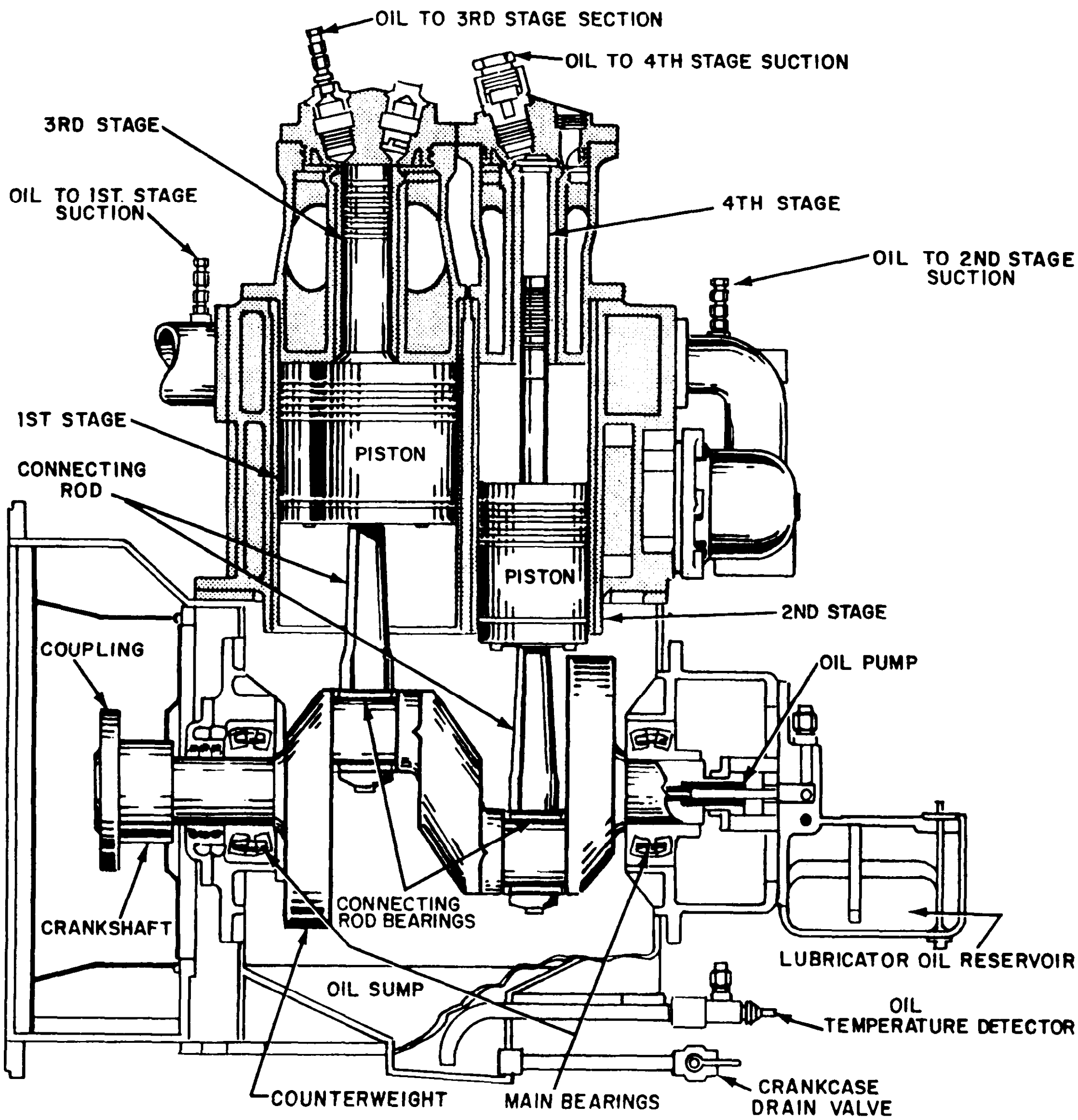

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Figure 13-7.—High-pressure air compressor.

through a filter to an oil cooler (if installed). From the cooler, the oil is distributed to the top of each main bearing, to spray nozzles for the reduction gears, and to the outboard bearings. The crankshaft is drilled so that oil fed to the main bearings is picked up at the main bearing journals and carried to the crank journals. The connecting rods contain passages which conduct lubricating oil from the crank bearings up to the piston pin bushings. As oil leaks out from the various bearings, it drips back into the oil sump (in the base of the compressor) and is recirculated. Oil from the outboard bearings is carried back to the sump by drain lines.

Low-pressure air compressor lubrication is shown in figure 13-8. This system is similar to the running gear lubrication system for the high-pressure air compressor.

Nonlubricated reciprocating compressors have lubricated running gear (shaft and bearings) but no lubrication for the pistons and valves. This design produces oil-free air.

Cooling Systems

Most high- and medium-pressure reciprocating compressors are cooled by the ship's auxiliary fresh water or by seawater supplied from the ship's fire main or machinery cooling water system. Compressors located outside the larger machinery spaces may be equipped with an attached circulating water pump as a standby source of cooling water. Small low-pressure compressors are air-cooled by a fan driven by the compressors.

The path of water in the cooling water system of a typical four-stage compressor is illustrated

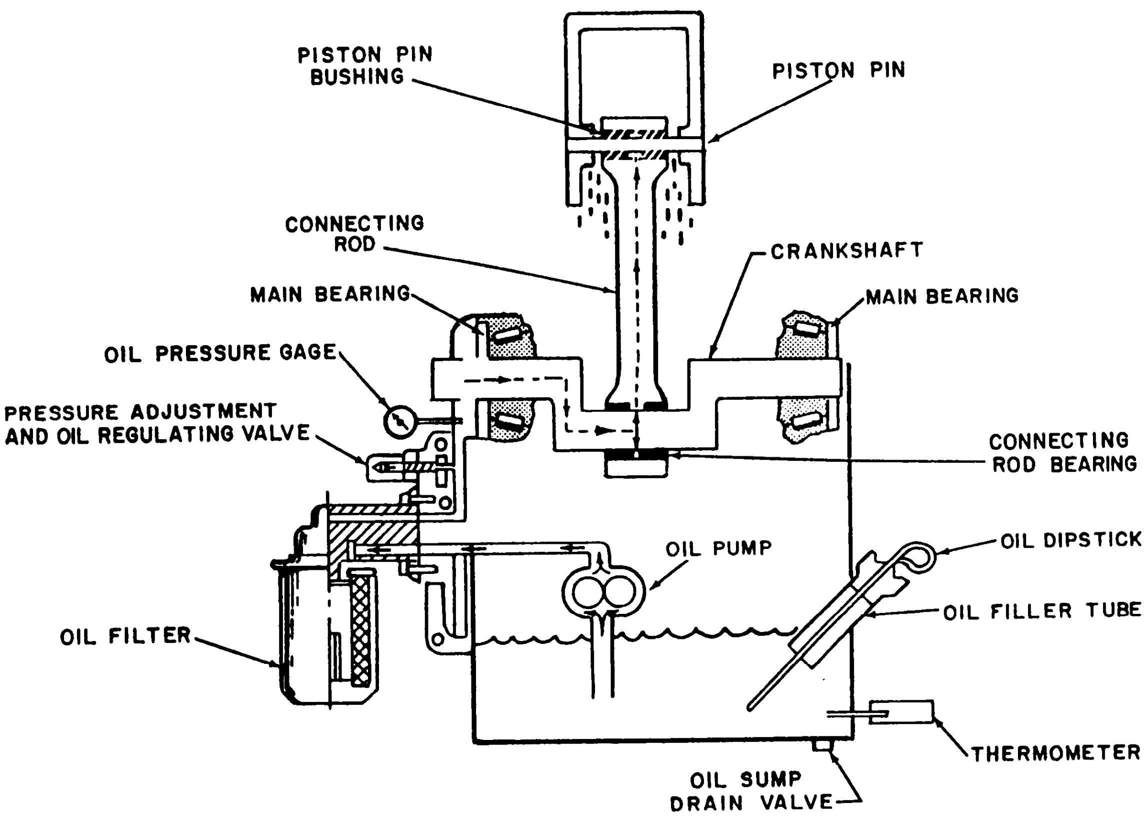

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Figure 13-8.—Lubricating oil system of a low-pressure air compressor.

in figure 13-9. Not all cooling water systems have identical path-of-water flow. However, in systems equipped with oil coolers it is important that the coldest water be available for circulation through the cooler. Valves usually control the water to the cooler independently of the rest of the system. Thus, oil temperature can be controlled without harmful effects to the other parts of the compressor. It is very important to cool the air in the intercoolers and aftercoolers as well as the cylinder jackets and heads. The amount of cooling water required depends on the capacity (cfm) and pressure. High-pressure air compressors require more cooling water (for the same cfm) than the low-pressure units.

When seawater is used as the cooling agent, all parts of the circulating system must be of corrosion-resistant materials. The cylinders and heads are therefore composed of a bronze alloy with water jackets cast integral with the cylinders. Each cylinder is generally fitted with a liner of special cast iron or steel to withstand the wear of the piston. Wherever practicable, cylinder jackets are fitted with handholes and covers so that the water spaces can be inspected and cleaned. Jumpers are usually used to make water connections between the cylinders and heads because they prevent possible leakage into the compression spaces. In some compressors, however, the water passes directly through the joint between the cylinder and the head. With this latter type, the joint MUST be properly gasketed to prevent leakage which, if allowed to continue, will damage the compressor.

The INTERCOOLERS and AFTERCOOLERS remove heat generated during compression and promote condensation of any vapor that may be present. Figure 13-10 is a diagram of a basic cooler and separator unit. It shows the collected condensate in the separator section. The condensate must be drained at regular intervals to prevent carryover into the next stage. If it accumulates at low points it may cause water hammer or freezing and bursting of pipes in exposed locations. It may also cause faulty operation of pneumatic tools and possible damage to electrical apparatus when air is used for cleaning. The removal of heat is also required for economical compression. During compression the temperature of the air increases. The air expands to a larger volume, which requires a corresponding increase of work to compress it. Multistaging, therefore, with interstage cooling of the air, reduces the power requirement for a given capacity.

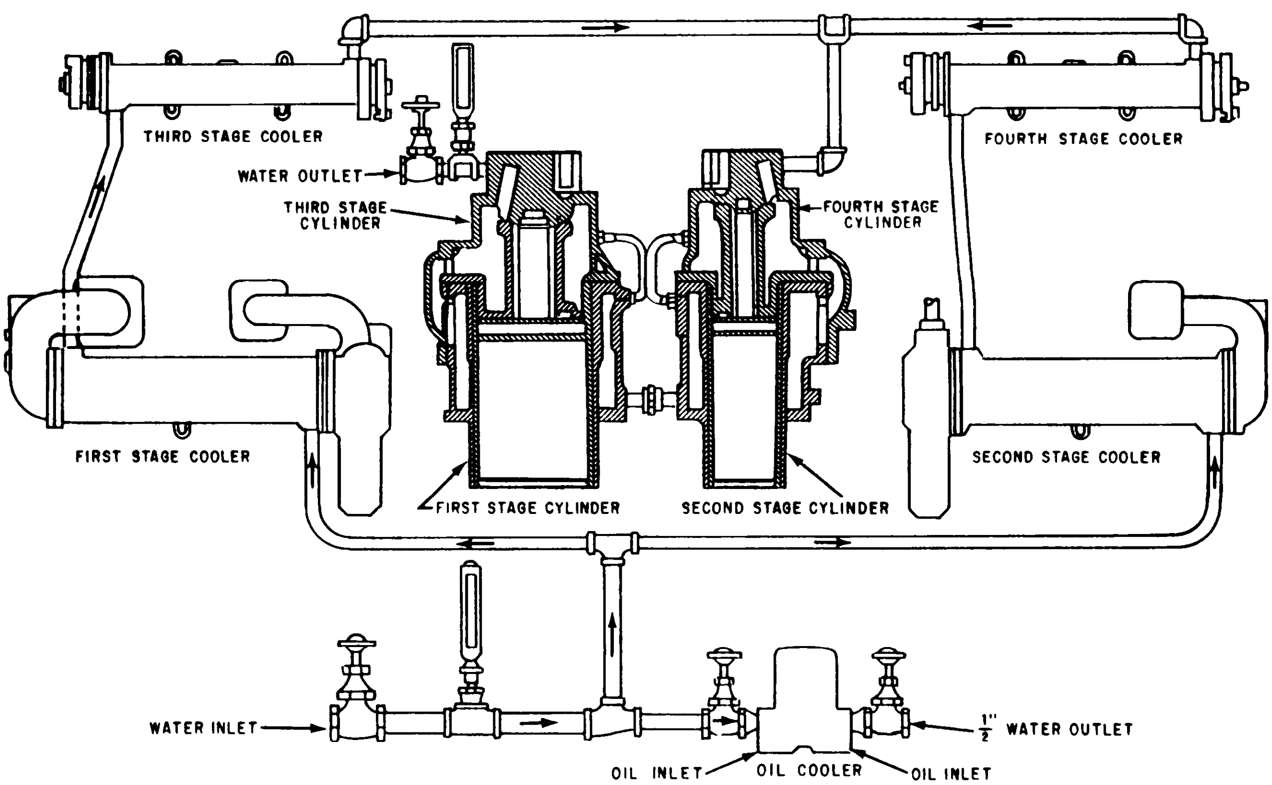

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Figure 13-9.—Cooling water system in a typical multistage air compressor.

The interstage cooling reduces the maximum temperature in each cylinder. This reduces the amount of heat that must be removed by the water jacket at the cylinder. Also, the resulting lower temperature in the cylinder ensures better lubrication of the piston and the valves. Figure 13-11 illustrates the pressures and temperatures through a four-stage compressor. The intercoolers and the aftercoolers (on the output of the final stage) are of the same general construction. The exception is that the aftercoolers are designed to withstand a higher working pressure than the intercoolers.

Water-cooled intercoolers may be the straight tube and shell type (fig. 13-10) or, if size dictates, the coil type. In coolers with an air discharge pressure below 150 psi, the air may flow either through the tubes or over and around them. In coolers with an air discharge pressure above 250 psi, the air generally flows through the tubes. In tubular coolers, baffles deflect the air or water in its course through the cooler. In coil-type coolers, the air passes through the coil and the water flows around the coils.

Some air-cooled intercoolers and aftercoolers are the radiator type. Others may consist of a bank of finned copper tubes located in the path of cooling air supplied by the compressor cooling fan.

Each intercooler and aftercooler is generally fitted with relief valves on both the air and the

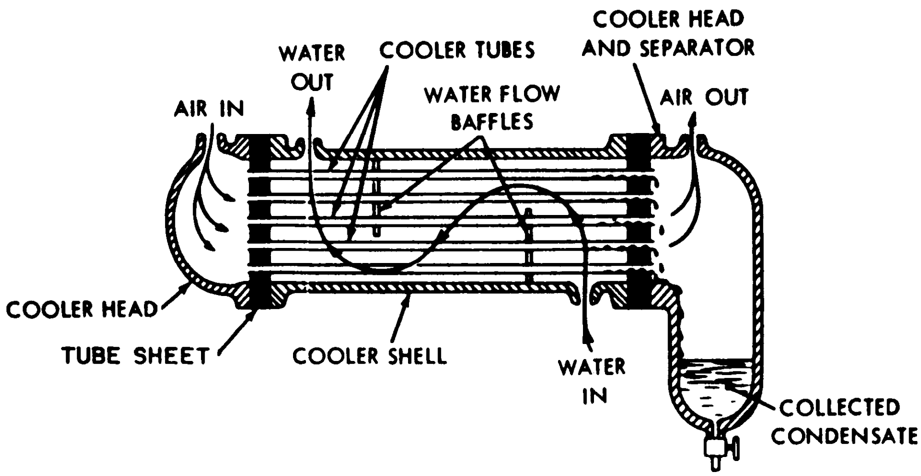

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Figure 13-10.—Basic cooler and separator.

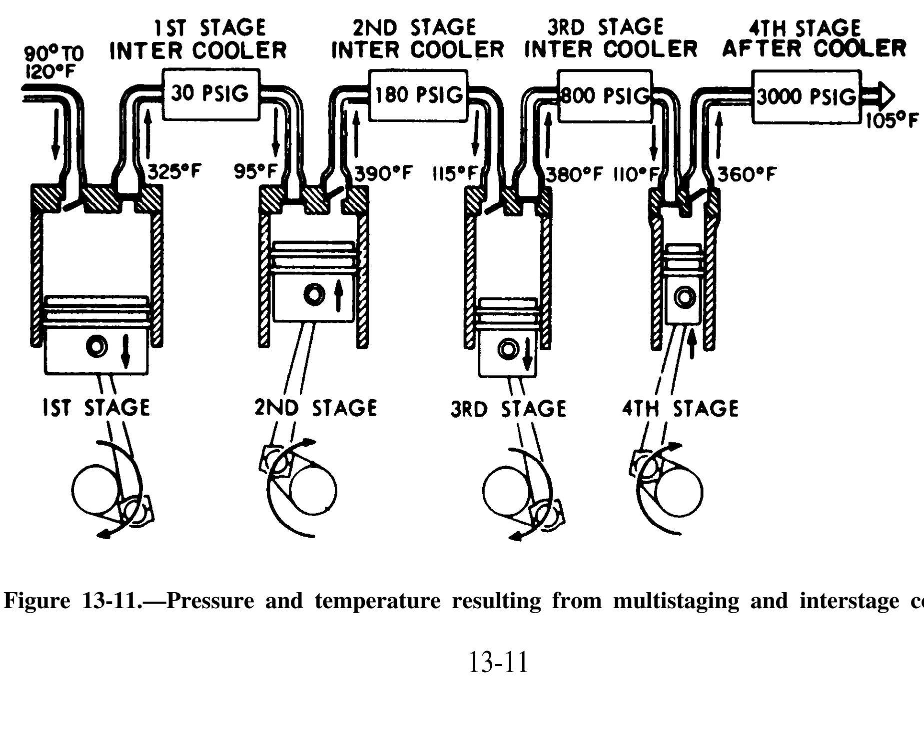

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Figure 13-11.—Pressure and temperature resulting from multistaging and interstage cooling.

water sides. The relief valve must be set according to PMS.

As seen earlier, intercoolers and aftercoolers are normally fitted with moisture separators on the discharge side. These remove the condensed moisture and oil from the air stream. The separators come in a variety of designs. Liquid is removed by centrifugal force, impact, or sudden changes in velocity and/or direction of flow of the air stream. Drains on each separator remove the water and oil.

Oil coolers are the coil type, tube and shell type, or a variety of commercial types. Although external oil coolers are generally used, some compressors are fitted with a base-type oil cooler. These circulate cooling water through a coil placed in the oil sump. As with the intercoolers and aftercoolers, the materials of the tubes, coils, or cores are made of copper-nickel alloy. The shell and tube sheets are of bronze composition. On all late model compressors the circulating water system is arranged so that the quantity of cooling water passing through the oil cooler can be regulated. This can be done without disturbing the quantity of water passing through the cylinder jackets, intercoolers, or aftercoolers. Thermometers or other temperature measuring devices are fitted to the circulating water inlet and outlet connections, to the intake and discharge of each stage of compression, to the final air discharge, and to the oil sump.

Control Systems

The control system of a reciprocating air compressor may include one or more control devices. These may include start-stop control, constant-speed control, speed-pressure governing, and automatic high-temperature shut-down devices.

Control or regulating systems for air compressors in use by the Navy are largely of the start-stop type. In these, the compressor starts and stops automatically as the receiver pressure falls or rises within predetermined set points. On electrically driven compressors the system is very simple. The receiver pressure operates against a pressure switch that opens when the pressure upon it reaches a given limit. It closes when the pressure drops a predetermined amount. Centrifugal compressors do not have automatic start-stop controls mainly because of their high horsepower. An automatic load/unload control system is used instead.

Some electrically driven units, such as the medium-pressure system, are required to start at either of two pressures. In these, one of two pressure switches is selected with a three-way valve or cock that admits pressure from the air accumulator to the selected pressure switch. Another method is to direct the air from the receiver through a three-way valve to either of two control valves set for the respective range of pressures. A line is run from each control valve to a single pressure switch may be set at any convenient pressure; the setting of the control valve selected will determine the operation of the switch.

The CONSTANT-SPEED CONTROL regulates the pressure in the air receiver by controlling the output of the compressor. This is done without stopping or changing the speed of the unit. This control prevents frequent starting and stopping of compressors when there is a fairly constant but low demand for air. Control is provided by directing air to unloading devices through a control valve set to operate at a predetermined pressure.

AUTOMATIC HIGH-TEMPERATURE SHUTDOWN DEVICES are fitted on all recent designs of high-pressure air compressors. If the cooling water temperature rises above a safe limit, the compressor will stop and will not restart automatically. Some compressors have a device that will shut down the compressor if the temperature of the air leaving any stage exceeds a preset value.

Unloading Systems

Reciprocating air compressor unloading systems remove all but the friction loads on the compressor. In other words, they automatically remove the compression load from the compressor while the unit is starting and automatically apply the compression load after the unit is up to operating speed. Units with start-stop control have the unloading system separate from the control system. Compressors with constant-speed control have the unloading and control systems as integral parts of each other.

We cannot give a detailed explanation for every type of unloading device used to unload air compressor cylinders. Still, you should know something about several of the unloading methods. These include closing or throttling the compressor intake, holding intake valves off their seats, relieving intercoolers to the atmosphere, relieving the final discharge to the atmosphere (or opening a bypass from the discharge to the intake), opening cylinder clearance pockets, using miscellaneous constant-speed unloading devices, and various combinations of these methods.

We will discuss one example of a typical compressor unloading device; the MAGNETIC-TYPE UNLOADER. Figure 13-12 illustrates the

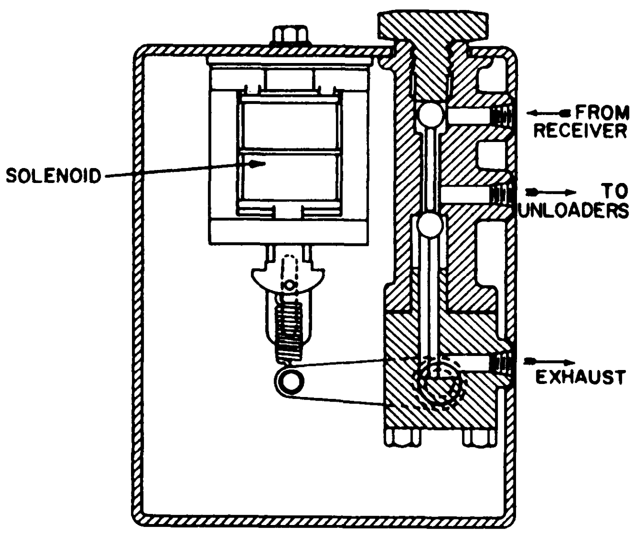

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Figure 13-12.—Magnetic type unloader.

unloader valve arrangement. This unloader consists of a solenoid-operated valve connected with the motor starter. When the compressor is at rest, the solenoid valve is de-energized. This admits air from the receiver to the unloading mechanism. When the compressor reaches near-normal speed, the solenoid valve is energized. This releases the pressure from the unloading mechanism and loads the compressor again.

The pertinent manufacturers' technical manuals contain the details of the unloading devices for the compressors in your ship.

ROTARY-CENTRIFUGAL AIR COMPRESSORS

A nonreciprocating type of air compressor aboard ship is variously called a rotary compressor, a centrifugal compressor, or a liquid piston compressor. Actually, the unit is something of a mixture. It operates partly on rotary principles and partly on centrifugal principles. It may, more accurately, be called a rotary-centrifugal compressor.

The rotary-centrifugal compressor supplies low-pressure compressed air. It can supply air that is completely free of oil. Therefore, it is often used as the compressor for pneumatic control systems and for other applications where oil-free air is required.

The rotary-centrifugal compressor, shown in figure 13-13, consists of a round, multibladed rotor which revolves freely in an elliptical casing.

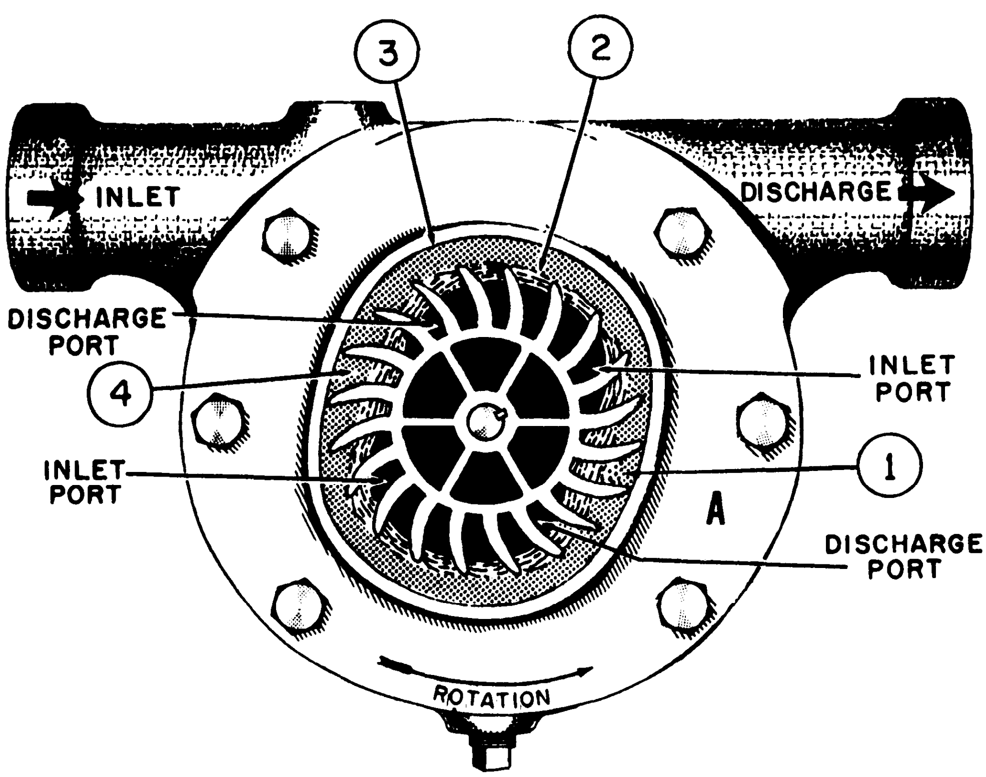

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Figure 13-13.—Rotary-centrifugal compressor.

The elliptical casing is partially filled with high-purity water. The curved rotor blades project radially from the hub. The blades, together with the side shrouds, form a series of pockets or buckets around the periphery. The rotor is keyed to the shaft of an electric motor. It revolves at a speed high enough to throw liquid out from the center by centrifugal force. This causes a solid ring of liquid to revolve in the casing at the same speed as the rotor but following the elliptical shape of the casing. This action alternately forces the liquid to enter and recede from the buckets in the rotor at high velocity.

To follow through a complete cycle of operation, look at figure 13-13. Start at point A (located at right center). The chamber [1] is full of liquid. The liquid, because of centrifugal force, follows the casing, withdraws from the rotor, and pulls air in through the inlet port. At [2] the liquid has been thrown outward from the chamber in the rotor and has been replaced with atmospheric air. As the rotation continues, the converging wall [3] of the casing forces the liquid back into the rotor chamber. This compresses the trapped air and forces it out through the discharge port. The rotor chamber [4] is now full of liquid and ready to repeat the cycle which takes place twice in each revolution.

A small amount of water must be constantly supplied to the compressor to make up for that which is carried over with the compressed air. The water that is carried over with the compressed air is removed in a refrigeration-type dehydrator.

COMPRESSED AIR RECEIVERS

An air receiver is installed in each space that houses air compressors (except centrifugal and rotary lobe types). The receiver is an air storage tank. If demand is greater than the compressor capacity, some of the stored air is supplied to the system. If demand is less than the compressor capacity, the excess is stored in the receiver or accumulator until the pressure is raised to its maximum setting. At that time, the compressor unloads or stops. Thus, in a compressed air system, the receiver minimizes pressure variations in the system and supplies air during peak demand. This will minimize start-stop cycling of air compressors. Air receivers may be horizontal or vertical. Vertically mounted receivers have convex bottoms. These permit proper draining of accumulated moisture, oil, and foreign matter.

All receivers have fittings such as inlet and outlet connections and drain connections and valves. They have connections for an operating line to compressor regulators, pressure gauges, relief valves (set at approximately 12 percent above normal working pressure of the receiver). They also have manhole plates (depending on the size of the receiver). The discharge line between the compressor and the receiver is as short and straight as possible. This eliminates vibration caused by pulsations of air and reduces pressure losses caused by friction.

In high-pressure air systems, air receivers are called AIR FLASKS. Air flasks are usually cylindrical in shape, with belled ends and female-threaded necks. The flasks are constructed in shapes to conform to the hull curvature for installation between hull frames.

One or more air flasks connected together constitute an air BANK.

COMPRESSED AIR SUPPLY SYSTEMS

The remainder of the compressed air system is the piping and valves which distribute the compressed air to the points of use.

HIGH-PRESSURE AIR

Figure 13-14A shows the first part of a high-pressure air system aboard a surface ship. The 3,000/150 psi reducing station is used for emergencies or abnormal situations to provide air to the low-pressure air system.

LOW-PRESSURE AIR

Low-pressure air (sometimes referred to as LP ship's service air) is the most widely used air system aboard the ship. Figure 13-14B shows the first part of a low-pressure air system. Many of the low-pressure air systems are divided into sub-systems; vital and nonvital air.

Vital air is used primarily for engineering purposes such as automatic boiler controls, water level controls, and air pilot-operated control valves. Vital air is also supplied to electronics systems. Vital air systems are split between all main machinery groups with cross-connect capability.

Nonvital air has many different purposes, such as laundry equipment, tank-level indicating systems, and airhose connection. Air for a

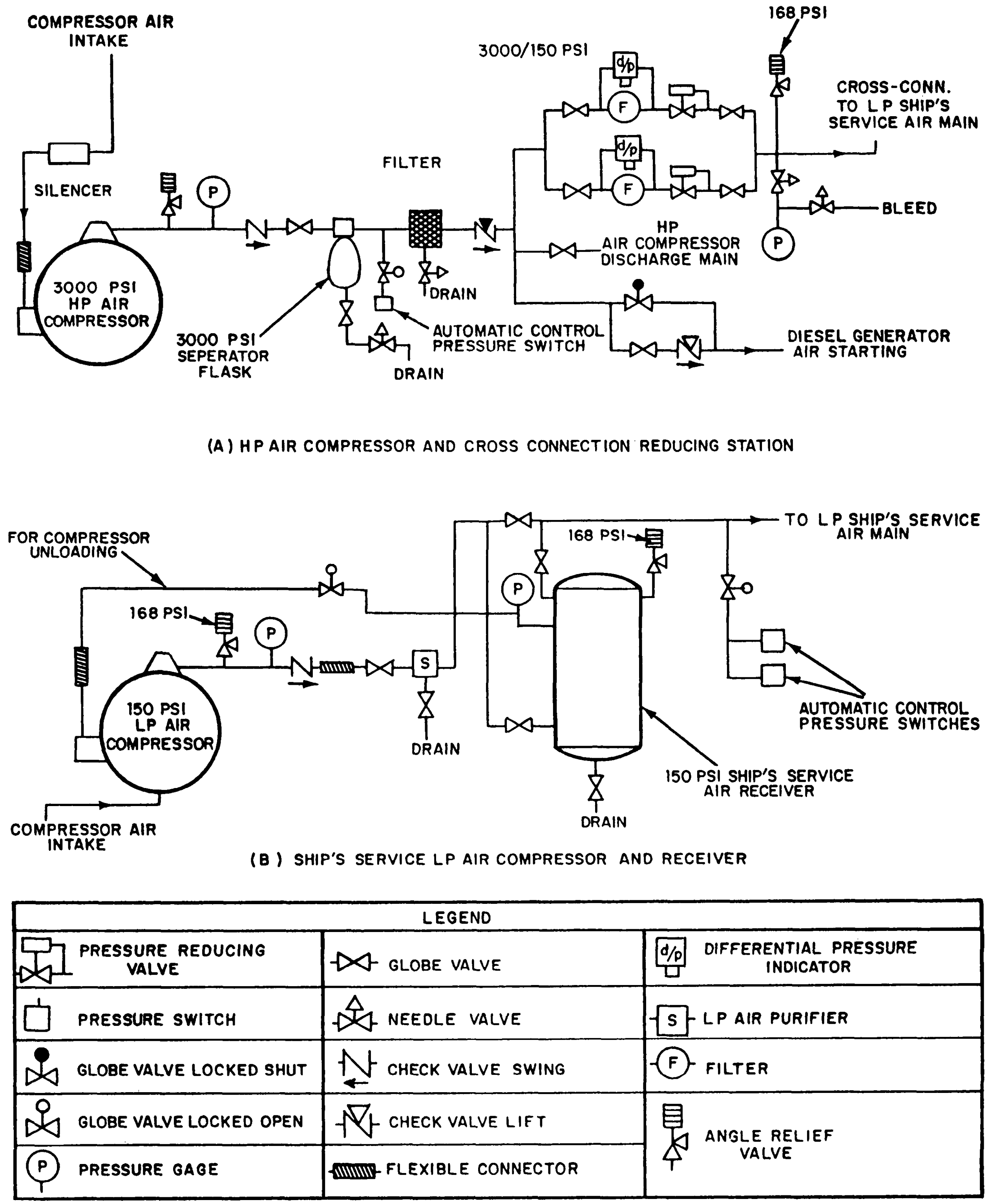

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Figure 13-14.—HP and LP air compressor and receiver.

nonvital air system is supplied through a PRIORITY VALVE. This valve will shut automatically to secure air to nonvital components when the pressure in the air system drops to a specified set point. It will reopen to restore nonvital air when pressure in the system returns to normal. This system gives the vital air first priority on all the air in the low-pressure system.

PRAIRIE-MASKER AIR SYSTEMS

A special purpose air system installed in many surface ships is the prairie-masker air system. This system supplies "disguise" air to a system of emitter rings or belts surrounding the hull and to the propeller blades through the propulsion shafts.

The emitter rings contain small holes which release the masker air into the sea, coating the hull with air bubbles. These bubbles disguise the shape of the ship so that it cannot be seen accurately by enemy sonar.

The prairie air passing through the propulsion shafts is emitted to sea by small holes in the propeller blades.

The air supply for the prairie-masker system is provided by a turbocompressor. The turbocompressor is composed of five major parts contained in one compact unit. They are the turbine-driven compressor, lube water tanks, air inlet silencer, lube water system, and control system.

The turbine-driven compressor consists of a single-stage centrifugal compressor driven by a single-stage impulse turbine. The compressor impeller and the turbine wheel are mounted at opposite ends of the same shaft. Two water-lubricated bearings support the rotor assembly. The compressor runs at speeds approaching 40,000 rpm. A control system for the unit provides constant steam admission, overspeed trip, overspeed alarm, low lube pressure trip and alarm, and a high lube water temperature alarm.

MOISTURE REMOVAL

The removal of moisture from compressed air is an important part of compressed air systems. If air at atmospheric pressure, with even a very low relative humidity, is compressed to 3,000 psi or 4,500 psi, it becomes saturated with water vapor. Some moisture is removed by the intercoolers and aftercoolers, as seen earlier in this chapter. Also, air flasks, receivers, and banks are provided with low point drains to periodically drain any collected moisture. However, many shipboard uses of air require air with an even smaller moisture content than is obtained through these methods. In addition, moisture in air lines can create other problems which are potentially hazardous, such as the freezing of valves and controls. This can occur, for example, if very-high-pressure air is throttled to a very low pressure at a high flow rate. The venturi effect of the throttled air produces very low temperatures which will cause any moisture in the air to freeze into ice. This makes the valve (especially an automatic valve) either very difficult or impossible to operate. Also, droplets of water in an air system with a high pressure and high flow rate can cause serious water hammer within the system. For these reasons, air dryers or dehydrators are used to dry the compressed air. Two basic types of air dehydrators are in use: the desiccant type and the refrigerated type.

Desiccant-Type Dehydrators

A desiccant is a drying agent. More practically, a desiccant is a substance with a high capacity to remove (absorb) water or moisture. It also has a high capacity to give off that moisture so that the desiccant can be reused.

Compressed air system dehydrators use a pair of desiccant towers (flasks full of desiccant). One is on service dehydrating the compressed air while the other is being reactivated. A desiccant tower is normally reactivated by passing dry, heated air through the tower being reactivated in the direction opposite to normal dehydration airflow. The hot air evaporates the collected moisture and carries it out of the tower to the atmosphere. The purge air is heated by electrical heaters. Once the tower that is reactivating has completed the reactivation cycle, it is placed on service to dehydrate air and the other tower is reactivated.

Another type of desiccant dehydrator in use is the Heat-Les Dryer. These units require no electrical heaters or external source of purge air. Figure 13-15A shows the compressed air entering at the bottom of the left tower. It then passes upward through the desiccant where it is dried to a very low moisture content. The dry air passes through the check valve to the dry air outlet. Simultaneously, a small percentage of the dry air passes through the orifice between the towers and flows down through the right tower. This dry air reactivates the desiccant and passes out through the purge exhaust. At the end of the cycle, the towers are automatically reversed, as shown in part B of figure 13-15.

Refrigerated-Type Dehydrators

Refrigeration is another method of removing moisture from compressed air. We pass the compressed air over a set of refrigerated cooling coils. Oil and moisture vapors will condense from the air and can be collected and removed via a low point drain.

Some installations may use a combination of a refrigerated dehydrator and desiccant dehydrators to purify the compressed air.

OIL-FREE LOW-PRESSURE AIR COMPRESSOR

The oil-free air compressors, like all reciprocating air compressors, have a compression and running gear chamber. The oil-free air compressors (fig. 13-16) have two major components that provide oil-free discharged air. They are the guide piston and the guide piston seal assembly.

The compression piston (fig. 13-17) is hollow, and is connected to the guide piston via the guide piston seal assembly. The piston rings are made from a Teflon-bronze material that will become damaged if contacted with lube oil.

The guide piston seal assembly (fig. 13-18) contains oil control rings, retainer rings, cup, and cover. This seal prevents oil from entering the compression chamber by scraping the piston connecting rod of oil from the running gear chamber.

The running gear chamber consists of a system of connecting rods, a crankshaft, and a flywheel. (**NOTE:** The connecting rods are connected to the guide piston in the oil-free air compressor.)

The valve assemblies are of the strip/feather type previously discussed in this chapter.

UNLOADER SYSTEM

The oil-free low-pressure air compressor unloader system consists of three suction valve unloaders. There is one for each cylinder head located directly above the suction

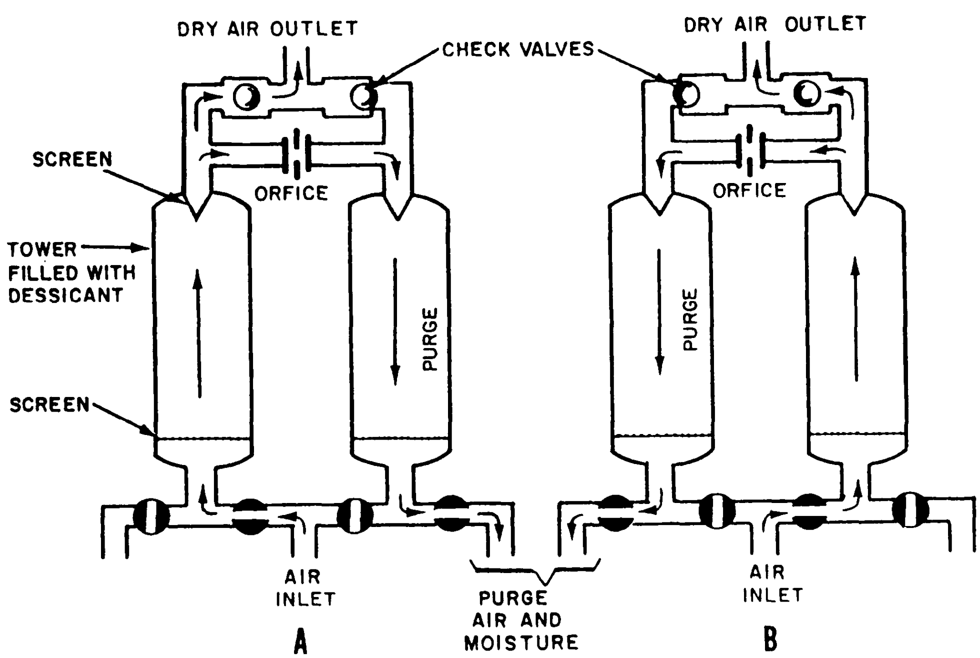

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Figure 13-15.—Heat-les dehydrator.

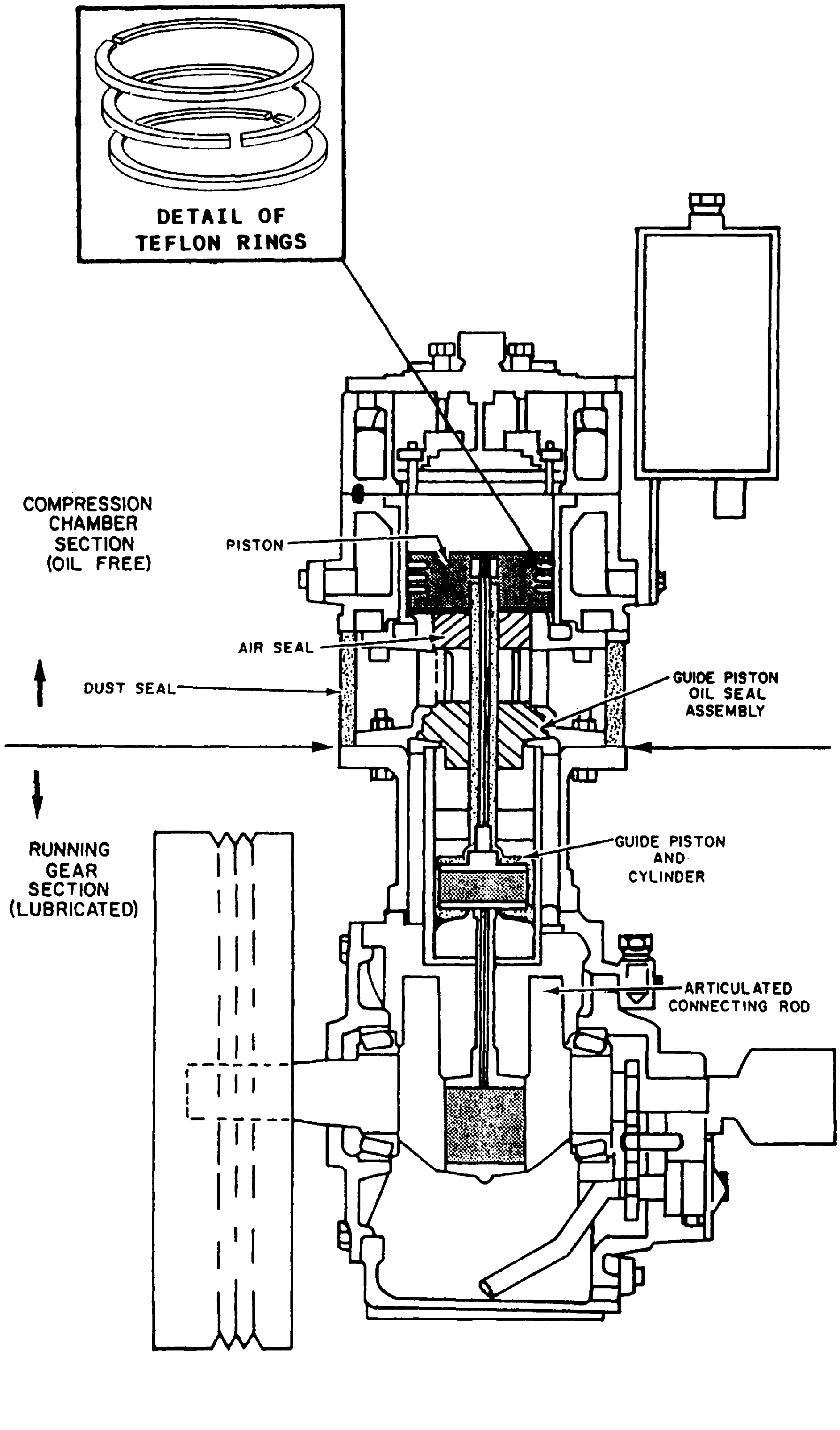

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Figure 13-16.—Cut-away view of an oil free low-pressure air compressor.

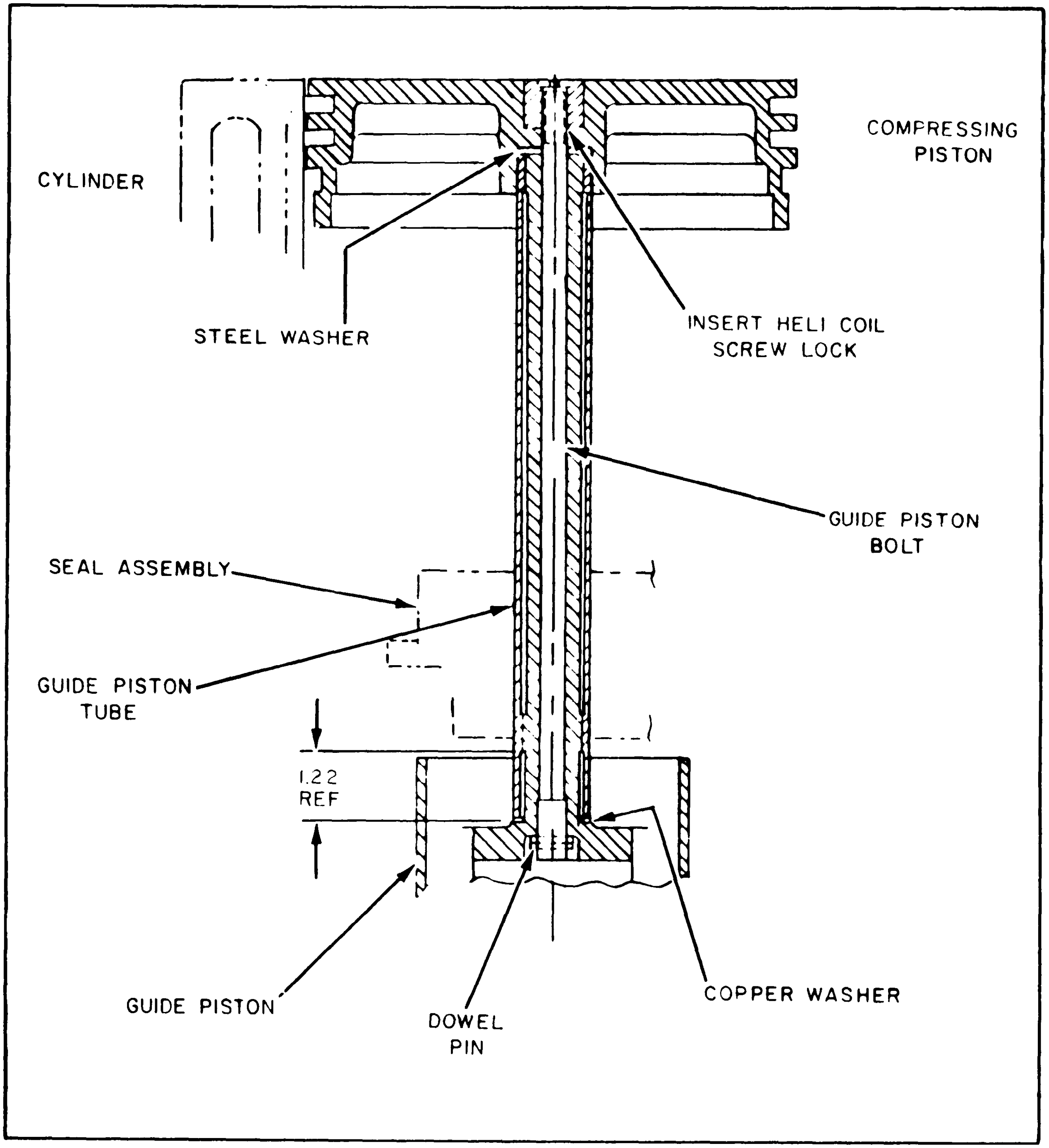

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Figure 13-17.—Hollow-type piston assembly.

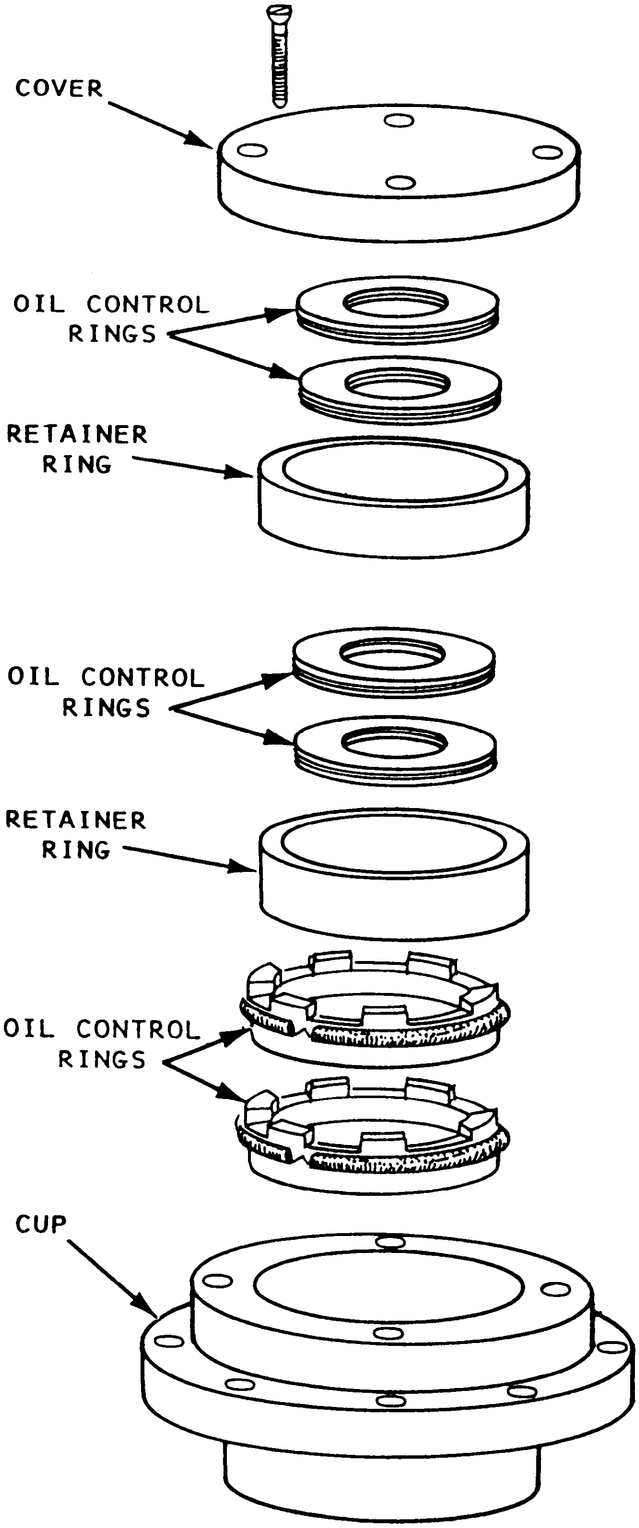

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Figure 13-18.—Guide piston scale assembly.

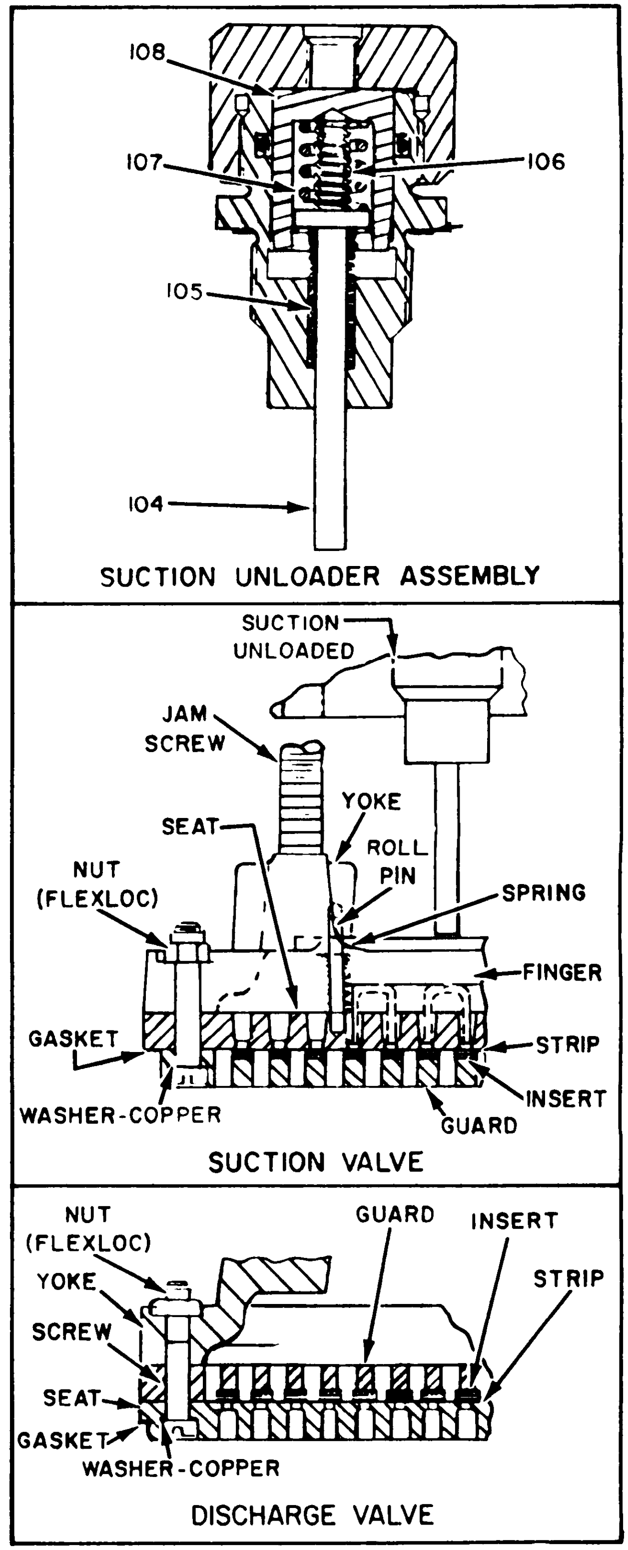

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Figure 13-19.—Valve assembly.

valve assemblies (fig. 13-19). The major components of the unloader assembly are the piston (108), springs (105, 106, and 107), and finger. The unloader assemblies (fig. 13-20) are actuated by a solenoid-operated valve that admits air to the top of the piston, forcing the piston and finger downward, unseating the suction valves, and causing the air compressor to be in an unloaded condition. The compressor becomes loaded when the solenoid-operated valve bleeds the air off the top of the piston in the unloader assemblies. The pistons and fingers are forced upward by a spring, causing the suction valves to seat. A flow control valve is provided to prevent instant full loading of the compressor. This is done by controlling the amount of airflow from the unloader assemblies and the solenoid-operated valve.

The oil-free air compressors have a moisture separator (fig. 13-21A) that receives air from an air cooler. It drains the collected moisture to a drain collecting holding bottle where it is

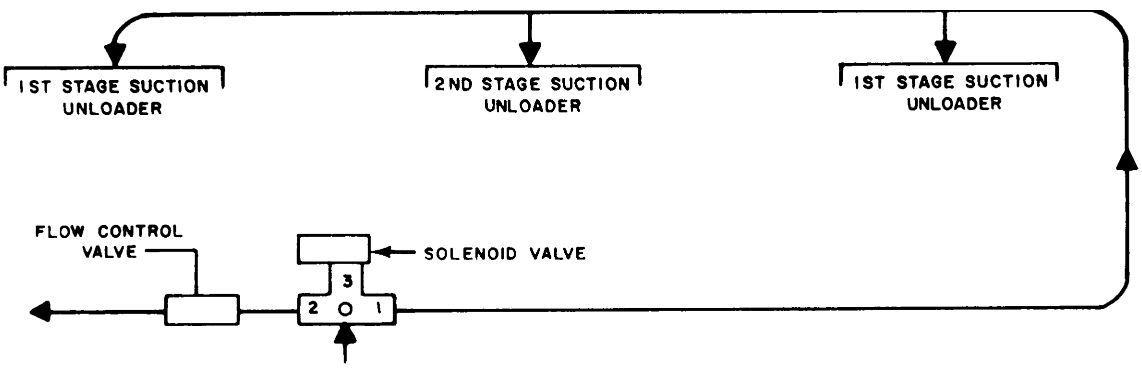

Figure 13-20.—Unloaded system from the oil-free low-pressure air compressor.

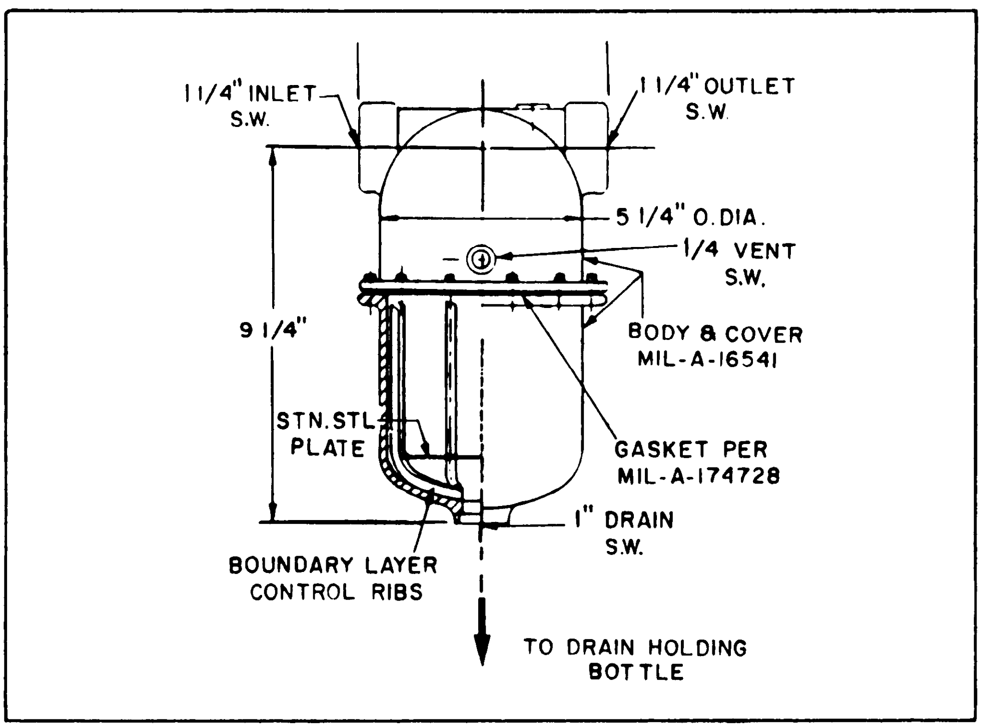

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Figure 13-21A.—Separator.

removed by either the automatic drain system or the manual drain valves. The separator has a level probe that shuts off the air compressor in the event that the drains are backed up because of a malfunction of the automatic drain system.

The automatic drain system operates using a solenoid-operated valve and a three-way air-operated valve (fig. 13-21B). The solenoid-operated valve is energized by a time relay device in the motor controller. The solenoid-operated valve admits air to the three-way air-operated valve which allows drainage of the moisture separator and the holding bottle.

Oil-free air compressors have a freshwater cooling system that provides cooling of the cylinder walls. The fresh water is mixed with an antifreeze solution that allows continuous cleaning of the water passages and piping. The freshwater cooling system (fig. 13-22) consists of a pump, expansion tank, heat exchanger, and thermostatic valve. The thermostatic valve maintains freshwater temperature at a prescribed setting by recirculating the fresh water through a heat exchanger.

COMPRESSED AIR PLANT OPERATION AND MAINTENANCE

Any air compressor or air system must be operated in strict compliance with approved operating procedures. Compressed air is potentially very dangerous. Cleanliness is of utmost importance in all maintenance that requires opening compressed air systems.

SAFETY PRECAUTIONS

There are many hazards associated with pressurized air, particularly high-pressure air.

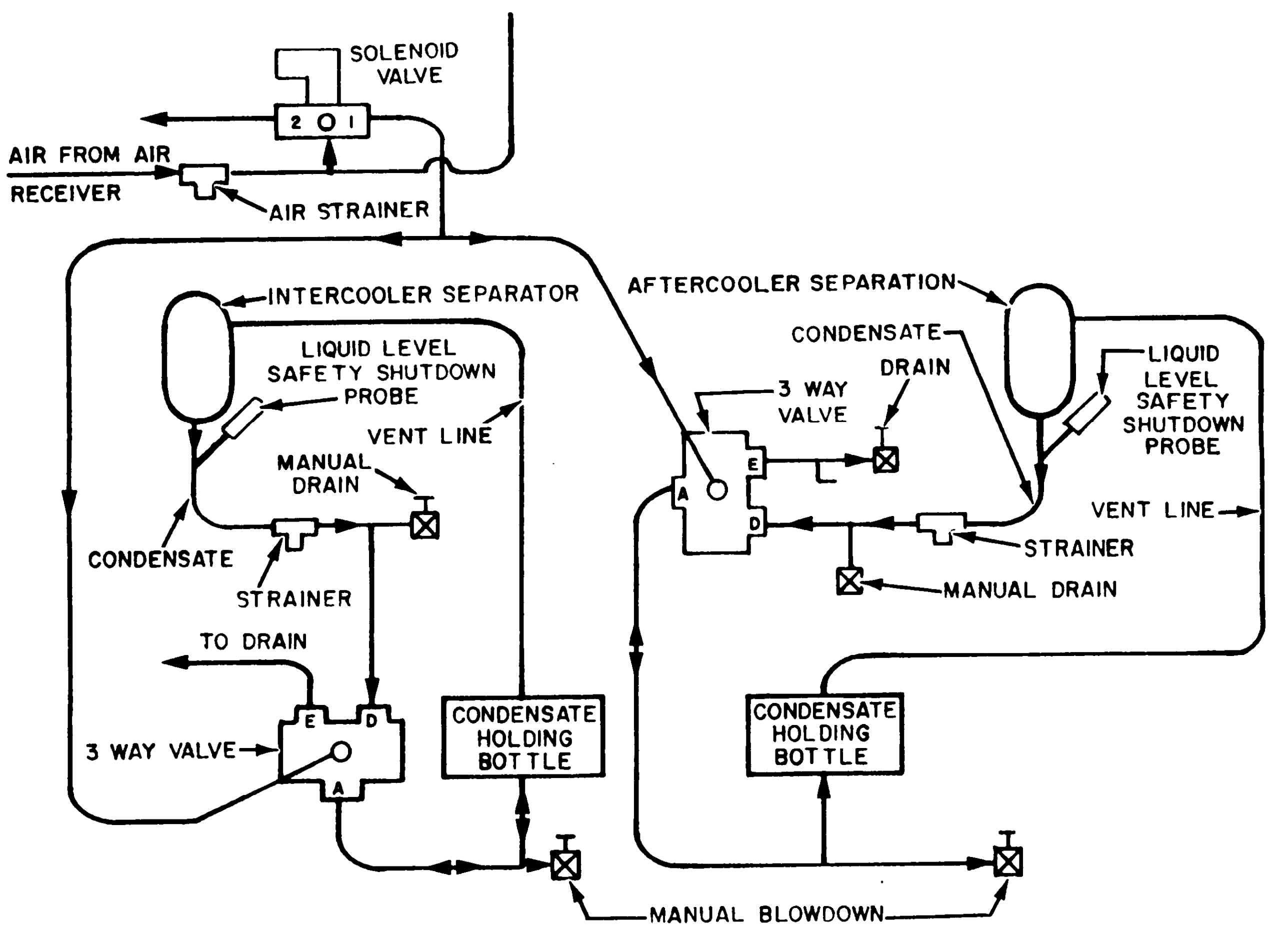

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Figure 13-21B.—Condensate drain system.

Serious explosions have occurred in high-pressure air systems because of diesel effect. If a portion of an unpressurized system or component is suddenly and rapidly pressurized with high-pressure air, a large amount of heat is produced. If the heat is excessive, the air may reach the ignition temperature of the impurities present in the air and piping (oil, dust, and so forth). When the ignition temperature is reached, a violent explosion will occur as these impurities ignite. Ignition temperatures may also result from other causes. Some are rapid pressurization of a low-pressure dead end portion of the piping system, malfunctioning of compressor aftercoolers, and leaky or dirty valves. Use every precaution to have only clean, dry air at the compressor inlet.

Air compressor accidents have also been caused by improper maintenance procedures. These accidents can happen when you disconnect parts under pressure, replace parts with units designed for lower pressures, and install stop valves or check valves in improper locations. Improper operating procedures have also caused air compressor accidents with serious injury to personnel and damage to equipment.

You should try to minimize the hazards inherent in the process of compression and in the use of compressed air. Strictly follow all safety precautions outlined in the manufacturers' technical manuals and in *Naval Ships'*

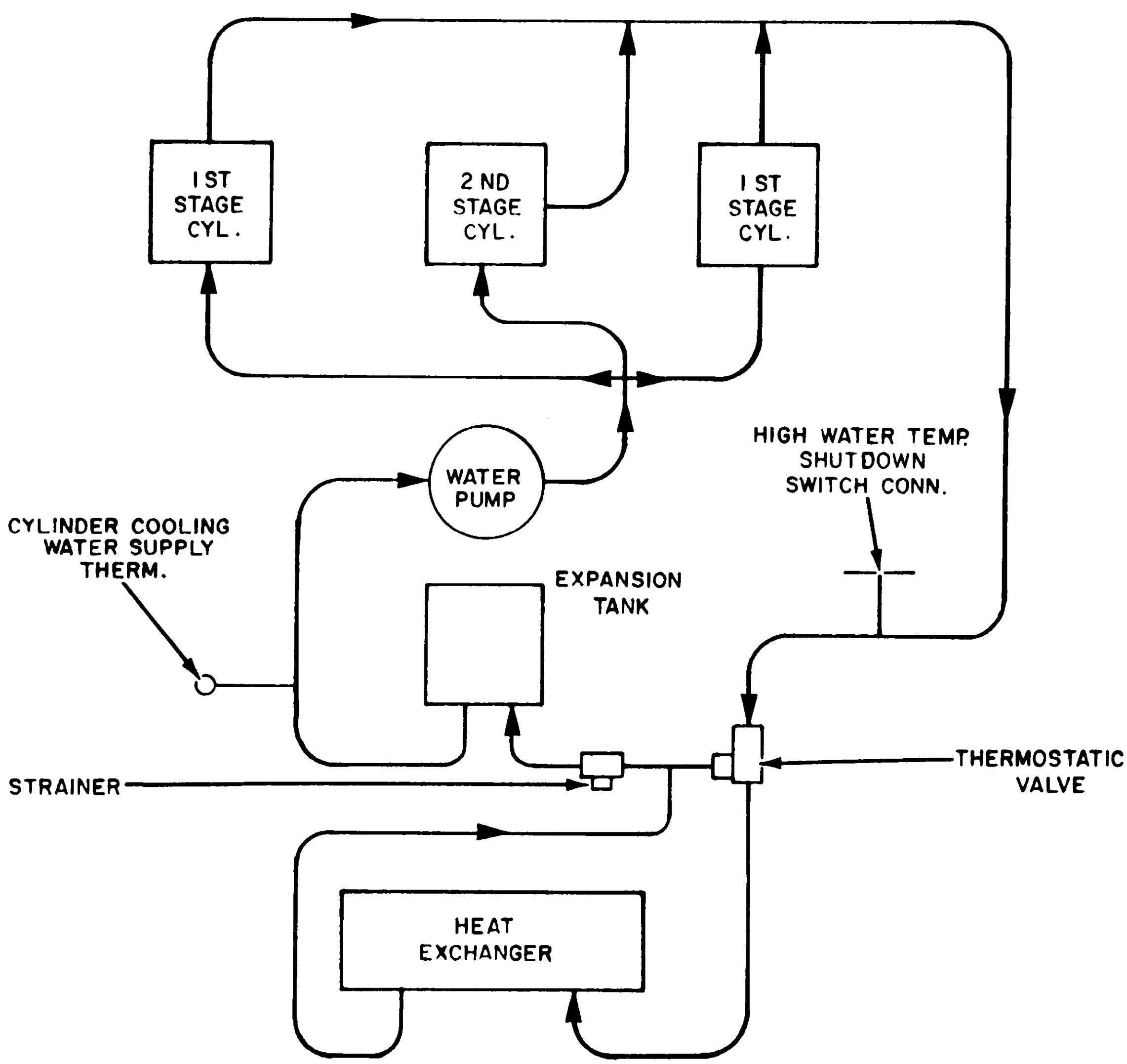

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Figure 13-22.—Cylinder cooling water flow diagram.

Technical Manual, chapter 551 (9490). Some of these hazards and precautions are as follows:

1. Explosions may be caused by dust-laden air or by oil vapor in the compressor or receiver. The explosions are triggered by abnormally high temperatures, which may be caused by leaky or dirty valves, excessive pressurization rates, and faulty cooling systems.

2. NEVER use distillate fuel or gasoline as a degreaser to clean compressor intake filters, cylinders, or air passages. These oils vaporize easily and will form a highly explosive mixture with the air under compression.

3. Secure a compressor immediately if you observe that the temperature of the air discharged from any stage exceeds the maximum temperature recommended.

4. NEVER leave the compressor station after starting the compressor unless you are sure that the control, unloading, and governing devices are operating properly.

5. To prevent damage because of overheating, do NOT run compressors at excessive speeds. Maintain proper cooling water circulation.

6. If the compressor is to remain idle for any length of time and is in an exposed position in freezing weather, thoroughly drain the compressor circulating water system.

7. Before working on a compressor, be sure that the compressor is secured and cannot start automatically or accidentally. Completely blow down the compressor, then secure all valves (including control or unloading valves) between the compressor and the receiver. Follow appropriate tag-out procedures for the compressor control and the isolation valves. (Leave the pressure gauge open at all times the gauges are in place.)

8. When cutting air into the whistle, siren, or a piece of machinery, be sure the supply line to the equipment has been properly drained of moisture. When securing the supply of air to the affected equipment, be sure all drains are left open.

9. Prior to disconnecting any part of an air system, be sure that the part is not under pressure. Always leave the pressure gauge cutout valves open to the sections to which they are attached.

10. Avoid rapid operation of manual valves. The heat of compression caused by sudden flow of high pressure into an empty line or vessel can cause an explosion if oil or other impurities are present. Slowly crack open the valves until flow is noted, and keep the valves in this position until pressure on both sides has equalized. Keep the rate of pressure rise under 200 psi per second.

In this chapter we have discussed the many uses of compressed air aboard ship. We have also discussed how the air is compressed, and some of the safety precautions to be used when operating or working on a compressed air plant or system.

CHAPTER 14

ADDITIONAL AUXILIARY EQUIPMENT

As a Machinist's Mate, you will work with a variety of equipment that is not directly related to the propulsion plant. Some examples are steering gear, cargo or weight-handling equipment, hydraulic systems, and laundry and galley equipment. Some equipment such as that in the laundrv and galley will be maintained by operating and maintenance personnel. However, you will be expected to handle preventive maintenance and repairs.

In general, the operator will clean the equipment and make minor adjustments. In some cases, the operator will perform routine maintenance. You, the Machinist's Mate, will handle any repairs, replacements, or adjustments. An Electrician's Mate will handle electrical work on all machinery, and may be responsible for the entire machine if its operation is primarily electrical.

ELECTROHYDRAULIC DRIVE MACHINERY

Hydraulic units drive or control steering gears, windlasses, winches, capstans, airplane cranes, ammunition hoists, and distant control valves. This chapter contains information on some hydraulic units that will concern you.

The electrohydraulic type of drive operates several different kinds of machinery. Here are some of the advantages of electrohydraulic machinery.

1. Tubing, which can readily transmit fluids around corners, conducts the liquid that transmits the force. Tubing requires very little space.
2. The machinery operates at variable speeds.
3. Operating speed can be closely controlled from minimum to maximum limits.
4. The controls can be shifted from no load to full load rapidly without damage to machinery.

ELECTROHYDRAULIC SPEED GEAR

An electrohydraulic speed gear is most frequently used in electrohydraulic applications. Different variations of the basic design are used for specific applications, but the principles remain the same. Basically, the unit consists of an electric motor-driven hydraulic pump (A-end) and a hydraulic motor (B-end). (See chapter 5 of this manual for a discussion on axial-piston variable-stroke pumps.)

The B-end (fig. 14-1) is already on stroke and will be made to rotate by the hydraulic force of the oil acting on the pistons. Movement of the pistons' A-end is controlled by a tilt box (also called a swash plate) in which the socket ring is mounted, as shown in part A of figure 14-1.

The length of piston movement, one way or the other, is controlled by movement of the tilt box and by the amount of angle at which the tilt box is placed. The length of the piston movement controls the amount of fluid flow. When the drive motor is energized, the A-end is always in motion. However, with the tilt box in a neutral or vertical position, there is no reciprocating motion of the pistons. Therefore, no oil is pumped to the B-end. Any movement of the tilt box, no matter how slight, causes pumping action to start. This causes immediate action in the B-end because of the transmission of force by the hydraulic fluid.

When you need reciprocating motion, such as in a steering gear, the B-end is replaced by a piston or ram. The force of the hydraulic fluid causes the movement of the piston or ram. The tilt box in the A-end can be controlled locally (as on the anchor windlass) or by remote control (as on the steering gear).

ELECTROHYDRAULIC STEERING GEAR

The steering gear transmits power from the steering engine to the rudder stock. The term *steering gear* frequently includes the driving engine and the transmitting mechanism.

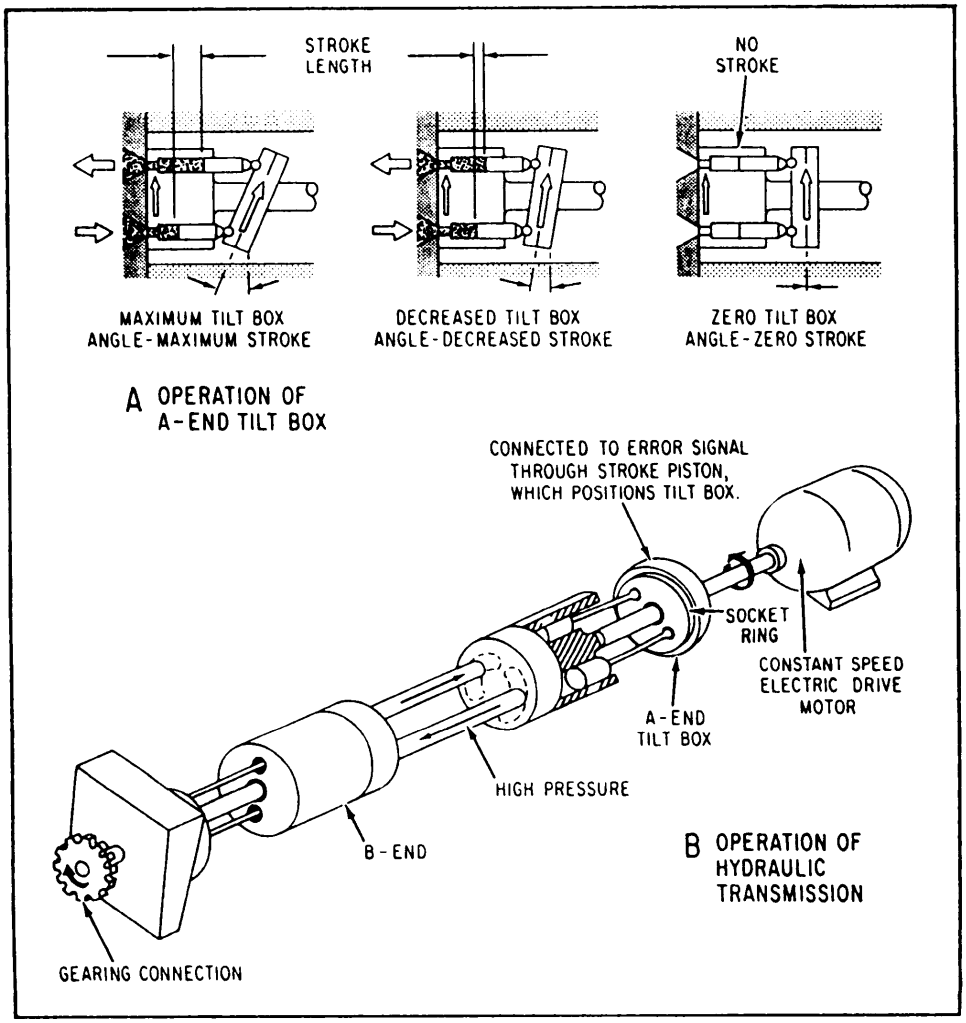


Figure 14-1.—Electrohydraulic speed gear.

Many different designs of steering gear are in use, but the principle of operation for all of them is similar. One type of electrohydraulic steering gear is shown in figure 14-2. It consists essentially of (1) a ram unit and (2) a power unit.

Ram Unit

The ram unit is mounted athwartship and consists of a single ram operated by opposed cylinders. The ram is connected by links to the tillers of the twin rudders. When oil pressure is applied to one end of the operating cylinder, the ram will move, causing each rudder to move along with it. Oil from the opposite end of the cylinder is returned to the suction side of the main hydraulic pump in the power unit.

Power Unit

The power unit consists of two independent pumping systems. Two systems are used for reliability. One pump can be operated while the other is on standby.

Each pumping system consists of a variable-delivery, axial-piston main pump and a vane-type auxiliary pump. Both are driven by a single electric motor through a flexible coupling. Each system also includes a transfer valve with operating gear, relief valves, a differential control box, and trick wheels. The whole unit is mounted on a bedplate, which serves as the top of an oil reservoir. Steering power is taken from either of the two independent pumping systems.

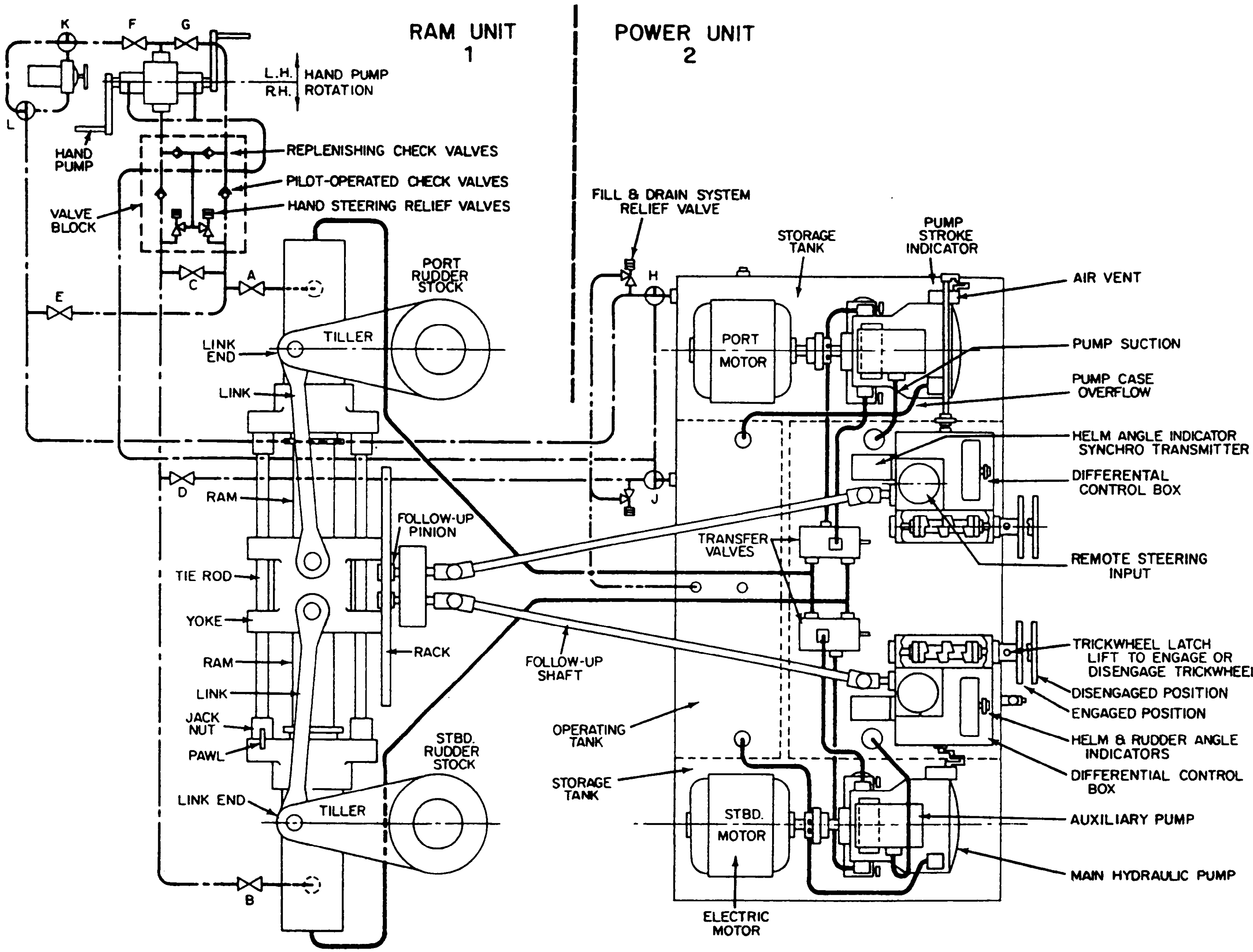


Figure 14-2.—Electrohydraulic steering gear.

The pumps of the power unit are connected to the ram cylinders by high-pressure piping. The two transfer valves are placed in the piping system to allow for the lineup of one pump to the ram cylinders with the other pump isolated. A hand lever and mechanical linkage (not shown) are connected to the two transfer valves in such a way that both valves are operated together. This allows for rapid shifting from the on-service pumping unit to the standby unit; it also prevents lining up both pumps to the ram at the same time. The hand lever is usually located between the trick wheels. It has three positions marked P, N, and S. P denotes the port pump connected to the ram; N denotes neutral (neither pump connected to the ram); and S denotes the starboard pump connected to the ram. Also, the hand lever is usually connected to motor switches. This permits the operator to connect the selected pump to the ram and start the pump drive motor in one quick operation. In most modern ships this valve is electrically controlled by the motor controller and by pressure switches.

Principles of Operation

The on-service hydraulic pump is running at all times and is a constant-speed pump. Unless steering is actually taking place, the tilt box of the main hydraulic pump is at zero stroke, and no oil is being moved within the main system. The auxiliary pump provides control oil and super-charge flows for the system. Assume that a steering order signal comes into the differential control box. It can come from either the remote steering system in the ship's wheelhouse or the trick wheel. The control box mechanically positions the tilt box of the main hydraulic pump to the required angle and position. Remember that direction of fluid and flow may be in either direction in a hydraulic speed gear. It depends on which way the tilt box is angled. For this reason, the constant speed, unidirectional motor can be used to drive the main hydraulic pump. The pump will still have the capability to drive the ram in either direction.

With the main hydraulic pump now pumping fluid into one of the ram cylinders, the ram will move, moving the rudders. A rack and gear are attached to the rudder yoke between the rudder links. As the ram and the rudder move, the rack gear moves, driving the follow-up pinion gear. The pinions drive follow-up shafts, which feed into the differential box. This feedback or servo system tells the differential control box when the steering operation has been completed. As the ordered rudder angle is approached, the differential control box will begin realigning the tilt box of the main hydraulic pump. By the time the desired rudder angle is reached, the tilt box is at zero stroke. This means that the ordered signal (from the pilothouse or trick wheel) and the actual signal (from the follow-up shafts) are the same. If either of these change, the differential control box will react accordingly to cause the main hydraulic unit to pump oil to one end or the other of the ram.

The trick wheels provide local-hydraulic control of the steering system in case of failure of the remote steering system. A hand pump and associated service lines are also provided for local-manual operation of the ram in case of failure of both hydraulic pump units.

Operation and Maintenance

The Machinist's Mate watch stander usually operates the steering equipment only in abnormal and emergency situations. For this reason, you should be thoroughly familiar with all emergency procedures. Examples are local-hydraulic steering with the trick wheel and local-manual steering with the hand pump. Operating instructions and system diagrams are normally posted near the steering gear. The diagrams describe the various procedures and lineups for operation of the steering gear. Be sure that the standby equipment is ready for instant use.

General maintenance of the steering gear requires that you clean, inspect, and lubricate the mechanical parts and maintain the hydraulic oil at the proper level and purity. The Planned Maintenance System (PMS) lists the individual requirements for the equipment. The electricians maintain the electrical portion of the steering system, including the control system.

WEIGHT-HANDLING EQUIPMENT

To qualify for advancement in rating, you must be familiar with the construction, operation, and maintenance of anchor windlasses, cranes, and winches. The following discussion of such machinery and other weight-handling equipment is supplementary to that given in *Fireman,* NAVEDTRA 14104. Most steam-powered weight-handling equipment is obsolete. If your ship has steam-powered equipment, refer to the technical manual for information.

Anchor Windlasses

In a typical electrohydraulic mechanism, one constant-speed electric motor drives two variable-stroke pumps through a coupling and reduction gear. Other installations include two motors, one for driving each pump. Each pump normally drives one wildcat. However, if you use a three-way plug cock-type valve, either pump may drive either of the two wildcats. The hydraulic motors drive the wildcat shafts with a multiple-spur gearing and a locking head. The locking head allows you to disconnect the wildcat shaft and permits free operation of the wildcat, as when dropping anchor.

Each windlass pump is controlled either from the weather deck or locally. The controls are handwheels on shafting leading to the pump control. The hydraulic system will require your attention. Be certain the hydraulic system is always serviced with the specified type of clean oil.

You will normally have to maintain three types of anchor windlasses. They are the electric, electrohydraulic, and hand-driven windlasses. Hand-driven windlasses are used only on small ships where the anchor gear can be handled without excessive effort by operating personnel.

The major work on a hand windlass is to keep the linkage, friction shoes, locking head, and brake in proper adjustment and in satisfactory operating condition at all times. In an electrohydraulic windlass, your principal concern is the hydraulic system.

A windlass is used intermittently and for short periods of time. However, it must handle the required load under severe conditions. This means that you must maintain and adjust the machinery when it is not in use. This practice will prevent deterioration and ensure dependable use.

Windlass brakes must be kept in satisfactory condition if they are to function properly. Wear and compression of brake linings will increase the clearance between the brake drum and band after a windlass has been in operation. Brake linings and clearances should be inspected frequently. Adjustments should be made according to the manufacturer's instructions.

Follow the lubrication instructions furnished by the manufacturer. If a windlass has been idle for some time, it should be lubricated. This protects finished surfaces from corrosion and prevents seizure of moving parts.

The hydraulic transmissions of electrohydraulic windlasses and other auxiliaries are manufactured with close tolerances between moving and stationary parts. Use every precaution to keep dirt and other abrasive material out of the system. When the system is replenished or refilled, use only clean oil. Strain it as it is poured into the tank. If a hydraulic transmission has been disassembled, clean thoroughly before reassembly. Before installing piping or valves, clean their interiors to remove any scale, dirt, preservatives, or other foreign matter.

Winches

Winches are used to heave in on mooring lines, to hoist boats, as top lifts on jumbo booms of large auxiliary ships, and to handle cargo. Power for operating shipboard winches is usually furnished by electricity and, on some older ships, by steam. Sometimes delicate control and high acceleration without jerking are required, such as for handling aircraft. Electrohydraulic winches are usually installed for this purpose. Most auxiliary ships are equipped with either electrohydraulic or electric winches.

CARGO WINCHES.—Some of the most common winches used for general cargo handling are the double-drum, double-gypsy and the single-drum, single-gypsy units. Four-drum, two-gypsy machines are generally used for minesweeping.

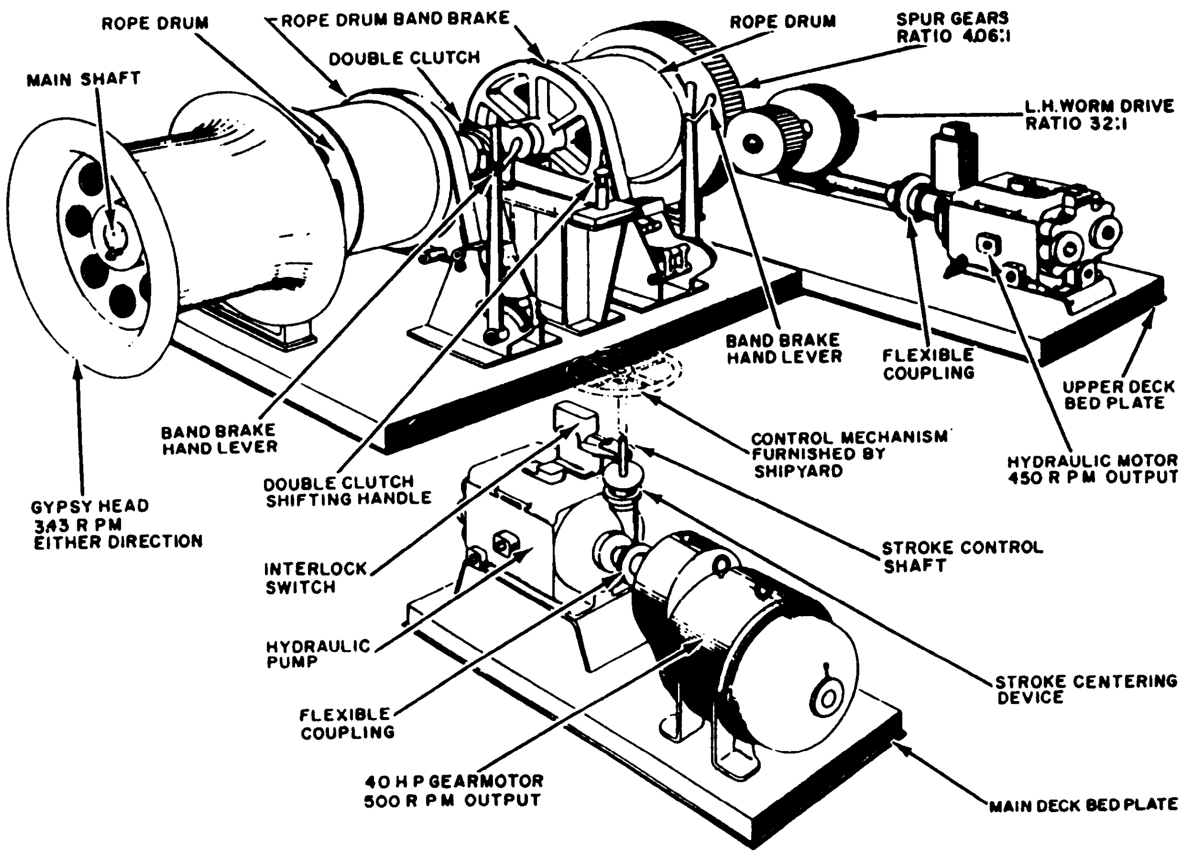


Figure 14-3.—Electrohydraulic winch unit.

ELECTROHYDRAULIC WINCHES.—Electrohydraulic winches (fig. 14-3) are always the drum type. The drive equipment is like most hydraulic systems. A constant-speed electric motor drives the A-end (variable-speed hydraulic pump), which is connected to the B-end (hydraulic motor) by suitable piping. The drum shaft is driven by the hydraulic motor through reduction gearing.

Winches normally have one horizontally mounted drum and one or two gypsy heads. If only one gypsy is required, it may be easily removed from or assembled on either end of the drum shaft. When a drum is to be used, it is connected to the shaft by a clutch.

ELECTRIC WINCHES.—An electrically driven winch is shown in figure 14-4. This winch is a single-drum, single-gypsy type. The electric motor drives the unit through a set of reduction gears. A clutch engages or disengages the drum from the drum shaft. Additional features include an electric brake and a speed control switch.

Capstans

The terms *capstan* and *winch* should not be confused. A winch has a horizontal shaft and a capstan has a vertical shaft. The type of capstan installed aboard ship depends on the load requirements and type of power available. In general, a capstan consists of a single head mounted on a vertical shaft, reduction gearing, and a power source. The types, classified according to power source, are electric and steam.

Electric capstans are usually of the reversible type. They develop the same speed and power in either direction. Capstans driven by alternating-current motors run at either full, one-half, or one-third speed. Capstans driven by direct-current motors usually have from three to five speeds in either direction of rotation.

Maintenance of Winches and Capstans

In several respects, the maintenance of a winch or a capstan is similar to that for a windlass.

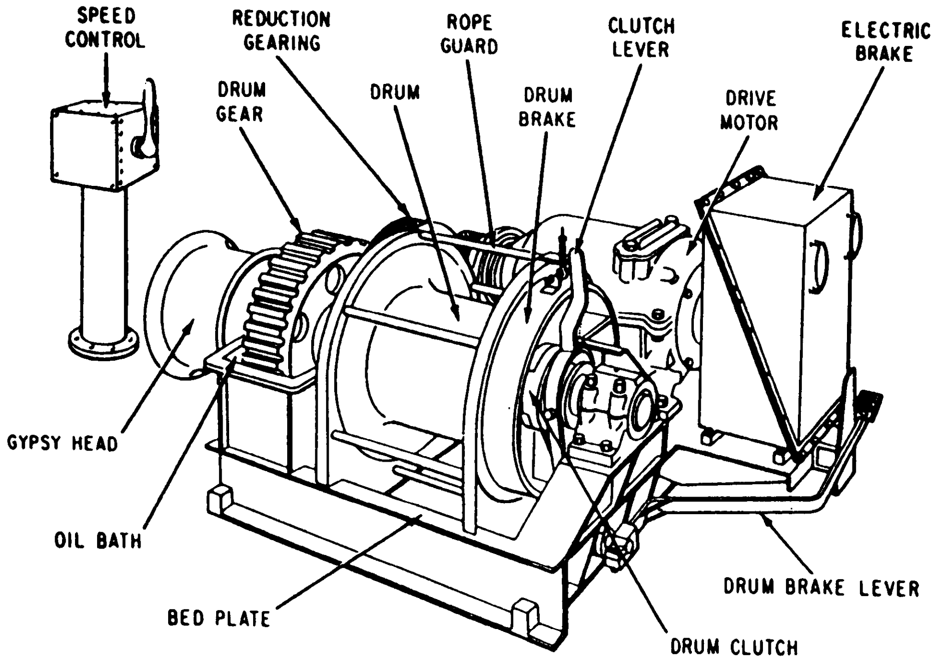


Figure 14-4.—Electric winch.

Where band brakes are used on the drums, inspect the friction linings regularly and replace when necessary. Take steps to prevent oil or grease from accumulating on the brake drums. Check the operation of brake-actuating mechanisms, latches, and pawls periodically.

Frequently inspect winch drums driven by friction clutches for deterioration in the friction material. Check also to see if oil and grease are preventing proper operation. Lubricate the sliding parts of positive clutches properly. Check the locking device on the shifting gear to see if it will hold under load.

Cranes

Cranes are designed to meet the following conditions:

1. Hoist, lower, top, and rotate a rated load at the specified speed and against a specified list of the ship.
2. Handle 150 percent of the rated load at no specified speed.
3. Withstand a static, suspended load of 200 percent of the rated load without damage or distortion to any part of the crane or structure.

The types of cranes installed on ships vary according to the equipment handled.

The crane equipment generally includes the boom, king post, king post bearings, sheaves, hook, and rope, machinery platforms, rotating gear, drums, hoisting, topping and rotating drives, and controls. The important components are described in the paragraphs that follow.

BOOMS.—A boom, used as a mechanical shipboard appliance, is a structural unit used to lift, transfer, or support heavy weights. A boom is used in conjunction with other structures or structural members that support it, and various ropes and pulleys, called blocks, that control it.

KING POST BEARINGS.—Bearings on stationary king posts take both vertical load and horizontal strain at the collar, located at the top of the king post. On rotating king posts, bearings take both vertical and horizontal loads at the base and horizontal reactions at a higher deck level.

SHEAVES AND ROPES.—The hoisting and topping ropes are led from the drums over sheaves to the head of the boom. The sheaves and ropes are designed according to recommendations by the Naval Sea Systems Command. This command sets the criteria for selection of sheave diameter, size, and flexibility of the rope. Sufficient fair-lead sheaves are fitted to prevent fouling of the rope. A shock absorber is installed in the line, hoisting block, or sheave at the head of the boom to take care of shock stresses.

MACHINERY PLATFORMS.—Machinery platforms carry the power equipment and operator's station. These platforms are mounted on the king post above the deck.

ROTATING GEAR AND PINIONS.—Rotation of the crane is accomplished by vertical shafts with pinions engaging a large rotating gear.

DRUMS.—The drums of the hoisting and topping winches are generally grooved for the proper size wire rope. The hoisting system uses single or multiple part lines as required. The topping system uses a multiple purchase as required.

OPERATION AND MAINTENANCE OF CRANES.— The hoisting whips and topping lifts of cranes are usually driven by hydraulic variable-speed gears through gearing of various types. This provides the wide range of speed and delicate control required for load handling. The cranes are usually rotated by an electric motor connected to worm and spur gearing. They may also be rotated by an electric motor and hydraulic variable-speed gear connected to reduction gearing.

Some electrohydraulic cranes have automatic slack line take-up equipment. This consists of an electric torque motor geared to the drum. These cranes are used to lift boats, aircraft, or other loads from the water. The torque motor assists the hydraulic motor drive to reel in the cable in case the load is lifted faster by the water than it is being hoisted by the crane.

Electrohydraulic equipment for the crane consists of one or more electric motors running at constant speed. Each motor drives one or more A-end variable-displacement hydraulic pumps. The pump strokes are controlled through operating handwheels. START, STOP, and EMERGENCY RUN push buttons at the operator's station control the electric motors. Interlocks prevent starting the electric motors when the hydraulic pumps are on stroke. B-end hydraulic motors are connected to the A-end pumps by piping. They drive the drums of the hoisting and topping units or the rotating machinery.

Reduction gears are located between the electric motor and the A-end pump and between the B-end hydraulic motor and the rotating pinion. Each hoisting, topping, and rotating drive has an electric brake on the hydraulic motor output shaft. This brake is interlocked with the hydraulic pump control. It will set when the hydraulic control is on neutral or when electric power is lost. A centering device is used to find and retain the neutral position of the hydraulic pump.

Relief valves protect the hydraulic system. These valves are set according to the requirements of chapter 556 of the *Naval Ships' Technical Manual.*

Cranes usually have a rapid slack take-up device consisting of an electric torque motor. This motor is connected to the hoist drum through reduction gearing. This device works in conjunction with the pressure stroke control on the hydraulic pump. It provides for fast acceleration of the hook in the hoisting direction under light hook conditions. Thus, slack in the cable is prevented when hoisting is started.

Some cranes have a light-hook paying-out device mounted on the end of the boom. It pays out the hoisting cables when the weight of the hook and cable beyond the boom-head sheave is insufficient to overhaul the cable as fast as it is unreeled from the hoisting drum.

When the mechanical hoist control is in neutral, the torque motor is not energized and the cable is gripped lightly by the action of a spring. Moving the hoist control to LOWER energizes the torque motor. The sheaves clamp and pay out the cable as it is unreeled from the hoist drum. When the hoist control is moved to HOIST, the torque motor is reversed and unclamps the sheaves. A limit switch opens and automatically de-energizes the paying-out device.

Maintain cranes according to the PMS requirements or the manufacturers' instructions. Keep the oil in the replenishing tanks at the prescribed levels. Keep the system clean and free of air. Check the limit stop and other mechanical safety devices regularly for proper operation. When cranes are not in use, secure them in their stowed positions. Secure all electric power to the controllers.

Elevators

Some of the hydraulic equipment that you maintain will be found in electrohydraulic elevator installations. Modern carriers use elevators of this type. The elevators described in this chapter are now in service in some of the ships of the CV class. These ships are equipped with four deck-edge airplane elevators that have a maximum lifting capacity of 79,000 to 105,000 pounds. The cable lift platform of each elevator projects over the side of the ship and is operated by an electrohydraulic plant.

ELECTROHYDRAULIC POWER PLANT.— The electrohydraulic power plant for the elevators consists of the following components:

1. A horizontal plunger-type hydraulic engine
2. Multiple variable-delivery parallel piston-type pumps
3. Two high-pressure tanks
4. One low-pressure tank
5. A sump tank system
6. Two constant-delivery vane-type pumps (sump pumps)
7. An oil storage tank
8. A piping system and valves
9. A nitrogen supply

The hydraulic engine is operated by pressure developed in a closed hydraulic system. Oil is supplied to the system in sufficient quantity to cover the baffle plates in the high-pressure tanks and allow for piston displacement. Nitrogen is used because air and oil in contact under high pressure form an explosive mixture. Air should not be used except in an emergency. Nitrogen, when used, should be kept at 97 percent purity.

The hydraulic engine has a balanced piston-type valve with control orifices and a differential control unit. This control assembly is actuated by an electric motor and can be operated by hand. To raise the elevator, move the valve off-center to allow high-pressure oil to enter the cylinder. High-pressure oil entering the cylinder moves the ram. The ram works through a system of cables and sheaves to move the platform upward. The speed of the elevator is controlled by the amount of pressure in the high-pressure tank and the control' valve.

When the elevator starts upward, the pressure in the the high-pressure tank drops. The pressure drop automatically starts the main pumps. These pumps transfer oil from the low-pressure tank to the high-pressure system until the pressure is restored. An electrical stopping device automatically limits the stroke of the ram and stops the platform at the proper position at the flight deck level.

To lower the elevator, move the control valve in the opposite direction. This permits the oil in the cylinder to flow into the exhaust tank. As the platform descends, oil is discharged to the low-pressure tank (exhaust tank). The original oil levels and pressures, except for leakages, are reestablished. The speed of lowering is controlled by the control valve and the cushioning effect of the pressure in the exhaust tank. Leakage is drained to the sump tanks. It is then automatically transferred to the pressure system by the sump pumps. An electrically operated stopping device automatically slows down the ram and stops the platform at its lower level (hangar deck).

SAFETY FEATURES.—Some of the major safety features incorporated into modern deck edge elevators are as follows:

1. If the electrical power fails while the platform is at the hangar deck, there will be enough pressure in the system to move the platform to the flight deck one time without the pumps running.
2. Some platforms have serrated safety shoes. If all the hoisting cable should break on one side, the shoes will wedge the platform between the guide rails. This will stop the platform with minimum damage.
3. A main pump may have a pressure-actuated switch to stop the pump motors when the discharge pressure is excessive. They may also have to relieve the pressure when the pressure switch fails to operate.
4. The sump pump system has enough capacity to return the unloaded platform from the hangar deck to the flight deck.
5. The oil filter system may be used continuously while the engine is running. This allows part of the oil to be cleaned with each operation of the elevator.

CONVEYORS

Two types of conveyors are used for shipboard handling: gravity and powered.

GRAVITY CONVEYORS

Gravity conveyors may be wheel, roller, or ball type with straight, curved, or angular sections provided in the quantities and lengths required to facilitate stores strikedown. Folding conveyor stands are furnished with each conveyor section.

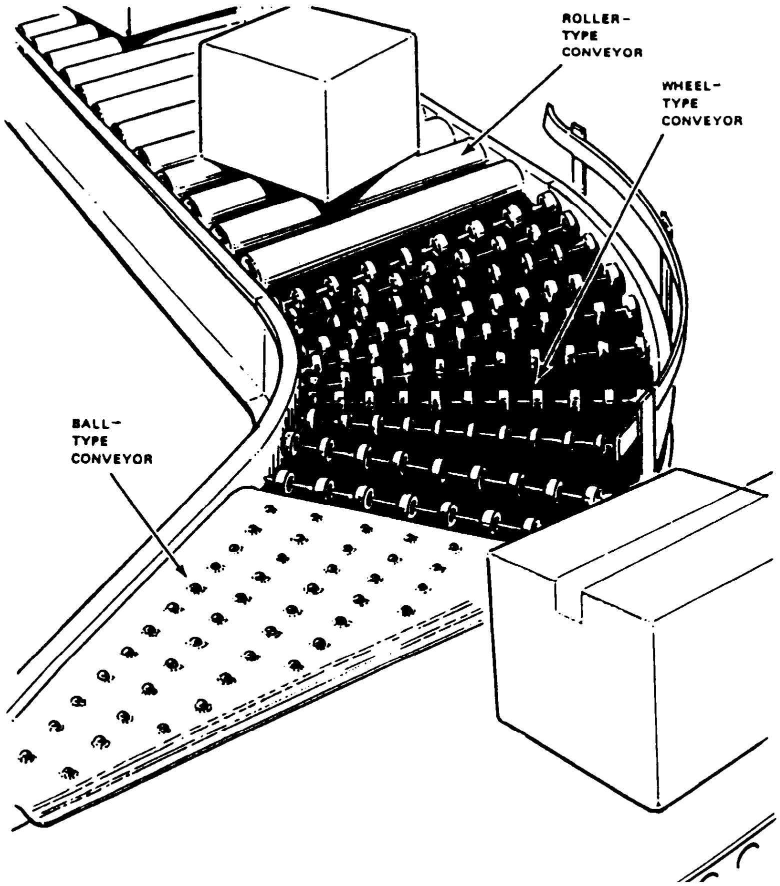


Figure 14-5.—Gravity conveyor.

Conveyors are usually 18 inches wide, but they may be 12 inches wide for use in restricted passageways. Most conveyors are of the roller type and are used to handle dry provisions and chilled and frozen food (fig. 14-5).

POWERED CONVEYORS

Powered conveyors are configured either vertically or horizontally.

Vertical Conveyors

Vertical conveyors (figs. 14-6 and 14-7), for shipboard use, consist of the following components:

1. Structural frame (head, tail, and intermediate sections)
2. Drive system
3. Conveyor system
4. Operating controls
5. Safety devices

The structural frame may be designed as a truss frame installed in a trunk closure. Shields running the length of the conveyor provide a smooth unbroken surface in the area of the moving tray loads and isolate the load side from the idle return side of the conveyor tray cycle.

The drive system components are the friction clutch (package conveyor), magnetic clutch (pallet conveyor), speed reducer, motor brake, drive shafts with chain sprockets, and connecting roller chain. The drive units are located at the head section of the conveyor frame and can be positioned at the side, back, or top of the conveyor.

The conveying system consists of the chain sprockets mounted in the head and tail sections of the conveyor frame. The carrier (tray) chain is driven by the head chain sprockets. Each tray is supported on two sides by the carrier chain, and each tray is guided on two sides by cam guide arms with rollers that ride in guide tracks mounted to the conveyor frame.

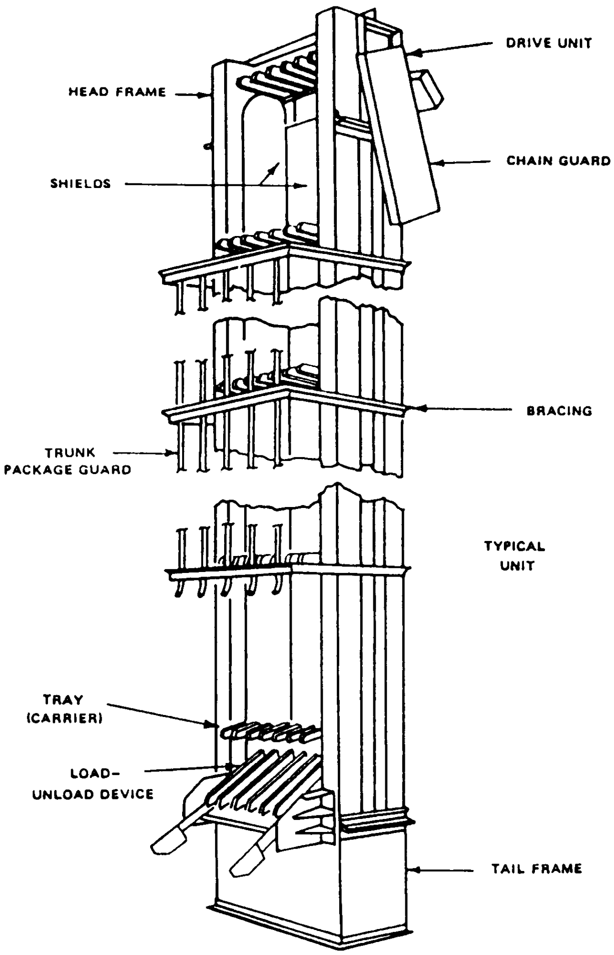


Figure 14-6.—Vertical conveyor, package, tray type.

The operating controls consist of a motor controller that provides electrical power for the conveyor electrical components, a switching network for operation on electrical circuits, and a control station that provides operating switches for directional control. STOP, stops the conveyor; UP-DOWN, controls the direction of the conveyor; and RUN, starts the conveyor. An EMERGENCY RUN push button permits operation of the conveyor when the thermal overload relay in the motor controller has tripped. A communication system is provided at control stations for operating personnel to control conveyor operation.

Safety Features

Safety devices are installed for the safety of personnel and to increase the reliability of the conveyor.

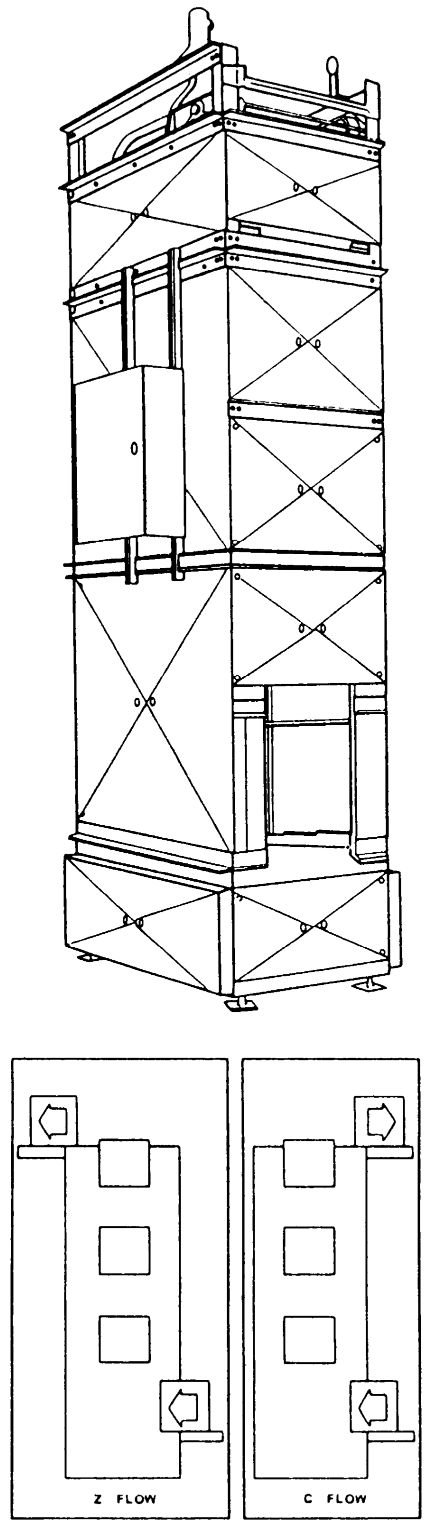


Figure 14-7.—Vertical conveyor, pallet, tray type.

The lockout device, located at each control station, secures the operating controls from unauthorized operation. When secured, the lockout device permits operation of the STOP push button from each control station to stop the conveyor motion.

The package conveyor has a load and unload device capable of loading and unloading the conveyor at each load station, and it can be placed in three positions:

1. Load position (horizontal) for UP direction loading
2. Unload position (30-degree incline) for DOWN direction unloading
3. Stowed position (vertical)

An interlock switch is placed at each load-unload device to prevent downward operation of the conveyor when the load-unload device is in the load position.

A door block device is provided at each package conveyor load station equipped with a load-unload device so that the trunk door will not close unless the load-unload device is in the stowed position.

Two-way communication should continuously be maintained between operating levels to prevent injury to personnel or damage to equipment.

Horizontal Conveyors

Horizontal conveyors arc similar to vertical conveyors except that belts or driven rollers (figs. 14-8 and 14-9) are used in place of chains and trays to support the loads. Powered conveyors can bridge a span and operate at an incline.

To ensure accident-free conveyor operation, use the following procedures:

1. Inspect all interlocks and safety devices to make sure they are operational before further conveyor operations, as per PMS requirements,
2. Verify all warning plates are in place.
3. Establish positive communications between all operating control stations using sound-powered telephones or intercom systems.
4. Do not use the conveyor trunk as a voice tube.
5. Use the two-man rule at all times while operating the conveyor.

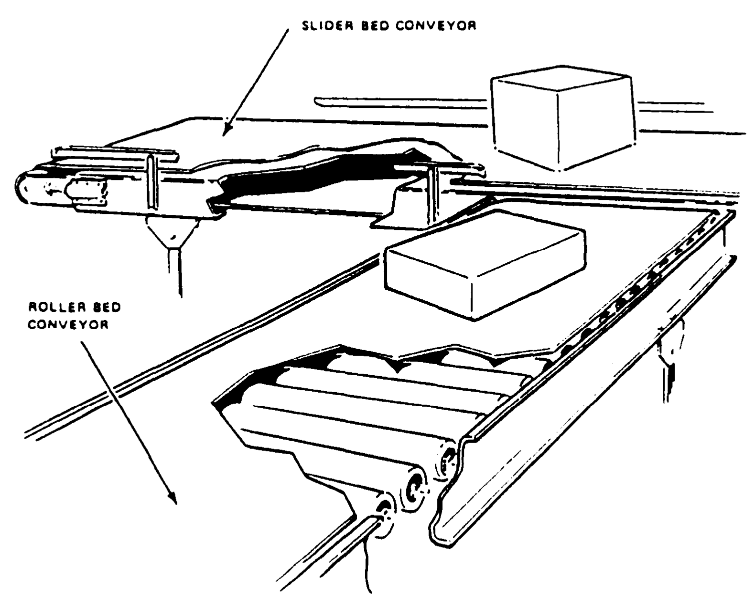


Figure 14-8.—Powered belt conveyor.

GALLEY AND LAUNDRY EQUIPMENT

The Navy uses a variety of galley and laundry equipment. The type of equipment depends on the size of the ship, the availability of steam, and other factors. You will need the equipment manufacturer's technical manual for each different piece of gear aboard. Schedule and perform preventive maintenance according to the 3-M systems.

STEAM-JACKETED KETTLES

Steam-jacketed kettles (fig. 14-10) come in sizes from 5 to 80 gallons. The kettles are made of corrosion-resisting steel. They operate at a maximum steam pressure of 45 psi. A relief valve in the steam line leading to the kettles is set to lift at 45 psi. Maintenance on these units is normally limited to the steam lines and valves associated with the kettles.

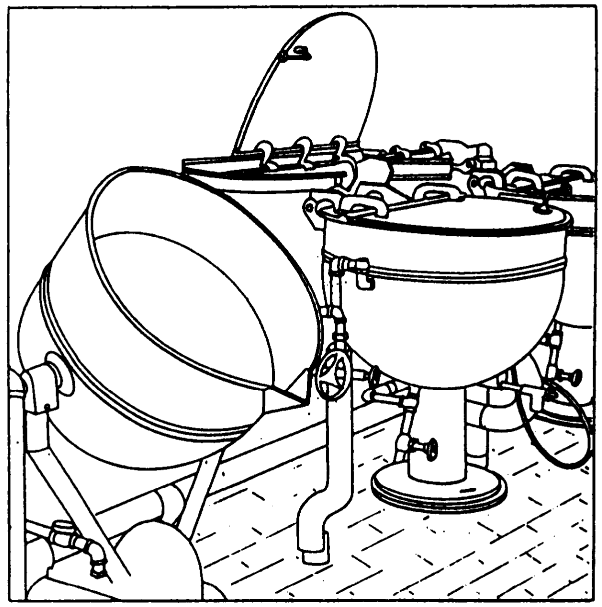


Figure 14-10.—Steam-jacketed kettles.

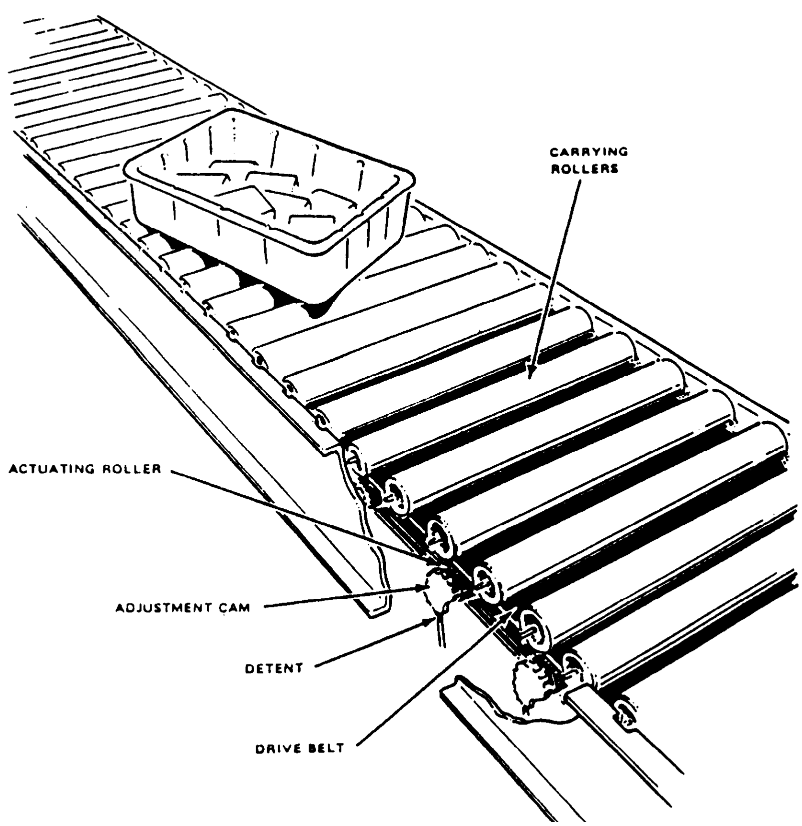


Figure 14-9.—Powered roller conveyor.

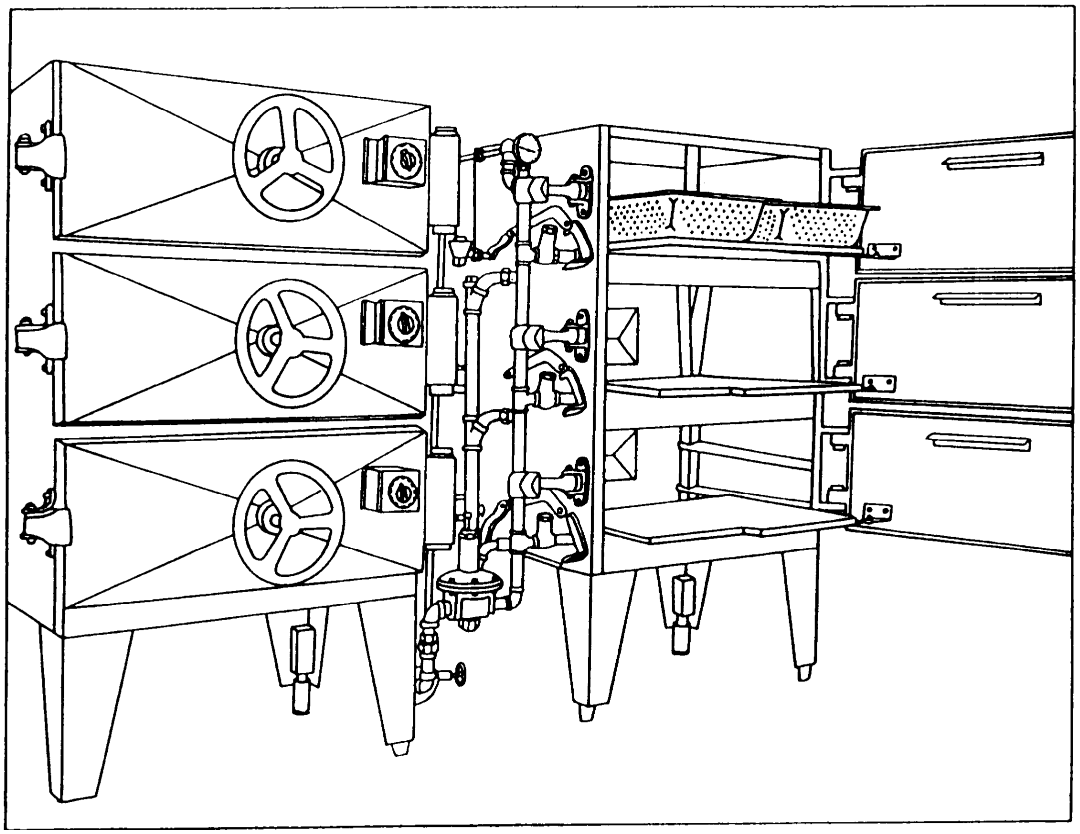


Figure 14-11.—Steamer.

Other steam-operated cooking equipment includes steamers (fig. 14-11) and steam tables (fig. 14-12). Steamers use steam at a pressure of 5 to 7 psi; steam tables use steam at a pressure of 40 psi or less.

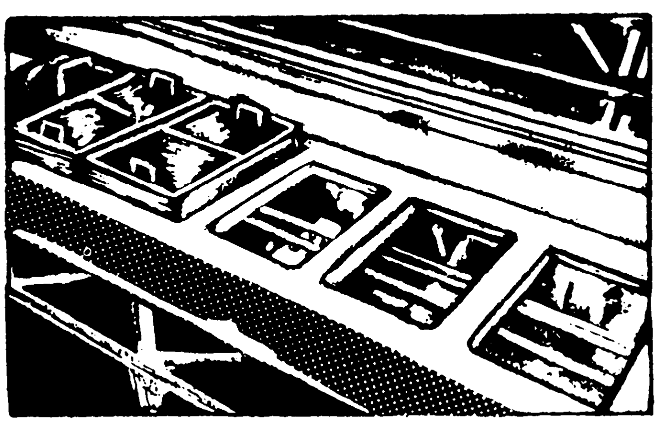


Figure 14-12.—Steam table.

DISHWASHING EQUIPMENT

Dishwashing machines used in the Navy are classified as one-, two-, or three-tank machines. The three-tank machine is a fully automatic, continuous racking machine. It scrapes, brushes, and provides two rinses. It is used at large activities.

Bacteria in these tanks must be controlled at a satisfactory level. This is done by controlling the temperature of the water. The temperature ranges will vary in one-, two- and three-tank machines.

Single Tank

Single-tank machines (fig. 14-13) are used on small ships where larger models are not feasible.

The temperature of the washwater must be at least 140°F and no greater than 160°F.

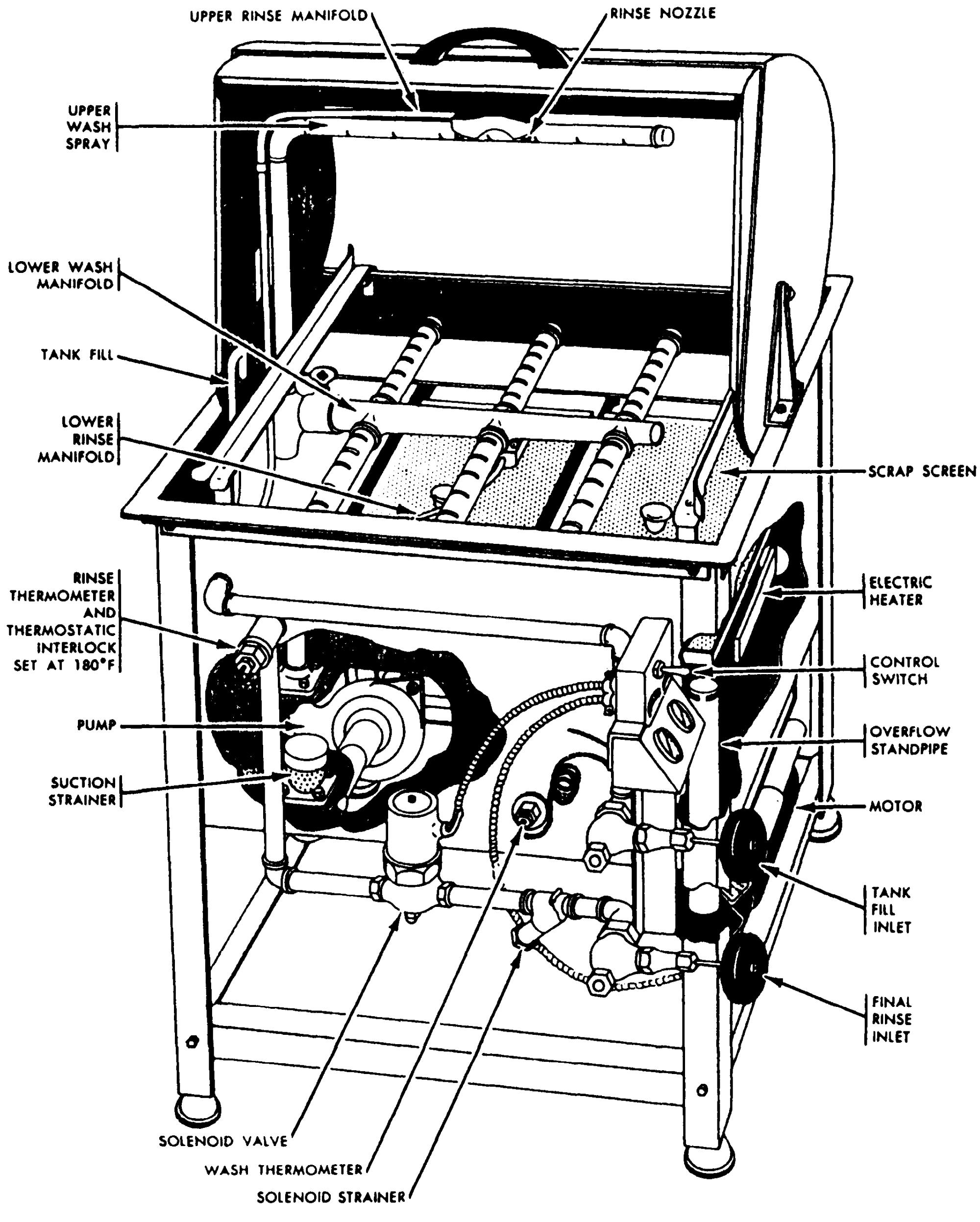


Figure 14-13.—Typical semiautomatic single-tank dishwashing machine.

Lower temperatures will not control bacteria, and higher temperatures are not efficient at removing some foods. These temperatures are controlled by a thermostat. The washing time is 40 seconds in the automatic machines.

For rinsing, hot water is sprayed on the dishes from an external source. It is controlled by an adjustable automatic steam-mixing valve that maintains the rinse water between 180°F and 195°F.

To conserve fresh water, the rinse time interval is usually limited to 10 seconds. When water supply is not a problem, a rinse of 20 seconds is recommended.

Wash and rinse sprays are controlled separately by automatic, self-opening and closing valves in the automatic machine.

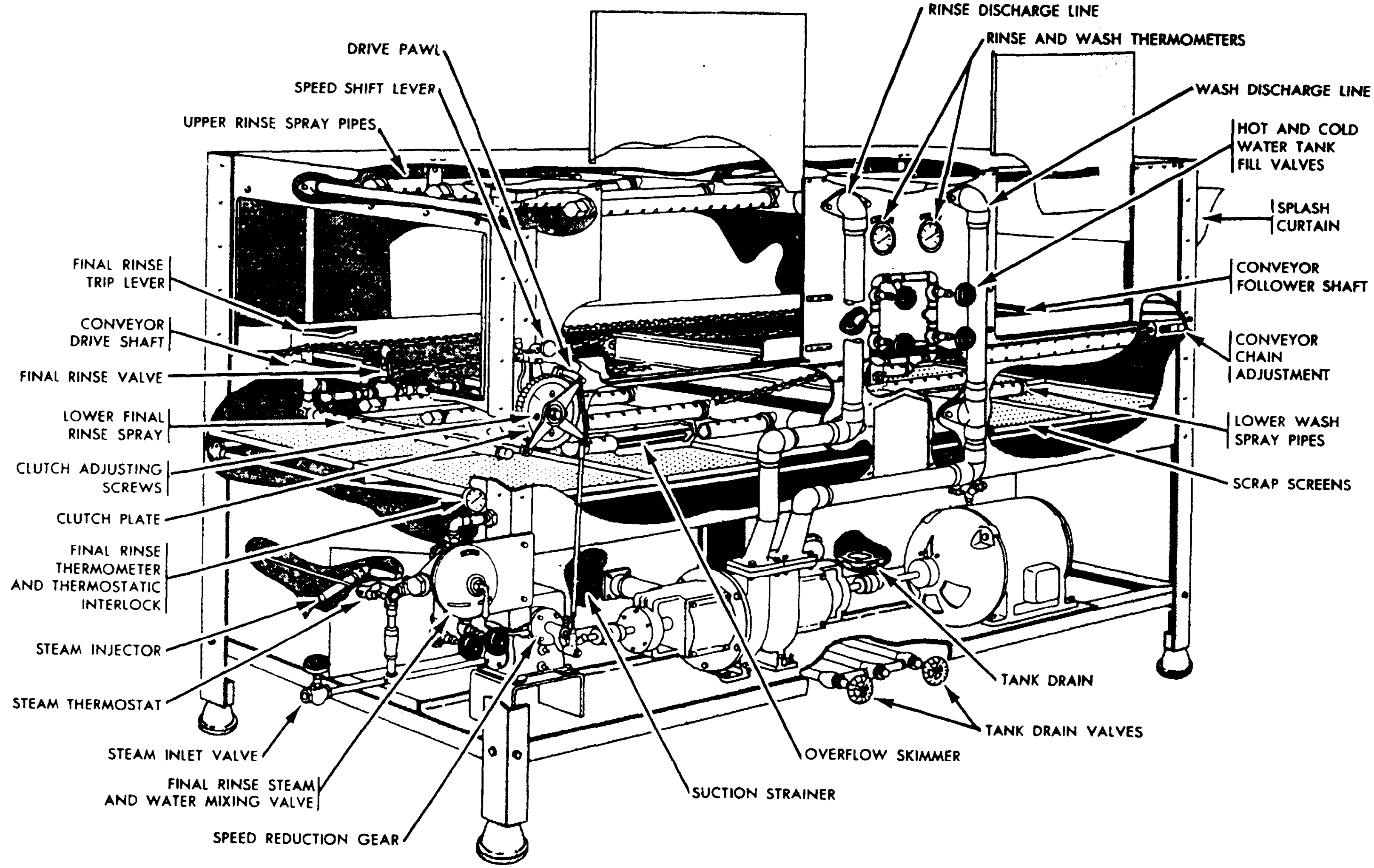


Figure 14-14.—Typical automatic double-tank dishwashing machine.

Double Tank

Double-tank machines (fig. 14-14) are available in several capacities. They are used when more than 150 persons are to be served at one meal. These machines have separate wash and rinse tanks. They also have a final rinse of hot water that is sprayed on the dishes from an outside source. This spray is opened by the racks as they pass through the machines. The spray automatically closes when the rinse cycle is completed. The final rinse is controlled by an adjustable automatic steam-mixing valve that maintains the temperature between 180°F and 195°F. Double-tank machines are also equipped with a thermostatically operated switch in the rinse tank. This switch prevents operation of the machine if the temperature of the rinse water falls below 180°F. The racks pass through the machine automatically on conveyor chains. Utensils should be exposed to the machine sprays for not less than 40 seconds (20-second wash, 20-second rinse).

Descaling Dishwashers

You should prevent the accumulation of scale deposits in dishwashing machines for at least two reasons. First, excessive scale deposit on the inside of pipes and pumps will clog them. This will interfere with the efficient performance of the machine by reducing the volume of water that comes in contact with the utensils during the washing and sanitizing process. Second, scale deposits provide a haven for harmful bacteria.

The supplies needed for descaling are available through Navy supply channels. See the following supply list:

Stock Number	Description of Material
9G6810-00-264-6722	Orthophosphoric acid, 85 percent technical, 7-pound bottle
9Q7930-00-282-9699	Detergent, general-purpose, 1-gallon can
9Q7930-00-985-6911	Detergent, general-purpose, 5-gallon pail

You should know the capacity of the dishwashing machine tanks. Measure (in inches) the inside dimensions of each tank and apply the following formula: length × width × depth (to waterline) ÷ 231 = capacity in gallons.

Use the following steps and key points in descaling the machine:

1. Fill the tanks halfway to the overflow level with hot, clean water. If tanks do not have water level indicators, remove a section of the scrap tray in each tank so that you can see the overflow pipe.
2. Add the required amount of acid and detergent to the water to prepare the cleaning solution. Measure amounts carefully. Use 7 fluid ounces of orthophosphoric acid 85 percent plus 1/2 fluid ounce of detergent, general-purpose. Use this measure for each gallon capacity of the tank when it is filled to the overflow level.
3. Complete filling the tanks. Fill to the over flow level.
4. Put scrap screens, spray pipes, and splash curtains in place. Remove scale deposits on all attachments.
5. Turn on the machine. Operate the machine at the highest permissible operating temperature for 60 minutes.
6. Turn off and drain the machine. Open the drain valves and allow all the cleaning solution to drain from the tanks.
7. Refill. Use fresh hot water.
8. Turn on the machine. Operate the machine at the highest temperature for 5 minutes.

Repeat steps 7 and 8 several times. Repeat the entire method at such intervals as may be required for operation of the dishwashing machine.

LAUNDRY EQUIPMENT

Equipment used in the cleaning, drying, and pressing of clothing includes washers, extractors, dryers, dry-cleaning machines, and various types of presses.

Most of the maintenance on this equipment is concerned with inspecting and lubricating the various parts.

Most laundry equipment is equipped with a number of safety devices. If disabled, these safety devices can and have caused shipboard fires and damage to equipment, clothing, and personnel. Pay special attention to these safety devices during preventive and corrective maintenance. Pay extra special attention to those devices designed to protect operator personnel.

CHAPTER 15

PROPULSION BOILERS

As a Machinist Mate (MM) Surface, you will need to know a great deal about the design, construction, and operating principles of naval boilers. Begin by learning all you can about the boilers in your own ship, but don't stop there. Learn as much as possible about all types of boilers used in the Navy.

Some things about boilers, such as the circulation of water and steam, you will learn through studying this manual, while there are other things you will learn through observation and practical experience. Neither method alone is completely satisfactory. Study everything you can find on the subject of boilers and take every opportunity to look at different boiler installations. When you go aboard other ships, take a look at the boilers. Although all boilers serve the same general purpose, there are many interesting differences in design and construction. Look for the differences as well as for the similarities.

This chapter deals primarily with the types of boilers commonly used in the propulsion plants of naval steam-driven surface ships. Chapter 221 of the *Naval Ships' Technical Manual* is the basic doctrine reference on boilers. For detailed information on the boilers in any particular ship, consult the manufacturer's technical manuals furnished with the boilers.

BOILER DEFINITIONS

Some of the terms used in connection with boilers are defined here. It is important that you understand these definitions and that you use the terms correctly.

BOILER FULL-POWER CAPACITY

Boiler full-power capacity, as specified in the contract specifications of the ship, is expressed as the number of pounds of steam generated per hour at the pressure and temperature required for all purposes to develop contract shaft horsepower of the ship divided by the number of boilers installed. Boiler full-power capacity is listed in the design data section of the manufacturer's technical manual for the boilers in each ship. It may be listed either as the capacity at full power or as the designed rate of actual evaporation per boiler at full power.

BOILER OVERLOAD CAPACITY

Boiler overload capacity is specified in the design of the boiler. It is given in terms of either steaming rate or firing rate, depending on the individual installation. Boiler overload capacity is usually 120 percent of boiler full-power capacity.

SUPERHEATER OUTLET PRESSURE

Superheater outlet pressure is the actual pressure at the superheater outlet at any given time.

STEAM DRUM PRESSURE

Steam drum pressure is the actual pressure in the boiler steam drum at any given time.

OPERATING PRESSURE

Operating pressure is the constant pressure at which the boiler is being operated. The constant pressure may be carried at either the steam drum or the superheater outlet, depending on the design features of the boiler. Therefore, operating pressure is the same as either the steam drum or the superheater outlet pressure (depending on which is used as the controlling pressure). Operating pressure is specified in the design of a boiler and is indicated in the manufacturer's technical manual.

DESIGN PRESSURE

Design pressure is a pressure specified by the boiler manufacturer as a criterion for boiler design. Design pressure is NOT the same as operating pressure. It is somewhat higher than operating pressure. Design pressure is given in the manufacturer's technical manual for the boiler.

DESIGN TEMPERATURE

Design temperature is the intended maximum operating temperature at the superheater outlet at some specified rate of operation. For combatant ships the specified rate of operation is normally full-power capacity.

OPERATING TEMPERATURE

Operating temperature is the actual temperature at the superheater outlet. Operating temperature is the same as design temperature ONLY when the boiler is operating at the rate specified in the definition of design temperature.

BOILER EFFICIENCY

The efficiency of a boiler is the amount of British thermal units (Btu) per pound of fuel absorbed by the water and steam divided by the Btu per pound of fuel fired. In other words, boiler efficiency is output divided by input, or heat used divided by heat available. Boiler efficiency is expressed as a percentage.

FIREROOM

A fireroom is a compartment that contains boilers, associated auxiliary equipment, and the operating station for operating them.

BOILER OPERATING STATION

The station from which a boiler or boilers are operated is referred to as a boiler operating station.

STEAMING HOURS

The term *steaming* hours indicates the time during which the boiler has fires lighted for raising steam and the time during which it is generating steam. Time during which fires are not lighted is NOT included in steaming hours.

TOTAL HEATING SURFACE

The total heating surface of any steam generating unit consists of that portion of the heat transfer apparatus (tubes) that is exposed on one side to the gases of combustion and on the other side to the water or steam being heated. Thus the total heating surface equals the sum of the generating (tubes) surface, superheater (tubes) surface, and economizer (tubes) surface, as measured on the combustion gas side.

SUPERHEATER SURFACE

The superheater surface is that portion of the total heating surface where the steam is heated after leaving the boiler steam drum.

ECONOMIZER SURFACE

The economizer surface is that portion of the total heating surface where the feedwater is heated before it enters the boiler steam drum.

MAXIMUM STEAM DRUM PRESSURE

Maximum steam drum pressure is that point at which the first boiler safety valve lifts.

MINIMUM STEAM DRUM PRESSURE

Minimum steam drum pressure is usually 85 percent of the boiler operating pressure.

BOILER CLASSIFICATION

Although boilers may vary considerably in details of design, most of them may be classified and described in terms of a few basic features or characteristics. Some knowledge of the methods of classification provides a useful basis for understanding the design and construction of the various types of naval boilers.

INTENDED SERVICE

A good place to begin classifying boilers is to consider their intended service. By this method of classification, naval boilers are divided into two classes: propulsion boilers and auxiliary boilers. Propulsion boilers are used to provide steam for ship propulsion and for vital auxiliary services. Auxiliary boilers are installed in diesel-driven ships and in many steam-driven combatant ships to supply steam or hot water for galley, heating, and other hotel services and for other auxiliary requirements in port.

LOCATION OF FIRE AND WATER SPACES

One of the basic classifications of boilers is according to the relative location of the fire and water spaces. By this method of classification, boilers are divided into two classes: fire-tube boilers and water-tube boilers. In the fire-tube boilers, the gases of combustion flow through the tubes and thereby heat the water that surrounds the tubes. In water-tube boilers, the water flows through the tubes and is heated by the gases of combustion that fill the furnace and heat the outside metal surfaces of the tubes.

All propulsion boilers used in modern naval ships are of the water-tube type. Auxiliary boilers may be either fire-tube or water-tube boilers.

TYPE OF CIRCULATION

Water-tube boilers are further classified according to the method of water circulation. Water-tube boilers may be classified as natural-circulation boilers or as forced-circulation boilers.

In natural-circulation boilers, the circulation of water depends on the difference between the density of an ascending mixture of hot water and steam and a descending body of relatively cool and steam-free water. The difference in density occurs because the water expands as it is heated, and thus becomes less dense. Another way to describe natural circulation is to say that it is caused by convection currents which result from the uneven heating of the water contained in the boiler.

Natural circulation may be either free or accelerated. In a boiler with free natural circulation, the generating tubes are installed almost horizontally, with only a slight incline toward the vertical. When the generating tubes are installed at a much greater angle of inclination, the rate of water circulation is definitely increased. Therefore, boilers in which the tubes slope quite steeply from the steam drum to the water drum are said to have natural circulation of the accelerated type.

Most modern naval boilers are designed for accelerated natural circulation. In such boilers, large tubes (3 inches or more in diameter) are installed between the steam drum and the water drum. These large tubes, or DOWNCOMERS, are located outside the furnace and away from the heat of combustion. They serve as pathways for the downward flow of relatively cool water. When a sufficient number of downcomers are installed, all small tubes can be generating tubes, carrying steam and water upward, and all downward flow can be carried by the downcomers. The size and number of downcomers installed varies from one type of boiler to another, but downcomers are installed in all modern naval boilers.

Forced-circulation boilers are, as their name implies, quite different in design from the boilers that use natural circulation. Forced-circulation boilers depend upon pumps, rather than upon natural differences in density, for the circulation of water within the boiler. Because forced-circulation boilers are not limited by the requirement that hot water and steam must be allowed to flow upward while cooler water flows downward, a great variety of arrangements may be found in forced-circulation boilers.

Forced-circulation boilers have been used in a few naval ships during the past few years. In general, however, they are still considered more or less experimental for naval use.

ARRANGEMENT OF STEAM AND WATER SPACES

Natural-circulation water-tube boilers are classified as drum-type boilers or header-type boilers, depending upon the arrangement of the steam and water spaces. Drum-type boilers have one or more water drums (and usually one or more water headers as well). Header-type boilers have no water drum; instead, the tubes enter a great many headers, which serve the same purpose as water drums.

What is a header, and what is the difference between a header and a drum? The term *header* is commonly used in engineering to describe any tube, chamber, drum, and similar piece to which tubes or pipes are connected in such a way as to permit the flow of fluid from one tube (or group of tubes) to another. Essentially, a header is a type of MANIFOLD or collection point. As far as boilers are concerned, the only distinction between a drum and a header is size. Drums may be entered by a person, while headers cannot. But both serve basically the same purpose.

Drum-type boilers are further classified according to the overall shape formed by the steam and water spaces—that is, by the tubes. For example, double-furnace boilers are often called M-type boilers because the arrangement of tubes is roughly M-shaped. Single-furnace boilers are often called D-type boilers because the tubes form a shape that looks like the letter *D*.

NUMBER OF FURNACES

All boilers commonly used in the propulsion plants of naval ships may be classified as either single-furnace boilers or double-furnace boilers. The D-type boiler is a single-furnace boiler; the M-type boiler is a double-furnace (divided-furnace) boiler.

BURNER LOCATION

Another recent development in naval boilers makes it convenient to classify boilers on the basis of where the burners are located. (Most burners in naval propulsion plants are located at the front of the boiler.) However, newer design ships (AO-177 and LKA-113 classes) have their burners located on the top of the boilers. These are called topfired boilers.

FURNACE PRESSURE

Recent developments in naval boilers make it convenient to classify boilers on the basis of the air pressure used in the furnace. Most boilers now in use in naval propulsion plants operate with a slight air pressure (seldom over 5 psig) in the boiler furnace. This slight pressure is produced by forced draft blowers that supply combustion air to the boilers. This pressure is not sufficient enough to justify calling these boilers pressurized-furnace boilers.

TYPE OF SUPERHEATERS

On almost all boilers currently used in the propulsion plants of naval ships, the superheater tubes are protected from radiant heat by water screen tubes. The water screen tubes absorb the intense radiant heat of the furnace, and the superheater tubes are heated by convection currents rather than by direct radiation. Hence, these superheaters are referred to as convection-type superheaters.

In a few older ships, the superheater tubes are not screened by water screen tubes but are exposed directly to the radiant heat of the furnace. Superheaters of this kind are called radiant-type superheaters. Although radiant-type superheaters are rarely used at present, it is possible that they may be used again in future boiler designs.

CONTROL OF SUPERHEAT

A boiler that provides some means of controlling the degree of superheat independently of the rate of steam generation is said to have CONTROLLED SUPERHEAT. A boiler in which such seperate control is not possible is said to have UNCONTROLLED SUPERHEAT.

Normally, the term *superheat control boiler* is used to identify a double-furnace boiler and the term *uncontrolled superheat boiler* or *noncontrolled superheat boiler* is used to identify a single-furnace boiler.

OPERATING PRESSURE

For some purposes, it is convenient to classify boilers according to operating pressure. Most classifications of this type are approximate rather than exact. Header-type boilers and some older drum-type boilers are often called 400-psi boilers even though the operating pressures may range from 30 psi (or even lower) to approximately 450 psi. The term *600-psi boiler* is often applied to various double-furnace and single-furnace boilers with operating pressures ranging from approximately 435 psi to approximately 700 psi.

The term *high-pressure boiler* is at present used rather loosely to identity any boiler that operates at a substantially higher pressure than the so-called 600-psi boilers. In general, we will consider any boiler that operates at 751 psi or above as a high-pressure boiler. Many boilers recently installed in naval ships operate at approximately 1200 psi. These boilers are referred to as 1200-psi boilers.

As you can see, classifying boilers by operating pressure is not very precise since actual operating pressures may vary widely within any one group. Also, any classification based on operating pressure may easily become obsolete. What is called a high-pressure boiler today may well be called a low-pressure boiler tomorrow.

BOILER COMPONENTS

Most propulsion boilers now used by the Navy have essentially the same components: steam and water drums, generating and circulating tubes, superheaters, economizers, and a number of accessories and fittings required for boiler operation and control.

DRUMS AND HEADERS

Drum-type boilers are installed in the ship in such a way that the long axis of the boiler drum runs fore and aft, rather than athwartships, so that the water will not surge from one end of the drum to the other as the ship rolls.

Steam Drum

The steam drum is located at the top of the boiler. It is cylindrical in shape, except that on some boilers the steam drum may be slightly flattened along its lower curved surface. The steam drum receives feedwater and serves as a place for the accumulation of the saturated steam which is generated in the tubes. The tubes enter the steam drum below the normal water level of the drum. The steam and water mixture from these tubes goes through separators, where the water is separated from the steam.

Figure 15-1 shows the construction of a steam drum. Two sheets of steel are rolled or bent to the required semicircular shape and are then welded together. The upper sheet is called the WRAPPER SHEET, the lower sheet is called the TUBE SHEET Notice that the tube sheet is thicker than the wrapper sheet. The extra thickness is required in the tube sheet

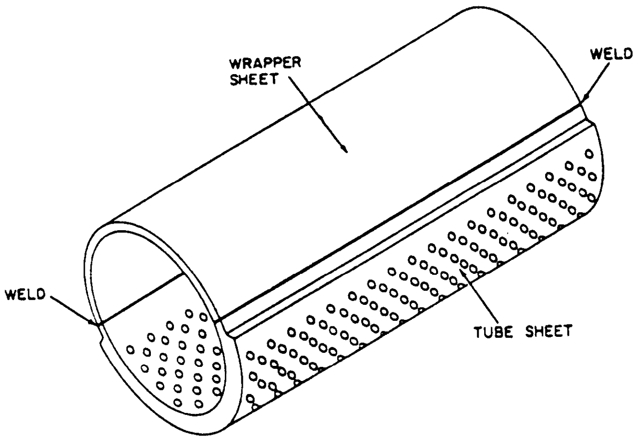


Figure 15-1.—Boiler steam drum.

to ensure adequate strength of the tube sheet after the holes for the generating tubes have been drilled.

The ends of the drums are closed with drumheads which are welded to the shell (as shown in fig. 15-2). At least one of the drumheads contains a manhole which permits access to the drum for inspection, cleaning, and repair; recently built boilers have a manhole in each drumhead.

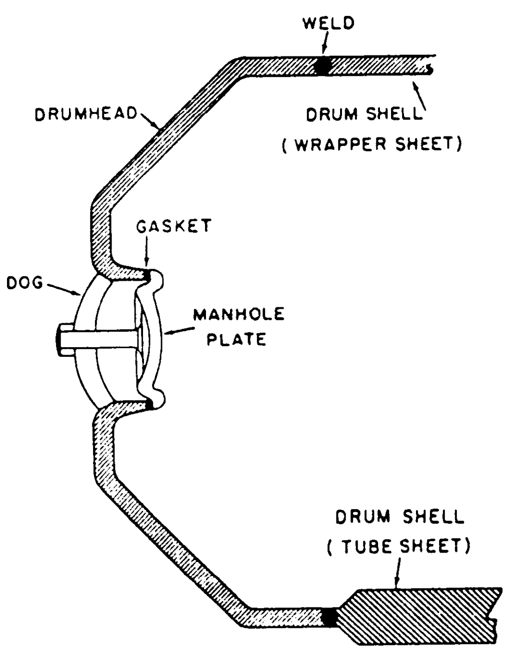


Figure 15-2.—Drumhead secured to steam drum.

The steam drum either contains or is connected to many of the important fittings and instruments required for boiler operation. Boiler fittings and instruments are discussed in chapter 16 of this training manual.

Water Drums and Headers

Water drums and headers equalize the distribution of water to the generating tubes and provide a place for the accumulation of loose scale and other solid matter that may be present in the boiler water. In drum-type boilers with natural circulation, the water drums and water headers are at the bottom of the boiler. Water drums are usually round. Headers may be round, oval, or square. Headers are provided with access openings, called handholes, of the type shown in figure 15-3. Water drums are usually provided with manholes similar to the manholes in steam drums.

GENERATING AND CIRCULATING TUBES

Most of the tubes in a boiler are generating and circulating tubes. There are four main kinds of generating and circulating tubes: (1) generating tubes in the main generating tube bank, (2) water wall tubes, (3) water screen tubes, and (4) downcomers. These tubes are made of steel similar to the steel used for the drums and headers. Most tubes in the main generating bank are about 1 inch or 1 1/4 inches in outside diameter. Water wall tubes, water screen tubes, and the two or three rows of generating tubes next to the furnace are generally a little larger. Downcomers are larger still, being approximately 3 to 11 inches in outside diameter.

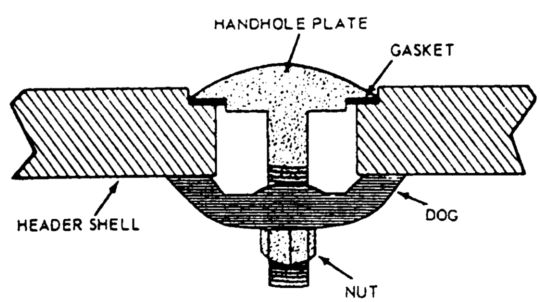


Figure 15-3.—Header handhole and handhole plate.

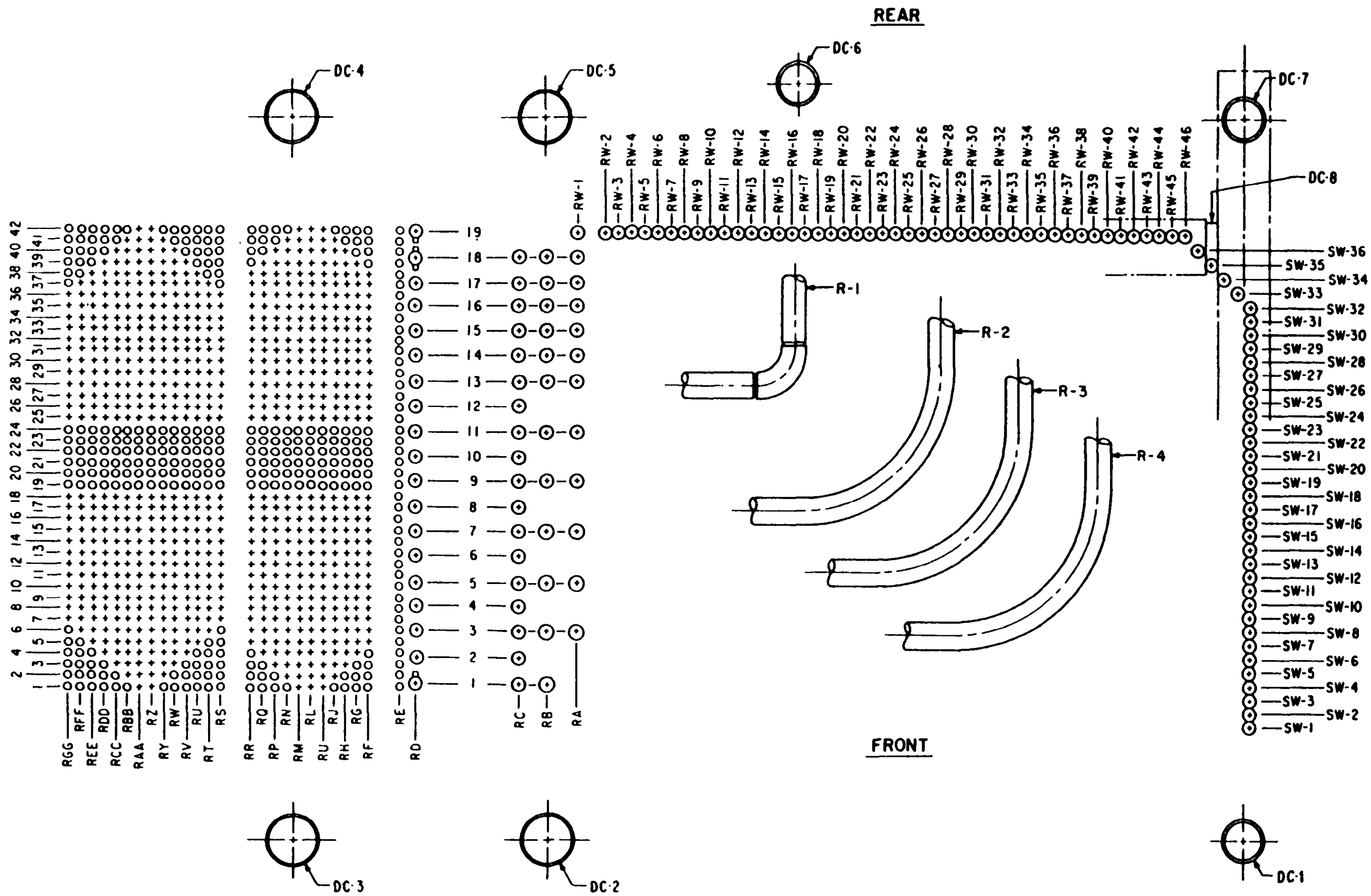


Figure 15-4.—Part of a boiler tube renewal sheet for a single-furnace boiler, showing tube identification.

Since the steam drum is at the top of the boiler and the water drums and headers are at the bottom, the generating and circulating tubes must be installed more or less vertically. In most cases, each tube enters the steam drum and the water drum, or header, normal to (that is, at right angles to) the drum surfaces. This means that all the tubes in any one row are curved in exactly the same way, but the curvature of different rows is not the same. Tubes are usually installed normal to the drum surfaces to allow the maximum number of tube holes to be drilled in the tube sheets with a minimum weakening of the drums. However, nonnormal installation is permitted if certain advantages in design can be achieved.

What purpose do all these generating and circulating tubes serve? Generating tubes provide the area in which most of the saturated steam is generated. The function of water wall tubes is to protect the furnace refractories, thus allowing higher heat release than would be possible without this protection. The water wall tubes are also generating tubes at high firing rates. Water screen tubes protect the superheater from direct radiant heat. Water screen tubes, like water wall tubes, are generating tubes at high firing rates. Downcomers are installed between the inner and outer casings of the boiler to carry the downward flow of relatively cool water and thus maintain the boiler circulation. Downcomers are not designed to be generating tubes.

In addition to the four main types of generating and circulation tubes just mentioned, there are a few large superheater support tubes which, in addition to providing partial support for the steam drum and for the superheater, serve as downcomers at low firing rates and as generating tubes at high firing rates.

Since a modern boiler is likely to contain between 1000 and 2000 tubes, some system of tube identification is essential. Generating and circulating tubes are identified by LETTERING on the rows of tubes and NUMBERING on the individual tubes in each row. A tube row runs from the front to the rear of the boiler. The row of tubes next to the furnace is row A, the next row is row B, the next is row C, and so forth. If there are more than 26 rows in a tube bank, the rows after 2 are lettered AA, BB, CC, DD, EE, and so forth. Each tube in each row is then designated by a number, beginning with 1 at the front of the boiler and numbering back toward the rear.

The letter that identifies a tube row is often preceded by an R or an L, particularly in the case of water screen tubes, superheater support tubes, and furnace division wall tubes. These letters may indicate that the tube is bent for either a right-hand or left-hand boiler. You should check your boiler manufacturer's technical manual to determine which boilers on your ship are right-or left-handed boilers.

Figures 15-4 and 15-5 show part of a boiler tube renewal sheet for a single-furnace boiler and illustrate the method use to identify tubes.

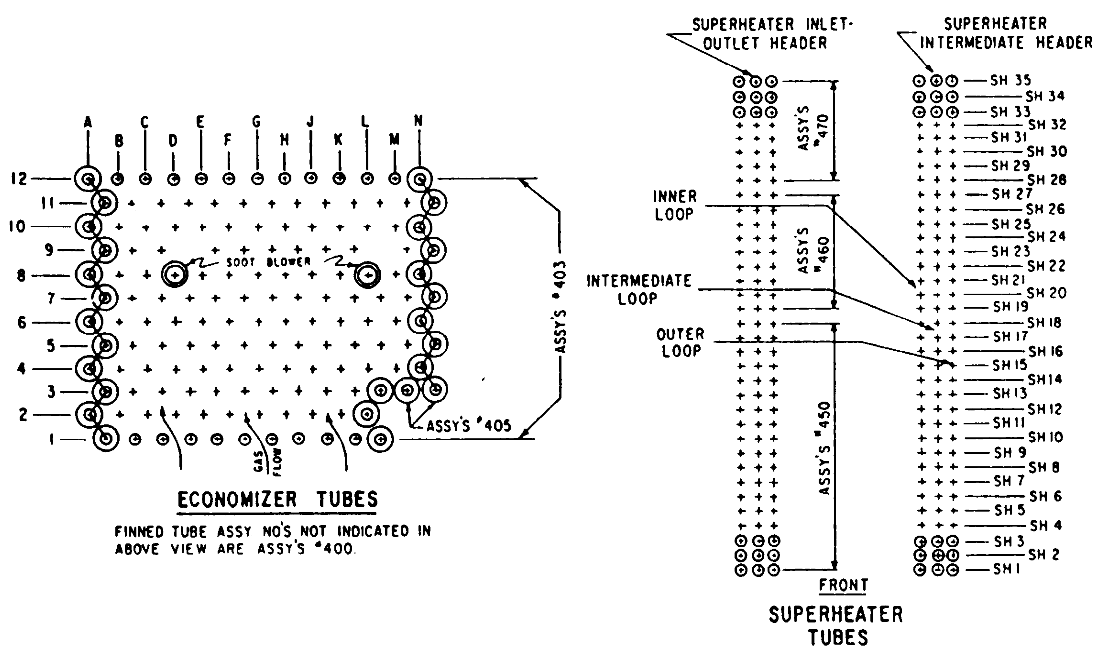


Figure 15-5.—Part of a boiler tube renewal sheet for a single-furnace boiler, showing tube identification.

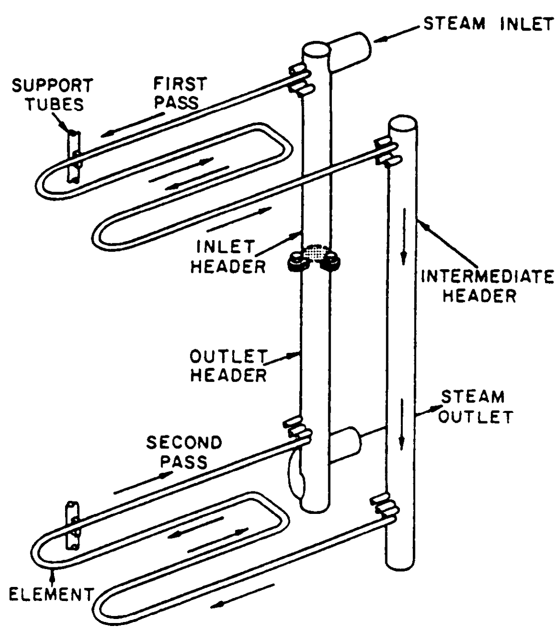


Figure 15-6.—Horizontal W-shaped tubes and steam flow through the superheater.

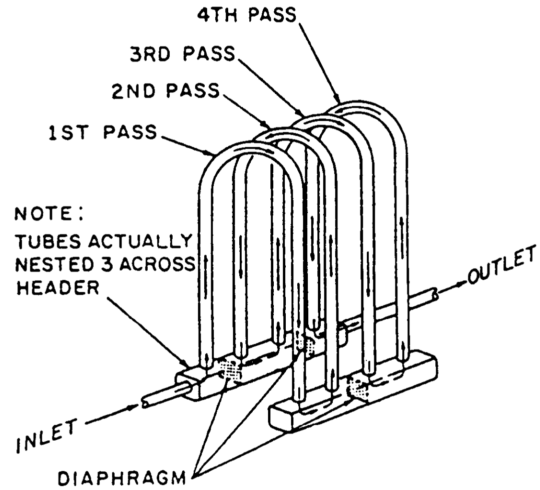


Figure 15-7.—Vertical U-shaped tubes and steam flow through the superheater.

The boiler tube renewal sheet, which is normally carried aboard ship, is one source of information on tube identification. Another source of information is the manufacturer's technical manual furnished with the boilers; some older technical manuals and most of the newer ones include a tube identification diagram. If precise identification of the boiler tubes cannot be made from either of these sources, you will have to consult the boiler plans to obtain the correct identification. You must also consult the boiler plans before ordering replacement tubes.

In all reports and correspondence concerning boiler tubes, proper identification and exact locations of the tubes is essential.

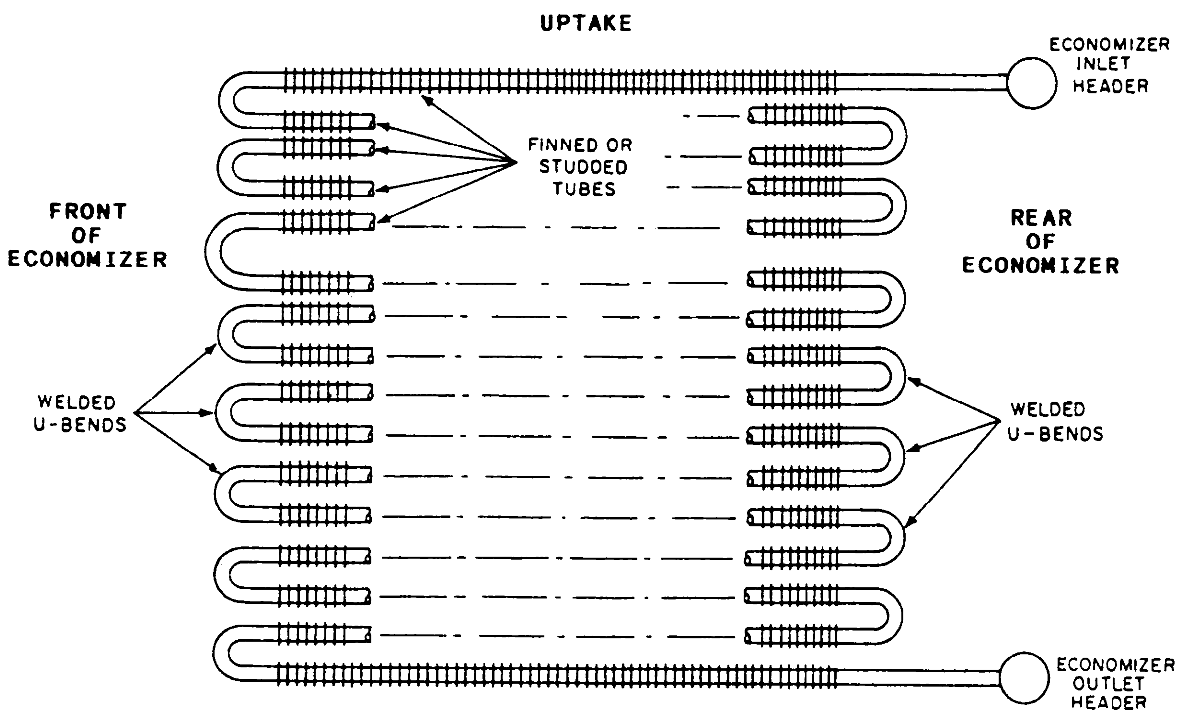


Figure 15-8.—Side view of economizer showing one element.

SUPERHEATERS

Propulsion boilers now in naval service have convection-type superheaters, with water screen tubes installed between the superheater tubes and the furnace to absorb the intense radiant heat and protect the superheater.

Most convection-type superheaters have U-shaped tubes, which are installed horizontally in the boiler, and two headers, which are installed more or less vertically at the rear of the boiler. One end of each U-shaped tube enters one superheater header, and the other end enters the other header. The superheater headers are divided internally by one or more division plates which act as baffles to direct the flow of steam. Some superheater headers are divided externally as well as internally.

The superheaters of some boilers have a WALK-IN or CAVITY-TYPE feature—an access space or cavity in the middle of the superheater tube bank. This cavity, which runs the full length and height of the superheater, provides accessibility for cleaning, maintenance, and repair. Some of the walk-in superheaters have U-shaped tubes; others have W-shaped tubes.

Some boilers have vertical, rather than horizontal, convection-type superheaters. In these boilers, the U-bend superheater tubes are installed almost vertically, with the U-bends near the top of the boiler; the tubes are approximately parallel to the main bank of generating tubes and the water screen tubes. Two superheater headers are near the bottom of the boiler, running horizontally from the front of the boiler to the rear.

Figures 15-6 and 15-7 illustrate the U- and the W-shaped tubes. U-shaped tubes are used with a vertical superheater, while the W-shaped tubes are used with a horizontal superheater. The arrows in the illustrations trace the steam flow through the superheater and show the number of passes the steam makes through the superheater.

ECONOMIZERS

An economizer is found on practically every propulsion boiler now in use by the Navy. The economizer is an arrangement of tubes installed in the uptake space from the furnace. The economizer tubes are heated by the rising gases of combustion. All feedwater flows through the economizer tubes before entering the steam drum and is warmed by heat, which would otherwise be wasted, as the combustion gases pass up the stack.

One type of economizer commonly used on naval propulsion boilers consists of two headers and a number of tube assemblies (or elements). The headers are at the rear of the economizer, with the inlet header at the top and the outlet header at the bottom. Each tube assembly (element) consists of a number of horizontal tubes, one above the other. The individual tubes are connected in sequence by U-bends at the tube ends, both at the rear of the economizer and at the front. The tube assemblies (elements) are arranged side by side in a casing. The top tube of each element is welded into the top, or inlet, header; the bottom tube of each element is welded into the bottom, or outlet, header. Thus, each element forms one continuous loop between the inlet header and the outlet header. The arrangement of one economizer element of this type is shown in figure 15-8.

Almost all economizer tubes have some sort of metal projections from the outer tube surfaces. These projections are called by various names, including FINS, STUDS, RINGS, and DISKS. They are made of aluminum, steel, or other metals, in a variety of shapes. Figure 15-9 illustrates three types of metal projections

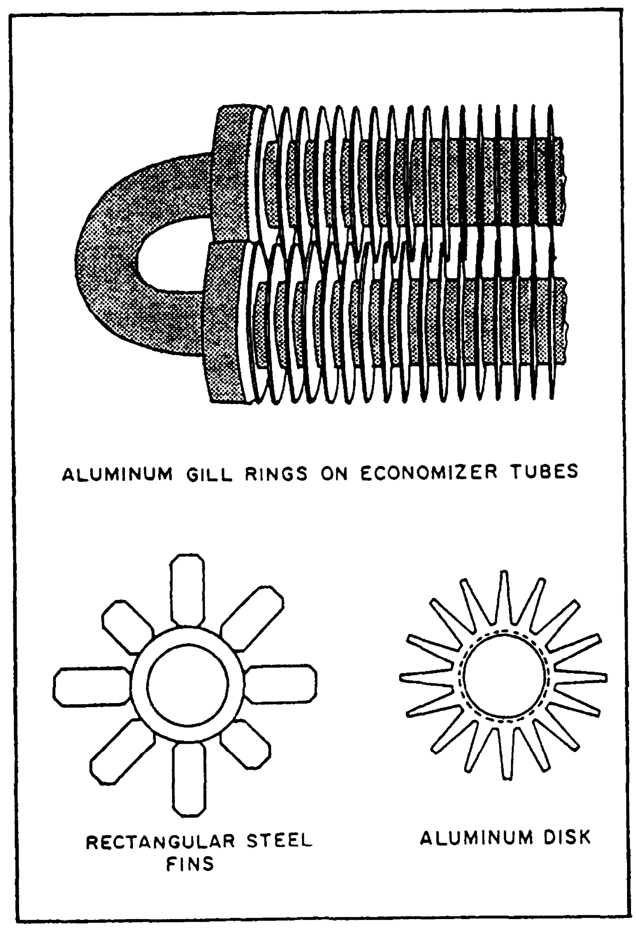


Figure15-9.—Three types of metal projections used on economizer.

that are used on economizer tubes. These projections serve to extend the heat transfer surface of the tubes on which they are installed.

FURNACES AND REFRACTORIES

A boiler furnace is a space provided for the mixing of fuel and air and for the combustion of the fuel. A boiler furnace consists of a more or less rectangular steel casing which is lined on the floor, front wall, side walls, and rear wall with refractory materials.

The refractory materials confine the heat to the firebox and protect the casing and structural members from overheating. Refractories are also used to form baffles, which direct the flow of combustion gases and protect drums, headers, and tubes from excessive heat and flame impingement.

REFRACTORY LINING LIFE FACTORS

The life of the furnace lining is influenced primarily by the quality of installation, the service environment, and the proper application of inspection criteria.

Quality of Installation

New refractory arangement drawings have been distributed widely for most boiler classes. These drawings include numerous improved arrangements and standardization features. They supersede all previous refractory arrangement drawings for applicable boilers and must be used when refractory is completely renewed and when major repairs are made. Before installing refractory, you should consult the drawing applicable to your boiler class for details such as location and type of anchors, thicknesses and types of materials, expansion joints, and clearances to tubes.

Service Environment

Service environment refers to the operation of boilers.

SUSTAINED HIGH FURNACE TEMPERATURE.—Refractory materials obtained from the Naval Supply System are tested and selected to provide a margin of safety relative to maximum temperature attainable at areas where they are designated on refractory arrangement drawings. It is unlikely that designated refractory can be damaged by overheating in a properly maintained and operated boiler.

RAPID CHANGES IN TEMPERATURE.—Ability to withstand sudden temperature changes is a factor in selecting the refractories for naval boiler use. However, rapid changes in temperature can be reduced to a minimum by intelligent boiler operation. Steam should never be formed in a cold boiler any faster than necessary. Refractories previously baked out and fired are more sensitive to rapid cooling than to rapid heating. When a boiler is secured, it should be closed up as tightly as possible and the furnace should be allowed to cool slowly. Since, however, emergencies do arise, occasionally these precautions must be ignored. The brickwork will probably stand the abuse, but its life will be shortened. Continued abuse could bring on furnace problems that will necessitate repairs.

SHOCK AND VIBRATION.—As shown on applicable drawings, all areas of refractory must be anchored or held in position by one of the following methods:

1. Brick bolts. Applicable to firebrick laid 4 1/2 inches thick and to burner tile.

2. Anchor strips. Applicable to castable refractory and plastic refractory.

3. Boiler tubes. As an example, superheater screen tubes, rear wall, and side wall tubes in D-type boilers do retain adjacent refractory.

Relatively small areas of castable refractory and plastic refractory may be keyed-in by cutting back the sides of adjacent brickwork.

Where other methods are not adequate, nichrome wire may be used to anchor small areas of castable refractory.

NOTE: Nichrome wire is considered an anchoring device, not a reinforcement. Also, nichrome wire must not be used with plastic because it interferes with proper pounding of the plastic.

PANTING OF THE BOILER.—Vibration or panting must be provided for by carefully laying up and securely anchoring the refractory; however, the strongest refractory will not withstand continuous and heavy vibration indefinitely. This is especially true of plastic or castable settings, such as burner fronts. Burner-front plates must be sufficiently rigid to reduce panting and vibration effects to a minimum.

If undue panting or vibration occurs, an effort should be made to determine its cause and, if practical, correct it. Panting is usually attributable to deficiency of air, excessive oil temperature, or poor air-oil intermixture.

Poor air-oil intermixture may be caused by improper register settings, improper atomizer withdrawal, or severe warping of burner parts. If the difficulty cannot be corrected by the ship's force, NAVSEA must be advised, and all pertinent information available which may aid in determining corrective measures must be given.

SLAG ACTION.—Slag does not form on refractories when distillate fuel is burned unless there is heavy and prolonged seawater contamination of the oil. Slagging is a slow, progessive action which is accelerated by oils having high ash content and by full power operation. The mere presence of molten slag on refractory is not a sound basis for refractory renewal; thickness of refractory remaining or other factors should govern the need for renewal. Mixtures of distillate fuel and Navy special fuel oil (NSFO) may result in slagging, depending on the proportions of the mixture and the duration of burning the mixture.

SCALE AND SOOT.—Scale and soot removed when cleaning firesides must be swept out of the furnace. Presence of this refuse on refractories lowers their melting point and contributes to slag formation. Sweeping of the furnace should be followed by cleaning the refuse from the expansion joints to allow the brickwork to expand freely when it is heated. Hard slag should not be chipped from refractory, except where interfering on burner throat rings or where slag accumulation on a floor causes carbon accumulation.

TYPES OF REFRACTORY MATERIALS

The following refractory and insulation materials are stocked in the Navy supply system and are approved for use as shown on applicable refractory arrangement drawings. Other materials are not used except in an emergency.

Firebrick

The purpose of firebrick is to provide structural stability and to protect backup insulation from maximum temperatures, flame erosion, slag attack, and rapid temperature change. Firebrick must not be substituted if drawings specify insulating brick; increased heat loss and higher casing temperature would result. MIL-B-15606, grade A, is the type most generally used and shown on refractory arrangement drawings. MIL-B-15606, grade B, has a slightly lower maximum use temperature and is less resistant to slag attack, but it is equivalent to grade A in other respects. Grade A firebrick is used in furnace areas. Grade B is used in the superheater cavities of D-type boilers.

Firebrick have relatively poor insulation value, less than 1/10 that of insulation block MIL-I-2819.

Insulating Brick

Two types of insulating brick are commonly used in naval boilers: MIL-B-16008 and MIL-B-16305, class B.

MIL-B-16008 is used only for back-up insulation behind firebrick, plastic, or castable refractory.

MIL-B-16305, class B, is used as a gas-side layer at such lower temperature areas of D-type boilers as at the main generating bank areas and behind tangent sidewall and roof tubes. MIL-B-16008 brick have better insulating value but less strength and high temperature capability than MIL-B-16305, class B, brick. The insulating value of both types is intermediate between that of firebrick and insulation block.

Insulation Block MIL-I-2819, Class 3

Insulation block, used as the first layer on the inside of inner casings, is capable of withstanding surface temperatures up to 815°C (1500°F) when protected by other refractory from gas erosion and slag attack. Its physical strength is relatively low but adequate for its intended use. Its insulating value is much greater than other furnace lining components.

Refractory Mortar MIL-M-15842

Class 1 mortar is shipped in dry form and requires mixing with water before its use. Class 2 mortar is furnished ready-mixed, but may require mixing with additional water to obtain the proper consistency. Class 1 mortar is preferred in general use. Class 2 mortar is used when laying MIL-B-16305, class 2, insulating brick. Insulating brick absorbs moisture from class 1 mortar so quickly that proper thin joints cannot be obtained easily. Both types of mortar are air-setting; that is, they develop strength after drying without being heated. The primary purpose of mortar is to seal joints in brickwork or tile installations and to cushion the pieces against concentrated stresses.

Burner Tile

MIL-B-15606, grade A, tile are available in various sizes and shapes for specific burner types. They can be used only with specific burner types for which they are designed.

Castable Fireclay Refractory MIL-C-717

Castable refractory is about equal to firebrick in maximum use temperature, but it is usually less durable because of lower strength. It contains a hydraulic-setting binder and develops strength without heating in a manner similar to concrete. It is installed by casting, tampering, or ramming, depending on circumstances. Large areas, such as a complete burner front, require use of a suitable form. Castable refractory is preferred to plastic refractory for small repairs or where standard size brick or tile cannot be used. Castable refractory must be air-cured for 2 days or longer before baking out. Baking out after an air cure of only 1 day may cause poor performance because of low strength. Performance is sensitive to installation technique and anchoring. Castable fireclay refractory MIL-C-717 is now used in other areas where plastic chrome ore was formerly used.

Plastic Fireclay Refractory MIL-P-15731

Plastic refractory has lower strength and slightly more shrinkage than castable refractory. It develops strength only after heating at about 1095°C (2000°F) or higher temperatures. Plastic refractory use should be avoided in low temperature areas. Plastic refractory's performance is sensitive to installation technique and anchoring.

Baffle Tile

Baffle tile is made of silicon carbide. They are characterized by high strength, good dimensional stability, and resistance to rapid temperature change, and low insulating value. Baffle tile is available in several sizes and is shaped to fit between 2-inch outside diameter (OD) tubes.

Castable Insulation MIL-C-19794

Castable insulation has good insulating value, moderate temperature resistance, but low strength. It is an approved substitute for insulating brick and insulating block (but not for insulating block only) in certain boiler walls. It is not suitable for use in a wall previously provided with 2-inch thick insulation block, in floors, or as a gas-side layer. Its advantage is the speed and economy of installation since handcutting of insulation or brick bolts is eliminated.

Plastic Chrome Ore MIL-P-15384

Plastic chrome ore is composed of chrome ore (rather than fireclay or aluminum silicates) and bonding agents which give it pronounced air-setting properties. It is used primarily on studded tubes in divided furnace boilers. Prolonged air-drying of plastic chrome ore (periods of a week or longer) should be avoided to minimized shrinkage and migration of chemical binder.

Chrome Castable MIL-C-15413

Chrome castable is composed of chromium ore and a hydraulic-setting binder. It is used primarily on studded tube walls in M-type boilers when early bake-out is not feasible. It is also used for repairing plastic chrome ore on studded tube walls. Chrome castable can be replaced with castable fireclay refractory MIL-C-717 in areas where chrome castable was formerly used. Chrome castable must be given 2 days or more air-curing before baking out.

Insulating Cement MIL-C-2861

Insulating cement is composed of mineral wool fibers and clay binder. It is an insulating space-filler used between insulation block and casing in certain boiler classes (as shown on applicable drawings). It is also used to fill voids in insulation block layers at missing corners or at cut-outs for anchor devices and to provide a straight backing for insulation block where minor casing warping has occurred. Insulating cement may also be used with certain other machinery insulation arrangements.

Anchor Devices

Anchor devices come in several forms to accommodate various specific anchoring requirements.

Anchor bolts and retainers for firebrick and burner tile are as shown in figure 15-10. Only one of the two anchor bolt slots in 9-inch long brick need to be used. In some instances, when indicated on applicable refractory arrangement drawings, the two end slots on 13 9/16-inch long brick may be used. Brick bolt retaining strips must be welded to inner casing by ring fillet welds, not merely by tack welds.

Anchors for castable or plastic refractory must be of the pennant type or suitable modification as shown

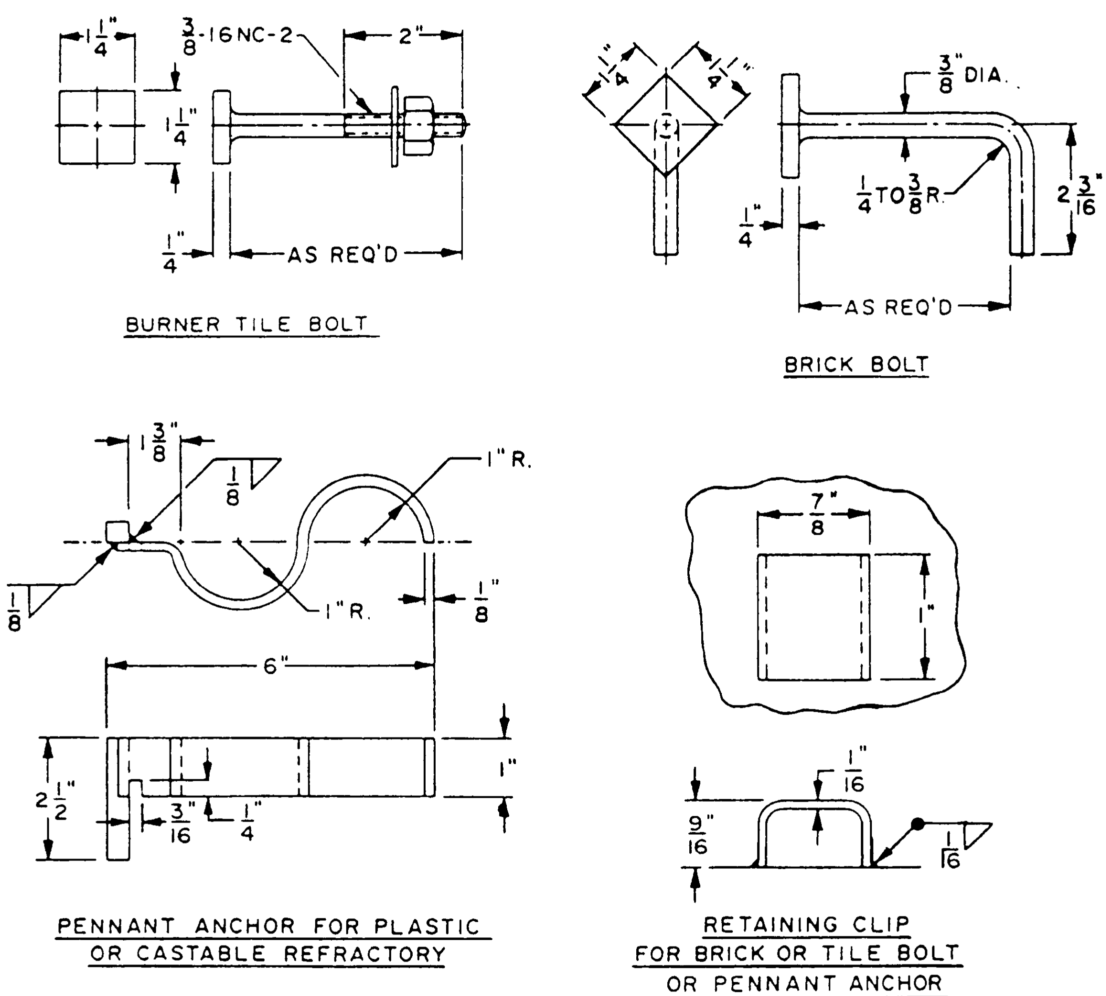


Figure 15-10.—Refractory anchor devices.

in figure 15-11. At furnace areas, the unsupported end of the anchor must extended to l/2 to 1 inch from the gas-side surface of the refractory. The anchors may be cut or compressed slightly in length by bending to suit conditions. For large areas, anchors should be spaced about 10 to 12 inches apart, but optimum spacing is influenced by configuration. Brick or burner tile anchors should be used to anchor castable or plastic refractory unless the pennant type shown in figure 15-10 is not available.

HANDLING AND STORAGE REFRACTORY MATERIALS

Refractory bricks are packed in cartons for convenient storage and handling. All refractory

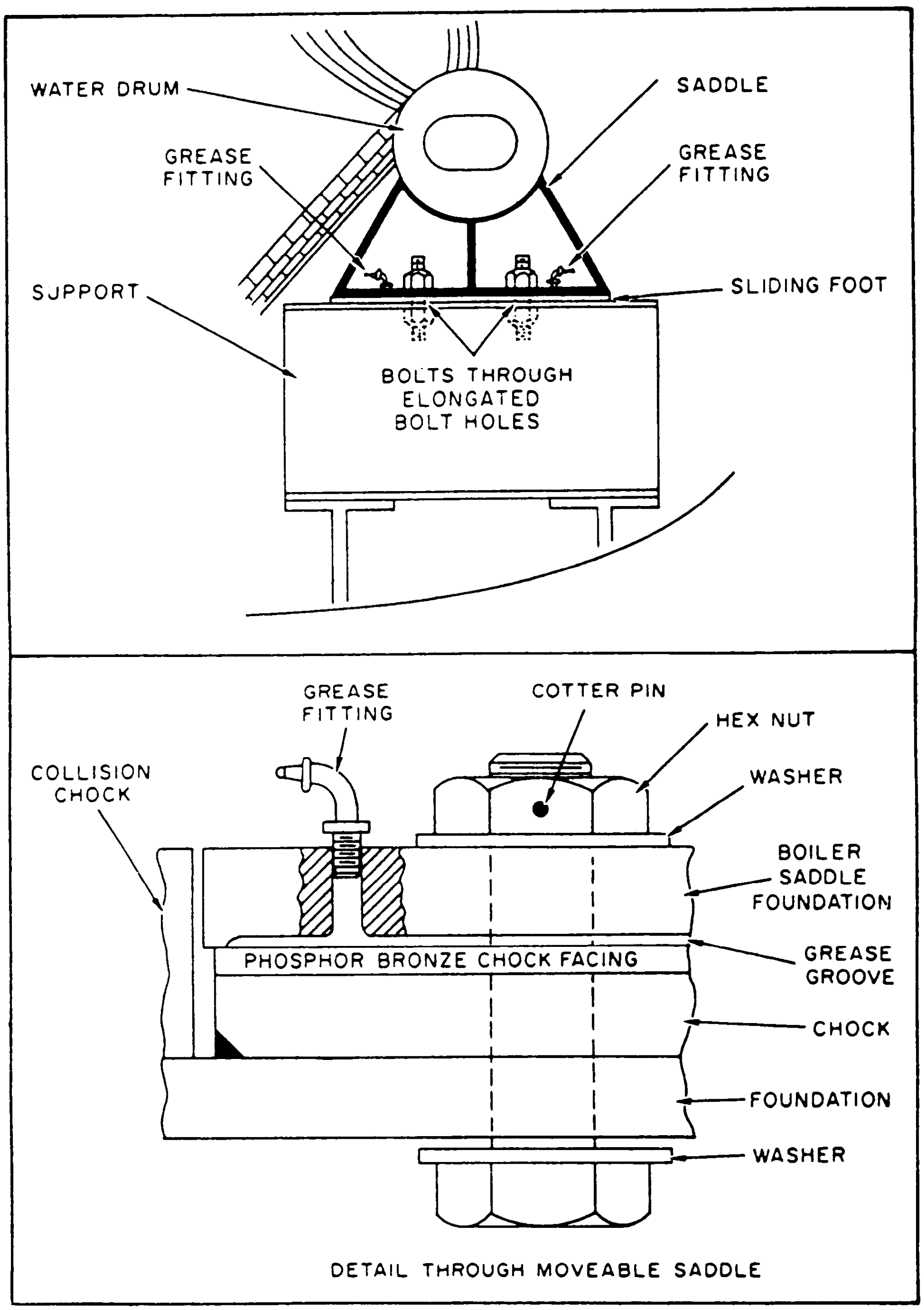


Figure 15-11.—Boiler saddle, support, and sliding feet.

materials should be stored in a weatherproof enclosed or compartment protected from seawater spray or accidental flooding. Insulating brick, insulating block, and material in bags are especially sensitive to moisture. Castable refractory in damaged or previously opened bags absorbs moisture from the atmosphere. The result is deterioration and hardening. If a bag of castable refractory contains hard, clustered lumps, the entire contents must be discarded. Plastic refractory requires only protection from drying out before installation and may be used regardless of age, as long as its workability is satisfactory. Remixing dried plastic refractory with additional water is likely to result in poor service. Plastic refractory and class 2 refractory mortar are subjected to freezing. If frozen, the material must be slowly and completely thawed before use.

EXPANSION JOINTS

Unless shown otherwise on the applicable refractory arrangement drawing, expansion joints in the firebrick layer should be l/4 inch wide. Expansion joints are constructed by either of two ways: Styrofoam or a l/5-inch thick, 3- to 5-foot piece of metal.

1. Styrofoam must be carefully cut to provide a uniform l/5-inch thickness. The Styrofoam is left in place to burn away during boiler operation. When this method is used, installation of insulating layers is started at an expansion joint, and a split firebrick (1 l/4 inches thick by 4 l/2 inches by 9 inches) is placed immediately behind the expansion joint.

2. The l/5-inch thick by approximately 3- or 5-foot long piece of metal is equipped with handles which are used to remove the metal when brickwork at an area is completed. When all brickwork in the boiler is completed, the expansion spaces are filled with loosely packed Fiberfrax FC-25. Whenever this method is used, installation of insulation need not start at an expansion joint, and the use of a split firebrick behind the joint is not necessary.

CASINGS, UPTAKES, AND SMOKEPIPES

In modern boiler installations, each boiler is enclosed in two steel casings. The inner casing is lined with refractory materials, and the enclosed space forms the boiler furnace. The outer casing extends around most of the inner casing, with an air space in between. At the boiler front, the outer casing usually comes up to a line just above the level of the top burner opening. Air from the forced draft blowers is forced into the space between the inner and the outer casings; from there the air flows through the registers into the furnace.

The inner casing encloses most of the boiler up to the uptakes. The uptakes join the boiler to the smokepipe. As a rule, the uptakes from two or more boilers connect with one smokepipe.

Both the inner and the outer casings are made of steel panels. The panels may be either flanged and bolted together (with gaskets used at the joints to make an airtight seal) or they may be of welded construction (except for the access doors).

SADDLES AND SUPPORTS

Each water drum and water header rests upon two saddles, one at the front of the drum or header and one at the rear. The upper flanges of the saddles are curved to fit the curvature of the drum or header and are welded to the drum or header. The bottom flanges are flat and rest on huge beams built up from the ship’s structure. The bottom flange of one of the saddles is bolted rigidly to its support. The bottom flange of the other saddle is also bolted to its support, but the bolt holes are elongated in a fore-and-aft direction. As the drum expands or contracts, the saddle that is not rigidly fastened to the support accommodates to the changing length of the drum by sliding forward or backward over the support. The flanges that are not rigidly fastened are known as BOILER SLIDING FEET. Figure 15-11 shows the general arrangement of the saddle, support, and sliding feet.

OTHER BOILER COMPONENTS

The major boiler components previously described in this chapter could not function properly without certain accessories, fittings, instruments, and control devices. Although these additional boiler parts are discussed in detail in other chapters of this manual, they are mentioned briefly at this point to provide a complete picture of what a boiler is and what components it requires.

FUEL-OIL BURNERS

Fuel-oil burners are discussed in chapter 16 of this manual. Several types of fuel-oil burners are now in use by the Navy. All serve the same basic purpose of mixing fuel and air so that combustion can take place.

INTERNAL FITTINGS

Internal fittings installed in the steam drum include equipment for (1) distributing the incoming feedwater, (2) separating and drying the steam, (3) giving surface blows to remove solid matter from the water, (4) directing the flow of steam and water within the steam drum, and (5) injecting chemicals for boiler water treatment. In addition, single-furnace boilers have desuperheaters for desuperheating the steam needed for auxiliary purposes. The desuperheater, which may be installed in either the steam drum or in the water drum, is referred to as an internal fitting.

EXTERNAL FITTINGS AND INSTRUMENTS

External fittings and instruments include drains and vents, sampling connections, feed stop and check valves, steam stop valves, safety valves, soot blowers, water gauge glasses and remote water level indicators, pressure and temperature gauges, superheater temperature alarms, superheater steam flow indicators, smoke indicators, oil drip detector periscopes, and feedwater regulators. These external fittings and instruments are also discussed in chapter 16 of this manual.

BOILER CONTROL SYSTEMS

Boiler control systems are installed on most boilers for the automatic control of combustion and water level. These systems are discussed in chapter 17 of this manual.

SINGLE-FURNACE PROPULSION BOILERS

Now that we have examined the basic components used in most naval boilers, let's put them together and see how they are arranged to form the boilers now in use in the propulsion plants of naval ships.

Since the majority of propulsion boilers used in the Navy are of the single-furnace type, we will discuss only this type. If your ship has another type, consult the appropriate manufacturer's manual or *Naval Ships' Technical Manual,* chapter 221.

COMBUSTION AIR AND GAS FLOW

Study figure 15-12 as you read this section. Combustion air is discharged from forced air draft blowers through duct work to the rear wall casing of each boiler. There are two blowers per boiler. In the duct work from each blower there are automatic shutters that permit the flow of air to the boiler but prevent reverse flow, air loss to an idle blower, and windmilling of the idle blower. The combustion air flows between the inner casing and the outer casing of the rear wall. The greater portion of the air travels down under the boiler between the boiler floor and the ship's hull to the front of the boiler. A small portion of the air flows between the two casings, around the side or back of the boiler to the front wall. The air circulating between the casings picks up some of the heat lost by the boiler and reduces the temperature of the outer casing. The heat recovered increases the temperature combustion and helps increase the overall boiler efficiency.

The primary combustion air passes through the registers and the burner diffuser to be mixed with the atomized oil. The boiler throat ring is equipped with vanes or blades, which give a swirling motion to the air by bypassing the diffuser (secondary air) to provide better mixing with the fuel. When the burner is in operation, the register doors should always be wide open to permit unrestricted airflow. When the burner is secured, the doors should be closed tightly.

It is at this point that the ignition takes place. Complete combustion takes place within the furnace. The gases of combustion heat the side and rear wall tubes. Water circulating within the tubes prevents overheating and tube burn-up.

The gases of combustion exit the furnace through the screen tubes. The function of the screen tubes is to greatly reduce direct flame impingement on the superheater tubes when the boiler is operating. From the screen tubes the gas flows through the superheater its cavity to the main generating bank. From the main bank the gas flows upward through the economizer and into the uptakes.

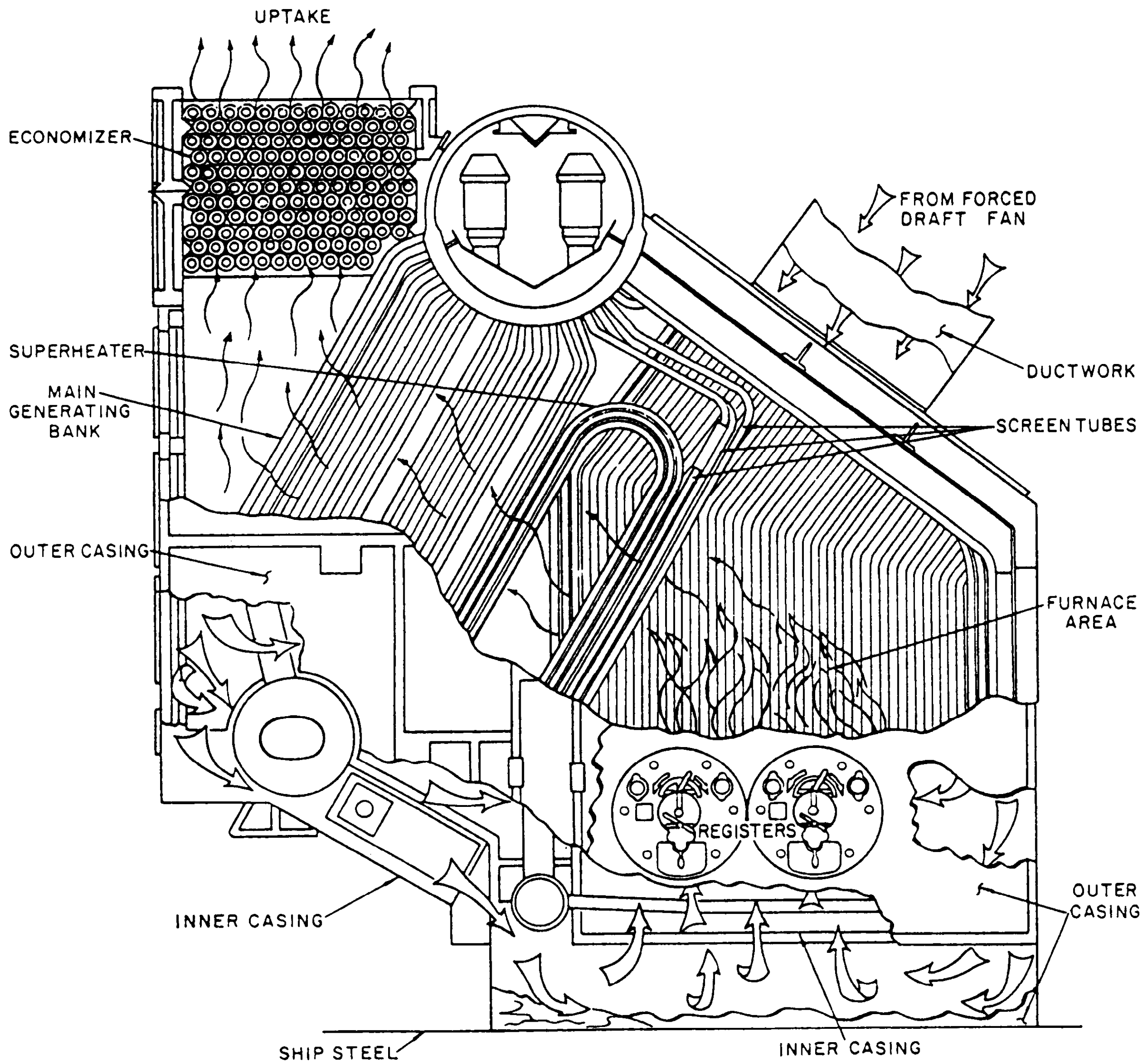


Figure 15-12.—Combustion air and gas flow.

BOILER WATER AND STEAM CIRCULATION

Study figure 15-13 as you read this section. Feedwater enters the economizer inlet header located at the top of the economizer. The inlet header connects to horizontal aluminum finned tubes which run perpendicular to the gas flow. Feedwater travels through these tubes and back through another set of finned tubes by U-bends. Each plane of 13 tubes is referred to as a row of economizer tubes. The feedwater passes through these rows of tubes before exiting the economizer through the outlet header. During full power conditions, the feedwater temperature is increased approximately 190°F (from 250°F to 440°F).

Feedwater enters the steam drum through a nozzle located in the rear drum head. Inside the steam drum, the water is directed below the normal water level by an internal pipe. This internal pipe, called a feed pipe, has holes which allow the water to disperse evenly along the length of the drum.

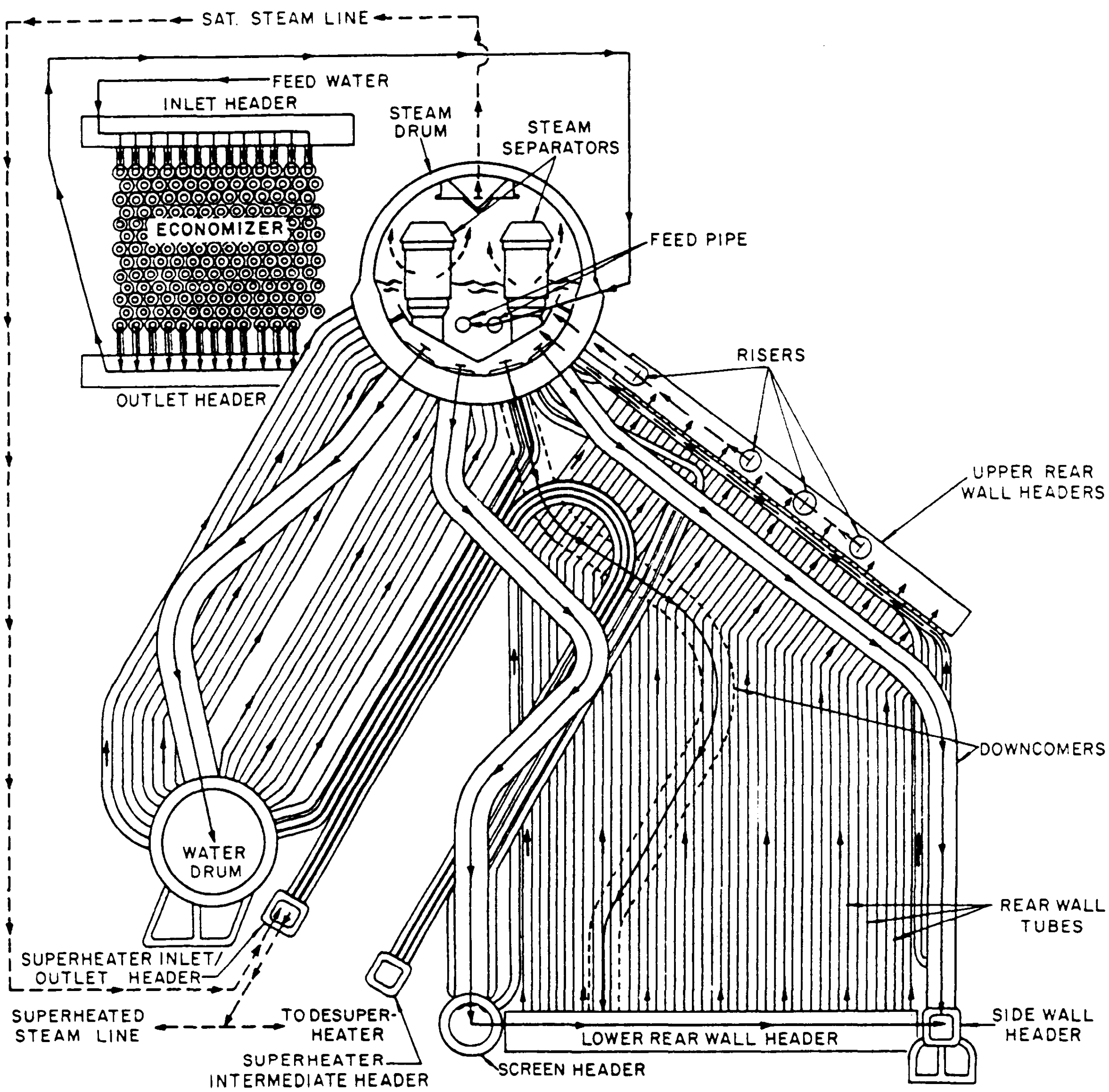


Figure 15-13.—Boiler water and steam flow.

The boiler in figure 15-13 is a natural-circulation type. The cooler, denser water flows downward to the water drum, while the heated, less dense mixture of steam and water in the tubes rises to the steam drum.

Downcomers are large distribution pipes. They ensure a positive flow of water to the lower parts of the boiler. Downcomers extend from the steam drum to the water drum, screen header, lower rear wall header, and sidewall header. They are located between the inner and outer casings and are kept relatively cool by the flow of combustion air to the burners.

The hot gases of combination heat the water in the generating, side wall, rear wall, and screen tubes. As the water is heated in these areas, the density is decreased and the water starts to rise. Continuing up the tubes, a portion of the water changes to steam. The water and steam mixture from the side wall screen tubes and generating bank enters the steam drum under the deflection plate assembly. The water and steam mixture from the rear wall travels upward to the upper rear wall header to the lower portion of the steam drum through riser pipes.

Steam separators connected to the deflection plate assembly permit steam to flow from under the deflection plate assembly to the top half of the steam drum. The steam separators separate the steam and water mixture by centrifugal action. The water falls back into the lower half of the steam drum while the steam rises to the dry box. The dry box extends longitudinally along the top of the drum. Saturated steam leaves the dry box through the saturated steam outlet nozzle located on top of the steam drum.

The saturated steam is piped from the steam drum nozzle to the superheater inlet/outlet header. The steam is directed through the superheater tubes by diaphragms located in the inlet/outlet and intermediate headers. The steam makes four passes, during which it is heated to superheat temperature.

Once the steam leaves the superheater via the inlet/outlet header it is split in two directions. The majority of the steam is directed to the main engines. A small portion of the steam is directed to the desuperheater. The desuperheater, located in the water drum, reduces the temperature of the superheated steam to that needed for use with auxiliary equipment.

How would you classify this boiler? On the basis of the classification methods previously discussed, we may consider this single-furnace boiler as one that has the following characteristics. It is a water-tube boiler with natural circulation of the accelerated type. It is a drum-type boiler with tubes that are arranged rougly in the shape of the letter *D;* hence, it is often called a D-type boiler. It has a convection-type superheater. It has only one furnace, which is not pressurized. This type boiler is used on 600-psi ships and 1200-psi ships.

Keep an open mind on the subject of boilers. New types of boilers are constantly being designed and tested, and existing boiler types are subject to modification. If you think the desuperheater is always installed in the steam drum of a single-furnace boiler, look again. You may find it installed in the water drum. If you think all superheater tubes are U-shaped, look at some of the W-shaped superheater tubes on newer boilers. And so it goes. You will have to be constantly on the alert to keep up with new developments in boiler design.

CHAPTER 16

BOILER FITTINGS AND INSTRUMENTS

Many fittings and instruments are used on naval boilers. Boiler fittings are attachments installed in, or closely connected to, the boiler. They are usually referred to as either internal or external fittings. Internal fittings (or internals) are installed inside the steam and water spaces of the boiler. External fittings (or externals) are installed outside the steam and water spaces. Boiler instruments, such as pressure gauges and temperature gauges, are regarded as external boiler fittings.

After reading this chapter, you will be able to identify internal and external fittings, and you will understand how each fitting operates with the boiler. You will also understand the basic procedures that must be followed when operating a boiler.

INTERNAL FITTINGS

The internal fittings installed in the steam drum include equipment for distributing the incoming feedwater, for giving surface blows, for separating steam and water, and for directing the flow of steam and water within the steam drum. Desuperheaters are heat exchangers that lower the temperature of superheated steam. The steam can then be used by auxiliary machinery. Desuperheaters are located in either the water drum or the steam drum of a boiler.

Internal fittings in some boilers also include equipment that injects chemicals for boiler- water treatment.

The specific design and arrangement of boiler internal fittings vary somewhat from one type of boiler to another and from one boiler manufacturer to another. Figures 16-1, 16-2, and 16-3 show typical arrangements of internals for single-furnace boilers. For comparison, figure 16-4 shows another arrangement of internals in a single-furnace boiler.

The following sections describe boiler fittings most commonly used on naval boilers.

STEAM DRUM INTERNAL FITTINGS

Follow the numbers on figure 16-2 as we discuss the operation of steam drum internals.

The internal feedwater pipe (9) extends along the entire length of the bottom of the steam drum. Feedwater enters the pipe from the economizer and is evenly distributed throughout the length of the drum.

The chemical feed pipe (11) extends straight through approximately 90 percent of the length of the drum just below the normal water level. It connects to the chemical feed nozzle on the end of the drum. A row of holes is located along the top center line. The prescribed chemicals, consistent with the requirements of the periodic feedwater analysis, are injected through the chemical feed pipe into the boiler.

The dry pipe (15), which collects the steam, is suspended near the top of the steam drum and runs the entire length of the drum. The top of the dry pipe is perforated throughout its entire length. The holes are located along the top of the dry pipe to prevent moisture from entering the pipe. Connections from the dry pipe pass through the top of the steam drum to the saturated steam outlet (l), where the steam passes to the superheater.

The surface blow pipe (8), located just below the normal water level of the drum, also extends the full length of the drum. It has a single row of holes drilled into its top. When the surface blow valve is open, this pipe carries off scum and foam from the surface of the water in the drum.

A continuous baffle (5) is fitted approximately 3 inches from the drum's internal surface. The baffle extends from just forward of the generating tubes to just aft of them. It does not extend as far as the downcomers in each end. The forward and after ends of the space

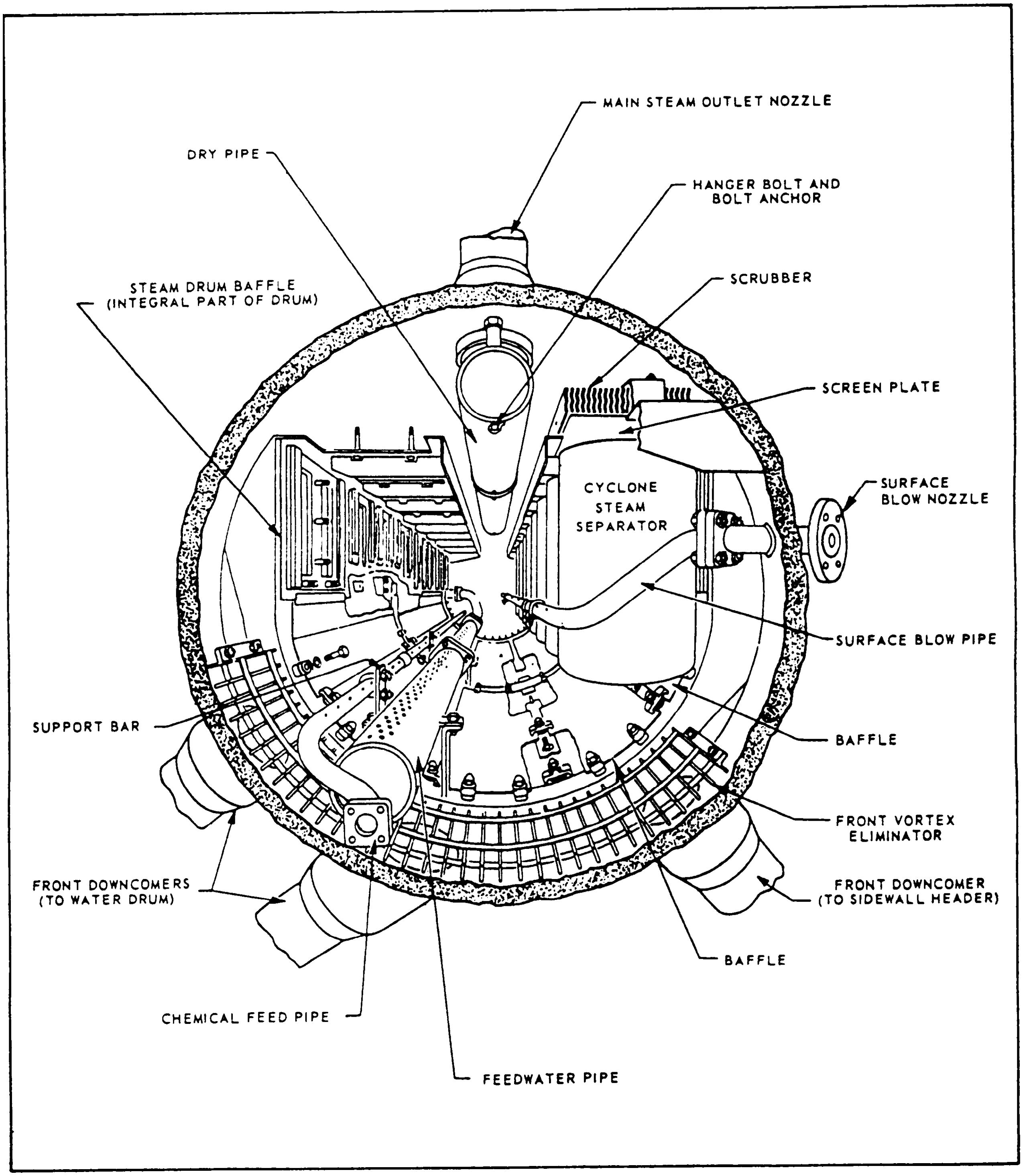
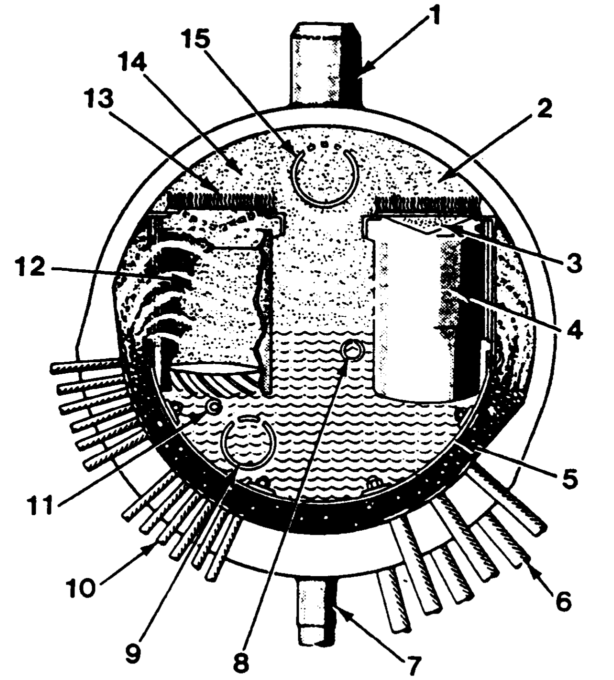
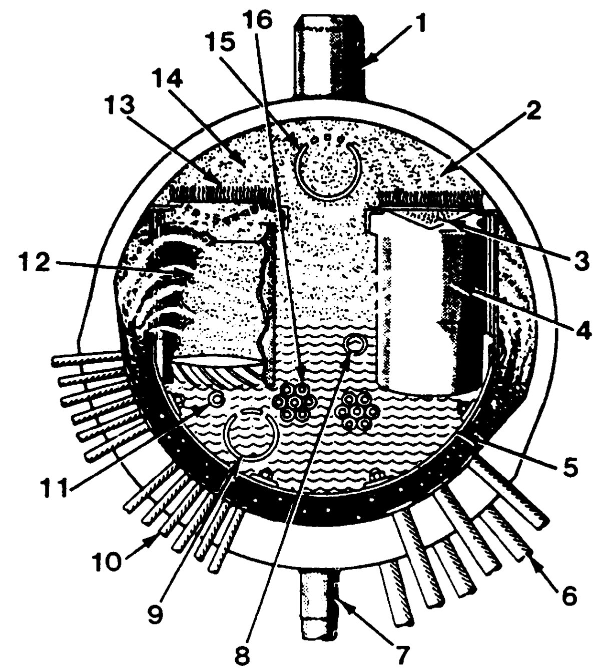


Figure 16-1.—Arrangement of internal fittings in a single-furnace boiler.



1. SATURATED STEAM OUTLET TO SUPERHEATER
2. STEAM
3. PERFORATED STRAINER
4. CYCLONE SEPARATOR
5. BAFFLE
6. SCREEN TUBES
7. SUPERHEATER SUPPORT TUBES
8. SURFACE BLOW PIPE
9. INTERNAL FEEDWATER PIPE
10. GENERATING TUBES
11. CHEMICAL FEED PIPE
12. STEAM INLET TO SEPARATOR
13. SCRUBBER
14. STEAM
15. DRY PIPE

Figure 16-2.—A steam drum.



1. SATURATED STEAM OUTLET TO SUPERHEATER
2. STEAM
3. PERFORATED STRAINER
4. CYCLONE SEPARATOR
5. BAFFLE
6. SCREEN TUBES
7. SUPERHEATER SUPPORT TUBES
8. SURFACE BLOW PIPE
9. INTERNAL FEEDWATER PIPE
10. GENERATING TUBES
11. CHEMICAL FEED PIPE
12. STEAM INLET TO SEPARATOR
13. SCRUBBER
14. DRY PIPE
15. DESUPERHEATER TUBES

Figure 16-3.—A steam drum with a desuperheater in the steam drum.

left between the baffle and the drum are closed. The baffle is attached at both sides to a flat bar, which is hung from the drum as shown, and extends the full length of the baffle. Ports are cut into each of these flat bars. Over each of these ports is placed a cyclone separator (4). This arrangement makes the space between the steam drum and the baffle an entirely enclosed space, with the exception of the ports leading to the cyclone separators.

The flow of steam and water through the drum is as follows: Water enters the drum through the internal feedwater pipe and flows through the downcomers to the water drum and to the side and rear wall headers. The generating tubes (10) discharge a mixture of steam and water upward into the space behind the baffle in the steam drum. The circulation from the sidewall headers is upward through the sidewall to the spaces in the drum behind the baffle. The circulation from the rear wall

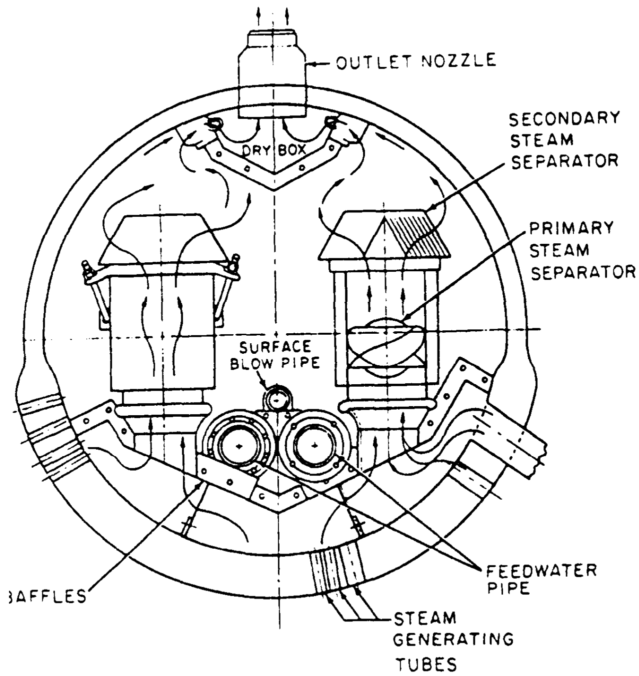


Figure 16-4.—Arrangement of steam drum internals in a single-furnace boiler.

header is up through the tubes to the upper rear wall header where tubes distribute the mixture of steam and water to the space behind the baffle in the steam drum. Since this space is entirely enclosed, the only passage (12) available for the steam and water is through the ports opening to the the cyclone separators. The separators on each side of the drum have sufficient capacity to pass all the steam and water that may flow through them. As the mixture passes through the cyclone separators, the steam is separated from the water and passes through the top of the separator. The water discharges from the bottom of the separator. As the steam leaves the cyclone separator, it passes through a scrubber (13) where it is further dried and then, finally, is led to the top of the drum where it enters the dry pipe.

Another interesting feature is illustrated in figure 16-1. It is the vortex eliminator, which reduces the swirling motion of the water as it enters the downcomers. A vortex eliminator consists of a series of gridlike plates arranged in a semicircle to conform to the shape of the lower half of the steam drum. One vortex eliminator is located at the front of the steam drum and another is located at the rear of the drum. In each case, the vortex eliminator is fitted over the ends of the downcomers.

As mentioned earlier, the desuperheater may be located in either the steam drum or in the water drum. The purpose of the desuperheater is to reduce the temperature of a portion of the superheated steam intended to be used in auxiliary steam systems. Figure 16-2 illustrates a steam drum without the desuperheater, and figure 16-3 shows one with the desuperheater (2). This is the only difference between the two steam drums.

STEAM DRUM INTERNALS

The internals in this section operate similarly to the ones discussed previously.

Primary Separators

The first step in the separation of steam and water in some boilers is performed by two primary separators (fig. 16-4). Each primary separator consists of a cylindrical shell with four inside spinner blades secured to dished heads.

The mixture of steam and water is directed into the primary separator through a lower support (not shown). As the steam passes up through the separator, the fixed spinner blades force the steam into a swirling motion. The heavier water is thrown to the sides, where it collects and drops back into the lower half of the drum. The lighter steam rises into the secondary separator.

Secondary Separators

Secondary separators are made of several corrugated plates in the shape of an inverted basket. They are located on top of, and are bolted to, the primary separators. The corrugated plates further separate the steam and water mixture by creating rapid changes in steam flow direction. The steam can adapt to these rapid changes but the heavier water cannot. The water collects and falls back into the lower portion of the steam drum.

Cyclone Separators

The purpose of the cyclone separators is to deliver dry saturated steam to the dry pipe with minimum agitation of the water, thereby reducing the possibility of priming. Priming takes place when boiler water is carried over into the superheater of a boiler.

The details of a cyclone separator with its strainer and scrubber are shown on the drawings of the internal fittings (figs. 16-1, 16-2, and 16-3). The steam enters the separator through its inlet connection, which is tangent to the separator body. Entering on this tangent, the steam meets the water, and the blades of the separator create a rotating motion in the mixture. Due to its weight, the water is thrown toward the side of the cyclone separator body, where the rapid change in direction helps to separate the water from the steam. Being lighter, the steam rises through the center toward the perforated strainer, while the heavy water drops down toward the base of the separator.

Curved stationary vanes near the bottom of the separator maintain the rotary motion of the water until it is finally discharged from the bottom of the separator. In the center of the separator, there is a flat plate to which the curved vanes are attached. The plate keeps the steam in the center of the separator and prevents its being carried out of the bottom by the water. The vanes, being located around the periphery of the plate, allow the water to pass from the separator around the outer edges of the body only.

The two end cyclone separators, one on each side, are fitted at their bases with a flat baffle. The baffle directs the flow of water from the separator to the center of the steam drum, where it is mixed thoroughly with the rest of the water in the steam drum and is kept from flowing directly from the separator into the downcomers.

Dry Box

The dry box is designed to separate any steam and water mixture not separated by the separators. The dry box works on the same principle as the separator (rapid change in direction). At either end of the dry box, there is a drain hole where collected water may drop back into the lower half of the steam drum.

Since there are other boiler manufacturers, and there are other differences between designs and arrangements which we have not covered, it is important that you be aware of these differences and consult the manufacturers' technical manuals when working on the boilers on your ship.

EXTERNAL FITTINGS AND CONNECTIONS

External fittings and connections commonly used on naval boilers include drains and vents, sampling connections, feed stop and check valves, steam stop valves, safety valves, soot blowers, blow valves, water gauge glasses, remote water-level indicators, superheater steam flow indicators, pressure and temperature gauges, superheater temperature alarms, smoke indicators, oil-drip detector periscopes, three-element feedwater regulators, steam-smothering systems, and other devices that are closely connected to the boiler but not installed in the steam and water spaces.

Any listing of boiler external fittings and connections tends to sound like a catalog of miscellaneous and unrelated hardware. Actually, however, all of the external fittings and connections serve purposes that are related to boiler operation. Some of the fittings and connections allow you to control the flow of feedwater and steam. Others serve as safety devices. Still others allow you to perform operational procedures—removing soot from the firesides, for example, or giving surface blows—that are necessary for efficient functioning of the boiler. The instruments attached to or installed near the boiler give you essential information concerning the conditions existing inside the boiler. To understand the purposes of the external fittings and connections, you must know how each item is related to boiler operation.

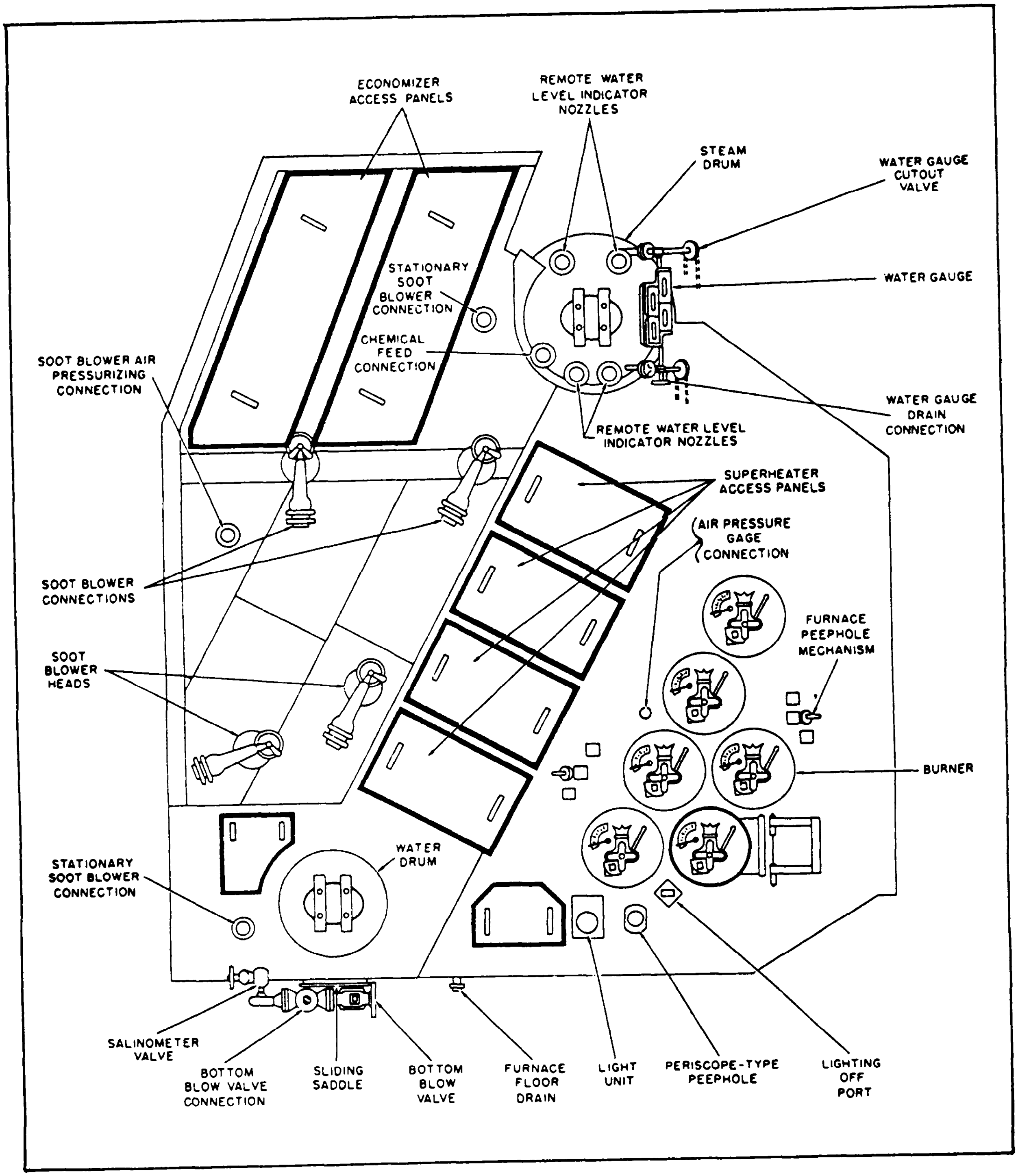


Figure 16-5.—External fittings and connections on a single-furnace boiler (front view).

Figures 16-5, 16-6, 16-7, and 16-8 show the locations of many external fittings and connections on a single-furnace boiler. As you study the following information on external fittings and connections, you may find it helpful to refer to these figures to see where the various units are installed on, or connected to, the boiler. Keep in mind, however, that the illustrations shown here are for one particular boiler, and differences

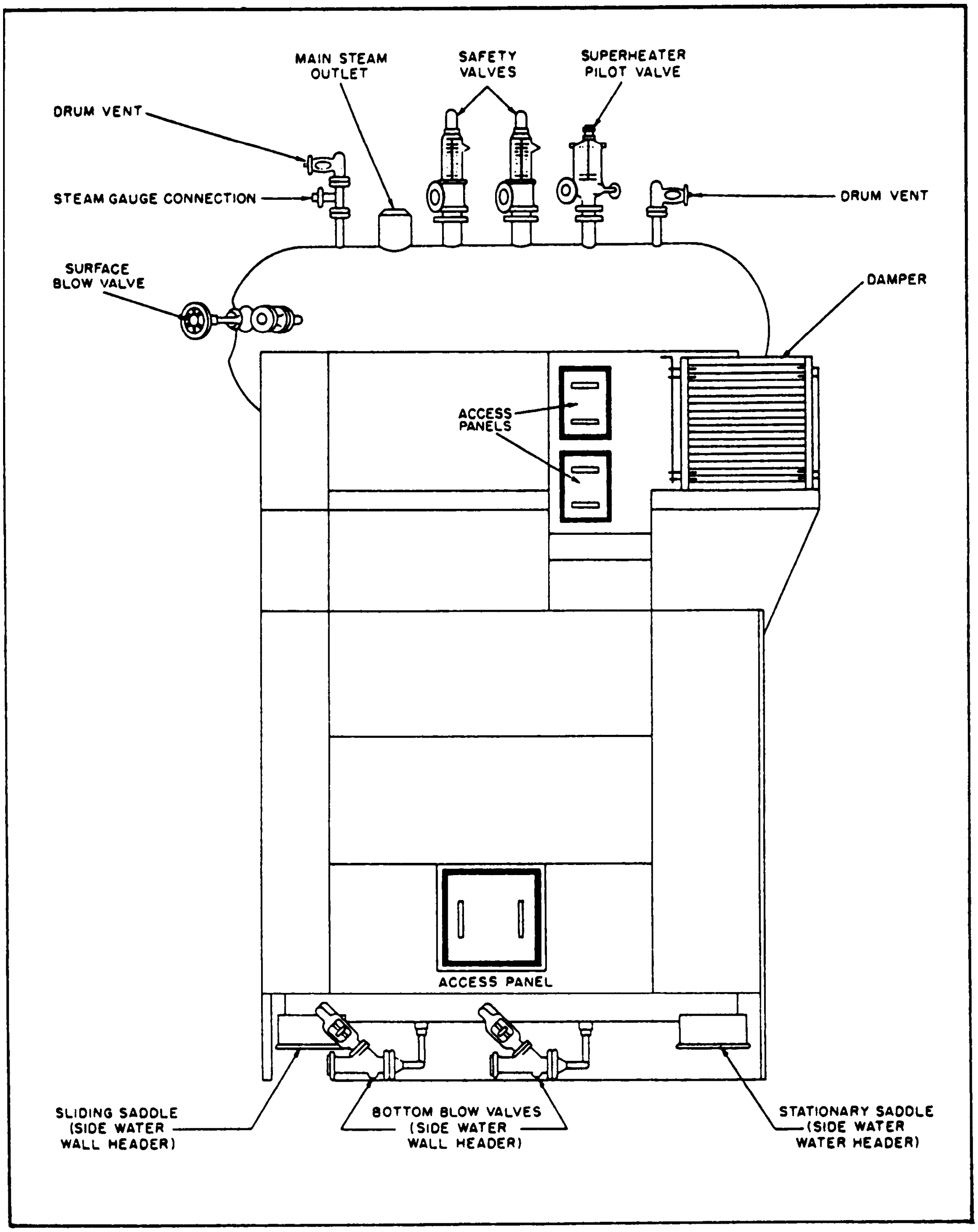


Figure 16-6.—External fittings and connections on a single-furnace boiler (side view).

in boiler design result in differences as to type and location of external fittings and connections. Drawings showing the location of external fittings and connections are usually included in the manufacturers' technical manuals for the boilers aboard each ship.

DRAINS AND VENTS

All the steam and water sections of the boiler, including the main part of the boiler, the economizer,

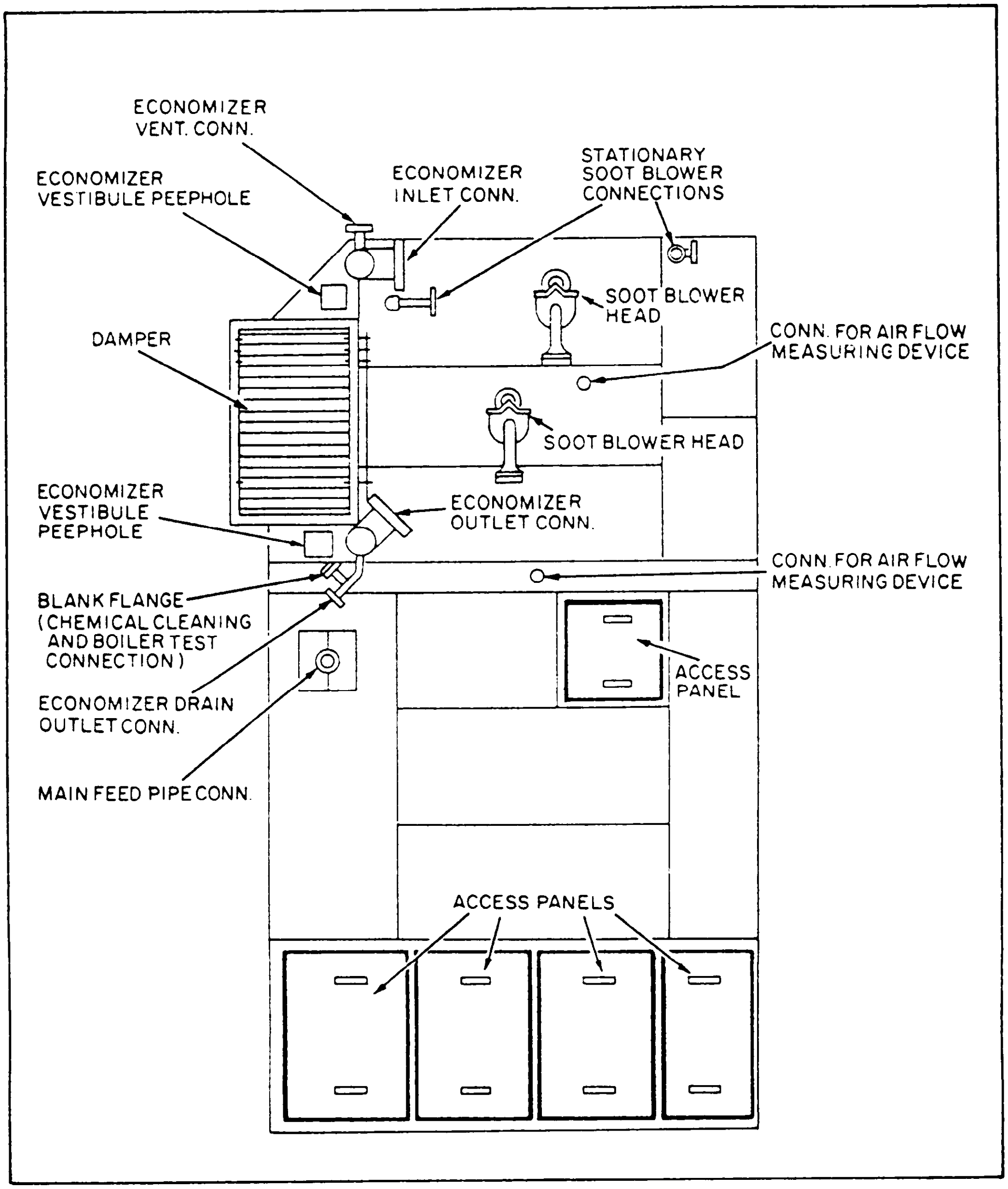


Figure 16-7.—External fittings and connections on a single-furnace boiler (economizer side view).

and the superheater, must be provided with drains and vents.

The main part of the boiler may be drained through the bottom blow valve and through water wall header drain valves. Normally, a boiler is vented through the aircock, which is a high-pressure globe valve installed at the highest point of the steam drum. The aircock allows air to escape when the boiler is being filled and when steam is first forming; it also allows air to enter the steam drum when the boiler is being emptied.

The economizer is vented through a vent valve on the economizer inlet piping. It is drained through a drain line from the economizer outlet header. Another drain line, coming from the drain pan installed below the headers, serves as an indicator of possible economizer leakage.

Superheater vents are installed at or near the top of each superheater header or header section; superheater drains are installed at or near the bottom of each header or header section. Thus, each pass of the superheater is vented and drained.

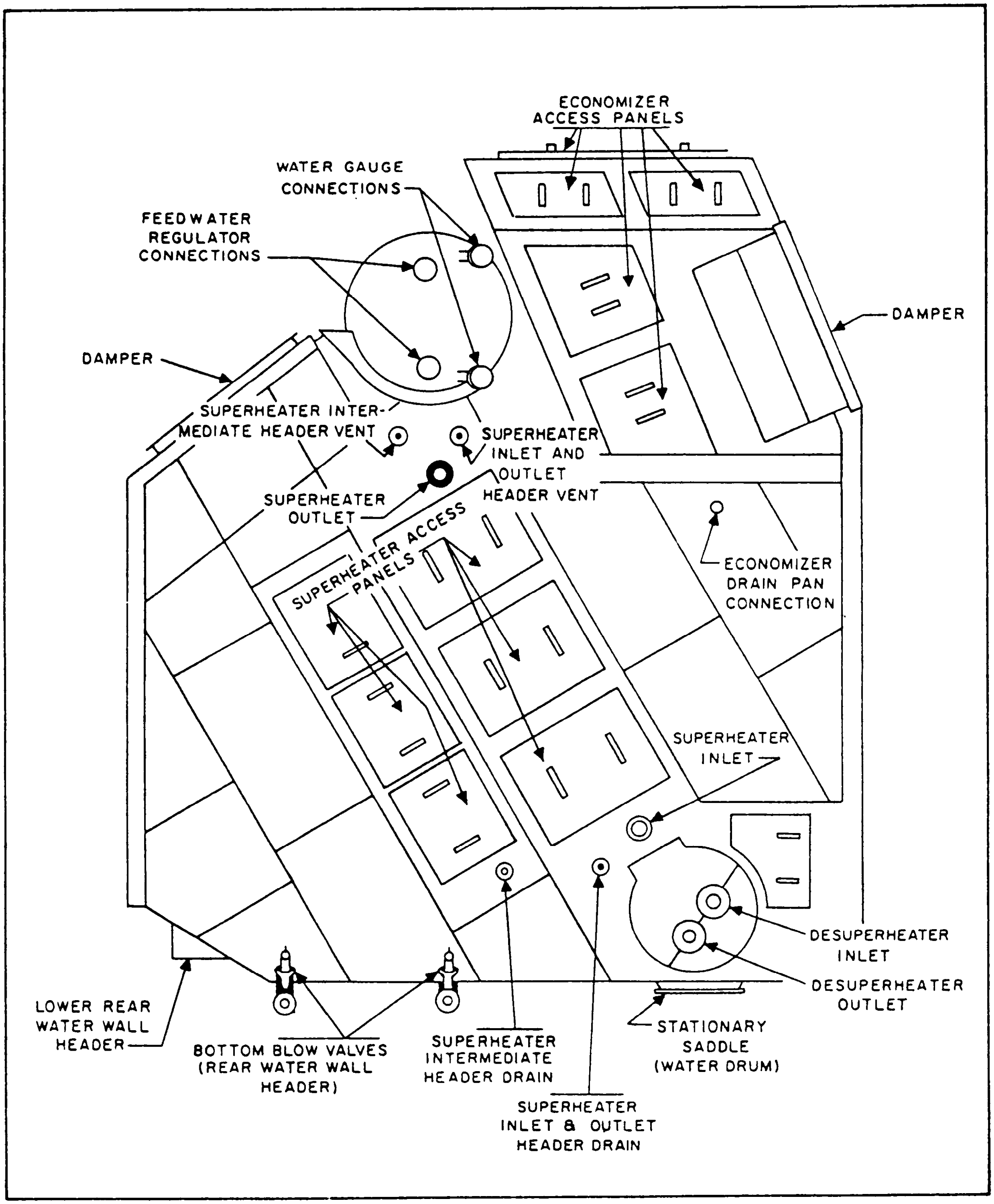


Figure 16-8.—External fittings and connections on a single-furnace boiler (rear view).

Superheater drains discharge through gravity (open-funnel) drains to the freshwater drain collecting system while steam is being raised in the boiler. After a specified pressure has been reached, the superheater drains are shifted to discharge through steam traps to the high-pressure drain system. The steam traps allow continuous drainage of the superheater without excessive loss of steam or pressure.

Figure 16-9 shows the arrangment of superheater vents and drains on a single-furnace boiler, as well as the superheater protection steam connections.

SAMPLING CONNECTIONS

To determine and condition of boiler water, tests must be performed on a representative sample of the boiler water. One can easily see that a sample can be obtained from the steam drum, the gauge glass, the water drum, or a header. A sample of boiler water taken from the water drum has the greatest probability of being representative of the water in the boiler. However, a sample from the water drum is only representative of the dissolved solids (material) in the boiler water. No sample can be considered representative of the suspended solids (sludge) in the boiler.

The boiler water sample cooling coil is placed on a line that is connected to the blowdown line from the water drum. At least two valves are on the sample line between the water drum and the cooling coil. The cooling coil brings the temperature of the sample water below the boiling point at atmospheric pressure and thus keeps the water from flashing into steam as it is drawn from the higher pressure of the boiler to the lower pressure of the fireroom.

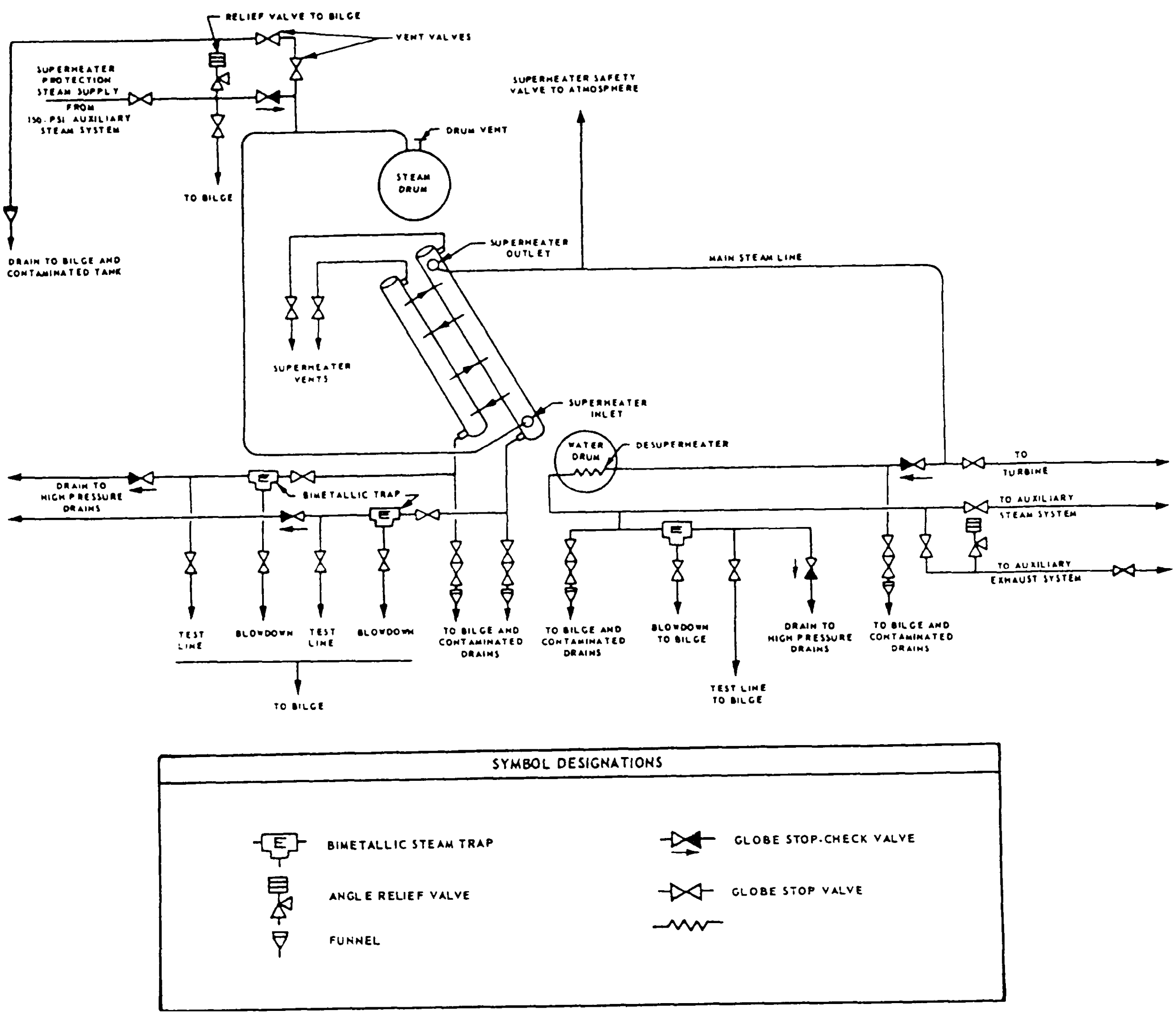


Figure 16-9.—Diagrammatic arrangement of superheater vents, drains, and protection steam connections.

STOP-CHECK VALVES

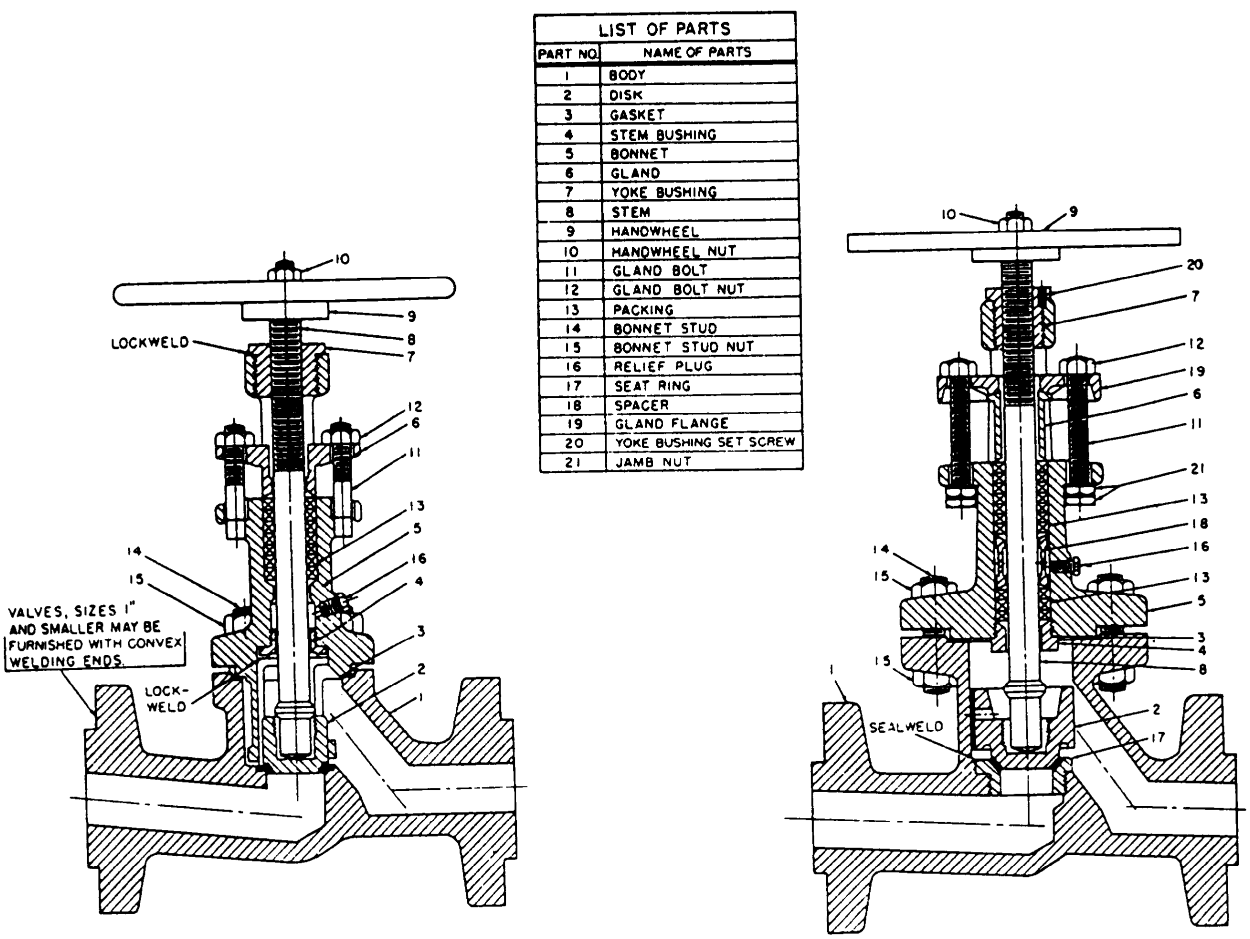
As you have seen, most valves can be classified as being either stop valves or check valves. Some valves, however, can function as either a stop or a check valve, depending on the position of the valve stem. These valves are known as STOP-CHECK VALVES.

Two similar stop-check valves are shown in a cross section in figure 16-10. As you can see, the flow and operating principles of this type of valve very much resemble the check valve. However, the stem is long enough so that when it is screwed all the way down, it holds the disk firmly against the seat. This prevents any flow of fluid. In this position, the valve acts as a stop valve. When the stem is raised, the disk can be opened by pressure on the inlet side. In this position, the valve acts as a check valve, allowing the flow of fluid in only one direction. The maximum lift of the disk is controlled by the position of the valve stem. Therefore, the position of the valve stem can limit the amount of fluid passing through the valve even when the valve is operating as a check valve.

Stop-check valves are used in various locations throughout the engineering plant. Perhaps the most familiar example is the boiler feed-check valve, which is actually a stop-check valve rather than a true check valve. Stop-check valves are used in many drain lines, on the discharge side of many pumps, and so exhaust steam valves on auxiliary machinery.

STEAM STOP VALVES

Main steam stop valves are used to connect and disconnect boilers to the main steam line. The main steam stop valve, located just after the superheater outlet, is usually called the MAIN STEAM BOILER



PART NO.	NAME OF PARTS
1	BODY
2	DISK
3	GASKET
4	STEM BUSHING
5	BONNET
6	GLAND
7	YOKE BUSHING
8	STEM
9	HANDWHEEL
10	HANDWHEEL NUT
11	GLAND BOLT
12	GLAND BOLT NUT
13	PACKING
14	BONNET STUD
15	BONNET STUD NUT
16	RELIEF PLUG
17	SEAT RING
18	SPACER
19	GLAND FLANGE
20	YOKE BUSHING SET SCREW
21	JAMB NUT

Figure 16-10.—Stop-check valves.

STOP. Figure 16-11 shows a cross-sectional view of a gate-type main steam stop (motor-operated).

The main steam boiler stop is either fully open or fully closed—that is, it is not used as a throttling valve. The valve can be operated manually either at the valve or at a remote operating station or by remote operating gear, which is also provided. Many steam stops are now fitted with pneumatic (air) motors which are actuated through toggle operating gear to close the valve from a remote position. The toggle operating gear provides the mechanical advantage required to close the valve against boiler pressure. These valves are opened manually.

Main steam boiler stops, like other main steam stop valves, are specifically designed for high-pressure and high-temperature service. The seating surfaces of the disks and seats are usually made of Stellite, a hard, erosion-resistant alloy.

Two-valve protection for each boiler is required on all ships built to U.S. Navy specifications. A second steam stop valve is therefore provided in the main steam line just beyond the main steam boiler stop. This second valve is called the main steam stop guarding valve.

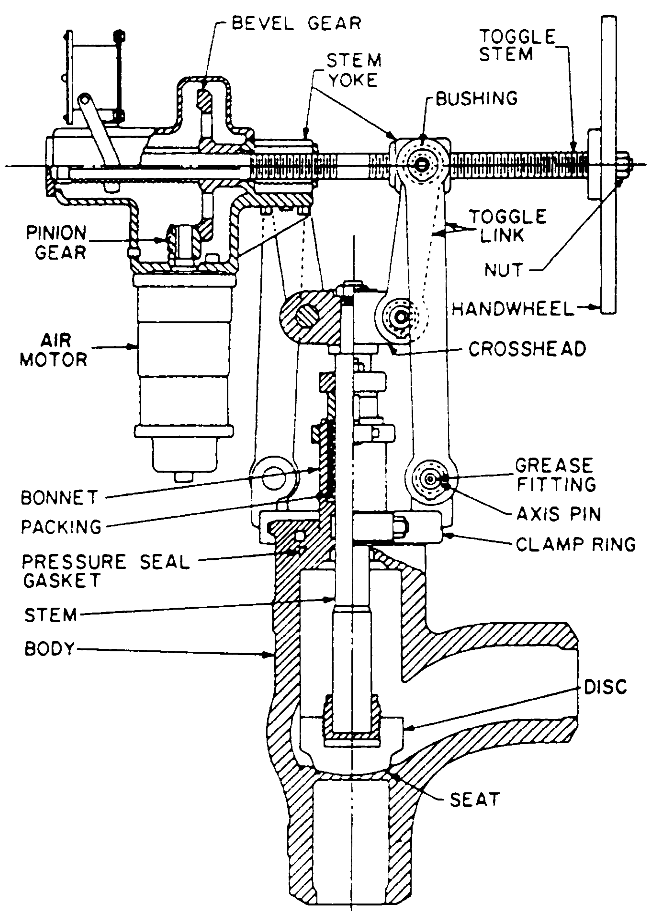


Figure 16-11.—Cross section of motor-operated gauge valve (main steam stop).

Auxiliary steam stop valves are smaller than main steam stop valves but are otherwise similar.

SOOT BLOWERS

Soot blowers are installed on boilers to remove soot from the firesides while the boiler is steaming. The soot blowers must be used regularly and in proper sequence to prevent the accumulation of heavy deposits of soot. Soot is an effective insulator, and any soot desposited on boiler tubes seriously interferes with heat transfer and thus reduces boiler efficiency. If the soot blowers are not used often enough, soot accumulates between the tubes on top of the lower drums and headers. Soot tends to absorb moisture from the air. The moisture combines with the soot to form sulfuric acid, which corrodes the boiler tubes. Moisture also tends to make the soot pack down into such a solid mass that it cannot be removed by the soot blowers. Another important reason that soot must be removed at regular intervals is that any large accumulation of soot on the boiler firesides constitutes a serious fire hazard.

When distillate fuel is being burned, soot blowers must be used to blow tubes on the steaming boilers at least once each week while the ship is underway and, when in port or at anchor, just after leaving or just before entering port. In addition, if practical, tubes should be blown as soon as possible after heavy smoke has been made.

Soot blowers must be used in the proper sequence so that the soot will be swept progressively toward the uptakes. Normally, the uppermost soot blowers are used at the beginning and then again at the end of the blowing sequence. The exact sequence for blowing tubes should be obtained from the manufacturer's technical manual for the boilers aboard each ship.

Before tubes are blown, due consideration must be given to the effect that the discharge of soot will have upon the upper decks. The engineering officer of the watch must obtain permission from the officer of the deck before instructing fireroom personnel to blow tubes.

Some ships are designed with stackdampers, which enable the bridge to direct soot from either the port or starboard side as desired.

There are two basic kinds of soot blowers: (1) the rotary (multinozzle) type and (2) the stationary type. Rotary soot blowers are used in most outlet locations of the boiler. The stationary type is used in a few special locations.

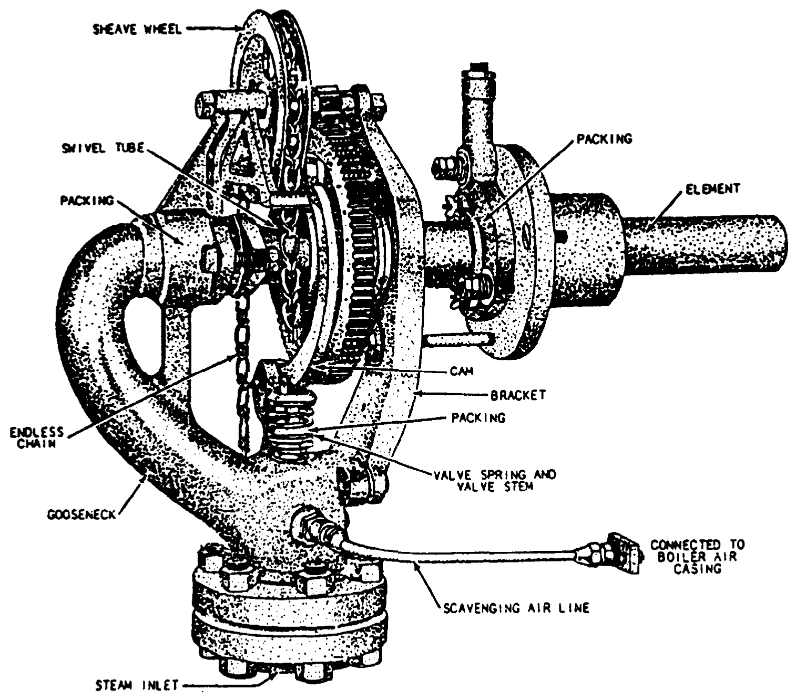


Figure 16-12.—External view of a rotary soot blower.

The soot blowers commonly used on naval boilers are designed by two different manufacturers. Although they are similar in many ways, they differ in certain details of construction. The manufacturer's technical manual for the boiler should be consulted for details of construction, operation, and maintenance of the soot blowers.

A rotary soot blower is shown in figures 16-12 and 16-13. The part of the soot blower that you can see on the outside of the boiler is called the HEAD. The soot

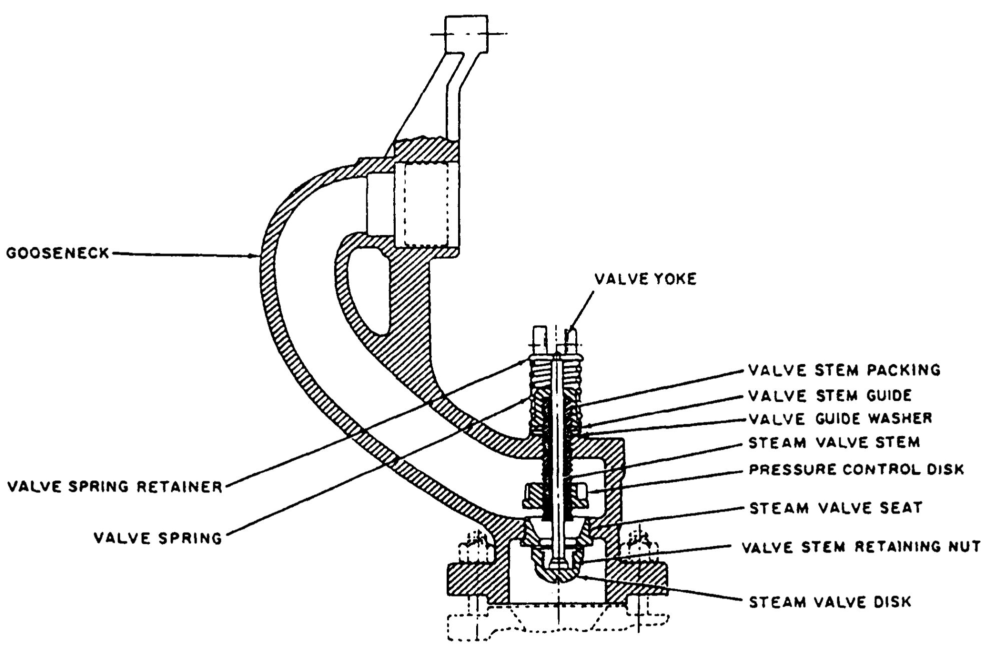


Figure 16-13.—Cross-sectional view of a rotary soot blower.

blower ELEMENT, a long pipe with multiple outlets, or nozzles, projects into the tube banks of the boiler. This soot blower is operated by an endless chain, which runs in a sheave wheel (as shown in fig. 6-12). When the chain is pulled, steam admitted through a steam valve (shown in fig. 16-13) and is discharged at high velocity from the nozzles in the element. The nozzles direct the jets of steam so that they sweep around the tubes, thus preventing direct impingement of steam on the tubes. The soot is thus loosened so that it can be blown out of the boiler.

Each steaming boiler uses its own steam to supply its own soot blowers. However, the steam used for blowing tubes is reduced from boiler pressure to approximately 300 psi. The pressure is reduced either by a pressure control disk above the steam valve (fig. 16-13) or by a pressure control orifice below the steam valve.

Some soot blowers are operated by manual turning of a crank, while others are operated by manual pulling on a chain. Aboard some ships, the soot blowers are operated by push buttons. A press on the button admits air to an air motor that drives the unit.

On some soot blowers, the admission and cutoff of steam is controlled so that the tubes are swept only during a part of each rotation of the element. The part of each rotation during which steam is admitted, and during which the tubes are swept, is called the BLOWING ARC. Blowing arcs are controlled by cams or stops. Figure 16-14 shows two cam-and-gear assemblies for controlling the blowing arcs on rotary soot blowers. The arrangement shown on the left is for a blowing arc of less than 360°; the arrangement on the right is for a blowing arc of 360°.

The scavenging air connection shown in figure 16-12 supplies air to the soot blower element and thus keeps combustion gases from backing up into the soot blower heads or the steam piping. A check valve is installed in the scavenging air piping, near the soot blower head. When tubes are being blown, steam enters the short length of air piping between the soot blower head and the check valve, closing the valve. When tubes are not being blown, air pressure in the scavenging air line keeps the check valve open.

On many boilers, the copper tubing for the scavenging air is connected to the boiler casing at the front of the boiler. On some boilers, however, the tubing is connected to some other part of the boiler casing so that a shorter length of tubing can be used.

The number of soot blowers installed, the way in which they are arranged, and the blowing arcs for each unit differ from one type of boiler to another. Figure 16-15 indicates the soot blower sequence for a single-furnace boiler.

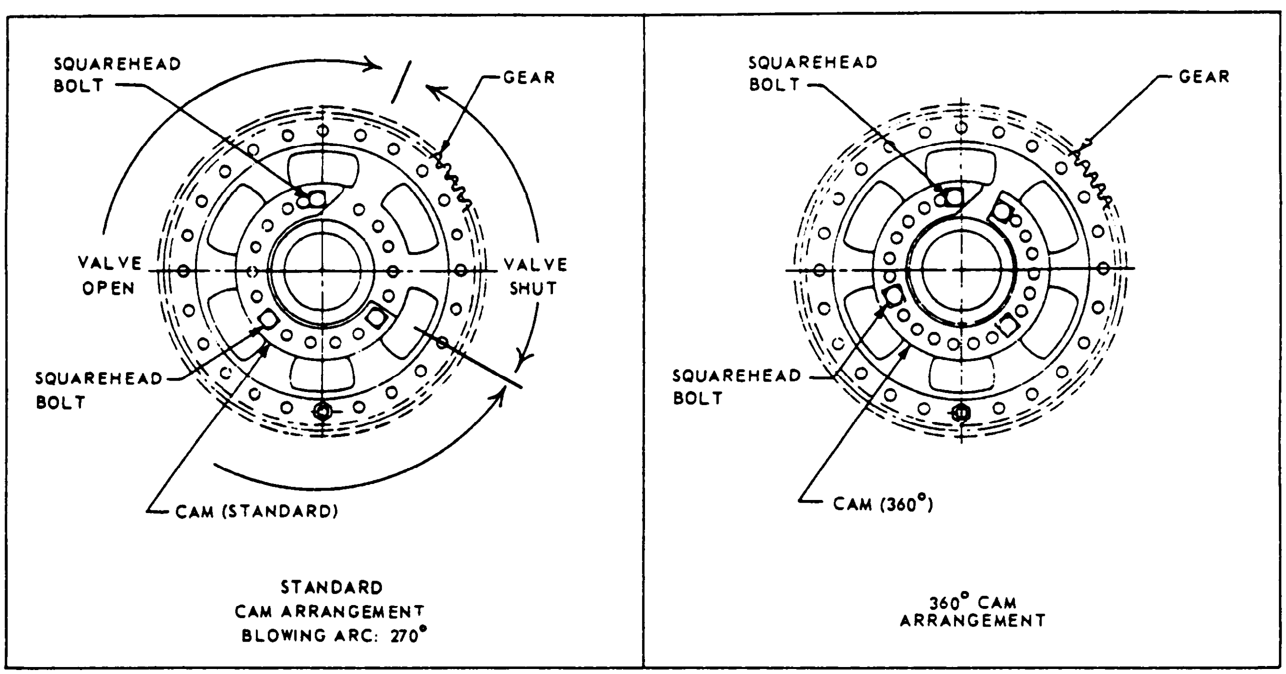


Figure 16-14.—Cam-and-gear assemblies for controlling blowing arcs on multinozzle soot blowers.

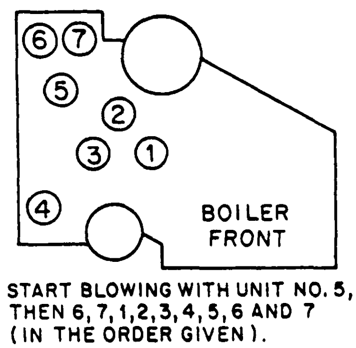


Figure 16-15.—Sequence of soot blowers on a single-furnace boiler.

BLOW VALVES

Some solid matter is always present in boiler water. Since most of the solid matter is heavier than water, it tends to settle in the water drums and headers. Solid matter that is lighter than water rises and forms a scum on the surface of the water in the steam drum. Since most of the solid matter is not carried over with the steam, the concentration of solids remaining in the boiler water gradually increases as the boiler is steamed. For the sake of efficiency and for the protection of the boiler pressure parts, some of this solid matter must be removed from time to time. Blow valves and blow lines are installed below the boiler for this purpose.

Light solids and scum are removed from the surface of the water in the steam drum by the surface blow line which, as we have already seen, is an internal boiler fitting. Heavy solids and sludge are removed by opening bottom blow valves, which are fitted to each water drum and header. Both surface blow valves and bottom blow valves on modern naval boilers are globe-type stop valves.

Both the surface blow valves and the bottom blow valves discharge to a system of piping called the BOILER BLOW PIPING. The boiler blow piping system is common to all boilers in any one fireroom. Guarding valves are installed in the line to prevent leakage from a steaming boiler into the blow piping and to prevent leakage from the blow piping into a secured boiler. A guarding valve installed at the outboard bulkhead of the fireroom gives protection against saltwater leakage into the blow piping. After passing through this guarding valve, the water is discharged through an overboard discharge valve (sometimes called a skin valve), which leads overboard below the ship's waterline. Figure 16-16 shows the general arrangement of boiler blow piping.

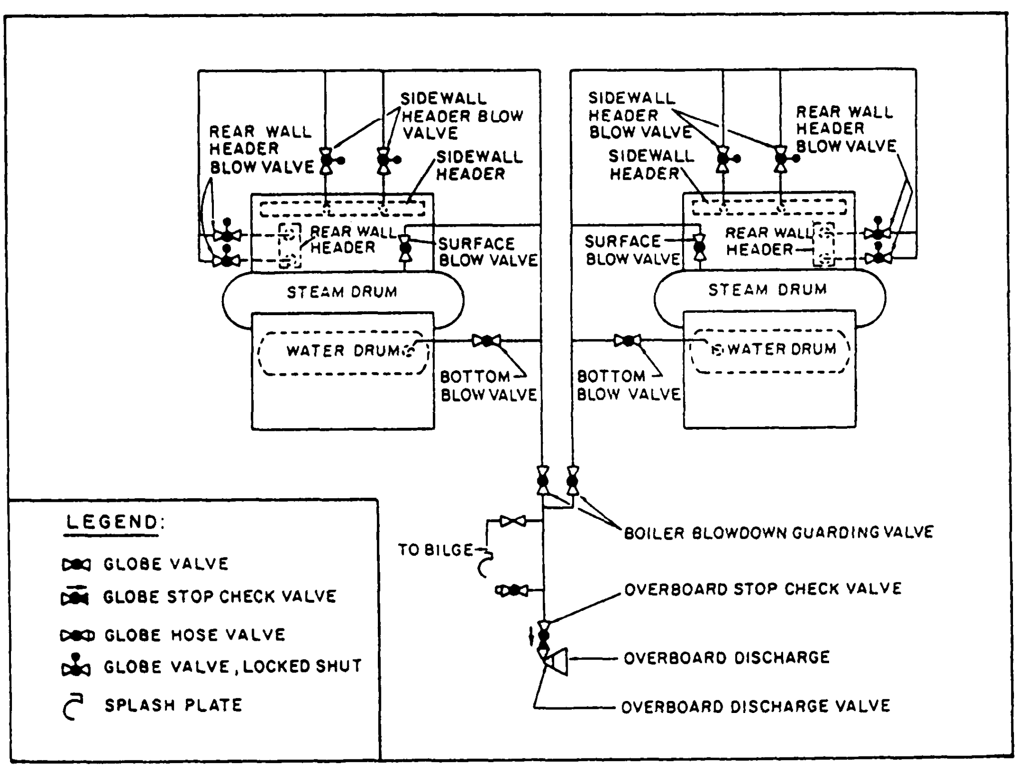


Figure 16-16.—Boiler blow piping.

INSTRUMENTS AND MONITORING DEVICES

Some of the instruments and monitoring devices that enable the Machinist's Mate (Surface) to determine how the boiler is working are water gauge glasses, remote water-level indicators, superheater temperature alarms, smoke indicators, and oil-drip detector periscopes.

WATER GAUGE GLASSES

Various combinations of water-level indicating devices are used on naval boilers. On older boilers, perhaps the most common arrangment has two water gauge glasses, one 10 inches long and one 18 inches long. Newer boilers may have two water gauge glasses and one remote water-level indicator, or they may have one water gauge glass and two remote water-level indicators.

Every boiler must be equipped with at least two independent devices that show the water level in the steam drum, so that a false water level may be detected through a comparison of the two. At least one of these devices must be a water gauge glass. Some boilers have more than two devices for indicating water level.

Several types of water gauge glasses are used on naval boilers. Gauges are identified by the amount of visibility permitted and usually are installed in pairs: two 10-inch gauges or two 18-inch gauges at the same level, or one 10-inch and one 18-inch gauge, or two 10-inch gauges staggered vertically to provide a total visibility of 18 inches.

A more recent type of water gauge glass is shown in figure 16-17. This gauge is assembled with springs, as shown in the illustration. This type of assembly makes it unnecessary to retorque the studs after the gauge has warmed up. (Notice the numbering of the studs in fig. 16-17; the numbers indicate the proper

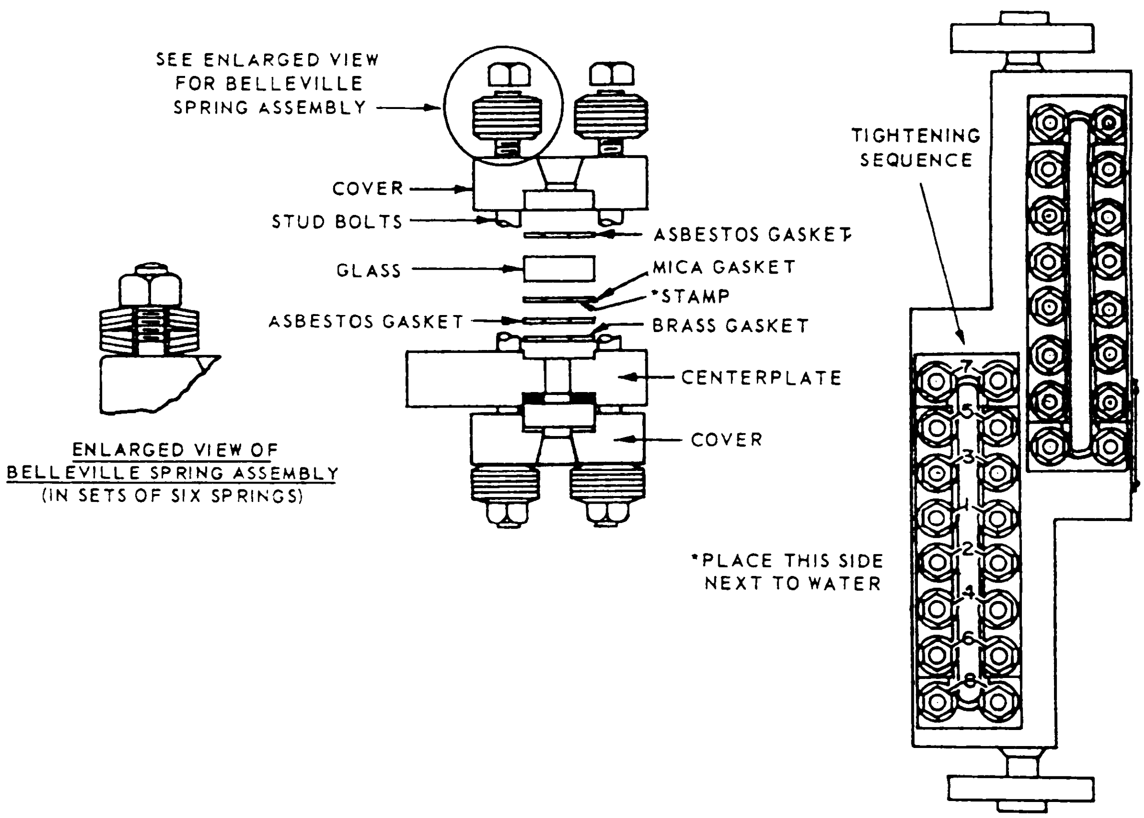


Figure 16-17.—Water gauge glass

sequence of tightening the studs in assembling the gauge.)

Each water gauge is connected to the steam drum through two cutout valves, one at the top of the drum and one at the bottom. The bottom cutout valve connection contains a ball-check valve. The ball rests on a holder. As long as there is equal pressure on each side of the ball, the ball remains on its holder. But if the water gauge breaks, the sudden rush of water through the bottom connection forces the ball upward onto its seat and thus prevents further escape of hot water. No check valve is installed in the top cutout connection.

Detailed information on the water glasses installed on any particular boiler is found in the appropraite manufacturer's technical manual.

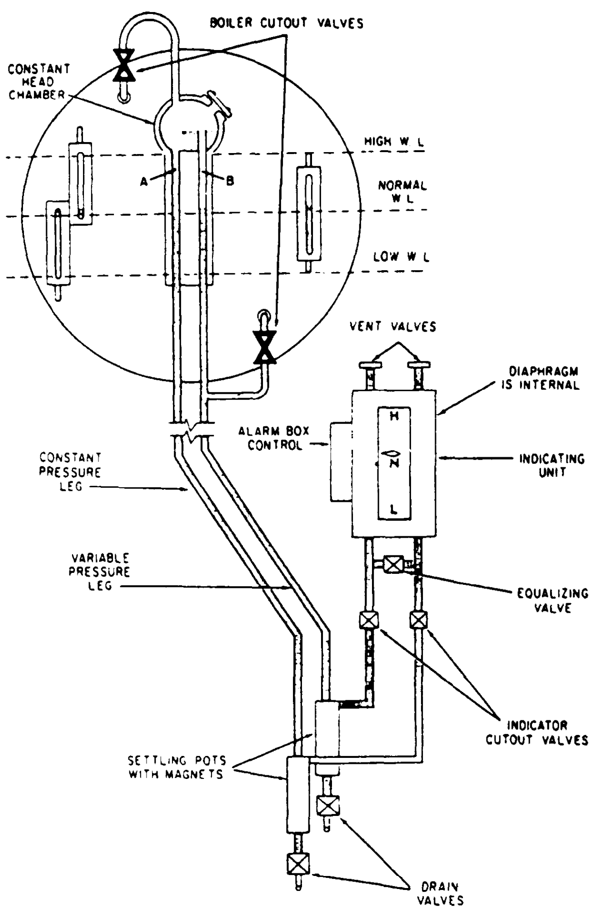


Figure 16-18.—General arrangement of a remote water-level indicator.

REMOTE WATER-LEVEL INDICATORS

Remote water-level indicators are used aboard most ships so that the boiler water level can be observed from the lower level of the fireroom or operating station. There are two types of remote water level indicators commonly used aboard combatant ships; other types may be found aboard auxiliary ships.

For information on specific remote water-level indicators, refer to the manufacturer's manuals.

The general arrangement of remote water-level indicators is shown in figure 16-18. The main parts of the unit are (1) the constant-head chamber, which is mounted on the steam drum at or near the vertical center line of the drum; (2) the graduated indicator, which is usually mounted on an instrument panel; and (3) two reference legs that connect the constant-head chamber to the indicator. The reference legs are marked A and B in figure 16-18.

A constant water level is maintained in leg A (constant-pressure leg), since the water level in the constant-head chamber does not vary. The level in leg B (variable-pressure leg) is free to fluctuate with changes in the steam drum water level. The upper hemisphere of the constant-head chamber is connected to the steam drum at a point above the highest water level to be indicated; because of this connection, boiler pressure is exerted equally on the water in the two legs. Variable leg B is connected to the steam drum at a point below the lowest water level to be indicated; because of this connection, the water level in leg B is equalized with the water level in the steam drum.

As you can see in figure 16-18, each leg is connected by piping to the indicator. In the indicator, the two columns of water terminate at opposite sides of a diaphragm.

Another type of remote water-level indicator is shown in figure 16-19. The operating principles of this device are very similar to the operating principles of the remote water-level indicator previously discussed.

The main difference is the differential pressure sensing unit (DPU) (fig. 16-20). This unit can be used either as a pneumatic transmitting unit by attaching a pneumatic transmitter to the DPU output shaft, or strictly as an indicator by attaching a gauge to the DPU output shaft. The bellows are liquid-filled and can withstand much more pressure than the diaphragm used in the first remote water-level indicator we discussed.

PRESSURE AND TEMPERATURE GAUGES

To operate a boiler, you must be constantly aware of pressures and temperatures in the boiler and in its associated machinery and systems. Pressure gauges are installed on or near each boiler to indicate steam drum pressure, superheater outlet pressure, auxiliary steam pressure, auxiliary exhaust pressure, feedwater pressure, steam pressure to the forced draft blowers, air pressure in the double casings, and fuel-oil pressure. Temperature gauges are installed to indicate superheated steam temperature, desuperheated steam temperature (if the boiler has a desuperheater), feedwater temperature at the economizer inlet and outlet, and—in some ships—uptake temperatures. Most of these pressure and temperature gauges are classified as boiler external fittings.

In some firerooms, the gauges that indicate steam drum pressure, superheater outlet pressure, superheater outlet temperature, and combustion air pressure are installed on the boiler front. As a rule, however, the indicating units of all pressure gauges are mounted on a boiler gauge board that is easily visible from the firing aisle. Distant-reading thermometers are also installed with the indicating unit mounted on the boiler gauge board. Direct-reading thermometers must, of course,

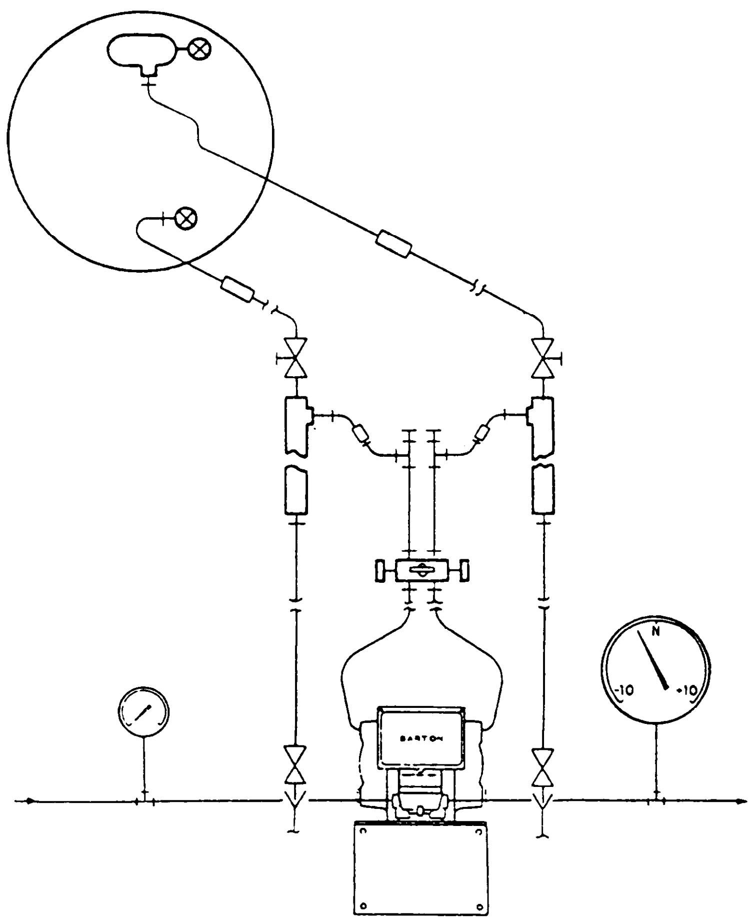


Figure 16-19.—Typical drum-level measurement installation for a second type of remote water-level indicator.

be read at their actual locations. In some installations, a common gauge board is used for all the boilers in one space, instead of having separate gauge boards for each boiler. Duplicate gauges for all major boiler operating parameters are located in the console operator's booth for ships with automatic boiler control (ABC) systems.

Most of the pressure gauges used in connection with boilers are of the Bourdon-tube type. However, some manometers and some diaphragm gauges are also used in the fireroom.

The temperature gauges most commonly used in the fireroom are (1) direct-reading liquid-in-glass thermometers and (2) distant-reading Bourdon-tube thermometers. However, bimetallic expansion thermometers are also used.

Some thermometers are of the bare-bulb type—that is, the bulb is in direct contact with the steam or other fluid being measured. Bare-bulb thermometers must NEVER be removed while the boiler is under pressure. Other thermometers are of the well or separable-socket type—that is, the bulb is inserted into a well or socket in the line where the temperature is to be measured. These thermometers are not designed to be used as bare-bulb thermometers; they must always be used in the well or socket.

SUPERHEATER TEMPERATURE ALARMS

Superheater temperature alarms are installed on most boilers to warn operating personnel of dangerously high temperatures in the superheater.

SMOKE INDICATORS

Naval boilers have smoke indicators (sometimes called smoke periscopes), which permit visual observation of the gases of combustion as they pass through the uptakes. Single-furnace boilers have one smoke indicator installed in the uptake.

OIL-DRIP DETECTOR PERISCOPES

Some boilers are equipped with oil-drip detector periscope, which allow operating personnel to inspect

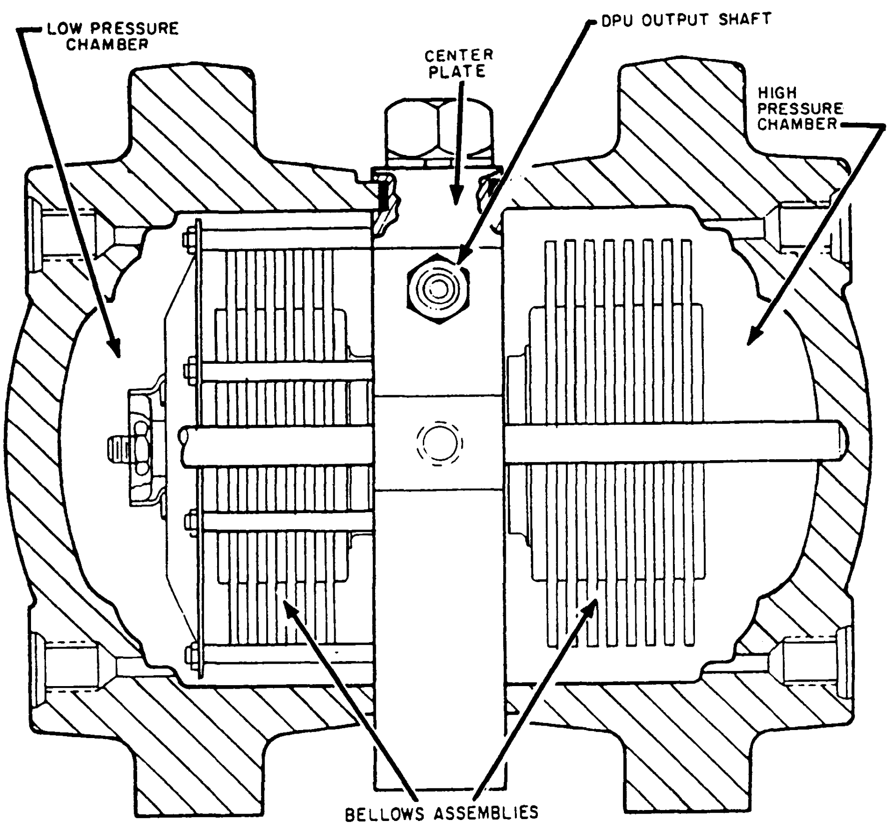


Figure 16-20.—Differential Pressure-Sensing Unit (DPU).

the floor between the inner and outer casing and under the burners to see whether any oil has accumulated there. These periscopes include a reflecting unit with an inner mirror, a vision unit with a mirror that can be seen by operating personnel, and a lamp unit. The reflecting unit can be rotated through 360° by turning the handle. The vision unit can be rotated to any angle to suit the operator. The mirror frame in the vision unit is adjustable to suit the line of sight.

SAFETY VALVES

Each boiler is fitted with safety valves to allow steam to escape from the boiler (escape steam piping directs steam out through the stack, or mack, to the atmosphere) when the pressure rises above specified limits. The capacity of the safety valves installed on a boiler must be great enough to reduce the steam drum pressure to a specified point when the boiler is being operated at minimum firing rate with all steam valves completely closed. Safety valves are installed on the steam drum and at the superheater outlet.

Several different kinds of safety valves are used on naval boilers, but all are designed to open completely (POP) when a specified pressure is reached and to remain open until a specified pressure drop (BLOWDOWN) has occurred. Safety valves must close tightly, without chattering, and must remain tightly closed after seating.

It is important to understand the difference between boiler safety valves and ordinary relief valves. The amount of pressure required to lift a relief valve increases as the valve lifts, since the resistance of the spring increases in proportion to the amount of compression. Therefore, a relief valve opens slightly at a specified pressure, discharges a small amount of fluid, and closes at a pressure that is very close to the pressure that causes it to open.

Can you see why such an arrangement will not do for boiler safety valves? If the valves were set to lift at anything close to boiler pressure, the valves would be constantly opening and closing, pounding the seats and disks and causing early failure of the valves. Furthermore, relief valves could not discharge the large amount of steam that must be discharged to bring the boiler pressure down to a safe point, since the relief valves would reseat very soon after they opened. To overcome this difficulty, boiler safety valves are designed to open COMPLETELY at the specified pressure.

STEAM DRUM SAFETY VALVES

The two types of steam drum safety valves we will discuss are (1) the huddling-chamber type and (2) the nozzle-reaction type.

A steam drum safety valve of the huddling-chamber type is shown in figure 16-21. The initial lift or opening of the valve is caused by the static pressure of the steam in the drum acting upon the bottom of the feather (disk). As soon as the valve begins to open, a projecting lip or ring of larger area is exposed for the steam pressure to act upon. The huddling chamber, which is formed by the position of the adjusting ring, fills with steam as the valve opens. The steam in the huddling chamber builds up a static pressure that acts upon the extra area provided by the projecting lip of the feather. The resulting increase in force overcomes the resistance of the spring, and the valve pops—that is, it opens quickly and completely. Because of the larger area now presented for the steam pressure to act upon, the valve reseats at a lower pressure than that which caused it to

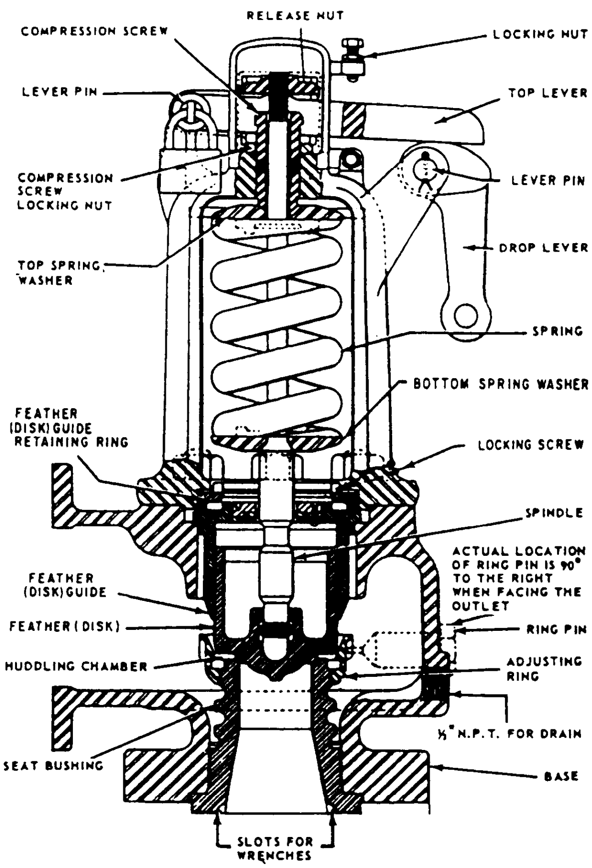


Figure 16-21.—Steam drum safety valve (huddling-chamber type).

lift initially. After the specified blowdown has occurred, the valve closes cleanly, with a slight snap.

The amount of compression on the spring determines the pressure at which the valve will pop. The position of the adjusting ring determines the shape of the huddling chamber and thereby determines the amount of blowdown that must occur before the valve will reseat.

A steam drum safety valve of the nozzle-reaction type is shown in figure 16-22. The initial lift of this valve occurs when the static pressure of the steam in the drum acts upon the disk insert with sufficient force to overcome the tension of the spring. As the disk insert lifts, the escaping steam strikes the nozzle ring and changes direction. The resulting force of reaction causes the disk to lift higher, up to approximately 60 percent of rated capacity. Full capacity is reached as the result of a secondary, progressively increasing lift, which occurs as an upper adjusting ring is exposed. The ring deflects the steam downward, and the resulting force of reaction causes the disk to lift still higher. Blowdown adjustment in this type of valve is made by raising or lowering the adjusting ring and by raising or lowering the nozzle ring.

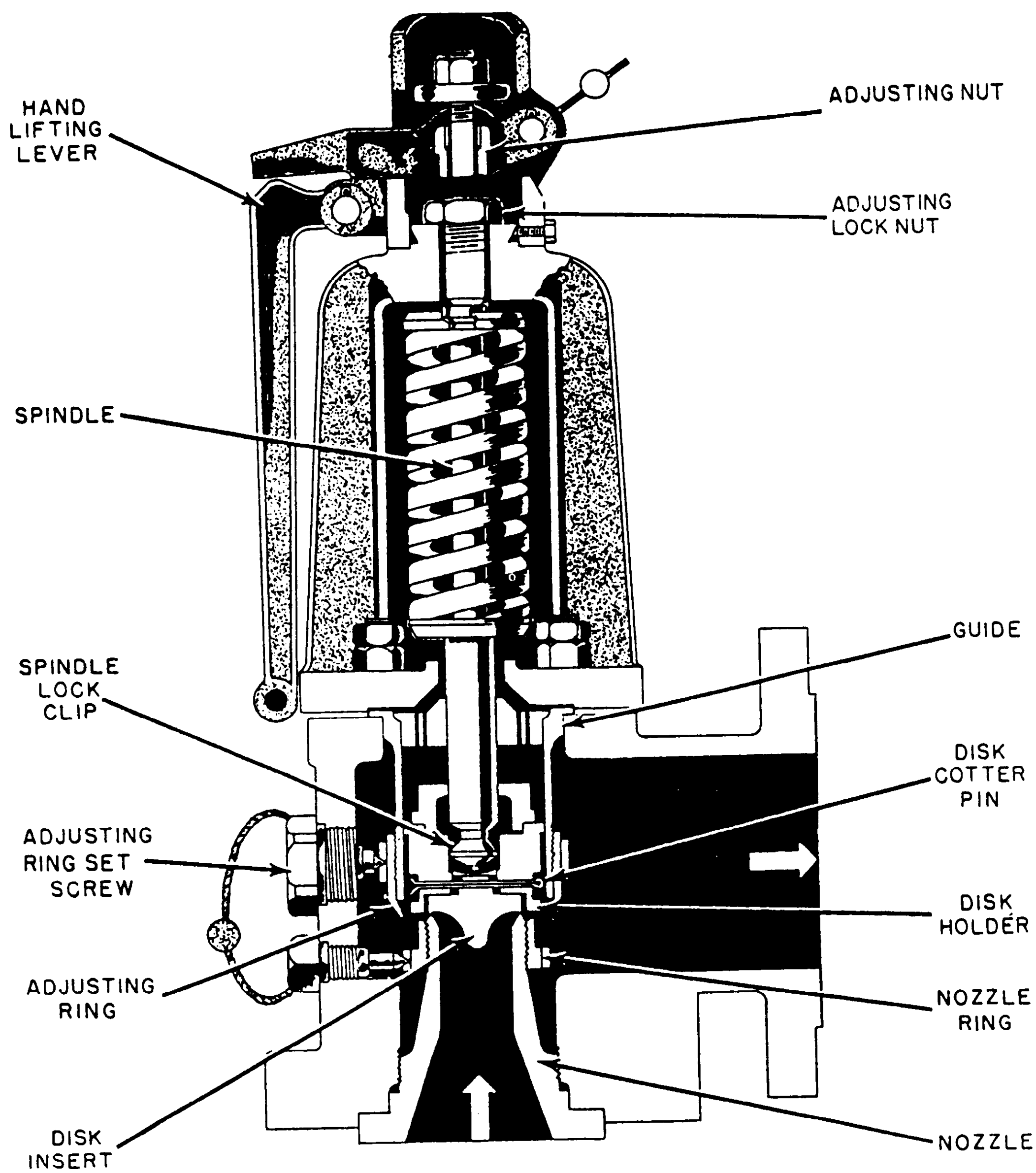


Figure 16-22.—Steam drum safety valve (nozzle-reaction type).

SUPERHEATER SAFETY VALVES

Safety valves are always installed at the superheater outlet as well as on the steam drum. To ensure an adequate steam flow through the superheater when the steam drum safety valves are lifted, superheater safety valves are sometimes set to lift at a lower pressure than which lifts the steam drum safety valves. We will discuss two kinds of superheater safety valve arrangements: (1) the two-valve superheater outlet safety valve assembly and (2) the three-valve superheater outlet safety valve assembly.

Most single-furnace boilers are equipped with two-valve superheater outlet safety valve assemblies of the type shown in figure 16-23. In an assembly of this type, both the valves are spring-loaded. The pilot valve on the steam drum and the superheater valve at the superheater outlet are connected by a pressure transmitting line, which runs from the discharge side of the drum pilot valve to the underside of the piston, which is attached to the spindle of the superheater safety valve.

The superheater valve is set to pop at a pressure approximately 2 percent higher than the pressure that causes the drum pilot valve to pop. When the drum pilot valve pops, the steam pressure is transmitted immediately through the pressure line to the piston; thus the superheater valve is actuated. If, for any reason, the drum pilot valve should fail to open, the superheater valve will open at a pressure approximately 2 percent higher to protect the superheater.

The three-valve superheater outlet safety valve assembly shown in figure 16-24 is used on some 1200-psi single-furnace boilers. The assembly consists of a pilot valve, a piston actuator, and an unloading valve.

The spring-loaded pilot valve is mounted on the top center line of the steam drum. The piston actuator and the unloading valve are assembled as a unit and mounted on the piping at the superheater outlet; they are connected to each other by a rocker arm. The piston acutuator has a cylinder with a piston inside it. The unloading valve contains (1) an actuating valve connected to the rocker arm by a stem and (2) a piston-type disk without a stem, which is held in line by the cylinder in which it works. The unloading valve is pressure-loaded, not spring-loaded.

Steam from the superheater outlet enters the unloading valve cylinder and gathers around the valve disk above the seat. The steam bleeds through small ports to the space above the disk. When the actuating valve is closed, the steam above the disk of the unloading valve cannot escape, so the pressure above the disk equalizes with the pressure below the disk—that is, the pressure above the disk is equal to the superheater outlet pressure.

Excessive pressure in the steam drum—NOT the excessive pressure in the superheater—causes the safety valve in this assembly to lift. When the pilot valve on the steam drum opens, pressure is transmitted from the pilot valve to the cylinder of the piston actuator. Pressure in the piston actuator cylinder is applied under the piston, causing the spring to compress. The rocker arm moves upward at the end over the piston actuator and downward at the end over the unloading valve, thus opening the actuating valve.

When the actuating valve opens, pressure above the piston-type unloading valve disk bleeds off to the atmosphere. The unloading valve therefore opens, allowing steam to flow from the superheater to the atmosphere, and thus protects the superheater tubes from excessive temperatures. When the pilot valve

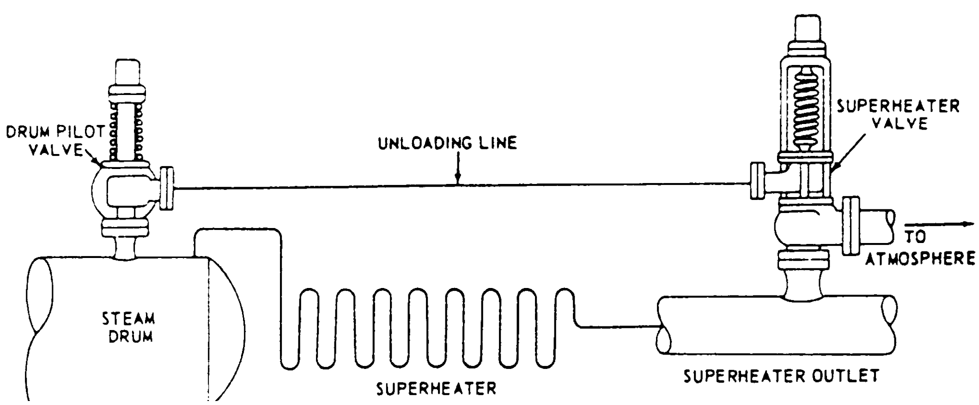


Figure 16-23.—Two-valve superheater outlet safety valve assembly.

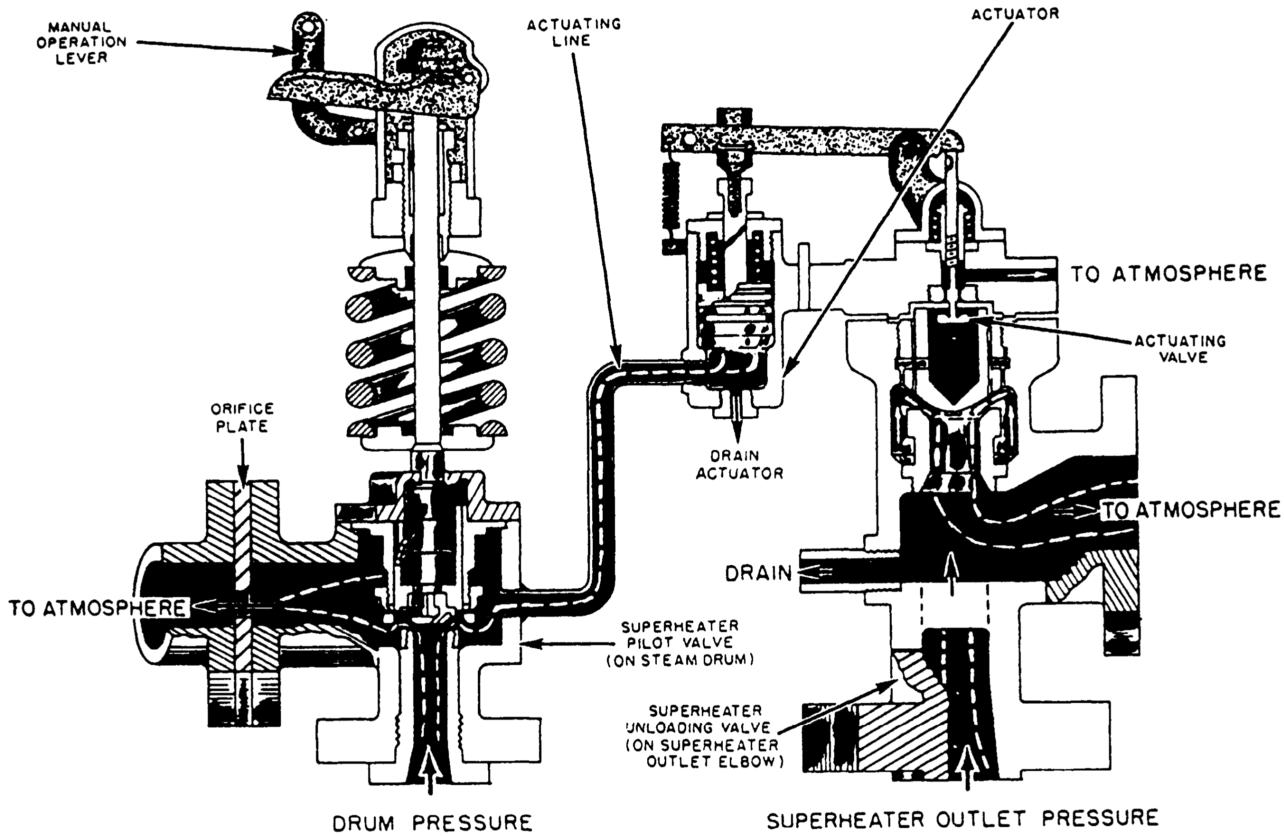


Figure 16-24.—Three-valve superheater outlet safety valve assembly.

reseats, the actuating valve also reseats. As steam bleeds through the ports to the space above the disk in the unloading valve, pressure builds up and rapidly equals the pressure below the disk. Then the unloading valve closes. In summary, then, the superheater unloading valve always opens immediately after the steam drum pilot valve opens, and closes immediately after the pilot valve closes.

FUEL-OIL BURNERS

Burners are essential to effective fuel-oil combustion. They provide combustible mixtures of fuel oil and air by reducing the liquid to finely divided particles with an atomizer, and mixing air with these droplets with a register.

ATOMIZERS

Mechanical as well as steam atomizers are in use on naval ships. With one exception, these are pressure atomizers. The exception, the use of which is confined to auxiliary boilers, is the rotary atomizer.

Underlying Principle of Pressure Atomization

In the type of pressure atomizers most commonly found in the Navy, oil is forced under high pressure through passages in the atomizer. The passages are arranged to give the oil a high rotation velocity, thus breaking up the oil by centrifugal force. Rotation is accomplished by either spiral or tangential grooves through which oil is discharged at high pressure into a small cylindrical chamber. The tip end of this chamber is coned out. The orifice through which oil is discharged is at the apex of the cone. As oil leaves the orifice, it breaks up into fog or mistlike particles and forms a hollow cone of finely atomized oil. A blast of air, which has been given a whirling motion in passing through the register, catches the oil mist, mixes with it, and enters the furnace, where combustion takes place. There are three most common types of atomizers: (1) the vented-plunger type, (2) the straight-through-flow type, and (3) the steam-assist type.

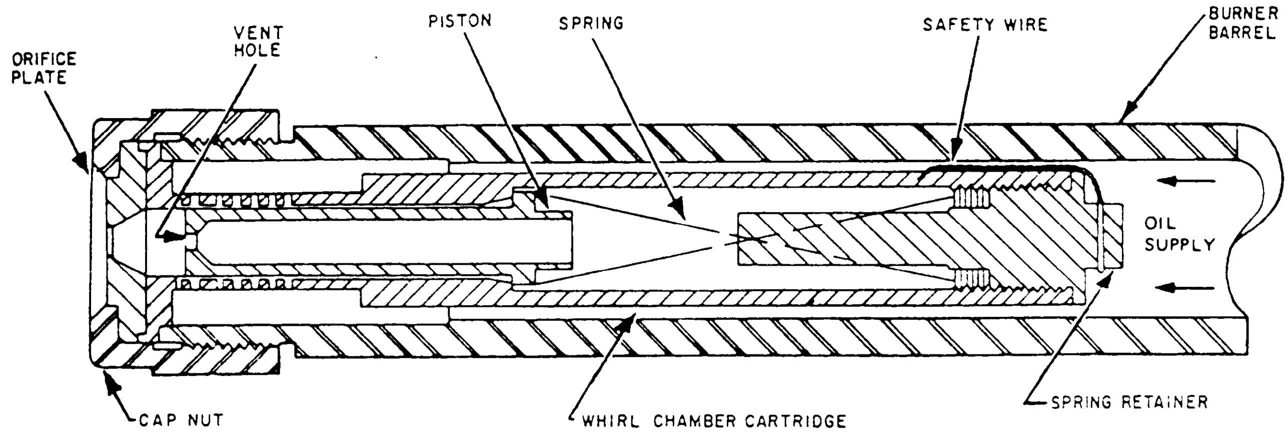


Figure 16-25.—Vented-plunger atomizer.

Vented-Plunger Atomizer

This atomizer is designed to permit wide-range operation using the straight mechanical pressure atomization principle, but it requires a maximum supply oil pressure of only (approximately) 350 psig. Refer to figure 16-25 as we describe the operation of the vented-plunger atomizer. Oil flows down the atomizer barrel around the atomizer cartridge and enters the whirl chamber through tangential holes drilled around its circumference. The piston in the whirl chamber is spring-loaded and is moved to cover or uncover the tangential holes in the whirl chamber by varying the oil supply pressure. Increasing oil pressure moves the piston to uncover more holes and increase oil rate; decreasing oil pressure does the opposite. Good atomization is maintained at all firing rates due to a high pressure drop maintained through the tangential holes by varying the tangential hole flow area. A hole is drilled through the length of the piston to vent the spring chamber to the furnace, allowing the spring to be compressed. This is possible due to the air core formed in the whirl chamber by the whirling oil. Any oil leakage along the piston into the spring chamber is vented into the furnace in the same manner.

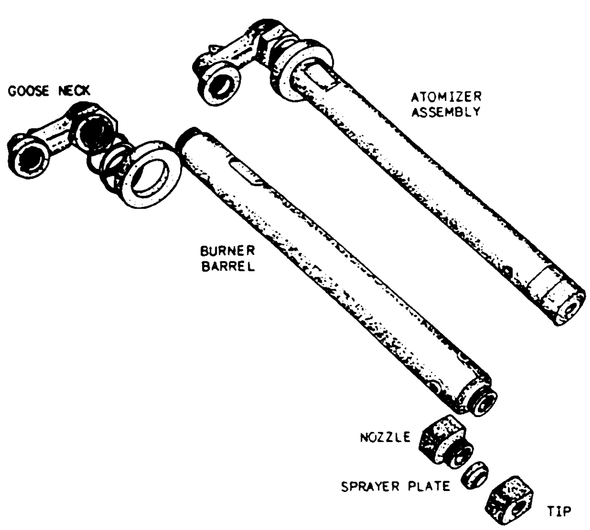


Figure 16-26.—Parts of a straight-through-flow atomizer assembly.

Straight-Through-Flow Atomizer

In the straight-through-flow atomizer, all oil pumped to the atomizer is sprayed into the furnace. The firing rate of this type of burner is controlled by varying the supply fuel-oil pressure and/or changing sprayer plates. These atomizers have been standardized to obtain maximum performance without undue complexity. Standard atomizer parts consist of the following: (See fig. 16-26.)

1. Tip. The tip serves to center the sprayer plate whirling chamber on the atomizer nozzle box and to hold the sprayer plate face tightly against the front face of the atomizer nozzles, preventing passage of oil into the whirling chamber anywhere except through the slots of the sprayer plate.

2. Nozzle. The nozzle serves to lead the oil from the atomizer barrel into the slots of the sprayer plate. The standard nozzle has a 0.5-inch diameter boss and has four oil lead holes.

3. Sprayer plate. The sprayer plate transforms solid streams of oil under high pressure into a cone of fine, foglike particles.

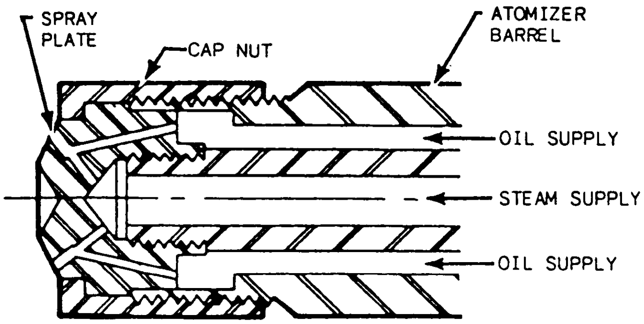


Figure 16-27.—Y-jet steam atomizer.

Steam-Assist Atomizer

In the steam-assist atomizer, steam is used to break up the oil mass into minute particles and to project the oil particles, in the shape of a cone, into the furnace. Two basic types of steam-assisted atomizers are in use in the fleet today: the Y-jet steam atomizer (fig. 16-27) and the LVS steam atomizer (fig. 16-28).

In the Y-jet steam atomizer, steam is supplied through the inner tube of the atomizer to the steam ports of the sprayer plate; oil is delivered to the sprayer plate oil ports through the annulus formed between the inner and outer atomizer tubes. Each steam port meets with an oil port and the mixture of oil and steam exits from a common hole. Six such exit ports are inclined at an angle of 40° around the axis of the sprayer plate.

In the LVS steam atomizer, a sprayer plate is used to spray oil from the inner tube of the atomizer into a mixing chamber. Steam from the atomizer outer tube also passes through the sprayer plate and into the mixing chamber. The steam and oil blend in the mixing nozzle. The mixture leaves the nozzle as a fine spray through concentrically drilled holes in the mixing nozzle.

When steam is not available, steam atomization burner systems have the capability to use low-pressure compressed air as a substitute for 150-psi auxiliary steam for cold plant light-off. After steam is cut into the atomizing steam system, precaution must be taken to ensure that the steam is thoroughly drained of condensate at the atomizing steam header before the atomizing steam is cut inot an individual burner atomizer.

Advantages of Steam Atomization

Steam atomization has the following advantages over other types of atomization:

1. High turndown (see NOTE)
2. Clean burning of residual fuel
3. Less fireside deposits
4. Satisfactory combustion in a cold furnace
5. Wide range with lower pressures

NOTE: Turndown, or turndown ratio when used in the modern sense, is a measure of the ability of a particular burner to operate satisfactorily over a wide range from low to high firing rates. To the boiler designer, it is the ratio of the maximum satisfactory firing rate to the minimum firing rate of a burner.

Character of Atomization

Factors affecting the character of atomization, including capacity, spray angle, and particle fineness, are primarily determined by size and relative passage

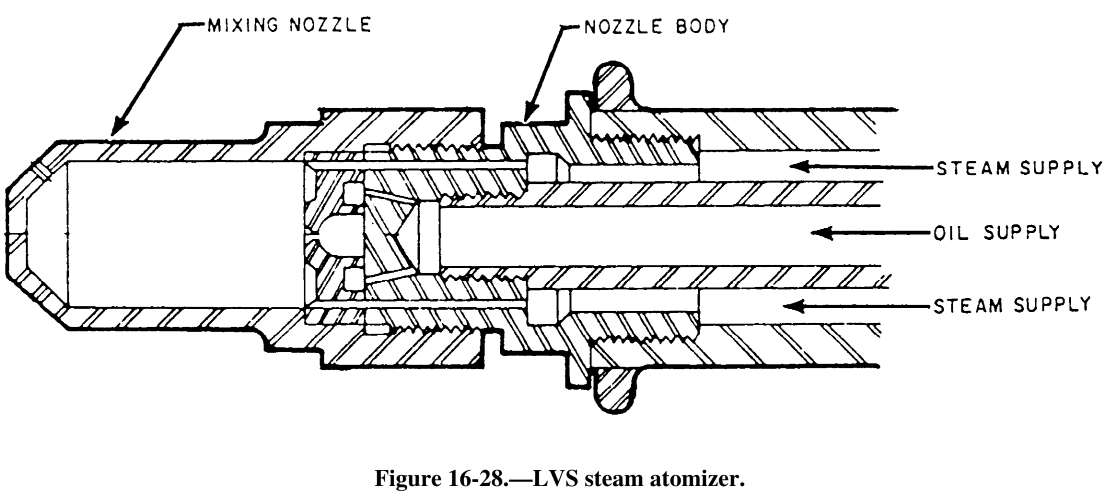


Figure 16-28.—LVS steam atomizer.

proportions in atomizer parts. They are also determined, to an important extent, by fuel-oil viscosity, steam pressure, steam dryness, and oil pressure. The angle of atomization required differs in various types of registers and boiler furnaces. For this reason, in standardized atomizer parts (all other conditions remaining unchanged), the relationship between the diameter of the orifice area and the combined cross-sectional area of the tangential slots is highly important because it controls the character of the spray. The size of the orifice of a sprayer plate and the ratio of the combined cross-sectional area of the slots to the area of the orifice are indicated by four numerals stenciled on the face of the plate. The first two digits indicate the bore of the orifice in United States standard drill size; the second two numbers are the quotient (omitting the decimal point) of the combined cross-sectional area of the tangential slots divided by the area of the orifice.

Care of Atomizers

As far as possible, operating personnel must maintain the atomizers in their original mechanical condition and polished finish. The importance of the proper care and cleanliness of the atomizer parts cannot be overemphasized. Atomizers are frequently ruined because personnel do not understand the importance of fineness of atomization and do not appreciate how easily an excellent atomizer may be ruined by careless handling. The following instructions must be observed in the operation and maintenance of the atomizers.

Under no circumstances must operating personnel make any changes in dimensions of atomizers or otherwise tamper with them. Slight variations from a set standard may have a noticeable effect on results. The engineer officer must make frequent inspections to ensure that sprayer plates and nozzles are in good condition. Inspection should include checking oil and steam orifice holes of sprayer plates with a Go/No-Go gauge. This gauge indicates proper sizing of orifices with the gauge being manufactured on the basis of wire drill sizes. Penetration into the orifice by the smaller end (green color) of the gauge indicates that the orifice is larger than the minimum acceptable size. Lack of penetration by smaller end of the gauge indicates that the orifice is undersized and that the plate must be discarded. Lack of penetration by the larger end (red color) of the gauge indicates that the orifice is smaller than the maximum acceptable size. Penetration by the larger end of the gauge indicates that the orifice is oversized and that the plate must be discarded.

Steel wire or steel tools must not be employed in cleaning sprayer plates, nozzles, or other atomizer parts.

Atomizers using DFM fuel, when withdrawn from burners, must not be cleaned by blowing through with steam or compressed air. Unless the atomizer barrels must be immediately put into service again with clean sprayer plates, allow the withdrawn atomizer barrels to cool at the burner bench for 15 minutes. After this cooling period, remove the sprayer plates, orifices, adaptor plates, and removable sliding nozzles, and place them in a pan of DFM or kerosene to soak until the carbon has become soft and they can be cleaned. The slots in the sprayer plates and the supply holes in the nozzles may be cleaned with matchsticks without danger of damaging the parts. Properly fitted wooden cleaning sticks may be used for cleaning and polishing the orifices and whirling chambers of sprayer plates, the annular grooves of the nozzles, and the faces of all parts. When you polish atomizers, use only a light lubricating oil. Never use emery paper or any other substance that will cut the metal. After the atomizer parts have been cleaned, wipe them with heavy lubricating oil to minimize the possibility of rusting.

If, after being carefully cleaned, a sprayer plate fails to give an even and finely atomized spray, discard it.

In assembling atomizers, take care not to overtighten the tips. Permanent deformation of the sprayer plate at the outer edge of the face and on the area of overlap of the sprayer plate and the nozzle boss can occur. Repeated over-tightening will undercut the sprayer plate to such an extent that oil will leak into the whirling chamber without traversing the slots and cause drooling, smoking, and carbon formation.

Never leave disconnected atomizers in place since the atomizer or valve may be unintentionally opened, allowing oil to run into firerooms, with disastrous results. On newly constructed ships, burners are fitted with safety shutoff devices which prevent the flow of oil when an atomizer is not in place. To light fires, line up safety shutoff devices (where provided) to admit fuel when putting atomizers in place. To cut in and secure fuel to individual atomizers, use root valves. A safety shutoff device is not normally used for this purpose.

Atomizer root valves should be either fully open (in lighted-off burners) or fully closed (in secured burners). Both the atomizer valve (safety shutoff) and the atomizer root valve should be closed on a secured burner and the atomizer should be entirely removed when not in use.

To maintain satisfactory atomizer machined edges and threads, atomizers should be stowed properly on stowage racks installed in the vicinity of the burner atomizer bench. Before placing cleaning atomizers in the stowage rack, loosely thread the cap nut or tip onto the end of the atomizer to prevent damage to the nozzle and the threads. Before any atomizer is placed in the boiler burners, it should be checked by the top watch for tightness and proper makeup. Whenever possible, the top watch should also visually sight through the peep sights or sight glasses to ensure that newly installed and cut-in atomizers are firing properly. The flame pattern is indicative of proper installation. These vital functions should not be delegated to inexperienced personnel.

REGISTERS

Air registers, when open, direct airflow from the forced draft blowers through the double casing into and around the stream of foglike oil particles produced by the atomizer. When closed, they prevent air from entering the furnace. Air registers employing standard atomizers consist of two principal parts: the diffuser and the air foils. Use of two separate air streams, the primary through the diffuser and the secondary through the air foils, has enabled capacity and flexibility to be increased greatly over that permitted by conical registers. The diffuser causes primary mixing of fuel-oil droplets with air and prevents blowing of the flame from the atomizer; the air foils guide the major quantity of air to mix with the oil particles after they leave the diffuser. Figure 16-29 shows one of most common air registers in use in the Navy today.

Air foils of some types of registers are fixed blades cast integrally in a cone which forms the entering side of the register throat. The principal purpose of the air doors in all registers of that design and manufacture is to close the registers.

Other types air foils of registers consist of curvilinear surfaces (or air scoops) welded to the air doors.

OPERATION AND CARE OF BURNERS AND REGISTERS

Use the following precautions in operating and caring for burners and air registers:

Check all parts of the register before the operation of any new installation of air registers and at frequent intervals thereafter. Register air doors should be

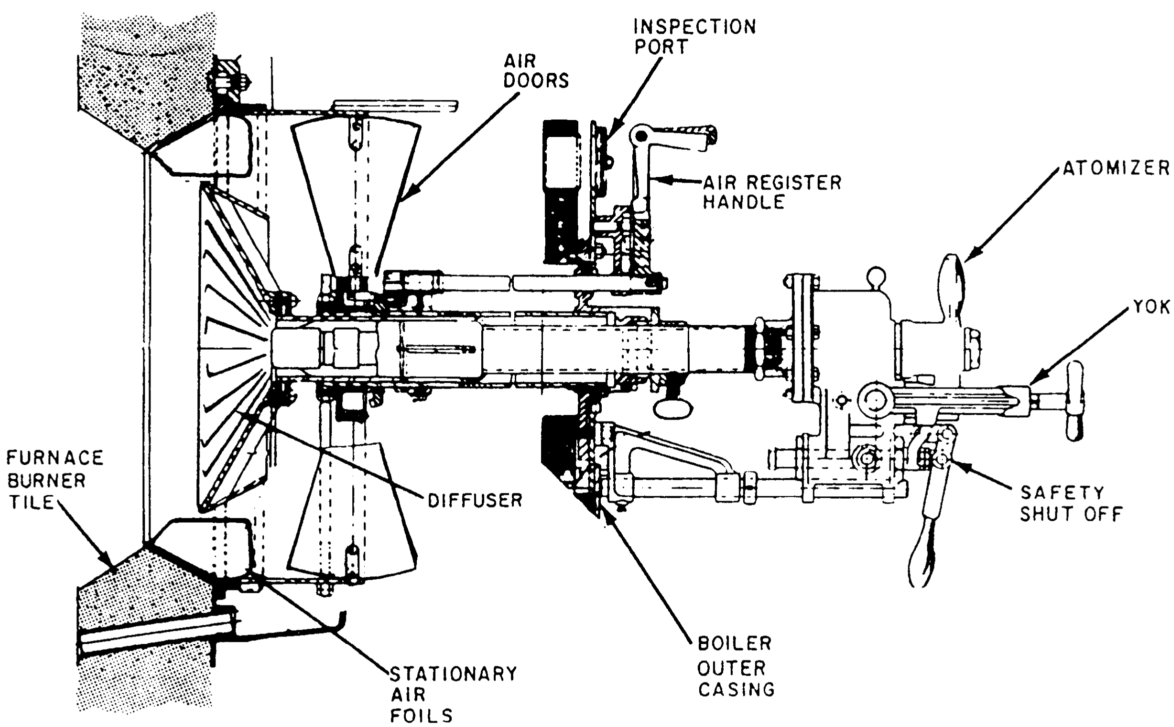


Figure 16-29.—Fuel-oil burner assembly.

examined periodically and any air doors found warped should be straightened or replaced.

All foil surfaces (blades of the bladed cones, air scoops, or air doors) and diffusers should be maintained free of oil, carbon, and dirt. Air slots in the impellers should be kept entirely clear and free of encumbrances.

Since diffusers which are heavily clogged with carbon or are not properly machined, especially in vane openings, can cause improper combustion and vibrations, duplicate and machine to the same tolerances all diffusers installed in any boiler. This is a furnace inspection item.

BURNER AND ATOMIZER SAFETY SHUTOFF DEVICE

The burner and atomizer safety shutoff device (fig. 16-30) is provided on most fuel-oil burner fronts to accept and position the atomizer. It functions solely to prevent personnel from accidentally cutting-in fuel to a burner that does not have an atomizer in place and to prevent uncoupling a fuel pressurized atomizer, with consequent spraying of fuel around the burner front, which could precipitate a fire. Do not use these safety shutoff devices to admit fuel to the atomizer or to shut off fuel; use the burner lead root valves for that purpose. If the Planned Maintenance System (PMS) is installed, preventive maintenance should be according to the maintenance requirement card (MRC). Safety shutoff devices were not designed for zero leakage. Present leakage criteria/test is as follows: When pressurized to fuel-oil service system pressure, there should be no external leakage in the form of a spray or constant stream. If such leakage occurs, corrective action must be taken. Weeping or dripping, not exceeding 8 ounces per hour per burner, is permissible and is not sufficient reason to prohibit steaming the affected or adjacent boiler, but the safety shutoff should be repaired as practicable by dismantling the shutoff device to replace seals, replace vitron O-rings, examine internal parts for scoring, and so forth. Normal dismantling period for a safety shutoff device for rebuilding is 1800 hours. Check the clevis (vise handle) of shutoff safety devices to ensure it's in the proper position after the atomizer is withdrawn. This could permit the safety shutoff slide valve to be accidentally opened.

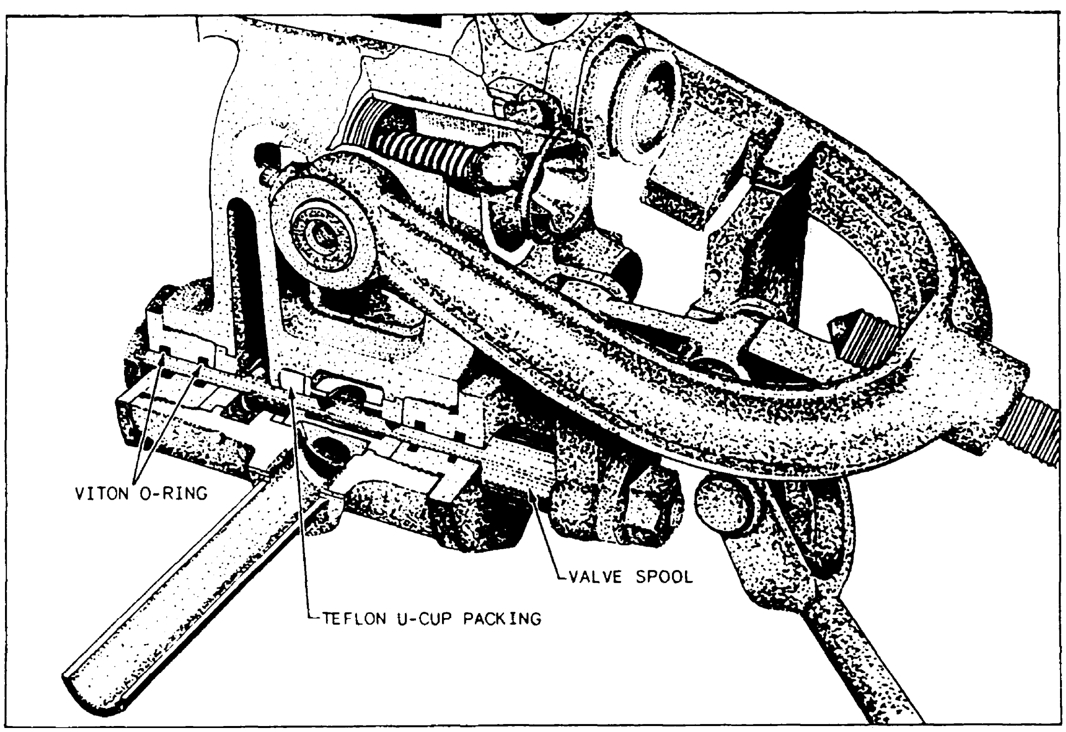


Figure 16-30.—Cutaway view of fuel-oil safety shutoff device.

CHAPTER 17

AUTOMATIC BOILER CONTROLS

Automatic combustion and feedwater control systems for boilers are installed on most naval ships. Boilers are now being constructed to withstand higher pressures and temperatures and require a rapid and sensitive response to feedwater, fuel oil, and combustion air. Automatic controls are almost a necessity. Automatic controls for naval boilers operate with a high degree of accuracy and reliability. They are definitely an aid to operating personnel.

This chapter contains basic information on boiler control systems, components, and terminology. Because of the variation in systems and equipment, the information is limited to general principles and examples.

You will find detailed information on each boiler control system in the manufacturer's technical manual furnished with the equipment. The manufacturer's technical manual is the authoritative source of information. These manuals are sometimes difficult to understand. This chapter will provide you with some of the background knowledge you will need to understand the information in these manuals. It will not make a control board operator out of you or make you an expert in the maintenance and adjustment of boiler control components. To achieve these goals, you will have to study the manufacturers' technical manuals and get practical experience.

SIMPLE CONTROL SYSTEMS

Look at the man shown in figure 17-1. He is an example of a control system. He is controlling the temperature of the water being discharged from a heating tank. By holding one hand on the

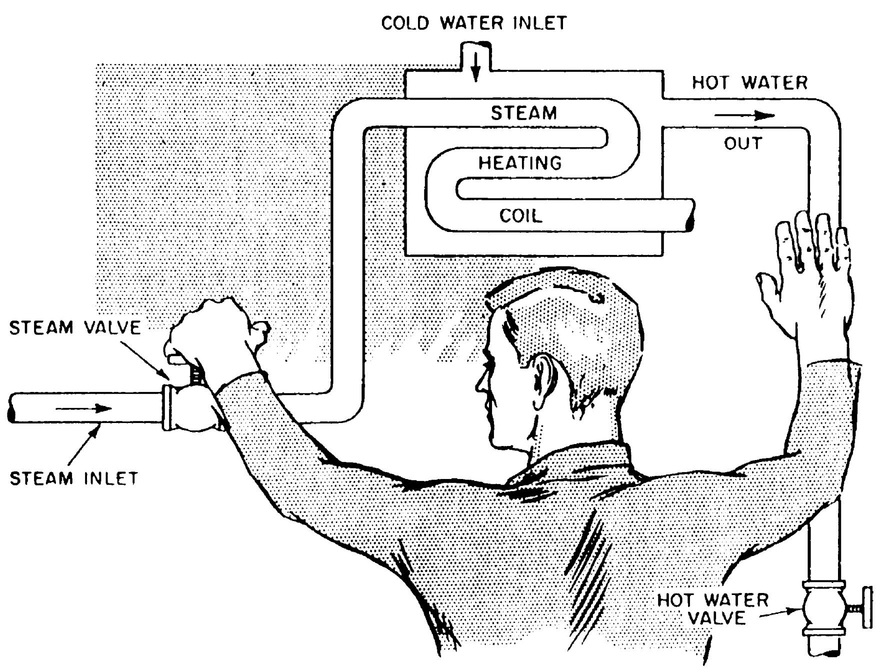


Figure 17-1.—A human control system.

discharge piping, he can tell how hot the water is. When he feels a change in the temperature, he determines how much he must open or close the steam valve to bring the temperature of the water back to the proper temperature. With his other hand, he will open or close the steam valve until he finds a position that will bring the temperature of the water back to the desired value. This man is accomplishing four basic procedures:

1. He is measuring the temperature of the water in the discharge piping from the tank.
2. He is comparing the measured temperature with the temperature he is trying to maintain.
3. He is determining (computing) the amount and direction he must turn the steam valve.
4. He is correcting the steam input by repositioning the steam valve.

He is controlling a simple heat exchange process manually rather than automatically. The four basic procedures this man is accomplishing are the same that must be done by any control system, whether human or automatic. Any control system must be designed to accomplish the following:

1. MEASURE a value (temperature, pressure, or level) on the output side of a process.
2. COMPARE the measured value with the desired value.
3. COMPUTE the amount and direction of change required to bring the measured output value to the desired output value.
4. CORRECT the value on the input side of the process to bring the output side of the process back to the desired value.

Measurement, comparison, computation, and correction: these are the basic operations performed by any control system. Taken together, they constitute a CLOSED LOOP of action and counteraction by which some quantity or condition is measured and controlled. The closed control loop is often called a FEEDBACK LOOP because it requires a feedback signal from the output side of the process to correct the value on the input side. The closed loop concept is illustrated in figure 17-2.

Any quantity or condition that is measured is a VARIABLE. Any quantity or condition that is measured and controlled by a control system is a CONTROLLED VARIABLE. The controlled variable in the heat exchange process of figure 17-1 is the temperature of the water leaving the heating tank. The hot water is called the CONTROLLED MEDIUM. The controlled variable is always some condition or characteristic of the controlled medium.

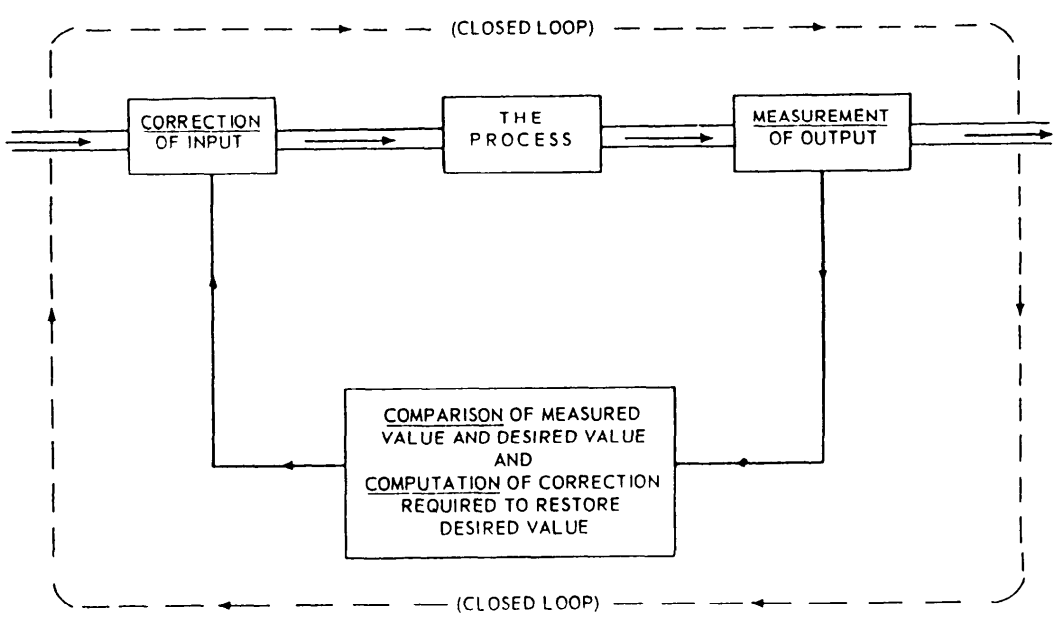


Figure 17-2.—Closed loop of control.

Any quantity or condition that is varied by a control system to affect the value of a controlled variable is called a MANIPULATED VARIABLE. In our heat exchange process, the rate of steam flow is the manipulated variable. The steam itself is called the CONTROL AGENT. The manipulated variable is always some condition or characteristic of the control agent.

At this point we might stop and ask: Why does the process shown in figure 17-1 require a control system? Why can't we just set the steam valve in one position and let the process take care of itself? If the energy input equals the energy output, the process is balanced. If a balanced process could be kept entirely free of all disturbing influences, one position of the steam valve could be found that would control the rate of steam flow and, thus, control the temperature of the hot water.

But everyday experience tells us that various disturbances will affect the process if it is left to itself. The disturbances may come from the input (supply) side of the process, from the output (demand) side, or from other sources. For example, what would happen if there were a change in steam pressure or temperature, change in temperature or in the rate of flow of the cold water, or a change in the demand for hot water? These and other changes, directly or indirectly associated with the process, would affect the output side of the process-that is, they would affect the temperature of the water leaving the heating tank. If we want to keep the hot water at a specified temperature, we need a control system. Until we can develop a better one, that man in figure 17-l will have to stay.

As long as he stays there, though, with one hand on the pipe and one hand on the valve, he is going to have problems. Many of these problems are caused by the fact that things do not happen instantly or all at once. Everything in the process and in the control of the process takes time. It takes time for a disturbance to become known. After the man recognizes that the temperature has changed, he must take time to compare the new temperature with the desired temperature. He must take time to compute the new steam valve position required to correct the temperature deviation. He must take time to reposition the steam valve.

Even after he has repositioned the steam valve, the man cannot just walk away. Now he must stand there and wait for the effects of his corrective action. If by chance he has made exactly the right correction, the water in the discharge piping will return to the desired value. On the other hand, suppose the man notices that the water is colder than it should be. He opens the steam valve approximately one-half turn, but must wait quite a while before he can tell whether his action was correct. Time is required for additional steam to flow to the heating coil. Time is required for heat to be transferred from the steam to the heating coil and from the heating coil to the water. Time is required for the hotter water in the discharge line to raise the temperature of the discharge piping. Time is required for the man to feel the change in temperature.

In reality, of course, it is rather unlikely that the man's first corrective action will be precisely correct. Since he has no way to know exactly how much to open the steam valve, he may open it too much or not enough. In either case, more time is required for the man to wait, note the effect of his action, reposition the valve, wait again, and note the effect.

And so it goes, round and round the closed control loop of measurement, comparison, computation, and correction. The man would find his job a good deal easier if each disturbance and each correction were immediately reflected in the temperature of the discharge piping, but we know that this is not possible. In this process-as indeed in all processes—there are bound to be delays all along the closed control loop. We understand this without question when a human operator is involved, and we allow for such things as reaction time, time required to take corrective action, and time required for the change to take effect. As we will soon see, the same thing applies to an automatic controller; the measuring means cannot immediately reflect a disturbance, the controlling means cannot immediately bring about a change, and the measuring means cannot immediately reflect the change after it has occurred.

Many of the things that slow down changes in a process, or the control of a process, are related to the various capacities and resistances of equipment and substances. For example, water has the capacity to store thermal energy, but time is required for this storage to take place. Piping, valves, and other equipment have the capacity to allow the flow of a certain quantity of water but, at the same time, they offer some resistance to flow. The slowing-down effects associated with capacity and resistance are referred to as LAG (capacity lag, process lag, transfer lag, and so forth).

The man in figure 17-l who is acting as a human control system must also think about DEAD TIME-the time required to transport a change from one place to another. Dead time can occur in various parts of the process. When the man opens the steam valve, a certain amount of time is required for the steam to travel from the valve to the heat exchanger. This period of time is dead time. Similarly, after the steam has heated the water, a certain amount of time is required for the hot water to travel from the heat exchanger to the discharge piping where the man is holding his hand. This, again, is dead time. Dead time is any definite delay between two related actions.

To distinguish between dead time and lag, remember that dead time is basically travel time and that lag is related to the capacity and the resistance of the equipment or substances involved in the process.

The heat exchange process shown in figure 17-1 could be controlled by various kinds of automatic control systems employing either electrical, hydraulic, or pneumatic methods of signal transmission, or some combination of these. Since we will later be concerned almost entirely with pneumatic systems used for boiler controls, let's take a simple pneumatic system such as the one shown in figure 17-3 and apply it to the control of the heat exchange process.

The automatic system must perform all the control functions performed by the human operator in figure 17-1, and it must perform them without human assistance. To perform these functions automatically, the system must have a measuring means, some arrangement for comparison and computation, and a controlling means.

The measuring means of the system shown in figure 17-3 consists of a thermometer bulb, a Bourdon tube, and connecting capillary tubing. A change in the controlled variable (temperature of the hot water) leads to a change in the pressure transmitted to the Bourdon tube. This leads to a change in the position of the Bourdon tube. Through a series of mechanical linkages, the position of the Bourdon tube affects the position of the vane in a nozzle-and-vane assembly located in the pneumatic transmitter.

The set point knob is linked to the nozzle of the nozzle-and-vane assembly in such a way that the setting of the set point knob affects the position of the nozzle. The set point knob is

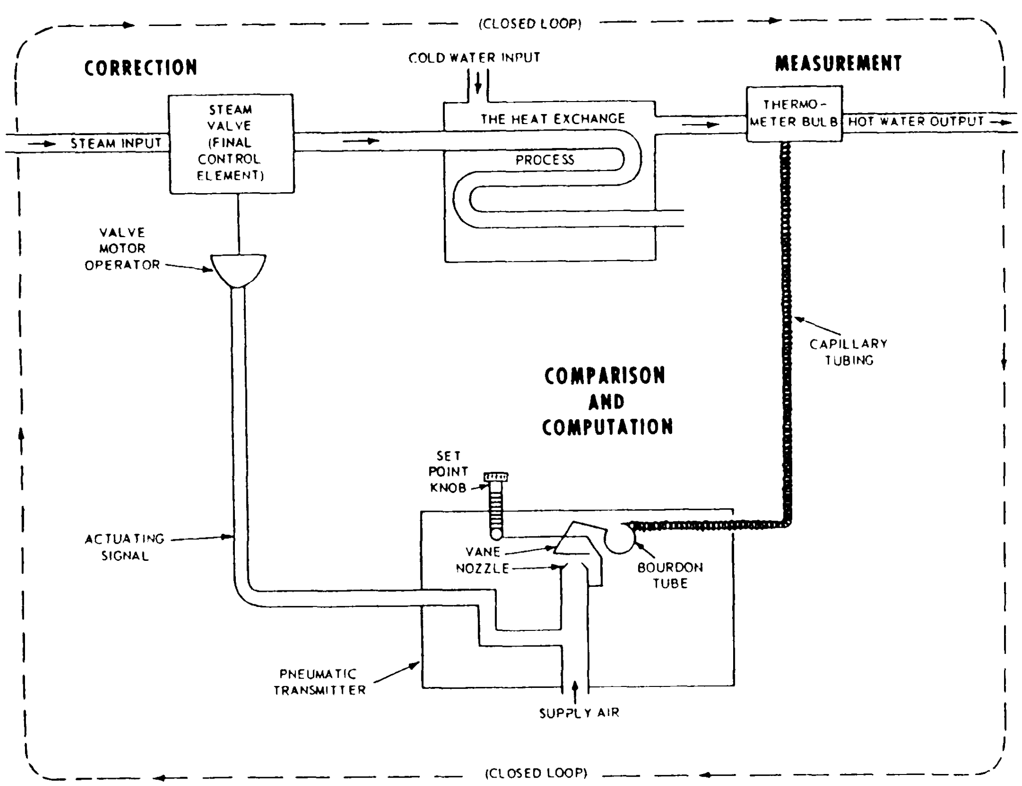


Figure 17-3.—Simple automatic control system (pneumatic) for control of heat exchange process.

positioned to represent the desired value of the controlled variable.

The nozzle-and-vane assembly is the comparing and computing device in this pneumatic transmitter. Since the position of the Bourdon tube affects the position of the vane, and the setting of the set point knob affects the position of the nozzle, the distance between the nozzle and the vane at all times represents a COMPARISON of the actual measured value (Bourdon tube) and the desired value (set point knob). The distance between the tip of the nozzle and the vane is responsible for the COMPUTATION of the amount and direction of change that must be made in the position of the steam valve, because (1) the rate of airflow from the nozzle depends on the distance between the nozzle and the vane, and (2) the rate of airflow from the nozzle determines how much pneumatic pressure will go from the transmitter to the valve motor operator. When the vane and nozzle are relatively far apart, a good deal of air flows out of the nozzle and there is relatively little air pressure going to the valve motor operator. If, on the other hand, when the vane and nozzle are closer together, the flow of air from the nozzle is restricted and more air pressure is directed to the valve motor operator.

The amount of air pressure going from the transmitter to the motor operator determines the position of the steam valve, since the motor operator positions the valve according to air pressure received from the transmitter. Thus the motor operator and the steam valve together form the controlling means of this system.

The nozzle-and-vane assembly discussed here is only one of many pneumatic devices that can accomplish the functions of comparison and computation. Bellows, escapement valves, and various other devices are also used in pneumatic systems to compare the measured value with the desired value and to compute the amount of correction required.

BASIC TERMINOLOGY

In considering the human control system shown in figure 17-1, we introduced a number of ideas and terms that are common to any type of control system, human or automatic. At this point, stop a few minutes and check your understanding of the following terms:

PROCESS

DESIRED VALUE

CLOSED LOOP (or FEEDBACK LOOP)

CONTROLLED VARIABLE

CONTROLLED MEDIUM

MANIPULATED VARIABLE

CONTROL AGENT

BALANCED PROCESS

DISTURBANCE

DEVIATION

CORRECTIVE ACTION

LAG

DEAD TIME

Do you have a clear understanding of the meaning of these terms? If not, go back and study the human control system again. These terms are either defined in that discussion or are used in such a way that you should be able to understand what they mean. The meaning of these terms is basic to any real understanding of automatic control.

In the simple automatic control system illustrated in figure 17-3, we touched upon several new ideas. Let us explore these ideas a little more and establish some basic definitions. Insofar as possible, the definitions given here follow the usage established by the American Society of Mechanical Engineers (ASME).

To begin with, an AUTOMATIC CONTROL SYSTEM is any operable arrangement of one or more automatic controllers connected in closed loops and used with one or more processes.

An AUTOMATIC CONTROLLER is a device that measures the value of a variable quantity or condition and operates to correct or limit deviation of this measured value from a selected reference. An automatic controller, therefore, must include both the measuring means and the controlling means.

The MEASURING MEANS consists of those elements of an automatic controller that are involved in ascertaining and communicating the value of the controlled variable to the controlling means.

The PRIMARY ELEMENT is the part of the measuring means that first either uses or transforms the energy from the controlled medium to produce the desired change in the value of the controlled variable. In the system shown in figure 17-3, the measuring means consists of a thermometer bulb, a Bourdon tube, and the connecting capillary tubing. The primary element of this measuring means is the thermometer bulb. It is the element that first uses or transforms energy from the controlled medium. The thermal energy of the hot water causes the liquid in the thermometer bulb to expand, thereby creating a fluid pressure which is transmitted to the Bourdon tube. The increased pressure causes the Bourdon tube to move. Thus, thermal energy is transformed into mechanical energy (work). In a sense, the entire measuring means is involved in this transformation of energy; but, by definition, the primary element is that part of the measuring means that FIRST uses or transforms energy from the controlled medium.

The CONTROLLING MEANS consists of those elements of an automatic controller that are involved in producing a corrective action. The controlling means includes a final control element and, in many cases, a motor operator.

The FINAL CONTROL ELEMENT is that portion of the controlling means that directly or indirectly changes the value of the manipulated variable. The steam valve is the final control element of the automatic control system shown in figure 17-3. It is also the final control element of the human control system shown in figure 17-1.

The MOTOR OPERATOR is a portion of the controlling means that applies power for operating the final control element. The motor operator is identified in the automatic control system shown in figure 17-3. In the human control system illustrated in figure 17-1, the man's left hand may be thought of as performing the functions of a motor operator.

Some automatic controllers are self-operated; others are relay-operated. In a SELF-OPERATED CONTROLLER, all the energy required to operate the final control element is derived from the controlled medium through the primary element. In the self-operated controller illustrated in figure 17-4, the fluid pressure from the controlled medium acts upon the diaphragm (primary element) and directly causes the operation of the valve (final control element).

In a RELAY-OPERATED CONTROLLER, the energy transmitted through the primary element is either supplemented or amplified to operate the final control element. The automatic controller of the system shown in figure 17-3 is a relay-operated controller, since a supplementary source of power (compressed air, in this case) is required to operate the final control element.

To compare an actual measured value with a desired value, an automatic controller must have a reference force representing the desired value, as well as an input signal representing the measured value. The input signal representing the desired value of the controlled variable is the REFERENCE INPUT. The input signal representing the actual measured value of the controlled variable is the PRIMARY FEEDBACK.

The reference input may represent a pressure, a temperature, a frequency, a voltage, a shaft position, a force exerted by a spring, or any other quantity or condition that serves as the independently set reference in the automatic controller. Since the reference input must be compared with the primary feedback, it is obvious that the two signals must use the same units of measurement—pounds per square inch, degrees Fahrenheit, and so forth.

The signal that results from the comparison between the reference input and the primary

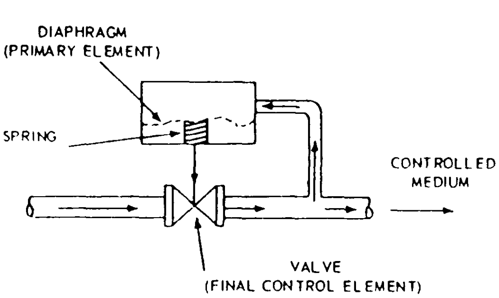


Figure 17-4.—Self-operated controller.

feedback is called the ACTUATING SIGNAL. The actuating signal is the difference, at any given time, between the reference input and the primary feedback. The actuating signal leads to corrective action-that is, the variation of the manipulated variable produced by the controlling means.

The SET POINT is the position to which the control-point setting mechanism is set to provide a reference input. The control-point setting mechanism shown in figure 17-3 is called a SET POINT KNOB. Set point knobs are used in some automatic controllers, but there are other types of control-point setting mechanisms that are used in other controllers. In some controllers, the set point is built in to the controller so that it cannot be changed unless the controller is taken apart and the mechanism is readjusted.

DEVIATION is the instantaneous difference between the actual value of the controlled variable and the value of the controlled variable corresponding to the set point.

The CONTROL POINT is the value of the controlled variable that, under any fixed set of conditions, the automatic controller operates to maintain.

So that you do not confuse set point and control point, think of set point as the reference force required to maintain the control point at a desired value. However, both are expressed in units of the controlled variable. So why do we need to make a distinction between the two?

For some automatic controllers the distinction between set point and control point is not really necessary, since the points coincide. But in controllers that have other types of controller action, set point and control point do NOT coincide; the distinction is necessary for these controllers. The steady-state difference between the control point and the value of the controlled variable corresponding to the set point is called OFFSET. Offset is an essential characteristic of certain types of controller action. Set point, deviation, control point, and offset are illustrated figure 17-5.

Another term that you will find in connection with automatic control is CYCLING. Cycling is a continuous changing of the controlled variable. Cycling occurs more with some types of controller action than with others.

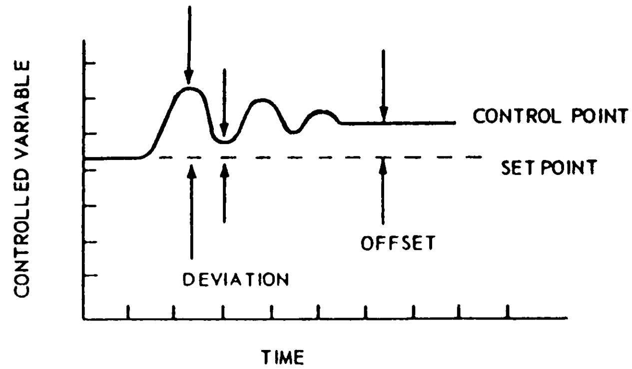


Figure 17-5.—Set point, deviation, control point, and offset in an automatic controller.

TYPES OF AUTOMATIC CONTROLLER ACTION

When the man in figure 17-1 notices a deviation in the temperature of the hot water, he can do several things to take corrective action. He may immediately open the valve wide or close it completely, depending on the direction of the deviation. He may open or close the valve quickly or slowly, at a constant rate or at a varying rate, by a constant amount or by a varying amount. He may continue opening or closing the valve until he can feel that the temperature has returned to the desired value, or he may stop his corrective action before the temperature has returned to normal so that he will not overcorrect. In short, there are a great many types of corrective action this man can take. Not all of them will be equally effective, of course, but all of them will work, more or less.

Automatic controllers, like human beings, are capable of various kinds of actions. The type of controller selected for any given system depends on the requirements of the system. The automatic controller actions discussed in this chapter include the following:

1. Positioning action
2. Floating action
3. Rate action
4. Multiple action

To make it simple, we will discuss the various kinds of controller action as they relate to the position of a final control element. Remember, however, that the terms and definitions used here can be applied equally well to other aspects of automatic control. They may apply to the value of a manipulated variable, for example, or to a signal sent from one controller to another.

As you study the material on the types of controller action, be sure to study the diagrams and illustrations that accompany the text. The relationship between the controlled variable and the controller action can often be understood more clearly from diagrams than from a mere description.

POSITIONING ACTION

Positioning action is any controller action in which there is predetermined relation between the value of the controlled variable and the position of the final control element. We will discuss two kinds of positioning action: two-position action (two types) and proportional-position action.

Two-Position Action

In two-position action, a final control element is moved from one of two fixed positions to the other. There are two kinds of two-position action. One is two-position single-point, and the other is two-position differential-gap action.

TWO-POSITION SINGLE-POINT ACTION.— Two-position single-point action is action in which a final control element is moved from one of two fixed positions to the other whenever the controlled variable reaches one certain value. Figure 17-6 illustrates the two-position single-point action. When the temperature of the water is at or above set point, the valve immediately closes; when it is below set point, the valve opens. As you can see, a two-position single-point controller cannot make exact corrections. Instead, it must always overcorrect; thus the process never achieves stability and the value of the controlled variable cycles continuously.

TWO-POSITION DIFFERENTIAL-GAP ACTION.—Two-position differential-gap action is action very much like two-position single-point action except that the controlled variable has a RANGE of values instead of a single value (or single point) to reach. This range of values is called the differential gap. No action of the final control element occurs when the value of the controlled variable is within the differential gap. But when the value of the controlled variable goes above the highest value of the differential gap or below the lowest value, the final control element is moved from one fixed position to the other. Obviously, this type of action must also result in overcorrection and consequent cycling of the controlled variable.

To illustrate the difference between the two types of two-position action, let's consider figure 17-6 again. Assume that the set point is 140°F. If the controller has two-position single-point action, the valve will close whenever the temperature of the hot water is 140°F or above and open

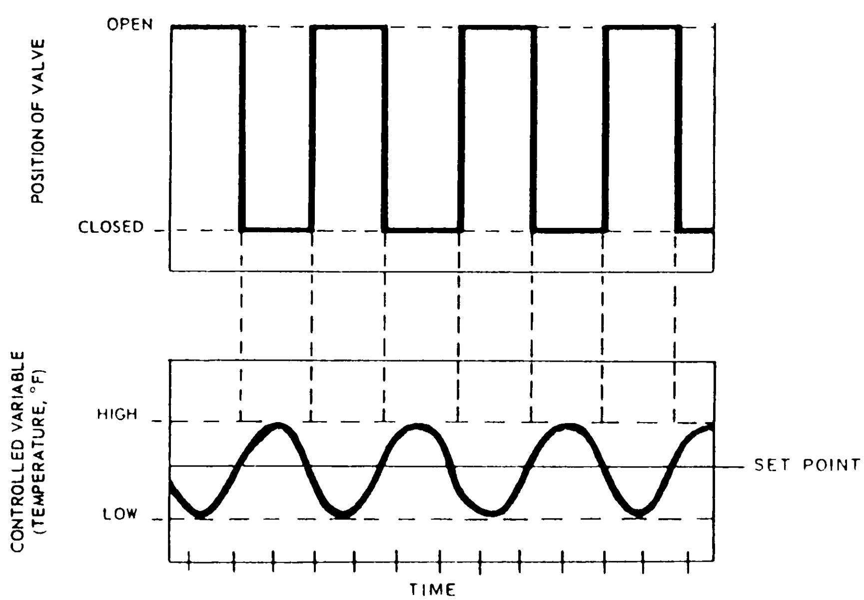


Figure 17-6.—Action of two-position single-point controller : valve position (top) and controlled variable (bottom).

whenever the temperature is below 140°F. If the controller has two-position differential-gap action, with a differential gap of 20°, the valve will close whenever the temperature of the water reaches 150°F and open whenever it reaches 130°F.

In both types of two-position action, the two fixed positions of the final control element can be something other than the zero or 100 percent positions. For example, the valve positions illustrated in figure 17-6 indicate that the valve must go from fully open to fully closed or from fully closed to fully open. The amount of cycling can be reduced by narrowing the range of the valve opening—that is, by having the valve move from one-fourth open to three-fourths open, instead of from fully closed to fully open. However, a narrow range will work well only for a very steady and constant process. If a process is subject to considerable load changes, a narrow range of the final control element will require constant manual readjustment.

Proportional-Position Action

Proportional-position action is that in which there is a continuous linear relationship between the value of the controlled variable and the position of the final control element. The amount of change in the value of the controlled variable that is necessary to cause a specified change in the position of the final control element depends on the PROPORTIONALITY ADJUSTMENT of the controller.

The proportionality adjustment of a controller may be expressed as (1) PROPORTIONAL BAND or (2) GAIN or SENSITIVITY adjustment. Gain and sensitivity mean the same thing. Proportional band and gain are not identical, but both have to do with the proportionality adjustment of a controller. Some manufacturers calibrate their controllers in such a way that the proportionality adjustment is made in terms of the proportional band, while other manufacturers use gain. In general, you will find that older controllers are calibrated to indicate proportional band, while newer ones are calibrated to indicate gain.

The term PROPORTIONAL BAND refers to the amount of change in the value of the controlled variable that is required to produce a specified change in the position of the final control element. Proportional band may be expressed either in units of the controlled variable or as a percentage of the controller scale range. For example, suppose a controller for a heat exchange process has a scale range of 100 percent, corresponding to a temperature range of 100°F, if the proportional band adjustment of this controller is set at 5 percent, a temperature change of 5°F will produce a 100 percent change in the position of the steam valve (fully open or fully closed). If the proportional band adjustment is set at 100 percent, a temperature change of 100 °F is required to produce the same change in the position of the valve. If the proportional band adjustment of this controller is 120 percent, a temperature of 120 °F is required to produce a 100 percent change in the position of the valve.

GAIN (or SENSITIVITY) describes the ratio between the input to a controller and the output from that controller. Gain is the RECIPROCAL of proportional band.

Although we define proportional-position action and proportional band (or gain, if the controller is so calibrated) in relation to the position of the final control element, remember that the controller actions and adjustments are described in the same way when they apply to other aspects of automatic control. For example, consider a proportional-position controller that receives a pneumatic input signal and sends a proportional pneumatic output signal to some unit that is NOT a final control element. This controller still has a proportionality adjustment—that is, it still has either a proportional band adjustment or a gain (sensitivity) adjustment.

Since proportional-position action causes a corrective action proportional to the amount of deviation, it is a very stable kind of controller action and is sometimes used for automatic control. However, proportional-position action has one serious disadvantage: it can make exact corrections for deviations of the controlled variable ONLY when there is no load change.

Under all conditions of load except the one for which the set point is established, proportional-position action produces a corrective action that stabilizes the controlled variable at some value other than the desired set point value. The new value is called the CONTROL POINT. The difference between the control point and the set point is called OFFSET. It is important to understand that offset is a basic characteristic of proportional-position action under conditions of load change.

Offset has been previously defined and illustrated (figure 17-5.) At this point, you may understand the whole idea more easily if we consider a sequence of events in a heat exchange process that is under the control of an automatic controller with proportional-position action.

Figure 17-7 illustrates such a heat exchange process. The original set point is 150°F. To begin with, the process is stable and is balanced to maintain the value of the controlled variable at the set point. Then, after 1 minute a deviation occurs. There is no change in load, but the temperature of the water drops to 140°F, corresponding with set point. The process is again stable and balanced at set point.

So far, so good. But at 5 minutes there is a sudden change in the demand for hot water—that is, there is a load change. Since proportional-position action is proportional only to the change in the controlled variable and NOT to the change in load, the process levels off and becomes stabilized at a new value that is somewhat below the original set point and, therefore, somewhat below the desired value. The new set point at which the process has stabilized is called the CONTROL POINT. The difference between the control point and the set point is called the OFFSET.

Two or three minutes later, someone complains about the temperature of the water; it is only 145°F when it should be 150°F. At 9 minutes, the set point is readjusted manually to establish a new and higher set point. The proportional-position action of the controller causes the steam valve to open wider, and the process stabilizes and levels off at the desired value—that is, the OLD set point and the NEW control point. Thus the temperature of the water is returned to the desired value. But notice that we have not gotten rid of the offset. There is still a difference between control point and set point; the whole thing has just been shifted upward.

Since the water is now at the proper temperature, the complaints may be expected to stop, for a while. But they will start up again as soon as there is another change in the demand for hot water. As long as we use proportional-position action alone to control this heat exchange process, we will need to station someone nearby to readjust the set point whenever necessary. For any process that is subject to frequent load changes, this would seem to be a rather poor form of control.

However, there are ways to overcome this difficulty. Instead of combining proportional-position action with MANUAL reset action, we can combine it with a floating action to produce an AUTOMATIC reset action.

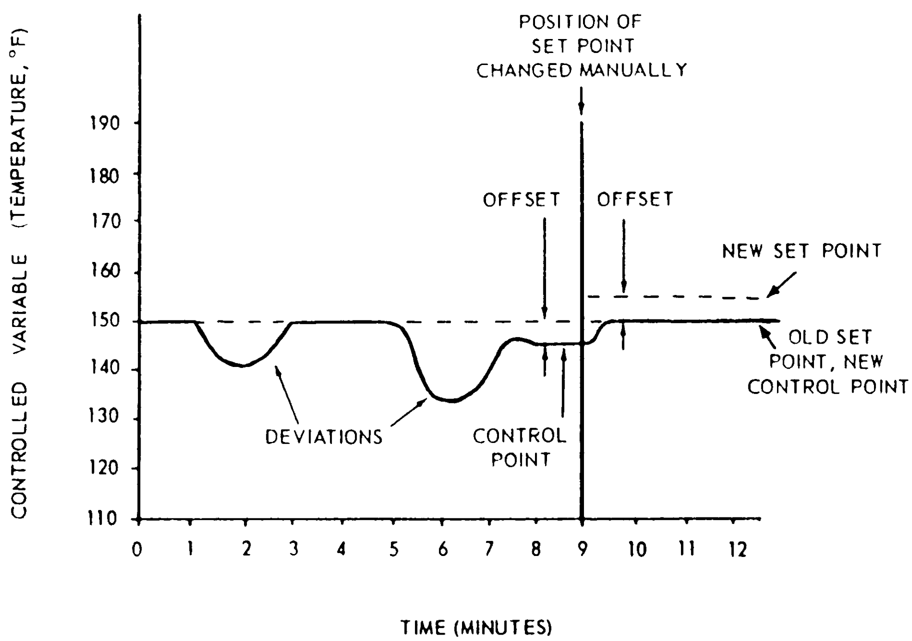


Figure 17-7.—Proportional-position action applied to a heat exchanged process.

FLOATING ACTION

A controller is said to have floating action when there is a predetermined relationship between the deviation and the speed (or rate of travel) of a final control element. With this type of action, the position of the final control element has no fixed relationship to the value of the controlled variable. Rather, the final control element is continuously floated in the required direction whenever the value of the controlled variable deviates from the set point.

In proportional-speed floating action, the final control element is moved at a rate of speed that is proportional to the deviation. In other words, the greater the amount of deviation, the faster the movement of the final control element. Proportional-speed floating action is capable of producing an exact correction for any load change.

The relationship between the amount of deviation and the rate of motion of the final control element is illustrated in figure 17-8. Assume that the graph refers to a controller used in a heat exchange process and that the final control element is a steam valve. Assume also that the controller has a 40 percent proportional band and that the set point is at the middle of the controlled scale. A temperature deviation of 20 percent causes the valve to move at maximum speed to the open or closed position. A temperature deviation of 5 percent causes the valve to move to the open or closed position at 30 percent of the maximum rate of travel.

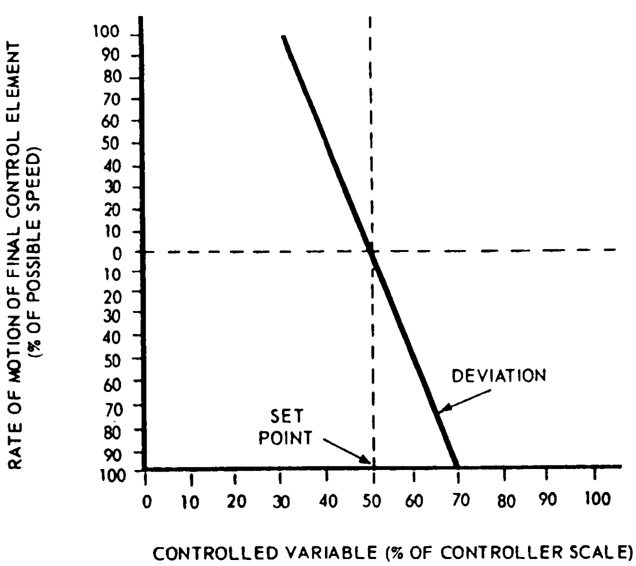


Figure 17-8.—Proportional-speed floating action.

In connection with proportional-speed floating action, the term FLOATING RATE describes the ratio of the speed of the final control element to the deviation.

RATE ACTION

Rate action is that action in which there is a continuous linear relationship between the RATE OF CHANGE of the controlled variable and the position of the final control element. Rate action may be combined with proportional action to form a multiple action.

MULTIPLE ACTION

Multiple action is that in which two or more types of controller action are combined. Three types of multiple action are discussed here: (1) proportional plus reset, (2) proportional plus rate, and (3) proportional plus reset plus rate.

Proportional Plus Reset

In discussing proportional-position action, we noted that a change in load causes offset that requires a new set point position if the controlled variable is to be maintained at the desired value. On the other hand, the floating action continues to correct the position of the final control element, even with load changes, until there is no further deviation.

A combination of some type of floating action, usually proportional-speed floating action, and proportional-position action produces a multiple action that has the stability of proportional-position action PLUS the continuous correction of deviation of the floating action. This combined or multiple action is called PROPORTIONAL PLUS RESET action.

Proportional plus reset action gives control without offset under all conditions of load. The proportional-position action makes the initial correction in the position of the final control element; the floating action makes the final exact correction by operating the final control element at a rate that is proportional to the deviation. In many controllers with proportional plus reset action, the floating action causes the proportional band to shift gradually up or down the scale until the controlled variable returns to the set point.

Many controllers with proportional plus reset action have a reset rate adjustment for changing the floating rate of the proportional-speed floating component. Reset rate is usually expressed as the NUMBER OF REPEATS PER MINUTE—the number of times per minute that the effect of the proportional-position action upon the final control element is repeated by the proportional-speed floating action.

Proportional Plus Rate

Proportional plus rate action is a multiple action that combines proportional-position action and rate action. As you have seen, the proportional-position action positions the final control element according to the value of the controlled variable, while the rate action positions the final control element according to the rate of change of the controlled variable. In a controller with proportional plus rate action, the general effect of rate action is to adjust the final control element more rapidly and to move it farther in response to sudden load changes than would the proportional-position action alone.

The time interval that it takes the rate action to advance the effect of the proportional-position action upon the final control element is called RATE TIME. Rate time is commonly expressed in minutes.

Proportional Plus Reset Plus Rate

When the proportional-position action, reset action, and rate action are combined in one controller, the resulting action is called PROPORTIONAL PLUS RESET PLUS RATE action. The effects of this multiple action are illustrated in figure 17-9.

AUTOMATIC BOILER CONTROL SYSTEMS

Thus far, we have considered some of the basic elements of an automatic control system and some of the types and characteristics of automatic controllers. We have applied these control concepts to a simple heat exchange process, since it is easier to understand automatic control when the process itself is not too complicated. Now we must consider how the principles of control are applied to the more complex boiler control systems found aboard ship.

FUNCTIONS OF BOILER CONTROL SYSTEMS

Functionally, a boiler control system may be considered as having two parts: a combustion

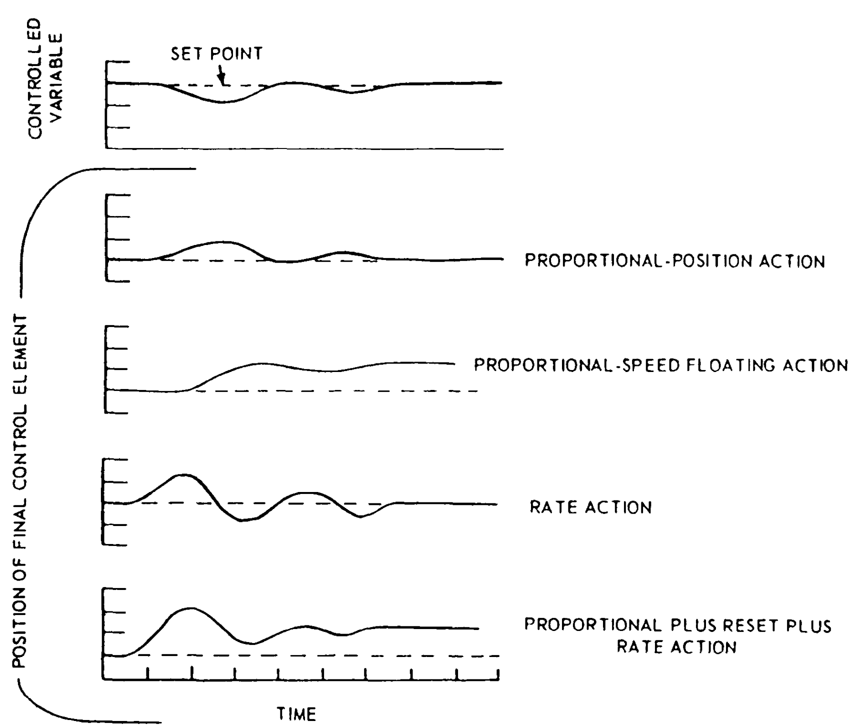


Figure 17-9.—Proportional plus reset plus rate action.

control system and a feedwater control system. All combustion control systems for boilers serve the same purpose-they maintain the fuel-oil input and the combustion-air input to the boiler according to the demand for steam. A related function of the combustion control system is to proportion the amount of combustion air to the amount of fuel to provide maximum combustion efficiency. Likewise, all feedwater control systems for boilers serve a similar purpose—to supply the right amount of feedwater to the boiler under all conditions of operation.

Although we may regard the combustion control system and the feedwater control system separately for some purposes, we must not forget that they are closely related and that they usually function together rather than separately.

METHODS OF CONTROL OPERATION

The components of the two control systems for each boiler are designed for three methods of control operation: (1) local manual, (2) remote manual, and (3) automatic control. Either one or both boilers may be operated under any one, or a combination, of the three methods. These methods of operation will be discussed later in this chapter.

The two control systems contain an airlock system designed to lock the setting to the forced draft blower, the fuel-oil control valve, and the feedwater flow control valve so as to maintain air, fuel, and water flows at a boiler rate of operation that existed at the instant of an air supply failure.

On diaphragm failure of the feedwater regulating valve, the valve will go to the full open position and on diaphragm failure of the fuel-oil control valve, the valve will go to the closed position.

TYPES OF BOILER CONTROL SYSTEMS

There are several manufacturers of control systems used aboard naval ships. The rest of this chapter will deal primarily with one type of boiler control. Remember, no two systems are identical in all details, even when they are made by the same manufacturer. The only authoritative source of information on the boiler control system of any particular ship is the manufacturer's technical manual for the equipment on that ship.

COMPRESSED AIR FOR BOILER CONTROL SYSTEMS

Obviously, any pneumatic boiler control system depends on compressed air for its operation. Compressed air is the controlling or balancing force for the operation of pneumatic units. At somewhat higher pressures, compressed air is the source of power for the operation of some, or all, of the final control elements.

In some systems, the main compressed air supply for the boiler controls is obtained from the ship's service compressed air system at approximately 100 psi. It is then reduced to the pressure required to operate the boiler controls. In most installations, a separate combustion control air system is installed to supply compressed air for boiler controls only. A combustion control system consists of an air compressor, an air dryer and/or drain regulator, an air receiver, and sufficient tubing to supply air to all components of the boiler control system. The air compressor for a combustion control system is usually installed in the fireroom.

Any pneumatic boiler control system consists of a number of pneumatic units that develop, transmit, and receive pneumatic "messages" or signals in the form of variable air pressures. The pneumatic units are interconnected by copper tubing. Each pneumatic unit operates by receiving one or more pneumatic pressures (signals) from one or more sources (frequently from other pneumatic units), altering and/or combining the pressure or pressures it receives, and then sending the resulting new pneumatic pressure to another pneumatic unit.

In considering the action of any pneumatic unit, it is necessary to distinguish three kinds of air pressure. Unfortunately, the manufacturers of boiler controls do not always identify these three kinds of pressure signals in quite the same way. For the purposes of this chapter we will define the three air pressure signals as follows:

SUPPLY AIR PRESSURE is the compressed air pressure that is supplied to each pneumatic unit so that it can develop the appropriate pneumatic messages or signals in the form of variable air pressure.

LOADING PRESSURE is the compressed air pressure that goes from one pneumatic unit to another pneumatic unit, EXCEPT when the pressure is imposed upon a motor operator or upon a final control element.

CONTROL PRESSURE is the compressed air pressure that goes from a pneumatic unit to a motor operator of a final control element.

To illustrate the three kinds of air pressure used in pneumatic control systems, let's construct a simple control system. It really doesn't matter which process we are trying to control. Although the number and arrangement of the pneumatic units will vary, depending on the nature of the process and the variables to be controlled, the basic principles are the same for any process. All units in the system except the final control element receive SUPPLY PRESSURE from the compressed air source. Each of the pneumatic transmitters develops and transmits LOADING PRESSURE signals to one or more of the pneumatic relays. These loading pressure signals, which represent the basic variables in the system, are altered and/or combined in various ways by the pneumatic relays. The output signal of one of the relays shown in figure 17-10 is a CONTROL PRESSURE signal because it goes to the motor operator of the final control element.

COMBUSTION CONTROL SYSTEM OPERATION

A combustion control system consists of pneumatic metering devices (transmitters), controllers, relays, and actuators. This equipment is arranged and interconnected to produce an integrated system designed to monitor the steam pressure and control the flow of air and fuel to the steam generating units to maintain steam pressure at the set point. Additionally, a control system is designed to maintain fuel/air (F/A) ratio throughout the operating range at a value that ensures optimum combustion.

The combustion control system serves all boilers located in the same machinery space or fireroom. There is only one boiler shown in figure 17-10. This system consists of components that (1) sense the steam drum pressure; (2) determine the loading signal for the air and fuel control loop of each boiler, which is necessary to hold steam pressure at the set point; and (3) control these variables accordingly.

This system is divided into three groups—the steam pressure control loop, the airflow control loop, and the fuel flow control loop. Component item numbers shown on the control system diagram (fig. 7-10) appear in parentheses in this discussion. So that you will understand the system, let us discuss each group individually.

Steam Pressure Control Loop

The steam pressure control loop consists of the following:

Two steam pressure transmitters (1 and 2)

One high signal selector (3)

One steam pressure controller (4)

One boiler master A/M station (5)

The steam pressure transmitters (1 and 2) are connected to their respective boiler steam drums. These components sense steam drum pressure, compare it with a set point force, apply proportional action to any error that may exist, and develop an output signal that, in conjunction with the rest of the control system, regulates the rate of combustion to the amount required to maintain a constant drum pressure.

The output signals from the direct-acting steam pressure transmitters are transmitted to the high signal selector (3). The high signal selector selects the higher of the pressure signals and sends it on to the steam pressure controller (4).

The steam pressure transmitter is direct-acting. When there is an increase in steam pressure, the steam pressure transmitter sends out an increased signal. Once this signal reaches the steam pressure controller, this increased input signal results in a decreased output.

From the steam pressure controller the signal is fed to the boiler master A/M station (5), where it is passed through and becomes the master demand signal. This completes the steam pressure control loop.

Airflow Control Loop

At the airflow controller (6), two signals are compared—the master demand signal, which is telling the system what it wants, and the airflow feedback signal from the airflow transmitter, which represents what the system has available. If these signals are equal, the output remains

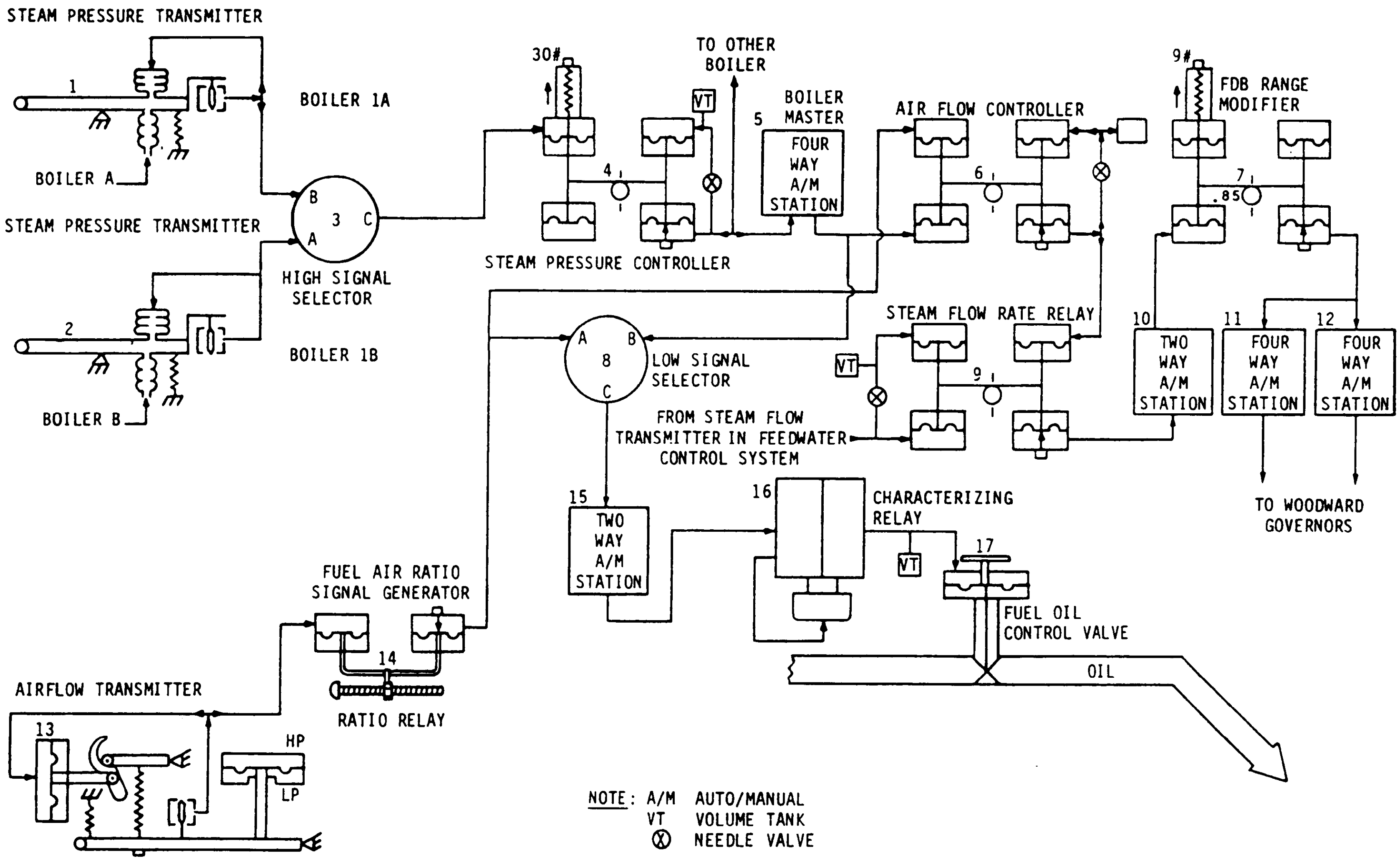


Figure 17-10.—Combustion control system (FF 1078) for one boiler.

constant at the value required. If the signals are different, the controller changes its output in the proper direction to the extent necessary to reduce the difference to zero; and, once again, the system is balanced.

For the airflow controller to match the demand signal with the feedback signal, the airflow to the burners must change. To accomplish this, the following components are required:

One airflow controller (6)

One steam flow rate relay (9)

One forced draft blower control station (10)

Two forced draft blower A/M stations (11 and 12)

One airflow transmitter (13)

One F/A ratio signal generator (14)

One signal range modifier (7)

Let us start with the airflow transmitter (13), which is located on the bottom left part of your diagram. It measures the differential between the wind box and the fire box and sends out a signal representing airflow for each burner. This airflow signal passes to the F/A ratio signal generator (14).

The F/A ratio signal generator provides you (the operator) with a means of modifying the airflow signal as necessary to provide the F/A ratio needed for optimum combustion throughout the firing range of the boiler. In other words, if some adverse condition results in poor combustion, you have the means to readjust the airflow and restore combustion to an acceptable state until corrective action can be taken or excess air can be added for blowing tubes.

The output of the F/A ratio signal generator is called the airflow feedback signal (a loading signal). The airflow feedback signal goes directly to the low signal selector (8) and to the airflow controller (6).

The airflow controller receives the master demand signal and the airflow feedback signal, compares these two signals, and applies proportional plus reset action to correct any difference between them. As long as the difference is zero, the output will remain constant.

The output of the airflow controller is fed to the steam flow rate relay (9). The steam flow rate relay also receives a signal from the steam flow transmitter. The steam flow transmitter is located in the steam flow, or demand, loop of the feedwater control system.

The output of the steam flow rate relay goes to the two-way forced draft blower master A/M (10). This signal then goes to the signal range modifier (7).

This signal must be modified because the airflow demand signal has a range of 0 to 60 psig while the forced draft blower governor (final control element) has a range of 9 to 60 psig. The signal must be modified so that a given airflow demand signal may produce the same change in the governor.

The signal range modifier sends a signal to the two forced draft blower A/M stations (11 and 12). From here the signals go to the final control element, to control the speed of the forced draft blowers.

Fuel Flow Control Loop

The fuel flow control loop consists of the following:

One low signal selector (8)

One fuel-oil A/M transfer station (15)

One characterizing relay (16)

One fuel pressure control valve (17)

The first component in the fuel control loop is the low signal selector (8). The two inputs to this device are the master demand signal (A) and the airflow feedback signal (B). The low signal selector transmits an output equal to the lower of its two input signals. The low signal selector ensures that the fuel flow never exceeds airflow, thereby preventing black smoke from occurring under all conditions.

If the boiler load is decreased, the master demand signal to the airflow controller and the low signal selector will also decrease. The low signal selector will transmit the lower master demand as a fuel demand signal. This action will decrease the amount of air and oil, preventing black smoke.

The fuel flow demand signal now passes to the fuel flow A/M selector station (15). Again, you can select the mode of operation; if it is automatic, the signal passes directly to the characterizing relay (16). To maintain efficient combustion, the fuel-oil flow to the burners must be regulated so that it is proportional to the airflow supplied to the burners. The fuel-oil control valve, as in the case of the forced draft blower governor, operates on a different signal range. The signal is modified in the characterizing relay. The output of the characterizing relay goes directly to the fuel pressure control valve (17) final control element.

This valve receives the output of the characterizing relay and develops an oil pressure that varies in a manner directly proportional to any pneumatic change in its input.

Now that you have a basic understanding of what each component does in the system, let us see what they do together when the boiler load increases. Look again at figure 17-10 and follow the signal, component by component.

INCREASE IN BOILER LOAD

In the following paragraphs we will discuss the effects of boiler load increase in the demand loop, the air loop, and the fuel loop.

Demand Loop

When the boiler load increases, the boiler steam drum pressure begins to drop. This change in pressure is sensed by the two steam pressure transmitters, which begin to generate decreasing signal pressures. Let's assume that in this case the decreasing pressures are 27 psig on boiler A and 28 psig on boiler B. These two signals are transmitted to the high signal selector, which will select the higher of the two signals. On your worksheet mark the output of the high signal selector as 28 psig. The 28 psig signal is transmitted to the steam pressure controller. Here a decrease input will result in an increase in the output (the output of the steam pressure controller may be anywhere between 0 and 60 psig, depending on what is needed to bring the pressures into balance). For the purpose of this discussion, let's say that the steam pressure controller is in balance with 40 psig output. This signal is transmitted to the boiler master A/M station, where the signal will pass unchanged through the A/M station (since it is in automatic) to the airflow controller and to the low signal selector.

Air Loop

The increase in the boiler load signal causes the airflow controller to generate a signal that is proportional to the difference between the boiler demand and the actual airflow signals. The 40 psig signal to the airflow controller will cause an increase in blower speed due to the action of the controller. Mark the output of the airflow controller at 40 psig. (The output may be anywhere between 0 and 60 psig.) The airflow controller signal is transmitted to the steam flow rate relay. The increased signal from the airflow controller and the input from the steam flow transmitter, which sensed the steam demand change instantly when the change occurred, cause an increase in output from the steam flow rate relay. The output from the steam flow rate relay is transmitted through the forced draft blower master A/M station to the signal range modifier.

The signal range modifier sends out an increased signal that is transmitted through the forced draft blower A/M stations to the final control elements, thus speeding up the forced draft blowers.

Fuel Loop

In the fuel control loop, the airflow signal generated by the airflow transmitter is still at the value it had before the steam pressure dropped. Mark it at 30 psig. The airflow signal is passing to the F/A ratio signal generator, which is a 1:1 ratio (or 1 pound in, 1 pound out). You have 30 psig to the low signal selector and the airflow controller. Since this 30 psig signal is less than the 40 psig demand signal, the low signal selector is still selecting the 30 psig. (The air pressure is increasing, but the oil pressure is holding. This condition eliminates smoking.)

The output of the airflow transmitter will begin to change as the differential between the wind box and the fire box changes. Mark it at 32 psig. This increase is transmitted through the F/A ratio signal generator to the airflow controller and the low signal selector. The low signal selector will pass this increased signal to the fuel-oil loop, thus increasing the oil pressure. The output of the airflow transmitter will continue to rise until air and oil flow have balanced and steam pressure has returned to normal. Mark the signal output of the airflow transmitter at 40 psig and pass it through the F/A ratio signal generator airflow controller and the low signal selector.

As the signal to the low signal selector increases, the signal passing through the fuel-oil A/M station to the characterizing relay is allowed to increase and to send out a higher signal to the fuel-oil control valve (final control element), thus increasing fuel pressure to the boiler.

As steam pressure increases, the steam pressure transmitters output will begin to increase until the set point is regained. It will then transmit a 30 psig signal through the high signal selector to the steam pressure controller. This will bring the system back into balance once again, at the new value required to hold the set point. The airflow controller had an output of 45 psig when the signal increased. This signal would begin to drop off as the airflow increased and as the opposing signal (feedback) increased from 30 to 32 psig up to the present 40 psig, which balanced the whole system.

COMPONENT OPERATION

You have read about the human control system (fig. 17-1), what the components do in the three groups, and how the system operates on an increase in demand. At this point, it is necessary that you understand how the different components operate. So, once again, let us take the components in groups and examine them carefully.

The ratio totalizer is used in various applications in all three groups, making it essential that you understand the basics of this very versatile component (refer to fig. 17-11). It consists of four diaphragm chambers, a balance beam, the adjustable fulcrum, and a poppet valve, which is located on chamber #l. Chambers #2 and #4 are positive chambers; #l and #3 are negative chambers. Any force (signal) applied to either chamber #2 or #4 will rotate the unit clockwise and open the poppet valve and increase the output. Force applied to either chamber #l or #3 will rotate the unit counterclockwise, closing the

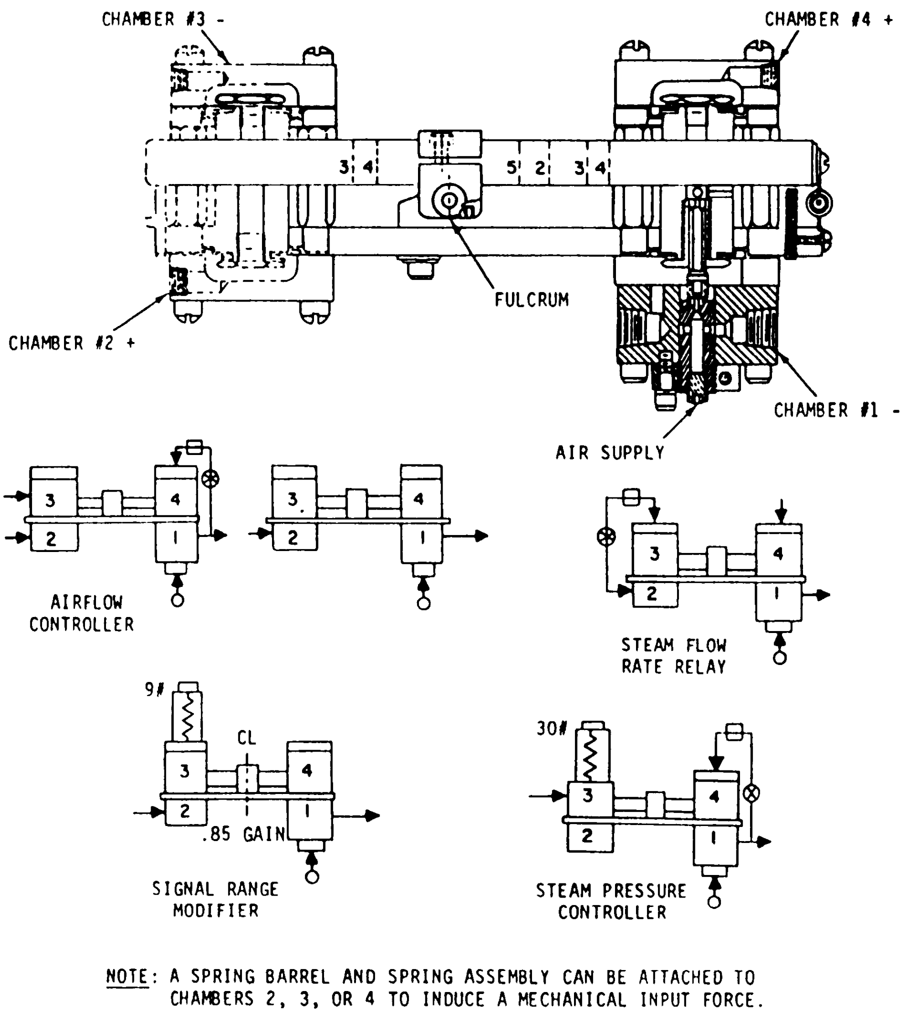


Figure 17-11.—Ratio totalizer showing different applications.

poppet valve and decreasing the output. By changing fulcrum position we can change the ratio of output (l:l, 1:15, and so on).

PRESSURE-SENSING GROUP

Look at the steam pressure transmitter (direct-acting) in figure 17-12. Steam pressure is introduced to the metallic bellows. Upward force resulting from the steam pressure is transmitted through the bellows post to the beam. Tension on the spring pulls downward and opposes the upward force. The amount of tension on the loading spring determines the steam header pressure setting at which the unit is balanced. Beam movement is transmitted through the flexible connector and adjustment screw to the upper end of the escapement valve.

Supply air at 65 psig is connected to the lower end of the escapement valve. The valve stem moves between the inlet and the exhaust seat. The relative position of the valve stem and the two seats determines the openings of the inlet and exhaust ports and controls the output loading pressure. The change in header pressure required to move the beam and escapement valve stem between zero and maximum loading pressure is the proportional band. This factor must be present in every control system to ensure stable operation.

The required gain (proportional band) is adjusted by the proportional band unit. The proportional band unit exerts a downward force on the beam, thereby opposing the tendency of the beam to move upward on an increase in header pressure.

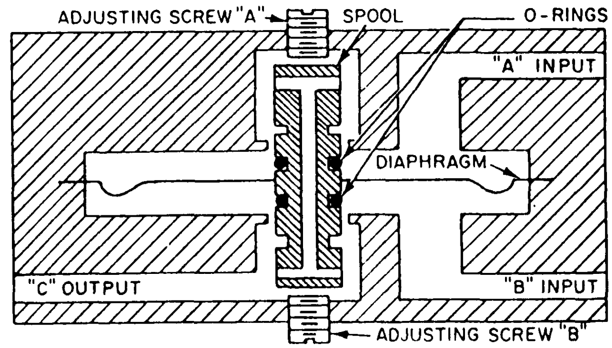


Figure 17-13.—High signal selector.

High Signal Selector

The high signal selector is used when the higher of two input signals is to be selected. The neoprene O-rings are placed in the two innermost grooves on the spool and pressure rises in either A or B input (one toward the lesser pressure port). As this occurs, the O-ring on the side of the lesser pressure will be forced against the circular port made by the casing and the spool, thus blocking that passage and allowing only the high pressure input to pass out port C to the steam pressure controller.

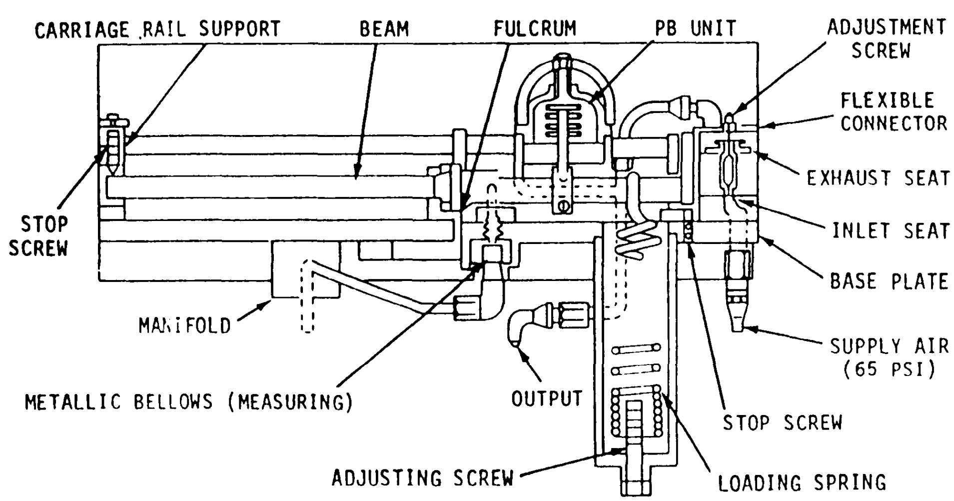


Figure 17-12.—Steam pressure transmitter.

Steam Pressure Controller

The steam pressure controller fig. 17-11 is the set point for the system. There is a 30-psig spring on chamber #3 which acts as a positive force. The output is fed back to chamber #4 through a needle valve and volume tank. The signal from the high signal selector is piped to chamber #3, so any increase in pressure from the high signal selector results in a decrease in output pressure. The needle valve controls the reset or speed at which the controller acts. The output from the steam flow controller goes to the boiler master A/M station as the master demand signal.

Boiler Master A/M Station (Four-way)

This component is used to select the mode of operation, either manual or automatic. When it is set for manual operation, the master demand signal is dead-ended and the manually generated signal is sent out to the rest of the system to control air and oil flow. When it is set for automatic operation, the master demand signal passes through the transfer section to the relay sender (hand generator), there the signal is transmitted through diaphragms and springs to the poppet valve. The output of the poppet valve is then sent back through the transfer station out to the combustion system. In the relay sender, bias can be added when the system is in automatic to compensate for small pressure differences between boilers. (A four-way A/M station is shown in fig.17-14.)

You must reset the transfer valve before shifting to automatic or remote manual. When the transfer valve is in the reset position, the output loading signal is locked out from the station.

Airflow Loop

The following paragraphs will discuss the operation of the components in the airflow loop.

AIRFLOW CONTROLLER.—The output signal from the boiler transfer station is connected to chamber #2 of the airflow controller, and the output signal from the airflow transmitter is connected to chamber #3 of the airflow controller. (See fig. 17-11.)

The two loading pressures exert a net force (the difference between the steam flow demand and the actual airflow) on the beam of the controller.

The controller transmits an output loading pressure that adjusts the actual airflow. To complete the balance of forces in the controller, the loading pressure in chamber #l is balanced by connecting chamber #l to chamber #4 through a needle valve and a volume tank, which is located between the two chambers. The delay introduced by the needle valve controls the speed of change (reset rate) in the output loading pressure at approximately the rate at which the control element can change the controlled airflow.

A small opening has a slower rate of reset; a large opening has a faster rate of reset.

The output loading signal is connected to chamber #4 of the steam flow rate relay.

STEAM FLOW RATE RELAY.—The output signal from the airflow controller is connected to chamber #4, which repeats it as the output signal under steady steaming conditions. When steam demand changes, this is the first component in the combustion control system to receive a change. The output from the steam flow transmitter in the feedwater control system is piped to chamber #2 and through a needle valve and volume tank to chamber #3. When a steam demand change occurs, the steam flow is the first to change, thus the steam flow rate relay (fig.l7-11) cuts down lag time caused by forced draft blower inertia. During steady steaming the pressures in chambers #2 and #3 are equal and do not affect the output signal. During load changes, when the steam flow signal changes, the output of the rate relay will temporarily change until the pressures in chambers #2 and #3 become equal again through the needle valve.

The output loading signal is connected to the forced draft blower transfer A/M station.

FORCED DRAFT BLOWER CONTROL STATION (TWO-WAY).—This station appears the same as a four-way station, except no reset is required when a shift is made from automatic to manual or manual to automatic and there is no biasing capability.

SIGNAL RANGE MODIFIER.—The signal range modifier relay (fig. 17-11) is a four-chamber totalizer with a spring mounted on chamber #3. The spring force is adjusted to equal 9-psi loading signal force so that the output of the totalizer is

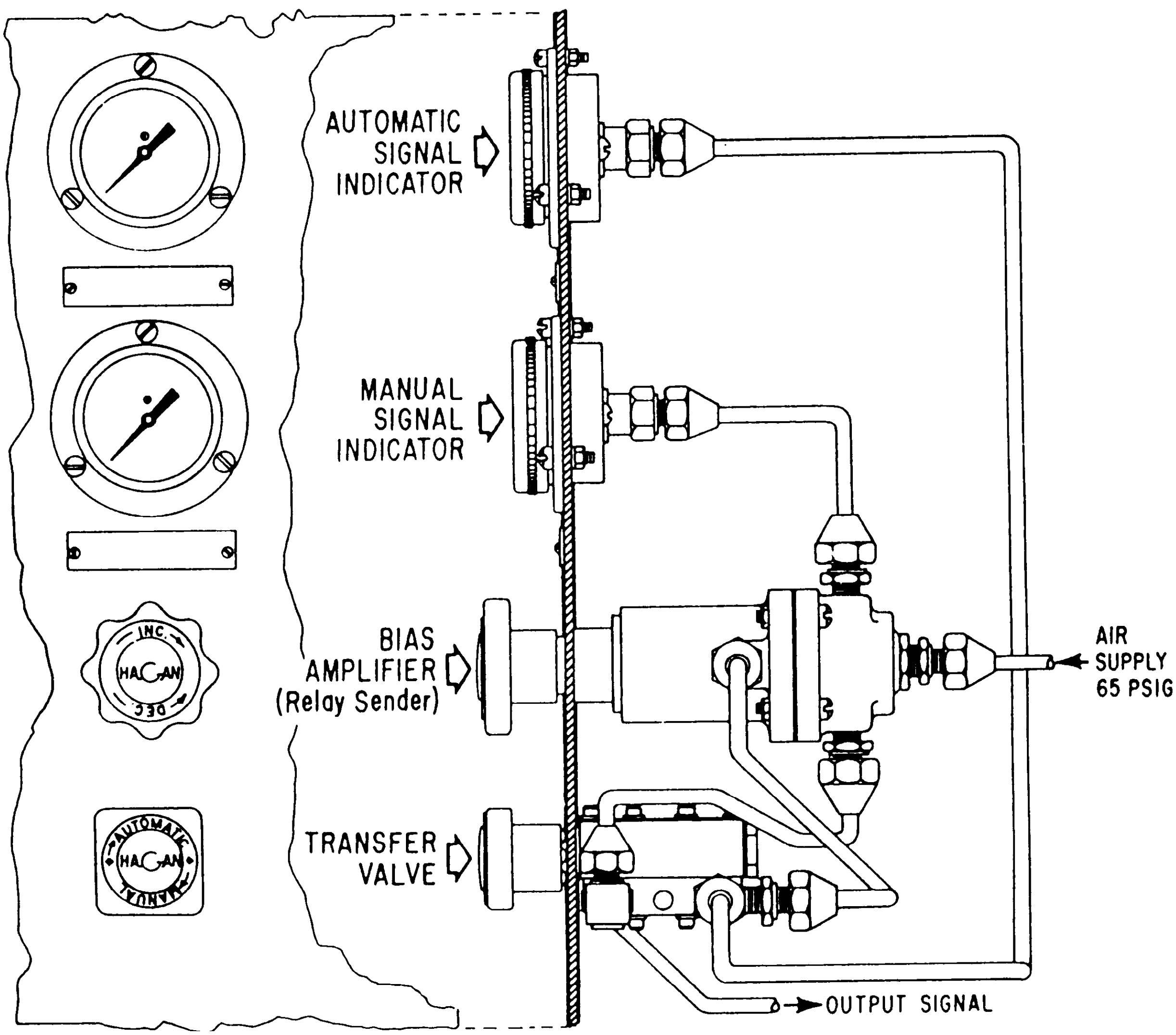


Figure 17-14.—Boiler four-way A/M station.

9 psi when the signal from the forced draft blower A/M station to chamber #2 of the totalizer is 0 psi.

The adjustable fulcrum is off-center to the left to give a 0.85 gain in output, so that the output of the signal range modifier will be 60 psi when the input signal value is 60 psi. When properly adjusted, the signal to the final control element of the forced draft blower will be 9 psi when the airflow controller output is less than 9 psi, thus preventing dead band, which occurs when the Woodward governor of the forced draft blower operates on a 0 to 60 psi signal range value.

FORCED DRAFT BLOWER A/M STATIONS (FOUR-WAY).—The same information applies as that listed for the boiler master four-way station (fig. 17-14), except bias is used to parallel forced draft blowers.

AIRFLOW TRANSMITTER.—The force applied at the measuring diaphragm is transmitted through the assembly as a force pushing downward on the beam. An escapement-type pilot valve is located so that the stem follows the slightest movement of the beam. (See fig. 17-15.)

The output loading pressure from the pilot valve is connected to the balancing diaphragm. Diaphragm movement is transmitted through the stem to the cam bar. The cam bar is forced to the right; the force of the cam pushes upward on the roller attached to the bell crank rotating around a bearing point. The bell crank pulls upward on the loading spring, which is connected to the beam. The force from the balancing diaphragm pulls upward on the same beam and opposes the force from the measuring diaphragm. The two opposing forces are in balance when the value of the output loading pressure is proportional to the flow causing the pressure differential.

F/A RATIO SIGNAL GENERATOR.—The beam rests on an adjustable ball bearing fulcrum. When the fulcrum is located midway under the beam between the two diaphragm chambers, the ratio of balance will be 1:1 (1 pound in, 1 pound out). If the fulcrum is shifted (by the turn of a handwheel) toward the input chamber, the beam will be unbalanced, causing it to tilt in a clockwise direction. The output pressure decreases as the diaphragm moves away from the exhaust seat. If the fulcrum is shifted toward the output chamber, the beam will be unbalanced, causing it to tilt in the counterclockwise direction and to increase the output loading pressure until the force once again balances and increases the ratio. The ratio remains the same over the entire operating range.

The F/A ratio signal generator (fig. 17-16) is used to make fine adjustment in the combustion control system for blowing tubes, changing burners, or changing from underway steaming to in-port steaming conditions.

Fuel Flow Control Loop

The following paragraphs will discuss the operation of the components in the fuel flow control loop.

LOW SIGNAL SELECTOR.—A minimum signal selector (fig. 17-17) is used when the lower of two signal is to be selected. In this application, the neoprene O-rings are placed in the outer grooves on the spool. As the pressure of either A input or B input rises (one toward the lesser pressure port), the O-ring on the side of the greater pressure will be forced against the outer seat of the circular port made by the

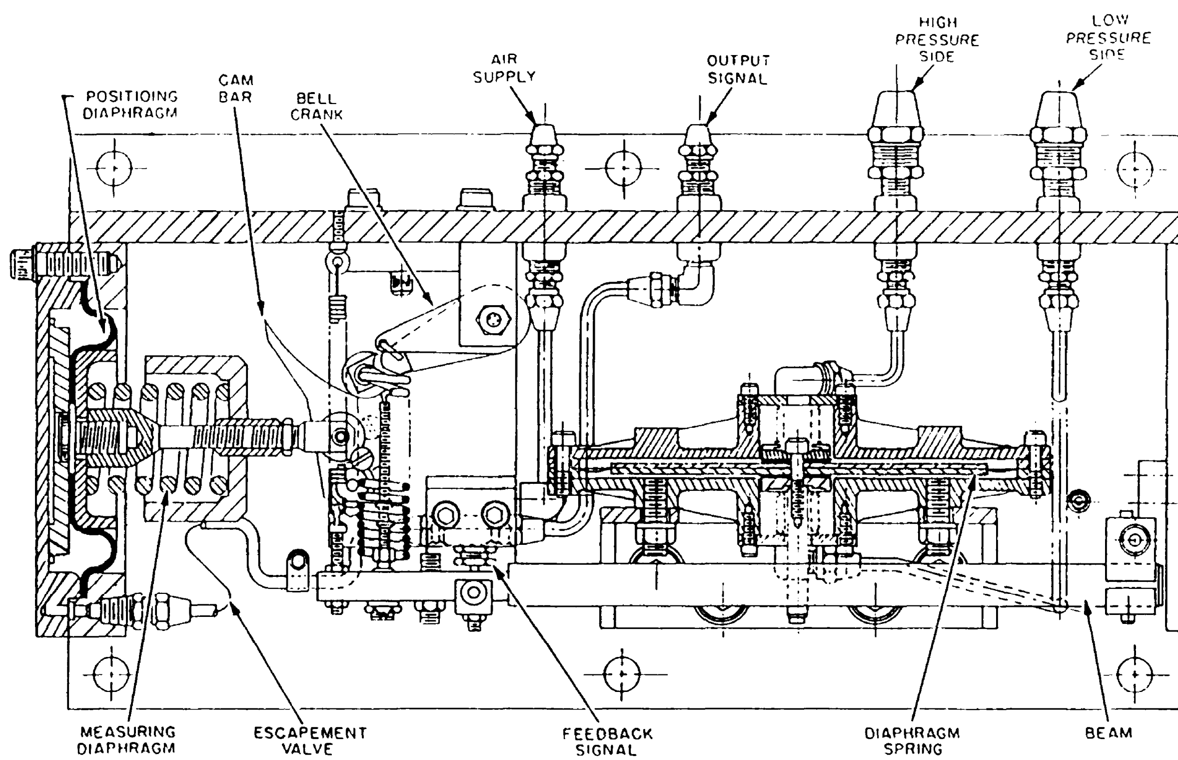


Figure 17-15.—Wind box airflow transmitter.

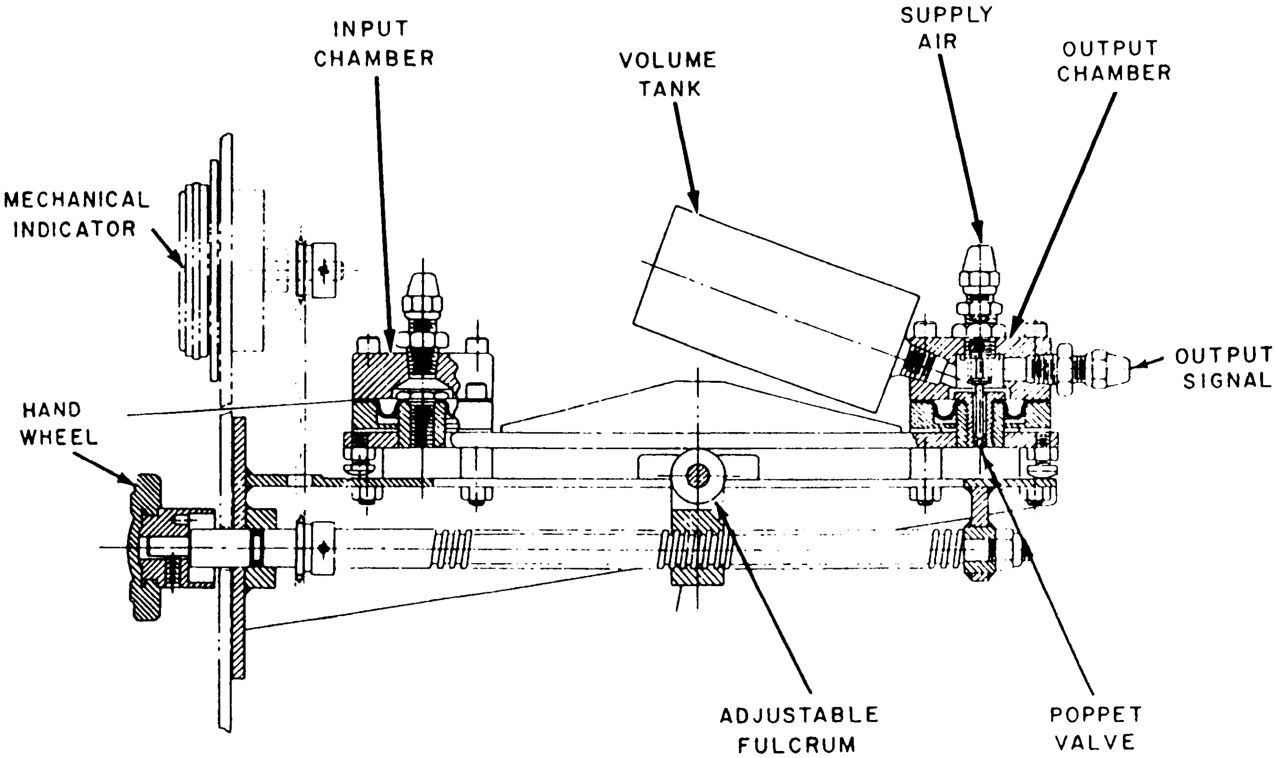


Figure 17-16.—F/A ratio signal generator (excess air adjuster).

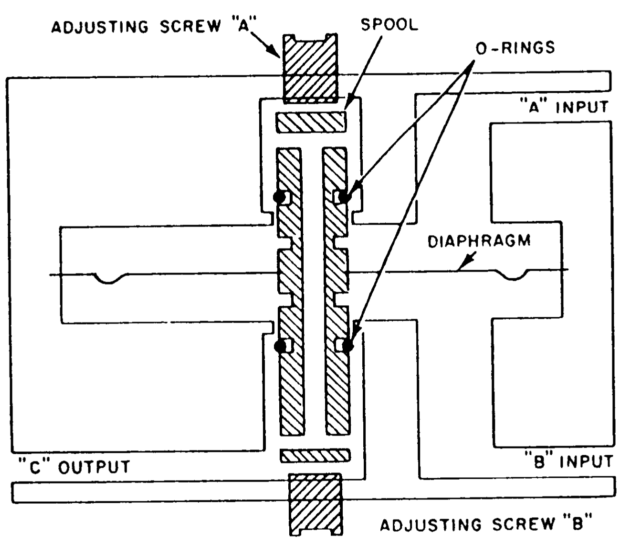


Figure 17-17.—Low signal selector.

casing and the spool, thus blocking that passage and allowing only the lower pressure input to pass out, through port C, to the fuel-oil A/M station.

FUEL-OIL A/M TRANSFER STATION (TWO-WAY).—The same information applies as that for the forced draft blower control station.

CHARACTERIZING RELAY.—To maintain efficient combustion, the fuel-oil flow to the burners must be regulated so that it is proportional to the airflow supplied to the burners. In this system, the signal generated by the wind box airflow transmitter (fig. 17-15) is proportional to actual combustion airflow and represents the oil flow demand signal. If the wind box airflow transmitter output signal were applied directly to the oil valve, this valve would act to regulate a proportional oil pressure. Since the oil flow varies in relation to the oil pressure, due to the characteristics of the burners, under this condition the oil flow will not be proportional to the airflow. Therefore, it is necessary to convert the output signal of the wind box airflow transmitter from an oil flow demand signal to an oil pressure demand signal. This is done by the actions of the characterizing relay (fig. 17-18).

FUEL-OIL CONTROL VALVE.—The fuel-oil control valve (fig. 17-19) receives the signal from the characterizing relay. This signal acts on the diaphragm and post, and changes the position of the piston, which in turn causes changes in oil flow through the fuel oil valve.

With an increase in the control pressure, the fuel-oil pressure will increase in the line between the control valve and the burners. The oil pressure will exert an upward force on the valve piston in opposition to the downward force of the diaphragm. The downward force of the oil pressure on the valve piston is eliminated by bleeding this pressure through the piston and into the barrel below by a hole drilled through the lower section of the piston. When the upward force, caused by the action of the burner pressure on the area of the piston, is equal to the downward force, caused by the action of the input signal on the area of the diaphragm, the valve piston stops moving and controls the flow of fuel oil through the valve to that quantity that holds the burner pressure at a value corresponding to the input pressure.

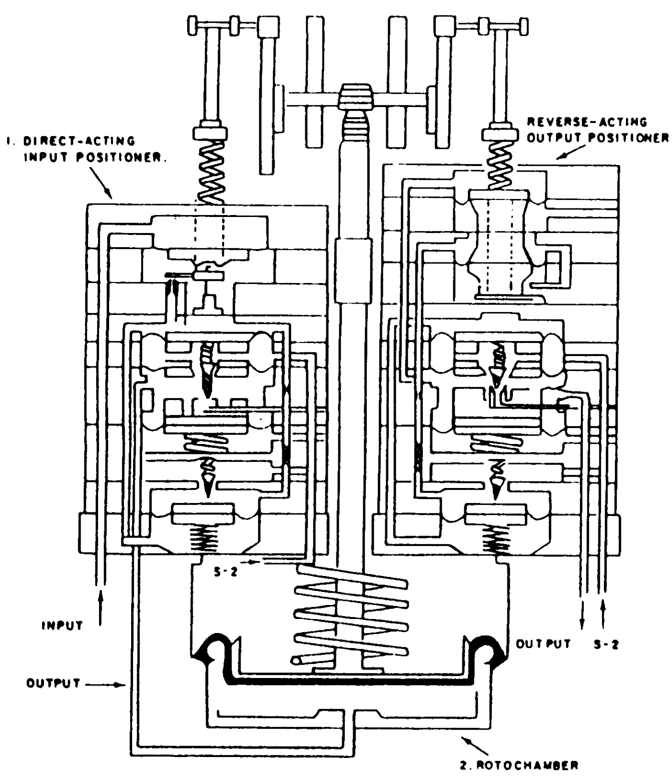


Figure 17-18.—Characterizing relay.

The oil control valve is fitted with a handjack operated by a handwheel that is used to manually position the valve piston. The handjack is normally used when the signal pressure is lost or shut off. The position of the valve piston can be set at any point in the full travel, but there is no control of burner oil pressure at a definite value. If pressure is on the diaphragm, the handjack can be used to limit the closing of the valve. For automatic operation, the handjack is moved clear of the head of the post.

Minimum burner pressure can be set by adjusting the spring tension. Minimum pressure is 40 psi. A minimum setting is necessary so that oil flow will never be reduced to the point that the burner operation will become unstable or will cause flame failure.

This completes our discussion on components. Before we go back to our increase and decrease in demand, let's cover a few things associated with the system.

BIASING

Biasing, used to bias machinery or boilers, can be done only from a four-way transfer station (boiler master and forced draft blowers) and can be done only when in the automatic mode. If you have two pieces of machinery and one is running slower than the other, you would bias the slower to the faster. This is done by manual adjustment of the handwheel of the compensating relay on the A/M station, which causes the loading pressure leaving the station to differ from the pressure coming to it. Biasing is simply paralleling to keep one piece of machinery or boiler from trying to overcome the other.

AIR LOCKS

An air lock system is provided to lock the settings of the forced draft blower valve operators, the fuel-oil control valve, and the feedwater flow control valve to maintain airflow, fuel flow, and water flow at values that existed at the instant of supply air failure. As a result, these flows are held constant until the control air supply has been restored and the air lock system is reset for normal operation, or until the boilers are transferred to local manual operation.

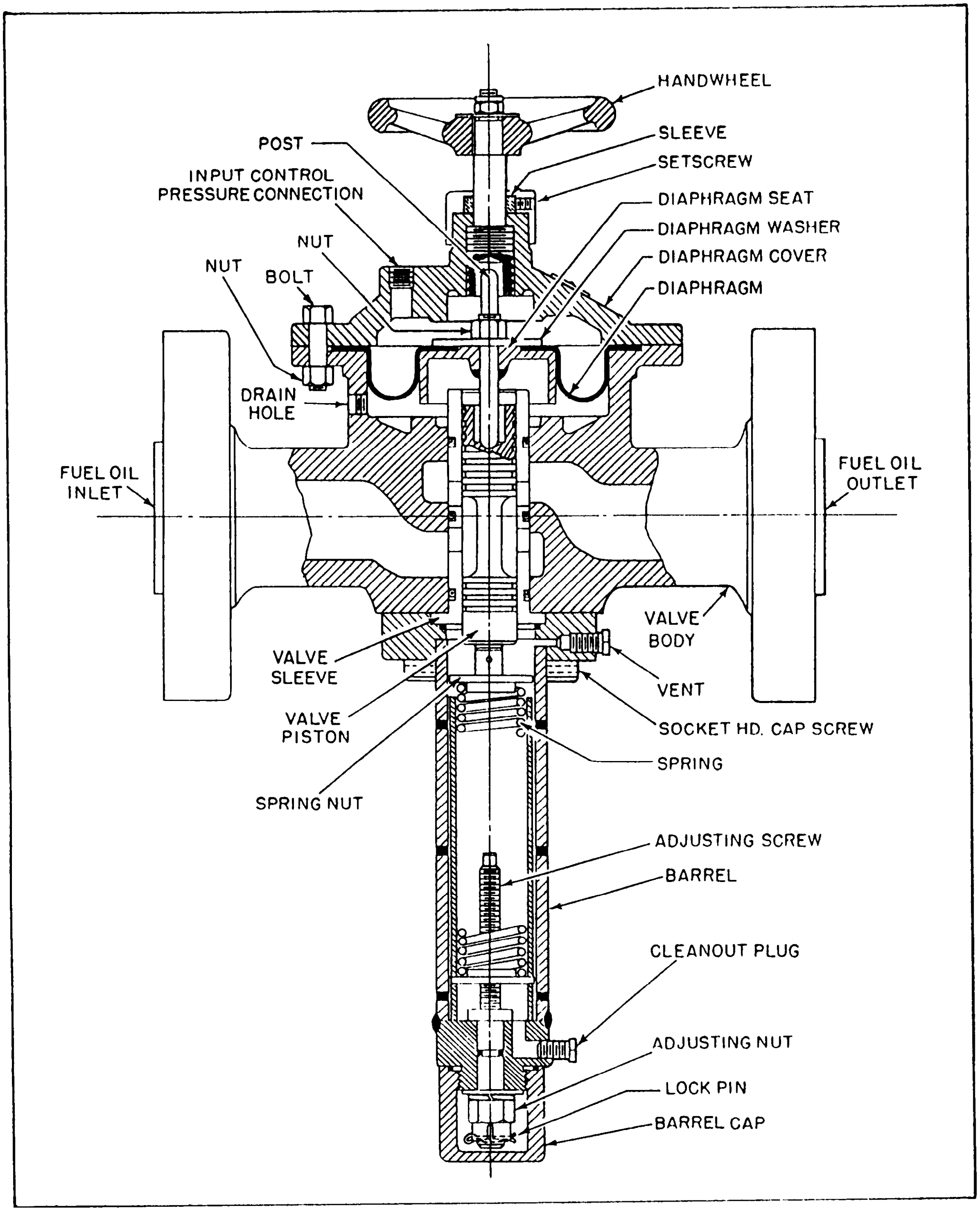


Figure 17-19.—Fuel-oil control valve

MODES OF OPERATION

There are three modes of operation: automatic, remote manual, and local manual.

Automatic

A system is in complete automatic operation when it operates without human assistance.

Remote Manual

All of the system, or individual components, are operated in remote manual by shifting the A/M station from automatic to manual and operating the station by manually generating the signal required.

Local Manual

Local manual is a method for operating the boilers and machinery from operating stations without the assistance of the automatic system.

GLOSSARY OF COMMON AUTOMATIC CONTROL TERMS

This is a glossary of common terms used in conjunction with automatic controls. It will provide you with a better understanding of the terms used in automatic control systems technical manuals.

ACTUATOR—That component part of a final control element that converts energy into a mechanical position change to change the operating point of the final control element.

ACTUATING SIGNAL—The difference between the reference input (set point) and the forces representing the controlled variable, which will cause a change (pneumatic or mechanical).

AUTOMATIC BOILER CONTROL (ABC)—Pneumatic components throughout the engineering plant that automatically monitor and control the operation of the main boilers and supporting auxiliaries.

AUTOMATIC COMBUSTION CONTROL (ACC)—Interconnected pneumatic components that automatically monitor and control the flow of air and fuel at the proper ratio for optimum combustion and that maintain steam pressure at a set point value.

AUTOMATIC CONTROL—The operation in which the value of a control condition is compared with a desired value and corrective action, dependent on the difference, is taken without human intervention.

BIAS—Increasing or decreasing a pneumatic signal a set amount while the system is in automatic operation.

CALIBRATION—The procedure for checking readings and/or adjusting an instrument to conform to an accepted standard.

CONTROL AGENT—Process energy or material used in controlling a controlled variable.

CONTROL POINT—The value of the controlled variable which, under any fixed set of conditions, the automatic controller operates to maintain.

CONTROL PRESSURE—The pneumatic pressure to the final control element.

CONTROLLER, AUTOMATIC—A device that operates automatically to regulate a controlled variable in response to a command and a feedback signal.

CONTROLLED MEDIUM—That process material in which a variable is controlled.

CONTROLLED VARIABLE—That process material in which a variable is controlled.

CYCLING—A periodic change of the controlled variable.

DEAD TIME—The interval of time between initiation of an input change and the start of the resulting response.

DEMAND SIGNAL—A signal generated by one component in a control system at the start of the resulting response.

DEVIATION—The difference between the instantaneous value of the controlled variable and the value of the controlled variable corresponding to the set point.

DIFFERENTIAL—The difference of two or more motions or forces.

ERROR—The difference between a value that results from a measurement and the corresponding true value.

FEEDBACK—Part of a closed loop system that provides information about a given condition for comparison with the desired condition.

FEEDBACK SIGNAL—A signal that is returned to the input of the system and compared with the reference signal to obtain an actuating signal that returns the controlled variable to the desired value.

FEEDWATER CONTROL (FWC)—Interconnected pneumatic components that automatically monitors and regulates the flow of feedwater to the boiler to maintain normal water level.

FINAL CONTROL ELEMENT—That portion of the controlling means that directly changes the value of the manipulated variable.

GAIN—The ratio of the signal change that occurs at the output of a device to the change at the input.

Hg—The symbol for the element mercury; a silvery, poisonous, metallic element, liquid at room temperature.

H_2O—The symbol for water.

HUNTING—The undesireable oscillation of an automatic control system. The controlled variable swings on both sides of set point without seeming to approach it.

INERTIA—The property of any material to resist a change in its state or motion (or rest).

INFERENTIAL—Deduced or deducible by inference. Measurements made in terms different from those we seek, or measurements inferred or deduced from other measurements.

LAG TIME—The interval of time between the start of a response and its completion.

LINEAR—A linear relationship exists between two quantities when a change in one quantity is proportional to the other quantity.

LOADING PRESSURE—The pneumatic signal between two items of pneumatic control equipment, except to the final control element.

MAIN FEED PUMP CONTROL (MFPC)/ RECIRCULATION CONTROL—Interconnected pneumatic components that control main feed pump speed recirculation control to maintain a predetermined feedwater discharge pressure under all load conditions and automatically ensures adequate flow of feedwater through the main feed pumps under low load conditions.

MANIPULATED VARIABLE—The quantity or condition that is varied by a controller to affect the value of the controlled variable.

OFFSET—The steady state difference between control point and the value of the controlled variable corresponding to the set point (any permanent excursion from the set point).

PARAMETER—A controllable or variable characteristic of a system, temporarily regarded as a constant, the respective values of which serve to distinguish the various specific states of the system.

PNEUMATIC—Run by or using compressed air.

POSITIONER—Serves to position the final control element in proportion to loading pressure.

PRIMARY ELEMENT—That part of a measuring device that affects or is affected by the variable being measured to produce a signal capable of being sensed by a transmitter or indicator.

PROCESS—The collective functions performed in and by the equipment in which a variable is controlled.

PROPORTIONAL—Being in proportion; relation of one part to another with respect to magnitude, quantity, or degree; ratio.

PROPORTIONAL BAND—The amount of deviation of the controlled variable from the set point required to move the final control element through the full range. An expression of gain of an instrument.

RANGE—The difference between the maximum and minimum values of physical output over which an instrument is designed to operate normally.

RATIO—The relation in degree or number between two similar things.

RELAY—A pneumatic device that receives one or more signals, alters and/or combines the signals in various ways, and produces an output signal proportional to the input.

RESET—The action of a controller that is proportional to the product of the error at the input and the amount of time the error exists.

SET POINT—The desired value of the controlled variable.

SPAN—The difference between the top and bottom scale values of an instrument. On instruments starting at zero, the span is equal to the range.

TRANSMITTER—A device that measures one of the basic variables in the control process and develops and transmits a pneumatic signal proportional to that measurement.

VARIABLE—A process condition, such as temperature, pressure, level, or flow, that is susceptible to change and that can be measured, altered, and controlled.

VELOCITY—Time rate of linear motion in a given direction.

CHAPTER 18

BOILER WATER/FEEDWATER TEST AND TREATMENT

Modern naval boilers cannot be operated safely and efficiently without quality boiler water. If the chemical conditions of boiler water are not exactly right, rapid deterioration of the boiler can occur.

Maintaining the required condition of boiler water is an extremely important part of your job. It is not an easy job. It involves a great deal more than just dumping chemicals into the boiler water. To control the quality of boiler water by proper treatment, you must have a good understanding of feedwater and boiler water chemistry. You must be able to perform the required feedwater and boiler water tests.

Let's take a moment to consider what you can expect from this chapter. After studying this chapter carefully, you will be able to answer the following questions:

Why is it important to control the quality of boiler water?

How does boiler water get contaminated?

How much boiler water/feedwater contamination is allowable?

What tests are used to measure boiler water/feedwater contamination?

How are the boiler water test results used to determine the need for boiler water treatment?

What special boiler water problems arise aboard certain types of ships, and how are the problems handled?

NOTE: This chapter will NOT provide you with any actual skill in making water tests or certify you to test and treat boiler water. You will acquire those skills with on-the-job training and practice. To become certified, you must go through the required certification course.

WATER IN THE SHIPBOARD WATER CYCLE

You must be able to distinguish between the different kinds of water at various points in the shipboard water cycle. There are different standards for the treatment of water at different points in the system. To identify the kinds of water at various points, look at figure 18-1. You should also study and become familiar with the following terms and definitions.

Distillate: Distillate is the evaporated water that is discharged from the ship's distilling plant. Water in the shipboard water cycle normally begins as distillate. This distillate is stored in the reserve feedwater tanks until needed in the main steam cycle.

Reserve feedwater and makeup feedwater: Distillate, while stored in the feedwater tanks, is called reserve feedwater. In ships without demineralizers, the water in all tanks (including the tank supplying makeup feedwater) is also called reserve feedwater. When the water is directed to the condensate system, it is called makeup feedwater. In ships equipped with demineralizers, the water entering the demineralizers from any tank is called reserve feedwater. The water flowing out of the demineralizer to the condensate system is called makeup feedwater.

Condensate: After the steam has done its work, it is returned to the liquid state by cooling in a condenser. The condenser is a heat exchanger in which steam, at a pressure below atmospheric, flows over and is condensed on tubes through which seawater flows. Any water condensed from steam is called condensate. Water from other sources (such as makeup feedwater and low-pressure drains) that is mixed with the condensate becomes part of the condensate.

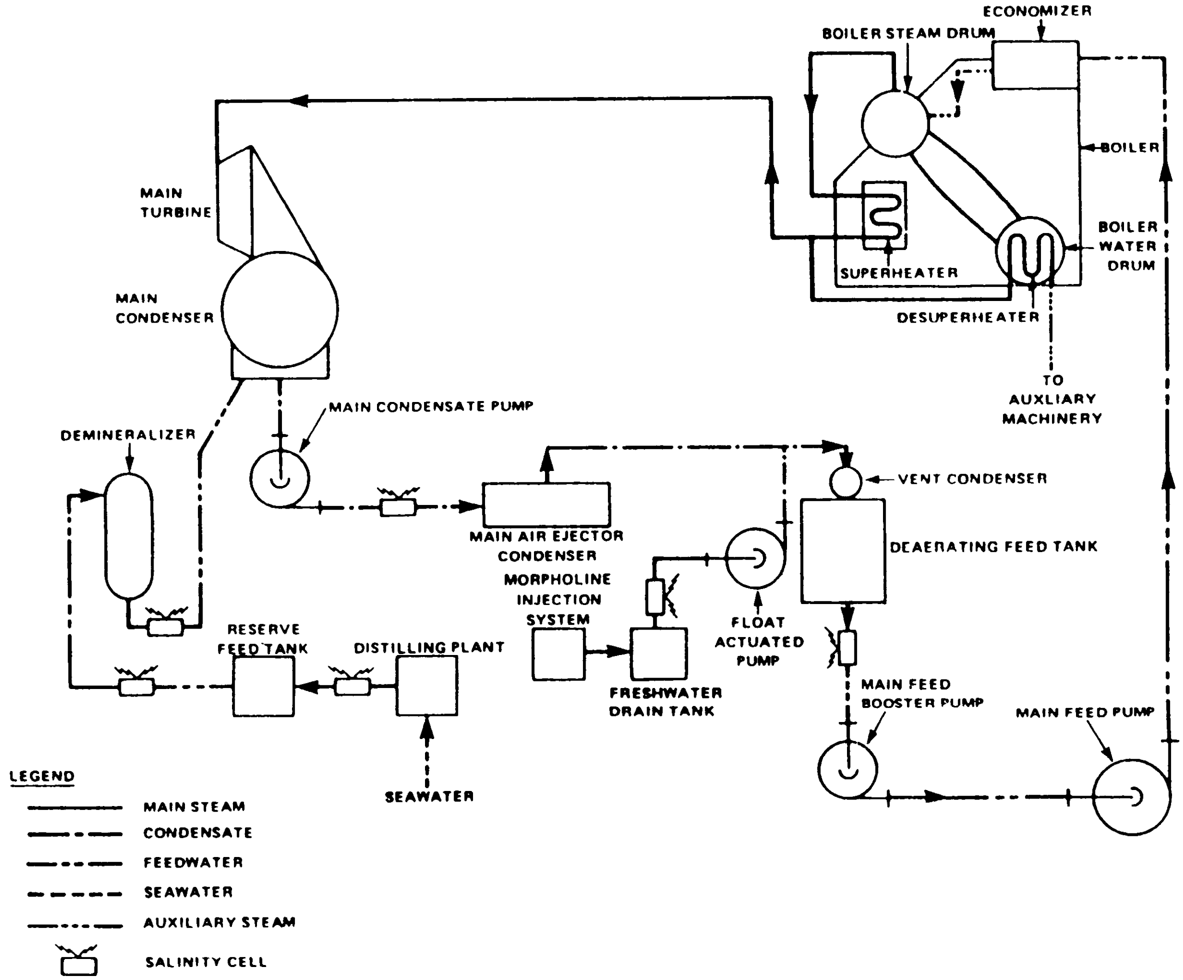


Figure 18-1.—Shipboard water cycle.

The principal sources of condensate are the main and auxiliary condensers. Other sources of condensate include the gland exhaust system, heating drains, distilling unit drains, steam coils, and other miscellaneous or service steam system drains. To maintain the proper quantity of water in the system, condensate from various sources is combined with makeup feedwater. It is then sent to a deaerating feed tank (DFT), where dissolved oxygen and other gases are removed from the water. The discharge from the DFT is called deaerated feedwater. When properly operated, the DFT will maintain the dissolved oxygen content of the deaerated feedwater at or below 15 parts per billion (ppb) (15 micrograms per liter (g/L).

Feedwater (deaerated feedwater) system: In a broad sense, the term *feedwater system* includes the makeup feed and transfer systems, the main and auxiliary condensate systems, and the deaerated feedwater system. In a narrow sense, it includes only the deaerated feedwater system. The two usages of the term *feedwater system* should not be confused.

Boiler water: Boiler water is the name of the deaerated feedwater as it enters the boiler steam drum. The term *boiler water* describes the water in the steam drum, water drum, headers, and generating tubes of the boiler.

Fresh water: Aboard ship the term *fresh water* generally refers to potable water. However, certain steam drains that are returned to the condensate system are called freshwater drains.

PROPULSION BOILER WATER FLOW

Most naval boilers have an economizer through which the feedwater, under feed pump pressure, passes before entering the steam drum of the boiler. Figure 18-2 illustrates propulsion boiler water flow. The feedwater enters the internal feed pipe of the steam drum through the feed inlet. Water within boilers circulates by natural convection. The hot boiling water rises and the cool (nonboiling) water descends. The relatively cool (nonboiling) water in the steam drum descends via the downcomers to the water drum and the headers. The water drum and the headers equalize the distribution of water to the generating tubes. (They also provide a place for the accumulation of sludge.) Boiler water circulates from the water drum and the headers to the boiler tubes, where saturated steam is formed.

The steam and water mixture in the tubes rises to the steam drum. The mixture enters the steam drum beneath the manifold baffle plates (also known as either girth plates or apron plates), where it is directed to steam separators and scrubbers. The liquid is separated from the steam by centrifugal force. It returns to the central portion of the steam drum, where it mixes with entering feedwater, and circulates again through the boiler circuits. The dry steam leaves the boiler via the dry pipe and steam drum outlet. It passes through the superheater, where it is heated to several hundred degrees Fahrenheit above saturation temperature. Most of this superheated steam goes to the main steam system to operate the main engine and some of the auxiliary machinery. Some of the superheated steam flows through the desuperheater and becomes desuperheated steam. Desuperheated steam is used to operate auxiliary equipment.

STEAM DRAINAGE SYSTEMS

Although not strictly part of the feedwater systems, service steam (low-pressure) drains and freshwater drains are important elements that may affect the quality of condensate and feedwater.

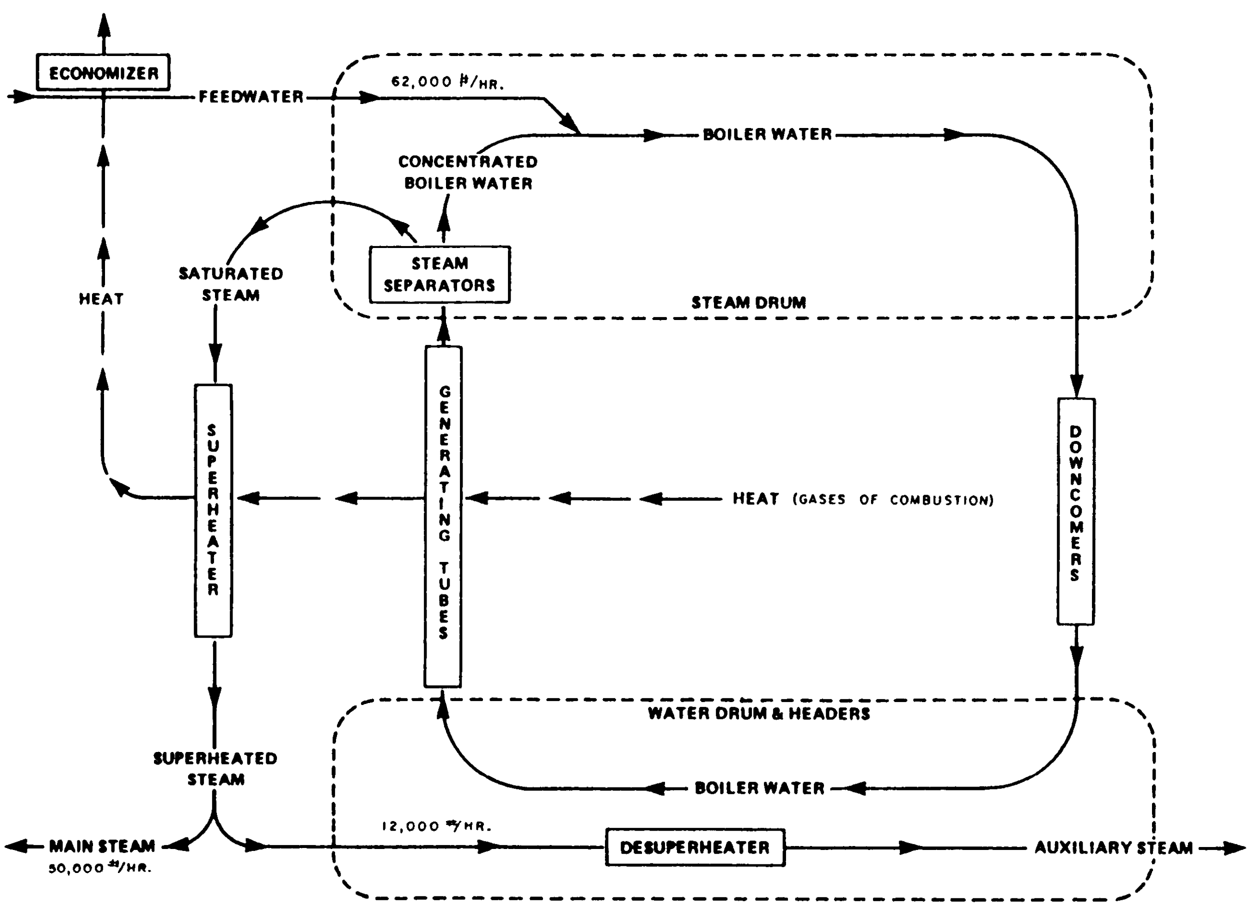


Figure 18-2.—Propulsion boiler water flow.

Service Steam (Low-Pressure) Drains

The service steam drain system collects drainage from steam piping systems and steam equipment outside machinery spaces that operate at pressures under 150 pounds per square inch (psi). These include such services as water heaters, space heaters, laundry, and food service equipment. Usually the service steam drains discharge into the freshwater drain-collecting tanks. On aircraft carriers they discharge into service steam drain-collecting tanks. The contents of these tanks are then either discharged by transfer pumps to the condensate discharge system or vacuum dragged into the main and auxiliary condensers. Service steam drains are subject to shore water and other types of contamination.

Freshwater Drains

Freshwater drain systems collect drainage from various piping systems and equipment in machinery spaces that operate at pressures under 150 psi. The drainage is discharged into the freshwater drain-collecting tanks and is pumped or vacuum dragged into the condensate system.

First Effect Tube Nest Drains (Saltwater Heater Drains) and Evaporator Air Ejector Condenser Drains

The saltwater feed heater drains and the air ejector condenser drains of the distilling plant discharge to the DFT and the freshwater drain tank. These drains may be subject to seawater contamination because of tube leakage or carryover within the evaporator.

WATER IN THE PLANT ENVIRONMENT

The chemical makeup of any water depends upon its past history. The chemistry of water is influenced by the amount and type of dissolved solids, suspended solids, and dissolved gases that contaminate it. Water is known as the universal solvent. Its solvent action is so great that it tends to dissolve everything that it touches, including any container holding it. Additionally, water will also dissolve gases, such as ammonia, hydrogen sulfide, oxygen, and carbon dioxide contained in the atmosphere. Water is the working fluid that transmits the energy by which steam-propelled ships operate. Water chemistry control is vital to prevent damage to boilers and other plant components by corrosion, fouling of heat transfer surfaces, and carryover of water with steam.

Water used in naval steam propulsion plants is relatively pure. However, within the steam cycle, it comes in contact with several metals at various temperatures and pressures. These conditions promote several chemical reactions that must be prevented or controlled by the use of specific chemicals.

EFFECTS OF BOILING ON DISSOLVED SOLIDS

When heat is applied to a boiler tube, a thermal gradient develops. The outside surface of the tube is hotter than the inside surface of the tube which, in turn, is hotter than the bulk of the boiler water. If the water contains dissolved solids, a film of nonboiling liquid forms at the tube surface. This liquid film contains a higher concentration of solids than that which is contained in the bulk of the boiler water. When boiling begins, steam bubbles form at the tube surface and further concentrate the solids around the bubbles. As the steam bubbles are released to the adjacent bulk boiler water, the solids that were concentrated around them are left behind. Normally, fresh boiler water redissolves these solids and prevents concentration or dry-out of chemicals.

Anything that interferes with the free flow of water through the tube surface prevents the less concentrated boiler water from washing the metal. In boiler water treatment, the bulk boiler water chemistry must be controlled so that corrosive conditions or fouling will not result when the water is concentrated at the tube surface.

CONTAMINANT CONCENTRATION

As a boiler is steamed, the chemical composition of the boiler water continuously changes because the level of contamination builds up. In most naval plants, if a boiler is producing steam at about 50 percent of its capacity, the dissolved and suspended materials brought into the boiler with the feedwater will concentrate in the boiler water at the rate of tenfold per hour. In 100 hours (a little more than 4 days of steaming) the chloride concentration will increase to 10 epm. The

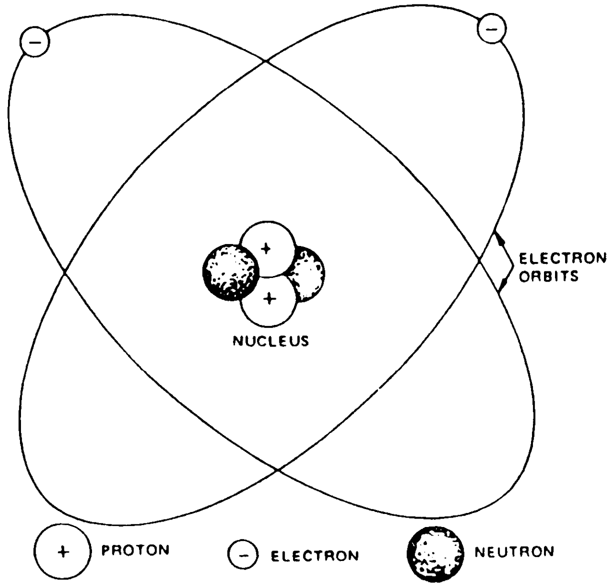


Figure 18-3.—Schematic diagram of a simple atom.

concentration of suspended solids in the boiler water will also increase in the same manner.

EFFECTS OF CONTAMINANTS

Modern naval boilers cannot be operated safely and efficiently without proper control of water chemistry. With proper control of water chemistry and proper layup during idle periods, naval boilers should last the life of the ship. When water conditions are not controlled within allowable limits, deterioration of waterside surfaces could cause boiler casualties. Boiler water quality depends directly upon the control of feedwater quality.

THE CHEMICAL NATURE OF WATER

To understand water chemistry, we must first understand the concept of atoms and molecules. A molecule is the smallest particle into which a compound can be dissolved without changing its chemical identity. A small amount of water is composed of a tremendously large number of molecules.

Atoms are extremely small, electrically neutral particles consisting of a positively charged nucleus surrounded by negatively charged electrons. The nucleus is composed of positively charged protons and uncharged neutrons. (See fig. 18-3.)

Normally, the number of electrons equals the number of protons contained in the nucleus, and their positive and negative charges cancel each other. The electrons are bound in the atom by electrostatic action, so the atom remains neutral unless some external force causes a change in the number of electrons.

Electrons, which are in constant motion around the nucleus, contain both kinetic and potential energy. Their total energy is the sum of both energies.

It will help us to visualize these states of energy as spherical shells surrounding the nucleus and separated by forbidden areas where the electrons cannot exist in a stable status. (See fig. 18-4.) Each shell contains one or more subshells (called orbitals), each with a slightly different energy. In order of increasing energy the orbitals are designated by small letters: s, p, d, f, g, h, and so on. The first shell contains only one orbital-the s orbital. The second shell contains an s and a p orbital. The third shell consists of the d orbital plus the orbitals in the first two subshells (s and p). This is true for all additional shells.

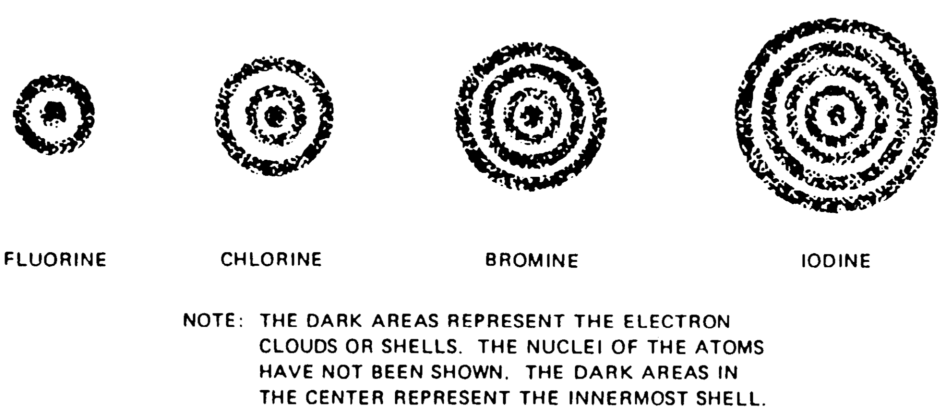


Figure 18-4.—Electron shells of atoms.

Each new shell contains its own orbital and all the others it encloses. Each orbital can hold a definite maximum number of electrons. (See table 18-1.)

Electrons closer to the nucleus have a lower energy state than those in the outermost shell—the furthest shell from the nucleus. Chemical reactions like those that occur in feedwater and boiler water involve primarily the electrons in the outermost shell of each atom in each molecule of water.

The forces that hold atoms together in a molecule (such as water) are called chemical bonds. Chemical bonds in which one or more electrons are transferred from one atom to another are called IONIC bonds. When such transfers occur, they cause imbalances of electrostatic charges of these atoms. Single atoms or groups of atoms that have either an excess or a deficiency of electrons relative to the charges on their nucleus are called ions.

pH Value

One important aspect of water is its capability for partial ionization. Pure water may break apart (ionize) slightly to yield hydrogen (H) ions and hydroxyl (OH) ions. The concentration of hydrogen ions and hydroxyl ions is determined by measuring pH.

The pH scale ranges from 0 to 14. A pH of 7 signifies that the solution is neutral. It has the same amount of hydrogen ions and hydroxyl ions. The pH number indicates the degree of alkalinity or acidity of water. If the pH is below 7, the water has more hydrogen ions and is acid. If the pH is above 7, the water has more hydroxyl ions and is alkaline. (See fig. 18-5.)

The combination of chemicals present in the water plus heat may contribute to the acidification of water. When this happens inside the boilers, corrosion takes place.

Let's see what happens. When pure, oxygen-free, water enters a boiler, an initial reaction takes place between the water and the iron in the boiler. This results in the formation of a microscopically thin layer of magnetic iron oxide (magnetite). This layer of magnetite protects the iron it covers, and further corrosion is limited. However, any damage to this coat of magnetite will allow corrosion to spread.

Table 18-1.—Electron, Orbital, and Shell Relationships in Atomic Structure

Shell Number	Type of Orbitals	Maximum Number of Electrons in each Orbital	Maximum Total Electrons in Shell
1	s	2	2
2	s	2	
	p	6	8
3	s	2	
	p	6	
	d	10	18
4	s	2	
	p	6	
	d	10	
	f	14	32
5	s	2	
	p	6	
	d	10	
	f	14	
	g	18	50

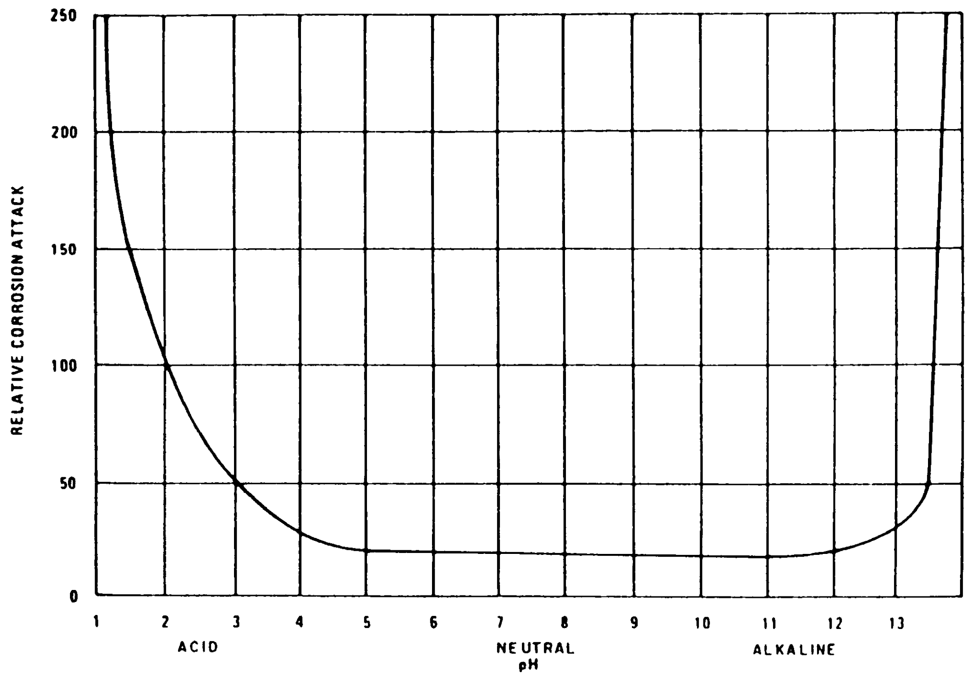


Figure 18-5.—pH effect on boiler metal corrosion.

Suppose, for instance, that the feedwater allowed to enter the boiler contains magnesium. The high temperature of the water makes the magnesium ions react with the hydroxyl ions in the water. The reaction produces magnesium hydroxide and hydrogen ions. The magnesium hydroxide forms a scale. The hydrogen ions, now in excess, acidify the water. Acidic boiler water dissolves the coating of magnetite on the boiler metals and attacks the metal itself.

The very small hydrogen gas molecules released during the corrosion process react with the carbon in the metal to form methane gas. Molecules of methane gas permeate the metal. As excessive pressures develop, they cause tube ruptures. If porous deposits are present on the metal surfaces, the acid in the boiler water can concentrate under the deposits. This can cause brittle failures known as hydrogen damage.

Both high and low pH can cause damage to boiler tubing. Normally, excessively high pH is caused by accidental overaddition of caustic soda and shore water contamination. Shore waters have relatively large amounts of bicarbonate. In the boiler the bicarbonate breaks into carbon dioxide and hydroxyl ions. Carbon dioxide is carried off with the steam, while the hydroxyl ions increase the pH. Excess hydroxyl ions can cause caustic corrosion, a damage as severe as that caused by acidic water corrosion.

Hardness (Scale Formation)

All scale deposits act as insulators and reduce the heat transfer across any surface. Deposits cause the temperature of the metal to increase until overheating, metal softening, blistering, and failure occur, Figure 18-6 illustrates such a situation

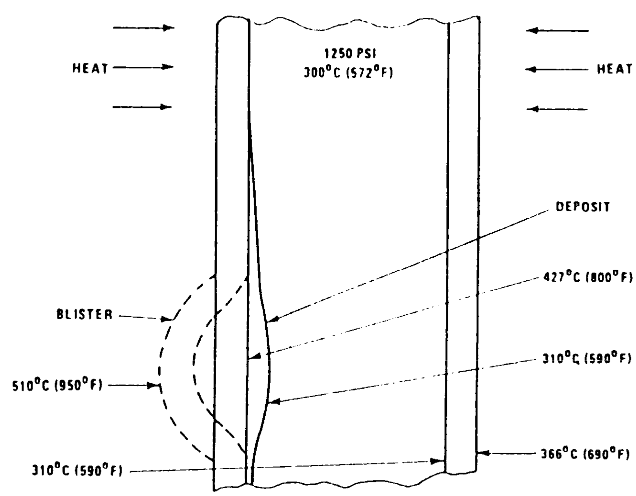


Figure 18-6.—Effect of boiler deposit.

in a boiler tube. As the deposit restricts heat transfer, the surface of the tube under the deposit increases in temperature. Eventually, as the deposit gets thicker, temperature increases, the metal softens, and the tube blisters. Because of very high furnace temperatures, modern naval boilers can tolerate no more than a few thousandths of an inch of scale on tube surfaces without suffering tube ruptures.

Dissolved Oxygen (Pitting Corrosion)

Water in contact with air will contain a certain amount of dissolved oxygen. The amount of oxygen that will dissolve in water depends upon the temperature of the water and pressure acting on the surface of the water. Figure 18-7 illustrates the oxygen-dissolving capabilities of water. As you can see from this graph, oxygen is more readily dissolved in water at lower temperatures. You will also note that oxygen solubility increases as the external pressure, the pressure in contact with the surface of the water, increases. When water containing dissolved oxygen enters the boiler, the dissolved oxygen causes localized corrosion and pitting of tube metal. The oxygen dissolved in the boiler water reacts with the iron of the boiler waterside metal. The iron dissolves and forms a substance known as ferrous hydroxide. Some of this ferrous hydroxide is converted to hydrated ferric oxide. The mixture of ferrous hydroxide and hydrated ferric oxide is dehydrated and forms black iron oxide. This black iron oxide undergoes a change on the metal surface, a further reaction with oxygen, which results in a reddish iron oxide.

As the oxygen attack continues over a period of time, the iron metal is dissolved and active oxygen causes tubercles (scabs) to develop on the tube metal surface. A tubercle has a hard, reddish brown outer shell. The shell covers a pit in the boiler metal. There may be one isolated point of attack on the metal surface, or many points. Once an active oxygen scab forms, the corrosion of the metal continues, even though the condition causing dissolved oxygen contamination in the boiler water has been corrected. As the pH of the boiler water decreases, the severity of the dissolved oxygen attack increases. Boiler watersides that are open to the atmosphere are subject to oxygen corrosion if the surfaces are wet or if the humidity is high. Idle boilers under wet layup are also subject to oxygen corrosion unless protective measures are instituted.

The presence of oxygen in systems causes general corrosion. Corrosion is particularly severe when steam condensate is acidic. Corrosion

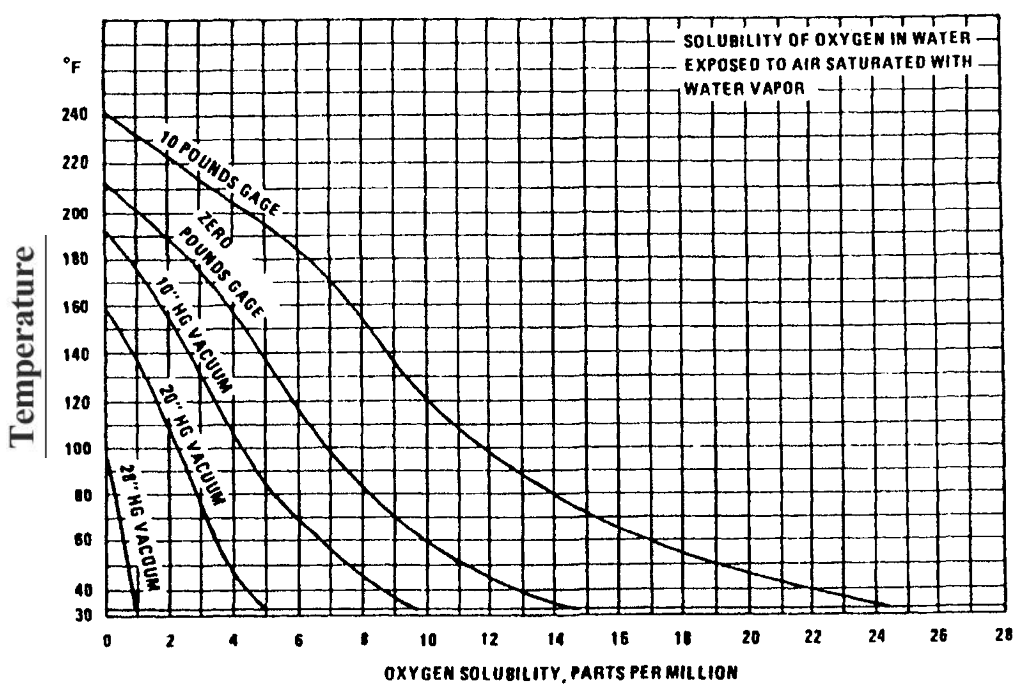


Figure 18-7.—Oxygen-dissolving capabilities of water.

products from the piping systems are carried into the boiler where they contribute to sludge formation.

Chloride (Pitting Corrosion and Stress Corrosion Cracking)

Chloride is used primarily as an indicator of seawater contamination. Chloride is an aggressive ion that causes dissolution of the protective magnetite layer on boiler metal and inhibits its reformation. Pitting corrosion rather than general corrosion occurs. The sulfate ion, always present, tends to inhibit the destructive effects of small amounts of chloride on generating tube surfaces. Chloride can cause stress corrosion cracking of stainless steel.

When stainless steel is subjected to chloride and oxygen, it will suffer transgranular cracking of its crystals. When chloride concentrates in the boiler water, the chloride may carry over with the saturated steam and deposit on the superheater tube surfaces. If the superheater has stainless steel tubes, chloride stress corrosion may begin and eventually lead to failure of the tubes.

Chloride stress corrosion of stainless steel components of the desuperheated steam system can also occur. If a desuperheater develops a leak, boiler water, containing chloride, will seep into the desuperheater. This will cause contamination of many systems.

Conductivity (General Corrosion and Carryover)

The ability to conduct an electrical current is called conductivity and is expressed in micromhos per centimeter (mho/cm). For a solution to conduct a current, ions must be present. Virtually all materials dissolved in seawater, shore water, feedwater, and boiler water are ionic and do conduct a current. An exception is silica which, since it is a nonionic dissolved solid, does not conduct electricity.

Boiler metal corrosion also results from electrolytic action. Electrolytic action depends on the presence of anodes and cathodes (positive and negative terminals). The chemical and physical variations in the boiler metal surface generate anodic and cathodic areas on the metal so that the surface of the metal has slight differences in electrical potential. For electrons to flow from the cathode to the anode, a conducting medium is needed. Since pure water has high resistance and low conductivity (about 0.1 mho/cm), metal corrosion rate is low in pure water. As conductivity increases, the resistance to electron flow decreases and corrosion increases. Some ions in boiler water, notably controlled hydroxyl and phosphate ions, suppress corrosion. Others, particularly chloride and hydrogen (acid) ions, increase it. Most of the conductivity in feedwater results from chloride, sulfate, and bicarbonate compounds of sodium, calcium, and magnesium. Boiler water conductivity results from these contaminants and from treatment chemicals.

High conductivity water causes carryover. Boiling water produces bubbles that contain steam encircled by the water. The bubbles break to release the steam and the water falls back into the vessel holding the water. If the water is very pure, the steam bubbles break easily and an almost complete separation of water from steam is achieved. However, if the concentrations of dissolved and suspended solids or oil increase in the water, the steam bubbles become stabilized and more difficult to break. The effectiveness of the separation of contaminated water from steam then deteriorates. Dissolved solids and suspended solids in boiler water increase in concentration with continued steaming. (They are controlled by blowdown.) As the steam drum area above the surface of the boiler water fills up with these stabilized bubbles, some boiler water is carried along with the saturated steam into the dry pipe. This type of boiler water carryover is termed *foaming.* Since the stabilized bubbles break at high superheat temperatures, the boiler water entrained with the saturated steam evaporates in the superheater. Particles of material that were dissolved and suspended in the boiler water are carried by the velocity of the steam to different parts of the superheater to be deposited on the superheater surfaces, primarily on those in the first pass. Restriction of heat transfer, blistering, and eventual superheater failure can result whenever a deposit builds up. Additionally, one of the materials dissolved in the boiler water, sodium chloride, can cause stress corrosion cracking if it is deposited on stainless steel superheaters.

Another type of boiler water carryover is called priming. Priming is caused by high water level in the steam drum, extreme rolling and pitching of the ship, or mechanical failure of the steam separators or other steam drum internal parts. Priming consists of slugs of boiler water carried into the dry pipe. A slug of water may reach as far as the turbine and cause damage to the unit.

Silica (Scale Formation)

Distillate contains only a small amount of silica. However, shore source feedwater, shore water, and condensed shore steam can contain silica. The silica is usually dissolved and is therefore considered to be a dissolved solid. Since it is not ionized, it does not conduct an electric current. Silica in the boiler water forms scale and can also be deposited in steam lines and on turbine blades. Silica scale behaves in the same manner as other scales and the deposits illustrated in figure 18-6. The DR-100 silica test kit is used to measure the silica content of shore source feedwater. This is done to assure that the use of unacceptable shore source feedwater is avoided. Poor quality shore source feedwater is the major cause of silica contamination. Suppliers of shore source feed are required to certify that the silica content of the water does not exceed 0.2 ppm. Ship personnel must test the water for silica to make sure the water meets this requirement.

The desiccant used in dry layup and sandblast grit can contain silica contamination. To avoid pH and silica control problems caused by desiccant, the desiccant should be removed from the boiler after dry layup.

Suspended Solids (Sludge Formation and Carryover)

Seawater and shore waters contain variable amounts of suspended materials. In the case of the seawater, most of the suspended solids are discharged overboard with the brine upon distillation of the water. Suspended solids from shore source potable water are generally removed by municipal pretreatment. Most suspended solids in the boiler result from corrosion and erosion of feed system metals when the water is not treated with morpholine. Suspended solids in boiler water cause the water to carryover and contribute to sludge formation.

After overhaul or long-term dry layup, rust can carry into boiler water during system operation. The hydroxide ion in boiler water reacts with rust to form magnetite, and the pH of boiler water decreases because of the loss of hydroxide ions.

Fuel, Lubricating Oil, and Preservatives (Deposits and Carryover)

Fuel oil and 2190 TEP lubricating oil accumulate in the steam drum to cause boiler water and oil to carryover. They also cause baked-on carbon deposits on the tubes and oily deposits (sludge balls) in the drums and headers. Detergent lube oils, like 9250, will not rise into the steam drum. They will emulsify throughout the boiler water and then will cause baked-on carbon deposits, blistering, and eventually tube failure. Conductivity equipment and pH electrodes will not work when coated with oil.

Ion Exchange Resin (Acidic or Caustic Corrosion Deposits)

The demineralizer contains both anion (negatively charged ions) and cation (positively charged ions) exchange resins. When heated, the anion resin forms mildly alkaline (caustic) decomposition products and the cation resin forms strongly acidic decomposition products. When heated, all calcium, magnesium, chloride, sulfate, and bicarbonate previously removed from the makeup water are released from the resin as it decomposes.

Dirt and Debris

Dirt, debris, and other foreign matter can cause feedwater problems. Water treatment may or may not be successful. It will not compensate for refractory brick, washers, wire brushes, bags of desiccant, or other such items left in the boiler.

SOURCES OF FEEDWATER CONTAMINANTS

The major feedwater contaminants are seawater, shore water, metal corrosion products, suspended solids, and oxygen. Other contaminants include fuel and lubricating oil, preservatives, ion exchange resin, dirt, and debris.

Seawater

Contaminated seawater can enter the feedwater system from carryover in the distilling plant and seawater leakage into the main and auxiliary condensers. It can also come from malfunctioning or improper operation of units in the feedwater systems, and bilge water leakage into the tanks, piping, and pumps.

Seawater contamination requires increased chemical treatment of' the boiler water. Such treatment increases the amount of dissolved and suspended solids in the boiler water, and the boiler requires more frequent blowdown. Excessive seawater contamination results in the consumption of all of the protective treatment chemicals in the boiler water. It is the cause of corrosion, scale formation, and sludge formation. High concentrations of dissolved and suspended solids result in carryover. If the problem is allowed to continue, generating and superheater tubes will corrode, blister, and eventually rupture.

Shore Water

Shore water can contaminate the feedwater system by leakage through malfunctioning swing check valves, galley mixing valves, laundry equipment, and water heaters. Shore water contains high concentrations of dissolved solids and silica and may have either high or low pH. In the boiler, shore water causes high pH. Excessively high pH will cause boiler metal corrosion. High concentrations of dissolved solids cause boiler water carryover. Hardness in shore water leads to excessive usage of boiler water treatment chemicals and causes corrosion, scale, and sludge buildup. Shore water contamination can also cause deposit buildup in auxiliary steam lines.

Metal Corrosion Products and Suspended Solids

The metal surfaces of the feedwater system are sources for metal corrosion found in feedwater. Water in the feed system that is not treated has a pH of approximately 5 and tends to cause corrosion of the metal surfaces. Also some erosion and mechanical washing of particles from the metal surface occur. The metal corrosion and erosion products contribute directly to sludge buildup in the boiler water.

Dissolved Oxygen

Figure 18-7 illustrates the solubility of oxygen in water at various temperatures and pressures. Air, the source of dissolved oxygen, enters the feedwater system with the makeup feed and through various parts of the condensate system. Excessive dissolved oxygen in feedwater is caused by malfunctioning or improper operation of the DFT. When feedwater containing dissolved oxygen enters the boiler, it causes localized corrosion of the boiler metal. This is described as active oxygen attack and can become so severe that eventually the tube wall will be completely penetrated. The use of temperature and pressure control in the DFT can minimize the concentration of dissolved oxygen in feedwater entering a boiler.

Fuel Oil

Naval distillate F-76 and JP-5 are potential sources of contamination to the feedwater system because of their presence in the bilges. Fuel oil carries over with the steam, recycles in the system, and eventually decomposes to form carbon deposits on boiler waterside surfaces and in superheater tubes. Fuel oil may coat salinity cells and cause them to malfunction.

Lubricating Oil

Lubricating oil (2190 TEP) is used extensively in steam plant machinery. Gland seals and oil seal rings are provided to keep lubricating oil from coming in contact with steam and condensate. Worn out seals and rings will allow oil to contaminate the feedwater system. As in the case of fuel oil, lubricating oil leaks and spills accumulating in the bilges can also cause lube oil contamination of the feedwater. Since 2190 TEP lube oil tends to rise in water, it will accumulate in the steam drum and will carry over. The oil recycles in the system to eventually decompose, leaving carbon deposits in the boiler or superheater. It also coats salinity cells, causing them to malfunction.

Preservatives

Metal preservative coatings are used to protect the boiler piping and system equipment during construction. Contaminants of this type are generally found on new ships when the preboiler system is not properly flushed. Water contamination of this type can also result from the replacement of a system component without removing the preservative. If not removed, these organic materials will bake on the waterside surfaces of boiler tubes to cause blistering and, eventually, tube failure.

Ion Exchange Resin

If not handled properly, resin beads can break and cause fine particles of resin to pass through the retention screen. Damaged screens also permit passage of intact resins into the makeup feed. When anion resin decomposes at 60°C (140°F) and cation resin at 121°C (250°F), they release alkaline and acidic products in addition to calcium, magnesium, chloride, sulfate, and bicarbonate. Water contaminated by granules of ion exchange resin will have a fishy odor.

Dirt and Debris

Poor housekeeping can lead to dirt and debris contamination. If a boiler or piping system is open, dirt can enter. Openings should be covered unless required to be open. Components must be properly cleaned before they are installed in boilers or piping systems. Care must be taken to avoid contaminating treatment chemicals and to ensure that the right chemicals are used.

CONTROL OF FEEDWATER CONTAMINANTS

Feedwater conditions must be controlled if corrosion and scale in the feed system are to be minimized. More importantly, corrosion, scale, various deposits, and carryover in high-pressure boiler systems will advance if care of feedwater purity is neglected. Boiler water treatment protects the boiler against feed system upsets from contamination. It does not replace proper preboiler plant operation. Feedwater having low concentrations of dissolved and suspended solids, and no oxygen, is considered good quality feedwater. This type of feedwater is obtained when all units in the preboiler system are functioning properly.

Contaminant Testing

Feedwater quality is determined by testing samples for chloride, conductivity, salinity, hardness, dissolved oxygen, and pH from various points in the system. All of these tests are necessary for rapid location and correction of contaminant sources.

Morpholine Condensate/Feedwater Treatment

Morpholine is a water treatment chemical that raises pH and reduces corrosion in the condensate and deaerated feedwater lines of the preboiler system. Preboiler system corrosion is caused principally by the reaction of carbon dioxide with the water in which it is dissolved. There are two sources of carbon dioxide: air containing carbon dioxide, which can enter at almost all points in the preboiler system, and the bicarbonate ion in seawater, which is released when the water is heated in distilling plants, thereby acidifying the reserve feedwater.

Seawater and shore water are the major contributors of bicarbonate. Carbon dioxide reacts with water and forms carbonic acid, which decreases the pH. By raising the pH of the condensate and deaerated feedwater, corrosion in these parts of the preboiler system is reduced.

Morpholine is a neutralizing amine that is added to the freshwater drain-collecting tank. It combines with hydrogen ions produced from the reaction of carbon dioxide in water. It also combines with some hydrogen ions present from water's ionization. As the concentration of hydrogen ions decreases, pH increases and corrosion is reduced. This reduces the amount of sludge that will form in the boiler. The morpholine added to the condensate enters the boiler with the deaerated feedwater; it is volatilized along with the steam; it disperses throughout the steam plant; it is condensed; and finally it is recycled. Although the cycle is continuous, additional morpholine must be fed to the condensate to compensate for losses that occur in the air ejectors, DFT vents, and leaks.

Demineralization of Makeup Feed

Makeup feed of very high purity is produced by the use of a demineralizer. When makeup feed is being taken on, reserve feedwater is passed through a mixed bed ion exchange resin called a demineralizer. The mixed bed ion exchange resin consists of a chemically balanced mixture of both cation exchange resins and anion exchange resins. The cation exchange resin, whose surface is rich in hydrogen ions, exchanges with cations such as magnesium and calcium. The anion exchange resin, whose surface is rich in hydroxyl ions, exchanges with anions such as chloride and sulfate. As the water passes over the mixed bed ion exchange resin, the dissolved cations and anions exchange with the hydrogen and hydroxyl ions and become attached to the exchange resins. The hydrogen ions displaced from the cation exchange resin combine with the hydroxyl ions displaced from the anion resin to form water. The mixed bed ion exchange resin removes all the cations and anions from the reserve feedwater and exchanges them with pure water. Besides removing the ions, the resin acts as a filter and removes the suspended solids from the reserve feedwater. This demineralization (also called deionization) is an extremely useful process that appreciably reduces the rate of sludge buildup in the boiler water. As the resin bed exhausts its exchange capacity, the makeup feed conductivity quickly rises above 1.0 mho/cm, indicating that the resin is spent and has to be replaced. If the reserve feedwater has a consistently high suspended solids content, the filtration action may clog the resin bed and will result in an early replacement of the resin.

BOILER WATER CONTROL

The boiler acts as a receiver far all of the materials that the feed system pours into it. Only the water and (if the condensate is treated) morpholine leave the boiler. All contaminants remain behind to advance the damaging conditions (corrosion, scale formation, and carryover) already discussed. To minimize damage, boiler water treatment programs have been established. The Navy treatment is based on regimen known as coordinated phosphate-pH control (more simply, coordinated phosphate control). The method is designed to serve the following purposes:

1. Maintain the pH and phosphate levels so that caustic corrosion cannot occur.

2. Maintain the pH sufficiently high to limit boiler metal corrosion and to protect against acid-forming magnesium reactions. (When magnesium hydroxide forms under alkaline conditions, it is in a sludgelike state unlike the scale that precipitates under neutral or acidic conditions.)

3. Maintain a phosphate residual in the water to precipitate calcium and magnesium as phosphate sludges, which are less adherent than scale.

Since water conditions are maintained in a manner conducive to precipitation of sludges, coordinated phosphate control is referred to as a phosphate precipitating program. Though the boiler water can accommodate some contamination, the boiler should not be considered a safe reaction vessel for the generation of sludge. Sludge is a deposit that has most of the objectionable properties of scale. Another boiler water control method, blowdown, helps to remove it.

Coordinated Phosphate-pH Control

The Navy uses two types of water treatment. The older treatment method is the coordinated phosphate (COPHOSO) treatment. The newer method is CHELANT treatment. In this chapter, we will only discuss the COPHOS method. For information on the CHELANT see *NSTM,* chapter 220, vol. 2, "Boiler Water/Feedwater Test and Treatment."

Coordinated phosphate-pH control prevents development of water having excess hydroxyl ions, which leads to caustic corrosion. The treatment chemicals are trisodium phosphate, dodecahydrate, and anhydrous disodium phosphate. The trisodium phosphate reacts with water to form sodium hydroxide and disodium phosphate. The sodium hydroxide contributes hydroxyl ions, which raise pH, while the disodium phosphate provides some of the needed phosphate. Although sodium hydroxide and disodium phosphate could be used in the treatment to produce the same results, the weights of sodium hydroxide needed would be so small that weighing errors would be large. In addition, accidental overaddition of sodium hydroxide would lead to caustic corrosion.

When boiler water containing the correct amount of sodium hydroxide and disodium phosphate is concentrated by heating, or evaporated to dryness, only the trisodium phosphate concentrate remains behind. There is no excess of hydroxyl ions (called free caustic). A primary aim in coordinated phosphate control is the elimination of free caustic, which forms in concentrated boiler water when pH is too high.

The calculations for trisodium phosphate is based on a curve (fig. 18-8). This curve divides the chart into two regions: the FREE CAUSTIC region, on the top, and the COORDINATED PHOSPHATE region, on the bottom. If 9.54 ppm of phosphate from trisodium phosphate were dissolved in water, the pH would be 10.00. You can determine this by locating 9.54 ppm on the bottom line between 9 ppm and 10 ppm, drawing a vertical line straight up until it crosses the coordinated phosphate curve, then drawing another line from that point to the pH scale on the left. You will see that it crosses pH 10. If 99.17 ppm of phosphate from trisodium phosphate were dissolved in water, the pH would be 11.00. As long as boiler water phosphate and pH levels are maintained BELOW the coordinated phosphate curve in figure 18-8, free caustic cannot result. When pH rises above the curve, free caustic is present and caustic corrosion of boiler metal can result.

If trisodium phosphate alone were used in treatment, boiler water control would have to follow exactly along the curve. The addition of extra disodium phosphate does not detectably change the pH of the water and permits assignment of a range for boiler water control. When added to boiler water, neither trisodium phosphate nor disodium phosphate can force boiler water into the free caustic region.

All naval boilers have boiler water controlled under the coordinated phosphate curve. Control

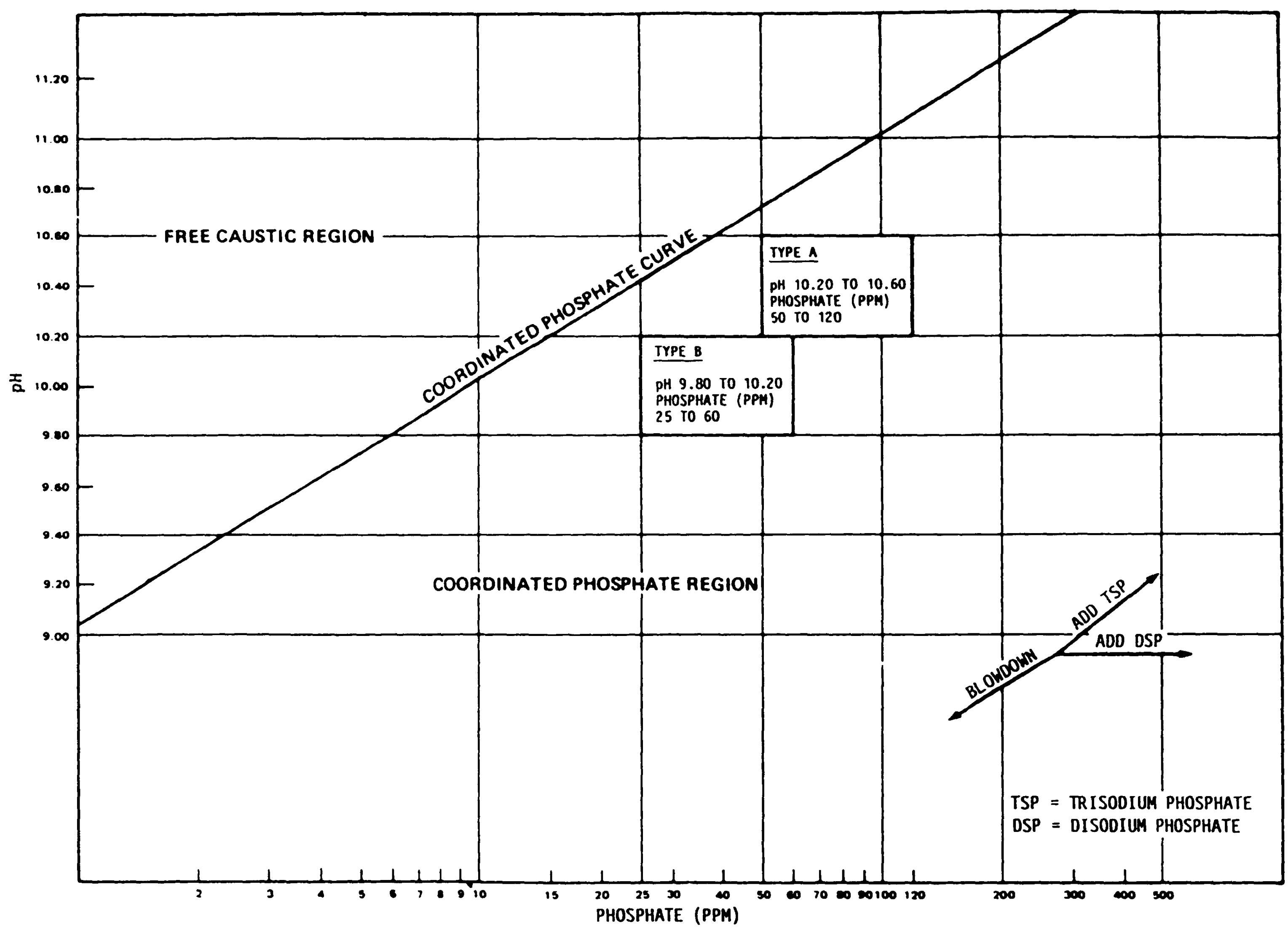


Figure 18-8.—Coordinated phosphate curve.

limits are based on heat transfer characteristics of the boiler. Boilers whose tube heat absorption is 150,000 Btu or less are classed as type A. These include all boilers having up to 600 psi nominal drum pressure. All 1,200 psi boilers have higher heat absorption and are classed as type B. The high heat transfer boilers have less tolerance to any chemical in the water, whether from treatment or contamination. In addition, the higher pressure boilers cannot tolerate as much conductivity as lower pressure boilers because of carryover. For these reasons, operating limits for type B boilers are lower than for type A boilers.

Reactions in Treated Boiler Water

The behavior of treatment chemicals in general and under various contaminant conditions are described in the following paragraphs.

PRECIPITATION REACTIONS (SLUDGE FORMATION).—The alkaline pH level in boiler water serves to minimize boiler metal corrosion. It also provides hydroxyl ions needed to react with the magnesium that would otherwise turn neutral water acidic. The magnesium hydroxide forms a sludge as long as the water remains alkaline. Both the sodium hydroxide and disodium phosphate in the water react with calcium and magnesium to form various phosphate sludges. Sludge in boiler water is an agglomeration of reaction products of boiler water treatment chemicals with calcium and magnesium contaminants as well as the suspended matter entering with the feedwater. The amount of sludge, if allowed to accumulate in the headers and water drum, will grow so large that particles will circulate with the boiler water. As sludge circulates, it begins to adhere to the generating surfaces. The adhering sludge is at first soft and is removable by mechanical cleaning. If allowed to remain on generating surfaces, the soft sludge is converted by heat to hard, baked-on sludge. Although baked-on sludge is physically different from scale (scale forms in place; sludge is carried to high heat transfer areas), it acts just like scale in that it restricts heat transfer and causes blistering and eventual rupture of the tube. Mechanical cleaning of the watersides will not remove baked-on sludge or scale. Scale is prevented by proper chemical treatment, and sludge is kept low in concentration by maintaining feedwater purity and by effective blowdown, primarily by bottom blowdown of a secured boiler.

EFFECT OF SEAWATER ON BOILER WATER CHEMICALS.—Seawater that enters boiler water contains contaminating chemicals, magnesium, calcium, and chloride, all of which raise the conductivity of the water. Because of the large amount of magnesium, the chemical reaction due to seawater contamination causes pH to drop. Both magnesium and calcium cause phosphate to decrease because the phosphate causes the formation of sludge. Chloride and conductivity increase. The pH and phosphate must always be kept under the coordinated phosphate curve and within specified limits. Damage will result if either pH becomes acidic or the concentration of phosphate falls below a safe value.

Salt will increase chloride and conductivity but will not affect pH or phosphate. Salt will not cause scale formation or acid attack.

EFFECT OF SHORE WATER ON BOILER WATER CHEMICALS.—The relatively large amount of calcium in shore water in comparison to magnesium causes phosphate to react first. The pH increases, conductivity increases slowly, and chloride does not change. Since shore water depletes phosphate, and increases pH, boiler water control parameters are forced into the free caustic range. To prevent scale formation and caustic corrosion, the pH and phosphate must always be kept under the coordinated phosphate curve and within specified limits.

CHEMICAL HIDEOUT.—Chemical hideout disrupts control of boiler water treatment. It is usually indicated by a diminishing level of phosphate as the boiler steaming rate increases. Phosphate returns when the steaming rate decreases or when the boiler is secured. The reasons for its occurrence are not well defined, but two likely mechanisms have considerable data to support them. Both are probably correct.

One mechanism shows that circumstance must allow concentration of chemicals. The other shows that reaction with the magnetite protective layer occurs.

If tube surfaces are smooth and free of deposits, boiler water circulates freely and is effective in continuously washing tube metal. Porous deposits, crevices, pits, and leakage sites interfere with circulation, creating areas conducive to concentration of boiler water. All of the normally soluble chemicals concentrate. If the interference is severe, localized dry-out of boiler water treatment chemicals and contaminants can occur. When such localized concentration of boiler water occurs, pH, phosphate, and conductivity decrease. A decrease in chloride may or may not be detected. As heat input to the boiler tubes increases, the concentrating effect at the metal increases. As heat transfer rate decreases, the chemicals return to the bulk boiler water.

Phosphates react directly with magnetite to form a solid sodium iron phosphate compound. This is a high-temperature reaction, and the compound decomposes when temperatures are reduced. When a reaction with magnetite is occurring, pH increases when the phosphate decreases; it decreases when the phosphate increases.

Virtually all instances of chemical hideout in naval boilers are reported after each of the following events has occurred:

1. Overhaul or boiler repair
2. Acid cleaning
3. Initiation of morpholine
4. Contamination

These events can cause generation of deposits in the boiler and the appearance of chemical hideout. Mechanical cleaning (via water-jet) alleviates this condition when it is caused by soft deposits. However, if contamination causes hard deposits, only acid cleaning will remove them. Hard deposits represent a hazard to boiler operation and in themselves cause hideout.

The reason for development of hideout soon after acid cleaning is not clear. Either or both of the previously described mechanisms may be at work when sensitized metal surfaces and soft deposits are present.

Blowdown

Blowdown provides control of accumulated boiler water solids, both suspended and dissolved.

SURFACE BLOWDOWN.—Surface blowdown reduces materials that have dissolved in the boiler water. Contamination and treatment chemicals contribute to the dissolved material, and the total amounts of them are measured by conductivity. Surface blowdown keeps conductivity, pH, and phosphate within limits. Surface blowdown must never be performed if the pH or phosphate drops below lower limits or if pH is above the coordinated phosphate curve (except in response to a high water casualty). Chemicals must first be added as necessary to raise pH or phosphate, and then the surface blowdown may be accomplished.

Surface blowdown also removes suspended solids and oil. Oil can be removed effectively only by blowing down through the surface blow pipe. Refer to *Naval Ships' Technical Manual (NSTM),* chapter 220, for detailed surface blowdown procedures.

BOTTOM BLOWDOWN.—The amount of sludge in the boiler is normally controlled by bottom blowdown. For a bottom blowdown to be effective, the boiler should be secured as long as possible before initiation of the blowdown. This will ensure that there is sufficient pressure on the boiler to accomplish the action. If the boiler is being secured for bottom blowdown and is then to be returned to the line, the blowdown is to be initiated when the boiler has been secured for at least 1 hour.

In a boiler where proper chemical treatment has been accomplished, the amount of sludge produced over a specified steaming period depends upon the amount and quality of its makeup feedwater. Refer to *NSTM,* chapter 220, for detailed bottom blowdown procedures.

Idle Boiler Maintenance

The primary consideration of idle boiler maintenance is the prevention of oxygen corrosion of the boiler metal. Wet iron exposed to air (oxygen) will corrode. Corrosion of the iron can be eliminated by removing either the air or the moisture through either one of two forms of idle boiler layup, dry and wet. These are summarized in the following paragraphs. However, for detailed procedures on idle boiler layup, refer to *NSTM,* chapter 221.

DRY LAYUP.—Dry layup of a boiler is accomplished either by using desiccant, in the case of a closed-up boiler, or by blowing warm air through circuits of the open watersides. Both methods prevent water condensation on the watersides and control oxygen corrosion.

In preparing for a dry layup of a propulsion boiler, 25 pounds of sodium nitrite are injected into the boiler when the drum pressure drops to less than 100 psi. The sodium nitrite solution reacts with the boiler waterside surfaces to form a passivating film. When dumped, this passivating film remains on the watersides to retard iron oxidation as long as the surfaces are kept perfectly dry.

WET LAYUP.—Wet layup of a boiler is accomplished by excluding oxygen from the water. After securing a boiler, one of the following wet layup methods is used to keep the boiler operational:

1. A steam blanket is applied when the boiler pressure reduces to steam blanket pressure. The superheater is drained.

2. A nitrogen blanket is applied when boiler pressure reduces to nitrogen blanket pressure.

3. Hot deaerated feedwater is added via the main feed connection until the boiler and superheater are filled, and a hydrostatic pressure between 15 and 50 psi is maintained. This method must not be used for boilers having stainless steel superheaters and is not normally recommended for other propulsion boilers.

4. Boilers with stainless steel superheaters, except the last boiler to be secured, are backfilled through the superheater with hot deaerated feedwater when the boiler pressure reduces to 15 psi. When the boiler and superheater are completely filled, a pressure not to exceed 100 psi is maintained on the boiler through the backfill connection.

5. After the DFT is secured, and hot deaerated feedwater is not available, the last boiler to be laid up is backfilled with reserve feedwater. A positive pressure not to exceed 100 psi is maintained through the backfill connection.

NOTE: Methods 4 and 5 may be used for all propulsion boilers, including those with stainless steel superheaters.

6. The boiler, the superheater, and the economizer are filled via the feed connection with reserve feedwater containing hydrazine and morpholine. A minimum of 15 psi hydrostatic pressure is maintained on the boiler using the treated water in the reserve feed tank. This method is authorized for use by industrial activities only.

Hydrazine is a liquid oxygen scavenger that does not add to the dissolved solids content of water. Hydrazine and morpholine are added to an empty reserve feed tank, which is then filled with cold feedwater. The solution is pumped to the boiler and a minimum 15 psi is maintained. This method is used for complete wet layup of a propulsion boiler that has completed overhaul and has had a successful hydrostatic test. The hydrazine reacts, under alkaline conditions, with oxygen in the feedwater to produce nitrogen and water. The alkaline condition is obtained by the addition of morpholine. If the boiler is steamed with water containing a high concentration of hydrazine, the hydrazine is converted to ammonia, which can be harmful to copper alloys in the condensate system. Therefore, before light-off, water containing hydrazine is completely drained from the boiler and the reserve feed tank before it is refilled with fresh feedwater.

The positive pressure of the wet layup keeps the air from entering the boiler watersides. An idle boiler under wet layup is not maintained within steaming boiler chemical treatment requirements. This is because a high heat flux is not being applied and contaminated feedwater is not continuously entering the boiler.

TEST PROCEDURES

Since you must complete the prescribed certification course to conduct boiler water and feedwater tests, the test procedures will not be covered in this chapter. The testing procedures can be found in *NSTM,* chapter 220. You should always use this manual when conducting tests.

LOGS AND RECORDS

The feedwater and boiler water chemistry logs and records are very important. Data collected and reflected in the logs and records are used by the engineer officer and assistants to measure the performance, stability, efficiency, and state of material readiness of the engineering plant. These logs and records support the decision-making process involved in an effective water chemistry program.

RECORDS MAINTENANCE

There are five forms available for recording data used to assist in maintaining proper water conditions in a steam propulsion plant.

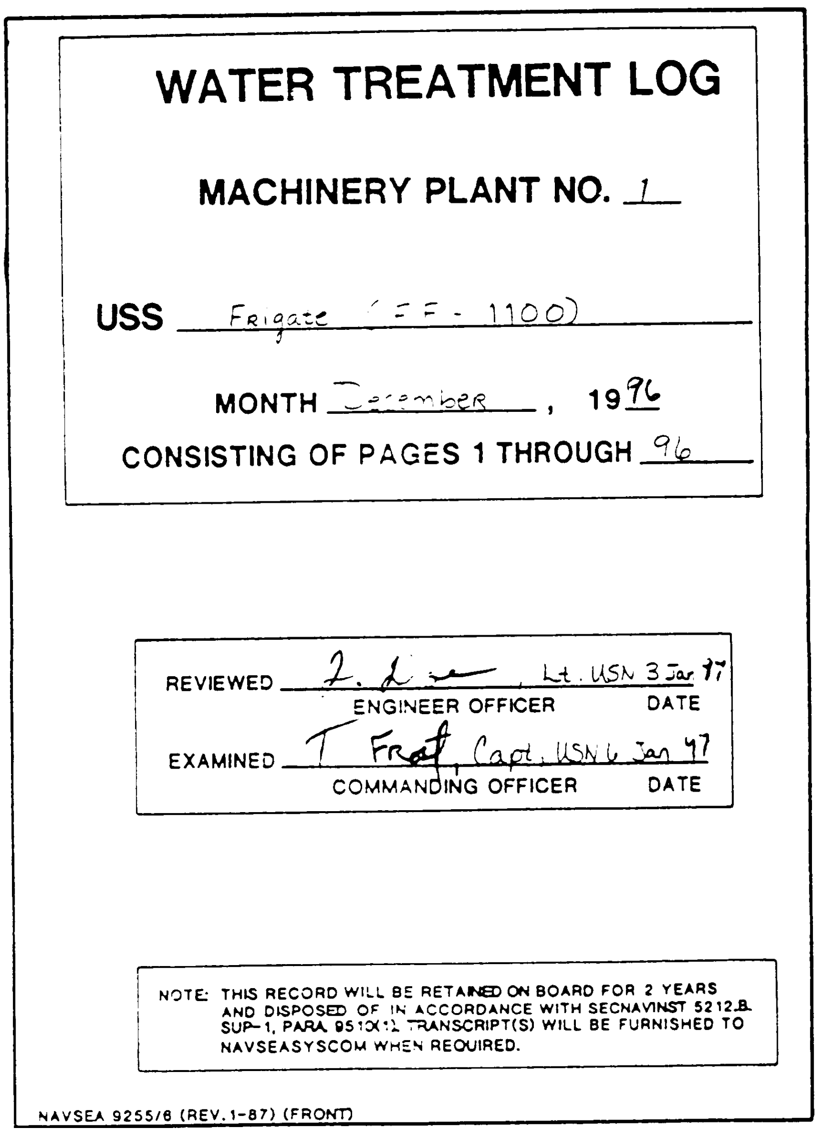
1. Water Treatment Log (figs. 18-9A and 18-9B)
2. Feedwater Chemistry Worksheet/Log (figs. 18-10A and 18-10B)
3. Boiler Water Chemistry Worksheet/Log (figs. 18-11A and 18-11B)
4. Reserve/Makeup Feedwater Tests Log (figs. 18-12A and 18-12B)
5. Fuel and Water Report (figs. 18-12A and 18-13B)

A complete Machinery Plant Water Treatment Log Package for a month is compiled for each machinery space. This package consists of the following:

1. The cover sheet and monthly boiler data
2. The daily Feedwater Chemistry Worksheet/Log
3. The daily Boiler Water Chemistry Worksheet/Log for each boiler in the space

The Machinery Plant Water Treatment Log Package is retained for 2 years.

The daily log for the reserve/makeup feedwater tests is retained for 3 months, and the daily Fuel and Water Report is retained for 1 month.



WATER TREATMENT LOG

MACHINERY PLANT NO. 1

USS Frigate (FF - 1100)

MONTH December, 1996

CONSISTING OF PAGES 1 THROUGH 96

REVIEWED ________, Lt. USN 3 Jan 97
ENGINEER OFFICER DATE

EXAMINED T Frost, Capt. USN 6 Jan 97
COMMANDING OFFICER DATE

NOTE: THIS RECORD WILL BE RETAINED ON BOARD FOR 2 YEARS AND DISPOSED OF IN ACCORDANCE WITH SECNAVINST 5212.5B SUP-1, PARA. 9510(1). TRANSCRIPT(S) WILL BE FURNISHED TO NAVSEASYSCOM WHEN REQUIRED.

NAVSEA 9255/8 (REV. 1-87) (FRONT)

Figure 18-9A.—Water Treatment Log (front).

BOILER NUMBER	1A	1B	
STEAMING HOUR DATA			
TOTAL STEAMING HOURS	38865.5	36245.3	
TOTAL LAST MONTH	461.1	398.4	
HOURS THIS MONTH	175.3	101.2	
INSPECTIONS			
SGPI			
DATE LAST INSPECTED	17 Aug 96	19 Aug 96	
INSPECTED BY	IMA	IMA	
STM. HRS. SINCE INSP.	2167.5	2218.0	
CHENG			
DATE LAST INSPECTED	3 MAR 96	7 MAR 96	
INSPECTED BY	P.P. PETERS	P.P. PETERS	
STM. HRS. SINCE INSP.	2714.0	2872.5	
CLEANINGS			
WATER JET, WIRE BRUSH OR EDTA WATERSIDE CLEANINGS			
DATE LAST CLEANED	6 JUNE 96	7 JUNE 96	
TYPE OF CLEANING	EDTA	EDTA	
STM. HRS. SINCE CLN.	3875.5	3947.3	
HYDROCHLORIC OR SULFAMIC ACID WATERSIDE CLEANING			
DATE LAST CLEANED	2 FEB 96	6 MAR 96	
STM. HRS. SINCE CLN.	29724.5	28998.2	
FIRESIDE CLEANING			
DATE LAST CLEANED	6 JUNE 96	7 JUNE 96	
STM. HRS. SINCE CLN.	3875.5	3947.3	
CONTAMINATION			
STM. HRS. MODERATE	22	16	
% STM. HRS. MODERATE	12.5	15.8	
STM. HRS. SERIOUS	2	5	
% STM. HRS. SERIOUS	1.1	4.9	
CHEMICAL AND BLOWDOWN DATA			
TOTAL OUNCES TSP	92	79	
TSP/1000 STM HR/1000 GAL	0.52	0.78	
TOTAL OUNCES DSP	83	85	
DSP/1000 STM HR/1000 GAL	0.47	0.84	
TOTAL OUNCES C.S.	0	0	
NO. OF SURFACE BLOWS	4	3	
TOTAL % SURFACE BLOW	60	48	
NO. OF BOTTOM BLOWS	2	1	

BOILER SAFETY VALVES SET	DATE	PRESSURE LIFT	PRESSURE RESEAT
BOILER NUMBER 1A			
PILOT	7 JUNE 96	1370	1295
SUPER HEATER	7 JUNE 96	1385	1315
#1 DRUM	7 JUNE 96	1390	1330
#2 DRUM	7 JUNE 96	1400	1350
#3 DRUM			
#4 DRUM			
BOILER NUMBER 1B	8 JUNE 96		
PILOT	8 JUNE 96	1360	1305
SUPERHEATER	8 JUNE 96	1390	1320
#1 DRUM	8 JUNE 96	1395	1320
#2 DRUM	8 JUNE 96	1405	1350
#3 DRUM			
#4 DRUM			
BOILER NUMBER			
PILOT			
SUPERHEATER			
#1 DRUM			
#2 DRUM			
#3 DRUM			
#4 DRUM			

WATER CHEMISTRY STANDARDS RUN

TEST	DATE	RESULT
CONDUCTIVITY	5 DEC 96	1350
CHLORIDE	5 DEC 96	1.96 EPM
ALKALINITY	15 DEC 96	6.0 EPM
HARDNESS	5 DEC 96	0.18 EPM

HYDROSTATIC TEST DATES

BOILER NUMBER	1A	1B	
LAST 150% HYDRO	4 JUNE 96	6 JUNE 96	
LAST 135% HYDRO	4 JUNE 96	6 JUNE 96	
LAST 125% HYDRO	4 JUNE 96	6 JUNE 96	

DATES OF IMPORTANT EVOLUTIONS

BOILER NUMBER	PSI/DATE	PSI/DATE	PSI/DATE
SOOT BLOWER NDT	1 FEB 96	1 FEB 96	
BOTTOM BLOWDOWN PIPING NDT	3 MAY 96	3 MAY 96	
AIR CASING TEST	1 OCT 96	5 SEPT 96	
SATISFACTORY BOILER FLEXIBILITY TEST	4 DEC 96	4 DEC 96	

GOVERNOR SETTINGS

NUMBER	1A1	1A2	1B1	1B2					
FORCED DRAFT BLOWERS	DATE 15 Nov 96 / SETTING 5[illegible]0	15 Nov 96 / 5780	16 Nov 96 / 5795	16 Nov 96 / 5780					
NUMBER									
FUEL OIL SERVICE PUMPS	DATE / SETTING								
NUMBER	1A	1B	1C						
MAIN FEED PUMPS	DATE 18 Nov 96 / SETTING 7750	18 Nov 96 / 7720	18 Nov 96 / 7700						
NUMBER									
MAIN FEED BOOSTER PUMPS	DATE / SETTING								

Figure 18-9B.—Water Treatment Log (back).

NAVSEA 9255/4 (Rev. 1-87)(FRONT)

FEEDWATER CHEMISTRY WORKSHEET/LOG

SYSTEM ONE SHIP USS CARRIER (CV-50) DATE 8 MAY 1996 PAGE 161

CHEMICAL TESTS AND SALINITY/CONDUCTIVITY INDICATOR COMPARISON (REQUIRED DAILY)

NOTE: μMHC÷146=EPM

TIME	INDICATOR LOCATION	CHLORIDE mL MERCURIC NITRATE×0.1= EMP CHLORIDE	INDICATOR READING μMHO/CM	INDICATOR READING EPM	COMP SAT/UNSAT	HARDNESS mL EDTA×0.2= EPM HARDNESS	OIL KING INITIAL
0015	MN CONDENSATE	.01		.01	SAT		
0038	AUX CONDENSATE	.02		.05	UNSAT	.02	
0100	FWDC	.01		.02	SAT		
0125	DFT	.02		.02	SAT		
0350	AUX CONDENSATE	.02		.02	SAT		

DEAERATED FEED WATER

TIME	CODE	DISSOLVED OXYGEN LIMIT: 15 PPB	MORPHOLINE pH RANGE: 8.8-9.0	MORPHOLINE ROTAMETER SETTING	MORPHOLINE TANK LEVEL (GALLONS)
0915	RTE	10			
0945	RTE		86-90	5	15

LEGEND/TEST CODE

MORPHOLINE TREATED SYSTEM		DISSOLVED OXYGEN TESTING	
AOL	60 TO 90 MIN. AFTER ON LINE	PTL	PRIOR TO BLR. LIGHT OFF
RTE	CARRIERS WITHIN 4 HRS.	AOL	WITHIN 2 TO 3 HRS. AFTER BLR. ON LINE
	OTHERS WITHIN 12 HRS.	RTE	WITHIN 24 HRS.

FEEDWATER TESTS

TIME	LOCATION	INDICATOR READING μMHO/CM / EPM	CHLORIDE mL MERCURIC NITRATE×0.1= EPM CHLORIDE	HARDNESS mL ETDA×0.2= EPM HARDNESS	OIL KING INITIAL
0300	AUX CONDENSERS		.02		

REQUIREMENTS/LIMITS		CHLORIDE EPM MAX. SALINITY INDICATOR	CHLORIDE EPM MAX. CHEMICAL TEST	CONDUCTIVITY μMHO/CM MAX.	HARDNESS EPM MAX.
DISTILLATE		0.066	0.07	10.0	0.02
MAKEUP	DEMINERALIZED	-	-	1.0	-
	NONDEMINERALIZED	0.10	0.10	16.0	0.10
COND., DRNS	MORPHOLINE TREATED	0.04	0.02	6.0	0.02
AND FDWTR	WITHOUT MORPHOLINE	0.02	0.02	3.0	0.02

Figure 18-10A.—Feedwater Chemistry Worksheet/Log (front).

NAVSEA 9255/4 (Rev. 1-87)(Back)

FEEDWATER CHEMISTRY WORKSHEET/LOG

PAGE 162

TIME	REMARKS
0038	COMPARISON TEST UNSAT. SALINITY INDICATOR READING IS GREATER THAN CHEMICAL CHLORIDE TEST RESULT BY MORE THAN
	0.02 EPM. WATER TESTED FOR HARDNESS. HARDNESS LIMIT FOR AUXILIARY CONDENSATE Δ.02 EMP. MORPHOLINE
	LEVEL WITHIN LIMITS. PER NSTM 220 PARA 22.6.3, WATER IS SAT FOR USE AND SALINITY INDICATOR
	WILL BE CHECKED FOR MALFUNCTION.

LCPO		MPA		REVIEWED: (ENGINEER OFFICER)	DATE
INIT.	DATE	INIT.	DATE		
DC	9MAY96	JS	9MAY96	J Doe	9 May 1996

Figure 18-10B.—Feedwater Chemistry Worksheet/Log (back).

NAVSEA 9255/8 (1-87) (FRONT)
0116-LF-092-6640

BOILER WATER CHEMISTRY WORKSHEET/LOG

BOILER NO. 1A SHIP USS SACRAMENTO (AOE-1) DATE 1 JUNE 1996 PAGE 1

TIME	CODE	pH RANGE: TYPE A: 10.20–10.60 TYPE B: 9.80–10.20				CONDUCTIVITY LIMIT: TYPE A: 800 TYPE B: 400 µMHO/CM	PHOSPHATE RANGE: TYPE A: 50–120 PPM TYPE B: 25–60 PPM				CHLORIDE LIMIT: 1.00 EPM		BOILER LOAD PERCENT	OIL KING INITIAL	EOOW/EDO INITIAL
		TEMP (°C)	pH METER READING	CORREC-TION	CORRECTED pH	CONDUCTIVITY µMHO/CM	mL PHEN-OLPH-THALEIN	APPROX-IMATE pH	mL METHYL PURPLE	mL×25 = PPM PHOSPHATE	mL MERC. NIT.	mL×0.4 = EPM CHLORIDE			
0010	PTL	25	9.5	0.00	9.5	80	.1	8.3-9.7	.6	15	.7	.28	—	MKF	FM
0052	LOF														
0230	ONL														
0249	AOL	26	9.57	+.02	9.59	90	.1	8.3-9.7	.7	17.5	.7	.28	6%	MKF	FM
0354	AOL	26	9.60	+.02	9.62	95	.1	8.3-9.7	.8	20	.7	.28	12%	FW	GWB
0454	AOL	26	9.60	+.02	9.62	100	.1	8.3-9.7	.9	20	.8	.32	15%	FW	GWB
0520	ADD														
0630	ACA	25	10.20	0.00	10.20	200	.6	10.2	2.0	50	.8	.32	20%	FW	GWB
1350	RTE	26	10.16	+.02	10.18	200	.6	10.2	1.8	45	1.0	.40	40%	JC	SA
1435	OTH	24	9.7	-.02	9.68	260	.1	8.3-9.7	.8	20	3.5	1.40	50%	JC	SA
1450	ADD														

CHEMICAL TREATMENT

TRISODIUM PHOSPHATE (OUNCES)	TSP CORREC-TION FOR PHOSPHATE	CURRENT PHOSPHATE LEVEL	CORRECTED PHOSPHATE	DISODIUM PHOSPHATE (OUNCES)	CAUSTIC SODA (OUNCES)	TIME
10.5	10	20	30	7.5	—	0520
10.5	10	20	30	7.5	—	1450

TOTAL TSP INJECTED	TOTAL DSP INJECTED	TOTAL CAUSTIC SODA INJECTED

BLOWDOWN

TIME		TYPE	CONDUCTIVITY		% BLOW-DOWN
START	FINISH		BEFORE	AFTER	

TOTAL PERCENT SURFACE BLOW-DOWN	TOTAL PERCENT BOTTOM BLOW-DOWN

pH METER STANDARDIZATION

TIME	% SLOPE (92% MIN)	INITIAL
0001	100	

Figure 18-11A.—Boiler Water Chemistry Worksheet/Log (front).

NAVSEA 9255/8 (1-87) (BACK)

BOILER WATER CHEMISTRY WORKSHEET/LOG

PAGE 2

TIME	REMARKS
0010	PTL - Meets Light off Requirements
0249	AOL - PH & Phosphates Low out of Limits, Satisfactory for First AOL
0354	AOL - PH & Phosphates Low out of Limits, Satisfactory for Second AOL
0459	AOL - PH & Phosphates Low out of Limits, Recommend treat Boiler to upper Limits
1435	OTH - Auxiliary Gland Exhaust Condenser ST HIGH out of Limits, EOOW
	ordered Boiler be tested, Boiler test Results indicate Moderate
	Seawater contamination, Phosphates and PH Low out of Limits,
	Chloride High out of limits, Gland Exhaust Condenser cut out of
	System, Recommend treat boiler to upper Limits AND conduct
	Surface blowdowns to return chloride to Limits.

LEGEND/TEST CODE

PTL	WITHIN 1 HR. PRIOR TO LIGHTOFF
AOL1	WITHIN 30 MIN. AFTER ON LINE
AOL2	WITHIN 60 TO 75 MIN. AFTER AOL1
AOL3	WITHIN 60 TO 75 MIN. AFTER AOL2
RTE	WITHIN 8 HOURS
ADD	CHEMICAL ADDITION
ACA	60 TO 90 MINS AFTER CHEMICAL ADDITION
PTB	WITHIN 1 HR. PRIOR TO BLOWDOWN
ABD	30 TO 45 MINS. AFTER BLOWDOWN
PTS	WITHIN 1 HR. PRIOR TO SECURING
FFT	FRESHLY FILLED AND TREATED
LOF	LIGHTOFF
ONL	ON LINE
SEC	SECURED
D	DUMPED
OTH	OTHER

BOILER LAYUP

DRY

DES	DESICCANT
HTD	HEATED AIR

WET LAYUP

STM	STEAM (SHIP)
STS	STEAM (SHORE)
NIT	NITROGEN
DFT	HOT DFW FILL
HYD	HYDRAZINE
SN	SODIUM NITRITE

BLOWDOWNS

S	SURFACE
B	BOTTOM

	TOTAL HOURS	HOURS STEAMED UNDER MODERATE CONTAMINATION	HOURS STEAMED UNDER SERIOUS CONTAMINATION
STEAMING HOURS CARRIED OVER			
STEAMING HOURS TODAY			
STEAMING HOURS THIS MONTH			
HOURS SINCE LAST WATERSIDE INSPECTION			
HOURS SINCE LAST FIRESIDE INSPECTION			
HOURS SINCE LAST BOTTOM BLOW			

LCPO INIT.	DATE	MPA INIT.	DATE	REVIEWED: (ENGINEER OFFICER)	DATE

Figure 18-11B.—Boiler Water Chemistry Worksheet/Log (back).

RESERVE/MAKEUP FEEDWATER TESTS LOG
(FILL IN APPLICABLE COLUMNS)

NAVSEA 9255/10 (1-87) (FRONT)

SHIP USS FRIGATE (FF-1100)   DATE 4 APRIL 1996

TANK NO.	TIME	CODE	SALINITY INDICATOR, EPM (LIMIT: 0.10 EPM)	CONDUCTIVITY INDICATOR, µMHOS/CM (LIMIT: 15 µMHO/CM)	CHLORIDE (LIMIT: 0.10 EPM MAX) mL MERCURIC NITRATE	CHLORIDE mL x 0.1 = EPM	HARDNESS (LIMIT: 0.10 EPM MAX) mL EDTA	HARDNESS mL x 0.2 = EPM	DEMINERALIZER CONDUCTIVITY INLET MAX 15 µMHO/CM	DEMINERALIZER CONDUCTIVITY OUTLET MAX 1 µMHO/CM	OIL KING INITIAL
5-107-0	0815	DAY			.4	.04	.1	.02			BE
5-110-0	0830	DAY			.2	.02	0	0			
WITH DEMINERALIZER											AW
3-92-1	0010	PPS			.2	.02			3.0	.15	AW
3-92-1	0035	AOS	.02								AW
3-92-2	0240	PPS			.1	.01			2.5	.10	BE
3-92-2	0255	AOS	.02								BE
3-92-1	0700	PPS			.1	.01			2.0	.10	BE
3-92-1	0720	AOS	.01								BE
3-92-2	1115	PPS			.1	.01					BE
WITHOUT DEMINERALIZER											
3-92-1	0010	AOS	.01								AW
3-92-2	0240	AOS	.01								AW
3-92-1	0700	AOS	.01								BE
3-92-2	0920	AOS	.02								BE
3-92-1	1115	AOS	.01								BE
3-92-2	1500	AOS	.02								NK
3-92-	359	AOS	.01								NK

LEGEND/TEST CODE

DAY DAILY	AOS AFTER ON SUCTION	PPS PRIOR TO PLACING ON SUCTION	OTH OTHER

Figure 18-12A.—Reserve/Makeup Feedwater Test Log (front).

RESERVE/MAKEUP FEEDWATER TESTS LOG

NAVSEA 9255/10 (Rev. 1-87) (Back)

TIME	REMARKS

INIT.	LCPO DATE	INIT.	MPA DATE
DWd	5 APRIL 1987	JJH	5 APRIL 1996

REVIEWED (ENGINEER OFFICER)	DATE
J. Do	5 April 1996

SHORE SOURCE FEEDWATER CHEMICAL TEST DATA

CONSTITUENT OR PROPERTY	STEAM CONDENSATE SUPPLIER	STEAM CONDENSATE SHIP	PROCESSED FEEDWATER SUPPLIER	PROCESSED FEEDWATER SHIP
pH RANGE	8.0–8.5	> 5.4	NOT REQ.	5.4–8.2
HARDNESS EPM LIMIT	0.10	0.10	NOT REQ.	0.10
CONDUCTIVITY μMHO/CM LIMIT	28	< 40	2.5	< 40
SILICA PPM LIMIT	0.2	0.2	0.2	0.2
ACTIVITY				

Figure 18-12B.—Reserve/Makeup Feedwater Test Log (back).

FUEL AND WATER REPORT

NAVSEA 9255/9 (1-87) (FRONT)
(FORMERLY NAVSEA 9810/1)

FRIGATE (FF-100)

DATE 15MAR96

TO: COMMANDING OFFICER, USS

	FUEL (GALLONS)		LUBE OIL STORAGE TANKS (GALLONS)		WATER (GALLONS)	
	BOILER FUEL	DIESEL FUEL	2190	9250	POTABLE	RESERVE FEED
ON HAND LAST REPORT	224,000	15,200	1,500	1,700	9,050	9,080
RECEIVED (+)	0	0	0	0	0	0
DISTILLED (+)						
EXPENDED (-)	20,200	200	100	0	6,400	8,570
GAIN (+) LOSS (-) BY INVENTORY	+ 150	0	0	0	0	0
ON HAND THIS REPORT	203,950	15,000	1,400	1,700	9,700	10,580
ON HAND %	92	76	70	100	94	91

POTABLE WATER RECORD		
PERSONNEL ON BOARD	GALLONS USED PER PERSON	STANDARD
243	26	27

FEEDWATER CONSUMPTION	
NOT UNDERWAY (GALLONS PER HOUR)	UNDERWAY (GALLONS PER HOUR)
	357

REMARKS:

BOILER WATER PH AND PHOSPHATE BELOW NORMAL LOW LIMITS BUT WITHIN FIRST AOL REQUIREMENTS. CHLORIDE ABOVE MAX LIMIT DUE TO FWDCT CONTAMINATION. CONDUCTIVITY ABOVE MAX LIMIT DUE TO TREATING BOILER TO RESTORE PH AND PHOSPHATE PRIOR TO BLOWDOWN TO REMOVE CONTAMINATION.

* STRIPPED 200 GALS FROM JP-5 SERVICE TANK
* GAINED 150 GALS SOUNDING TANKS DURING HEAVY SEAS.

Figure 18-13A.—Fuel and Water Report (front).

NAVSEA 9255/9 (1-87) (BACK)

FUEL AND WATER REPORT

HOURS SINCE INSPECTION	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.

BLR NO.	FIRE-SIDE	WATER-SIDE	LAST SAMPLE pH	LAST SAMPLE COND.	LAST SAMPLE PHOS-PHATE	LAST SAMPLE CHLOR-IDE	RANGE OF RESULTS	pH	COND.	PHOS-PHATE	CHLOR-IDE	HOURS STEAMED UNDER CONTAM-INATION	LAYUP CODE	DAYS/HRS UNDER LAYUP	HOURS SINCE BOTTOM BLOW-DOWN
1A	961.4	961.4	9.98	450	425	228	MAX	10.8	500	50.	2.52	MOD			23.2
							MIN	9.23	50	12.5	0.12	SER			
1B	1077.1	1077.1					MAX					MOD	STM	25	25
							MIN					SER			
							MAX					MOD			
							MIN					SER			
							MAX					MOD			
							MIN					SER			
							MAX					MOD			
							MIN					SER			
							MAX					MOD			
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							MAX					MOD			
							MIN					SER			
							MAX					MOD			
							MIN					SER			
							MAX					MOD			
							MIN					SER			
							MAX					MOD			
							MIN					SER			

FEEDWATER CONDITIONS

SYSTEM RANGE OF RESULTS	DISSOLVED OXYGEN (PPB) 1	2	3	4	EPM CHLORIDE 1	2	3	4	FEEDWATER pH 1	2	3	4
MAX	10				0.05					8.6-9.0		
MIN	0				0.01							

BOILER WATER LIMITS:

	TYPE A	TYPE B
pH	10.20 - 10.60	9.8 - 10.20
CONDUCTIVITY (µMHO/CM)	800 MAX	400 MAX
PHOSPHATE (PPM)	60 - 120	25 - 60
CHLORIDE (EPM)	1.0 MAX	1.0 MAX

FEEDWATER LIMITS:

	WITH MORPHOLINE TREATMENT	WITHOUT MORPHOLINE TREATMENT
DISSOLVED OXYGEN (PPB)	15 MAX	15 MAX
SALINITY INDICATOR (EPM)	0.04 MAX	0.02 MAX
CONDUCTIVITY INDICATOR (µMHO/CM)	8.0 MAX	3.0 MAX
pH	8.8 - 9.0	-

BOILER LAYUP

LAYUP CODE		TIME LIMIT
DRY		
DES	DESICCANT	UNLIMITED
HTD	HEATED AIR	UNLIMITED
WET		
STM	150 PSI STEAM (SHIP)	30 DAYS
STS	150 PSI STEAM (SHORE)	30 DAYS
NIT	NITROGEN	30 DAYS
DFT	HOT DFW FILL	2 WEEKS
HYD	HYDRAZINE	UNLIMITED
SN	SODIUM NITRITE	UNLIMITED

PREPARED BY: (OIL KING)	REVIEWED: (MPA)	REVIEWED: (ENGINEER OFFICER)

Figure 18-13B.—Fuel and Water Report (back).

Water Treatment Log

The Water Treatment Log is to be completed as follows:

1. On the cover sheet (fig. 18-9A) the following data are entered:

   a. The machinery plant number.
   b. The ship's name and hull number.
   c. The month and the year.
   d. The total number of pages for the complete Machinery Plant Water Treatment Package at the end of the month. (Each page in the package is numbered, beginning each month with the number 1.)

2. On the reverse side (fig. 18-9B) are entered the appropriate data for each boiler associated with this machinery plant system. Data that have changed during the month must be updated. Data that have not changed from the previous month must be brought forward. Additional blocks are provided in the areas of Dates of Important Evolutions and Governor Settings to record data that may be generated by repeated testing of equipment during a given month.

Feedwater Chemistry Worksheet Log

The Feedwater Chemistry Worksheet/Log (figs. 18-10A and 18-10B) consists of the following sections:

1. Chemical tests and salinity indicator comparison

2. Feedwater chemical tests

3. Shore feedwater/steam chemical test data

4. Remarks

A daily log is initiated by inserting the system number, ship's name and hull number, and date. When there is more than one condensate/ feedwater system, a separate log is required for each system.

CHEMICAL TESTS AND SALINITY INDICATOR COMPARISON SECTION.—This section applies to all feedwater components that are monitored by a salinity indicator and is used to enter the following information:

1. The location of any additional salinity indicators.
2. The time of simultaneous chemical sampling and reading of the salinity indicator; for makeup feed, the time of the salinity indicator reading.
3. The mL of mercuric nitrate used in testing and the calculated chloride chemical test result.
4. The salinity indicator result. In addition, the satisfactory or unsatisfactory blocks are checked and, when necessary, the mL of EDTA used in testing and the calculated hardness chemical test result are inserted in the appropriate blocks. Finally, the oil king initials this section and notifies the EOOW/EDO of the test results.

FEEDWATER CHEMICAL TESTS SECTION.—This section is for all feedwater system components except reserve/makeup. The following information is entered in the appropriate blocks:

1. The time of completion of sampling
2. The appropriate code as given on the back of the log
3. The location from which the sample was drawn
4. The test result, if the sample was taken to analyze it for dissolved oxygen content
5. The morpholine rotameter setting at the time of sampling and the test result

The Chloride column is used to record data obtained whenever a salinity indicator is faulty and it becomes necessary to chemically test for chloride once each watch. It is also used to record the data obtained when samples are tested to locate contamination sources:

1. When the chemical test for chloride is performed, CH is entered in the Code column; and the mL of mercuric nitrate used in testing and the calculated chloride chemical test result are entered in the Chloride column.
2. When a salinity indicator reading is obtained, SI is entered in the Code column, and the salinity indicator reading in the EPM column. The mL Mercuric Nitrate column is left blank.

The Hardness column is used to record the data obtained when samples are tested to locate the contamination sources. Hardness is not determined routinely for feedwater components (except for reserve feedwater, which is recorded on the Reserve/Makeup Feedwater Log). Results that exceed 0.10 epm (0.10 meq/L) hardness indicate unacceptable water quality. In such case, CH is entered in the Code column and the mL of EDTA used in testing for hardness and the calculated hardness test results are entered in the EDTA column.

The oil king initials this section and notifies the EOOW/EDO of the test results.

SHORE FEEDWATER/STEAM CHEMICAL TEST DATA SECTION.—In this section, used for shore source feedwater or shore steam, the following information is entered:

1. The pH, hardness, conductivity, and silica results provided by the activity supplying the shore source feedwater or shore steam.
2. The pH, hardness, silica, and conductivity as determined by ship's force. The lowest reading measurable on the shipboard conductivity meter is 40 mho/cm (40 s/cm).
3. The activity providing the shore feedwater or shore steam.

REMARKS SECTION.—The Remarks section contains an explanation of each test result that is out of limits, a brief summary of feed system repairs accomplished, the status of repairs or replacement for any malfunctioning salinity indicator, and a description of any unusual condition. All remarks are accompanied by the time as appropriate. Additional pages for remarks are inserted as necessary.

The Feedwater Chemistry Worksheet/Log need not be prepared on a daily basis if a plant is in a cold iron status and no testing is required. When no testing is required, the inclusive dates are entered on the front of one log and the reasons are given in the Remarks section.

For every day that there is a log, the LCPO and MPA must review and initial the log, and the log must be reviewed and signed by the engineer officer.

Boiler Water Chemistry Worksheet Log

The daily Boiler Water Chemistry Worksheet Log (figs. 18-11A and 18-11B) consists of the following sections:

1. Chemical test results
2. Chemical treatment
3. Blowdown
4. pH meter standardization
5. Steaming hour data
6. Remarks

The daily log for each boiler is initiated by inserting the boiler number, the ship's name and hull number, and the date.

CHEMICAL TEST RESULTS SECTION.—This section is maintained as follows:

1. The time is entered on a 2400-hour clock basis for completion of boiler water sampling, actual commencement of full layup conditions, light-off, on line, securing, completion of dumping a boiler, and completion of freshly filling a boiler.
2. The appropriate code as given on the back of the log for the boiler condition, the reason for testing, or the method of layup are given.
3. For each boiler water sample, the following information is recorded:
   a. The pH meter reading, the sample temperature, the pH correction for that temperature, and the corrected pH
   b. The sample temperature and the conductivity
   c. The mL of nitric acid needed to change phenolphthalein from pink to colorless, the mL of nitric acid needed to change methyl purple from green to purple, and the calculated phosphate test result
   d. The mL of mercuric nitrate used and the calculated chloride test result

The oil king and the reviewing EOOW/EDO enter their initials upon completion of the tests.

CHEMICAL TREATMENT SECTION.—This section is maintained by entering the following information:

1. The amount of trisodium phosphate required to raise pH to the upper limit
2. The phosphate correction that will be caused by the addition of trisodium phosphate
3. The phosphate reading obtained from the original sample results
4. The added correction to the original phosphate reading and the corrected phosphate
5. The amount of disodium phosphate required
6. The time of completion of the 10-minute flush when injecting boiler water treatment chemicals
7. The initials of the person who performed the chemical treatment calculations
8. The total amounts of chemicals used for the day

NOTE: If it is necessary to inject caustic soda, the weight of caustic soda is entered in the Trisodium Phosphate (ounces) column followed by c/s; for example, 1.0 c/s.

BLOWDOWN SECTION.—In the Blowdown section the following information is indicated:

1. The times of initiation and completion of a surface, bottom, or header blowdown operation. If a blowdown spans two dates, both times are recorded on the date of completion.
2. The appropriate code, as given on the back of the log, for the type of blowdown.
3. The conductivity before blowdown, the conductivity after blowdown, and the calculated percent blowdown.

pH METER STANDARDIZATION SECTION.—For this section the following information is entered: the time of completion of the standardization and the percent slope reading from the meter; the initials of the person performing the standardization; and the standardization data on the logs for all steaming boilers.

STEAMING HOURS DATA SECTION.—In this section, in addition to other data, the number of hours to the nearest 0.1 hour from light-off to securing is entered in the Steaming Hours Today block. If more than one log is used for the boiler on any one day, these data are entered on the last log sheet for the day.

REMARKS SECTION.—The Remarks section is used to describe significant events of the day related to that boiler. Additional pages for remarks are inserted as necessary. All remarks are accompanied by the time as appropriate. When a doubt exists as to whether or not an entry should be made in the Remarks section, it should be entered. The following types of events should be recorded:

1. The setting of boiler safety valves.
2. Hydrostatic tests, including purpose and pressure, and the signature of the witnessing individual.
3. A brief summary of boiler repairs accomplished.
4. Boiler inspection.
5. Explanation of each test result that is out of limits.
6. The reason for using an emergency pH or phosphate test and the action taken to correct the situation causing the use of the emergency tests.
7. Description of unusual conditions.
8. The results of tests of the boiler water/feedwater chemicals against standards, except the quarterly tests, are entered on the log for the 1 or 1A boiler. (The quarterly standard test results are entered on the monthly boiler data log for the number 1 plant.)

The Boiler Water Chemistry Worksheet/Log need not be prepared on a daily basis when the boiler is idle. When no testing is required and no change in boiler condition is occurring, the inclusive dates are entered on the front of one log, the type of layup applied is entered in the Code column, and any significant event occuring during the idle period is described.

For every day that there is a log, the LCPO and MPA must review and initial the log and the log must be reviewed and signed by the engineer officer.

Reserve Makeup Feedwater Tests Log

The daily Reserve/Makeup Feedwater Tests Log (figs. 18-12A and 18-12B) consists of the following sections:

1. Reserve/makeup feedwater tests (without demineralizers)
2. Reserve/makeup feedwater tests (with demineralizers)
3. Feedwater tank soundings
4. Remarks

The daily log is initiated by inserting the ship's name and hull number, and the date.

RESERVE/MAKEUP FEEDWATER SECTION (WITHOUT DEMINERALIZERS).— This section is designed for systems without demineralizers, and it is maintained as follows:

1. For a reserve feedwater tank that requires a daily chemical test, the tank number, the time of sampling, CH for chemical test code, the mL of mercuric nitrate used, the calculated chloride test result, the mL of EDTA used, and the calculated hardness test result are entered in the Daily section.
2. When the makeup feedwater salinity indicator is satisfactory and another reserve feedwater tank is placed on makeup feed, the tank number, the time the tank is placed on makeup, and SI for salinity indicator test code are entered below the Daily section. The salinity indicator reading is entered in the EPM column, and the Mercuric Nitrate column is left blank.
3. When the salinity indicator is faulty and the reserve feedwater tank is sampled within 30 minutes before being placed on makeup, the tank number, the time of sampling, CH for chemical test code, the mL of mercuric nitrate used, and the calculated chloride test result are entered below the Daily section.

RESERVE/MAKEUP FEEDWATER SECTION (WITH DEMINERALIZERS).—This section is designed for systems with demineralizers, and it is maintained as follows:

1. For a reserve feedwater tank that requires a daily chemical test, the tank number, the time of sampling, CH for chemical test code, the mL of mercuric nitrate used, the calculated chloride test result, the mL of EDTA used, and the calculated hardness test result are entered in the Daily section.
2. When a reserve feedwater tank is placed on makeup feed, the tank number, the time the tank is placed on makeup, the inlet conductivity reading, and the outlet conductivity reading are entered below the Daily section.
3. When the demineralizer system is not in operation, or is being bypassed, this fact is noted in the Remarks section and the requirements for reserve/makeup feedwater (without demineralizers) then apply.

RESERVE FEEDWATER TANK SOUNDINGS SECTION.—This section is provided for convenience and may be used to enter the following:

1. The tank numbers
2. The hourly tank soundings (in gallons), the total amount of reserve feedwater on board (in gallons), and the percent reserve feedwater on board

The Reserve/Makeup Feedwater Tests Log need not be prepared on a daily basis if all tanks are empty and no testing is required. When no testing is required, the inclusive dates are entered on the front of one log and the reason is given in the Remarks section.

For every day that there is a log, the LCPO and MPA must review and initial the log, and the log must be reviewed and signed by the engineer officer.

Fuel and Water Report

A daily report of the fuel and water status is prepared to reflect the conditions at 0000 hours. This report also provides information on feedwater and boiler water conditions. The daily Fuel and Water Report (figs. 18-13A and 18-13B) is prepared as follows:

1. On the front side (fig. 18-13A) are entered the date, and the ship's name and hull number.

   a. From the previous day's report, and the usage data as of 0000, the amount of boiler fuel and diesel fuel on board is determined and the onboard percentage is calculated and entered.

b. From the previous day's report, and the usage data as of 0000, the amount of lube oil on board is determined. The amount of lube oil should reflect that which is in all storage and settling tanks. Lube oil located in the main engine and the auxiliary sumps should be recorded as expended as of the time the lube oil is placed in the particular sump. The onboard percentage is calculated and entered. If desired, there is adequate space at the bottom of the form to indicate the amount of oil in the main engine sumps.
c. From the previous day's report, the amount distilled, and the usage data as of 0000, the amount of potable water and reserve feedwater on board is determined and the onboard percentage of capacity is calculated and entered.

NOTE: The total amount distilled should be equal to the total evaporator output during the day.

d. In the transfers/receipts section is entered the appropriate data on the applicable product line.
e. The amount of potable water expended and the number of personnel on board are used to determine the number of gallons used per person. These are entered. Each class ship has a standard usage that is based on a normal complement. This is entered.
f. Feedwater consumption in gallons per hour is entered.
g. Remarks concerning unusual conditions are entered.

2. On the reverse side (fig. 18-13B), the following information is entered:

a. The boiler designation.
b. The fireside hours since the last cleaning for each boiler.
c. The waterside hours since the last mechanical and chemical cleaning for each boiler.
d. The boiler water chemical test results for the last sample for each boiler from the previous day; the minimum and maximum values for the chemical test results obtained for each boiler from the preceding day. A boiler out of commission is so indicated. This data is determined from the Boiler Water Chemistry Worksheet/Log.
e. The layup code for the type of layup applied to each idle boiler.
f. The number of steaming hours since the last bottom blowdown. (See following note.)

NOTE: This log form was recently changed to require listing of hours since the last bottom blowdown instead of total steaming hours for each boiler. The remaining stock of logs with the column headed Total Steaming Hours will be issued until the supply is exhausted. The same stock number applies to the old and new forms. Cross out Total Steaming Hours and insert Steaming Hours Since Bottom Blow until retitled forms replace current forms.

g. The range of results obtained for feedwater in each system for the previous day ending at 0000. If only the Method C dissolved oxygen test is in use, the dissolved oxygen blocks may contain a single number rather than a range.
h. The oil king initials on the back of the report. The MPA and engineer officer review and sign the back of the report.

DATA EVALUATION

The logs serve to record the past history and present condition of the steam plant water chemistry. The evaluation of the data of a particular log enables the engineer officer and assistants to provide proper treatment and other corrective action to maintain the water chemistry of the steam plants within the proper ranges.

Fuel and Water Report

The following information may be drawn from an analysis of the Fuel and Water Report data:

1. Waterside and fireside hours serve as an aid in scheduling required maintenance and steaming of specific boilers.
2. Boiler water and feedwater data provide an overview of current water chemistry conditions.

3. Fuel and feedwater consumption is related to plant efficiency. These also serve as a guide for computing fuel and feedwater requirements.
4. Potable water and reserve feedwater consumption are two factors that must be compared to distilling plant output and capacity. Any unusual use in either potable water or reserve feedwater usage should be investigated.

Feedwater Chemistry Worksheet/Log

Analysis of the Feedwater Chemistry Worksheet/Log provide the following information, which may lead to appropriate actions:

1. Chemical tests and salinity indicator comparison. This section shows the reliability of the salinity indicating system. Salinity indicators detect an increase in contaminant level rapidly. Any salinity indicators that test unsatisfactory must be repaired as soon as possible.
2. Feedwater chemical tests. The dissolved oxygen test indicates the effectiveness of the DFT. Any reading above 15 ppb (15 g/L) must be investigated. Continually high or low pH results require a review of test procedures or a proportional adjustment in morpholine flow rate. The chloride result indicates the general level of seawater contamination. Since increasing chloride level or results above 0.02 epm (0.02 meq/L) indicate that seawater contamination is entering the feedwater system, the source of contamination must be determined and corrected. A hardness result above 0.02 epm (0.02 meq/L) with a normal chloride result indicates shore water contamination. When hardness is present in deaerated feedwater, the service steam system must be checked for hardness. A high salinity indicator reading with a low chemical chloride test result is also an indicator of shore water contamination. If shore water contamination is suspected, the affected component should be tested for hardness. The salinity indicator system will assist in locating both seawater and shore water contamination. Contamination of the feedwater will have an effect on boiler water chemistry and will therefore be reflected in the boiler water log and in the trend analysis graphs.
3. Shore feedwater/steam chemical test data. The results for shore feedwater or shore steam indicate the quality of the feedwater or steam that will be used.

Reserve Makeup Feedwater Tests Log

The quality of the reserve feedwater available for use or the actual quality of the makeup being used is reflected in the Reserve/Makeup Feedwater Tests Log. The makeup feed salinity indicator reading or the inlet conductivity reading of the reserve feed demineralizer represents the overall quality of reserve feedwater. Increasing or high values of either of these two readings indicate poor quality reserve or distillate. A fast rise of the outlet conductivity is a warning that the resin bed is about to be exhausted. If consistent low readings on the outlet conductivity are not obtained shortly after placing a fresh resin bed in the demineralizer, the resin may be of poor quality or the resin bed may not have been prepared properly. An increase in the daily chloride and/or hardness value of an unused reserve feedwater tank indicates that tank integrity is questionable.

ROUGH AND SMOOTH RECORDS

Every time that data is transferred from one sheet of paper to another, the likelihood of error exists. Any practice of increasing the number of times data is transferred, by maintaining rough working logs and then preparing smooth logs for file, is prohibited. The individual who is recording data should record data on the appropriate log only. The logs may be prepared either in ink or pencil at the option of the person who is developing the data. No erasure is permitted on the Feedwater Chemistry Worksheet/Log or the Boiler Water Chemistry Worksheet/Log. If an error is made, it should be lined through and initialed, then the correct data should be entered.

The oil king who is performing the analyses must maintain the Feedwater Chemistry Worksheet/Log and the Boiler Water Chemistry Worksheet/Log. It is permissible for convenience to record these data in another area, such as main/central control; however, the Boiler Water and Feedwater Chemistry Worksheet/Logs submitted in the log package must be those that were maintained in the laboratory by the oil king.

DISPOSAL/RETENTION REQUIREMENTS FOR WATER CHEMISTRY RECORDS

The Monthly Water Treatment Log Package including the Cover Sheet and Monthly Boiler Data, the Feedwater Chemistry Worksheet/Log, the Boiler Water Chemistry Worksheet/Log, and the trend analysis graphs are retained on board for 2 years, at which time they may be discarded. The Reserve/Makeup Feedwater Tests Log is retained for 3 months and may then be discarded. The Fuel and Water Report is retained for 1 month and may then be discarded.

OPERATION/SAFETY PLACARDS

Operation and safety placards for treatment and sampling procedures must be posted in appropriate places as follows:

1. Boiler water sampling—each boiler water sample cooler area
2. Desuperheater sampling—each desuperheater sample cooler area
3. Dissolved oxygen sampling—each DFT sample cooler area
4. Feedwater sampling—each DFT sample cooler area
5. Boiler chemical injection system—each injection tank area
6. Morpholine condensate treatment—each morpholine treatment tank
7. Makeup feed demineralizer operation and maintenance—each demineralizer tank area

Placards are normally supplied by the installing activity at the time of equipment installation. If placards are missing, they should be prepared locally. The necessary technical information for placards may be found in *NSTM,* chapter 220.

NOTE: This chapter does not certify you to test and treat boiler water or feedwater. It is designed to give you a basic understanding of the water chemistry program and make the certification course easier.

APPENDIX I

GLOSSARY

A

ABSOLUTE PRESSURE—Actual pressure (includes atmospheric pressure).

ABT (AUTOMATIC BUS TRANSFER)—An automatic electrical device that supplies power to vital equipment. This device will shift from the normal power supply to an alternate power supply anytime the normal supply is interrupted.

AFTERCOOLER—A terminal heat-transfer unit after the last stage.

AIR CHAMBER—A chamber, usually bulbshaped, on the suction and discharge sides of a pump. Air in the chamber acts as a cushion and prevents sudden shocks to the pump.

AIR EJECTOR—A jet pump that removes air and noncondensable gases.

AIR LOCK SYSTEM—A system of control devices combined to hold all final operating elements in the position existing prior to loss of air supply pressure.

AIR REGISTER—A device in the casing of a boiler which regulates the amount of air for combustion and provides a circular motion to the air.

ALLOY—A mixture of two or more metals.

ALTERNATING CURRENT (ac)—Current that is constantly changing in value and direction at regularly recurring intervals.

AMBIENT TEMPERATURE—The air temperature of the room or shipboard space.

AMPLIFIER—An instrument or device whose output is an enlarged reproduction of an input signal.

AMPLIFY—To increase the energy level of a signal by a proportional factor.

ATMOSPHERE ESCAPE PIPING—Piping that leads from safety or large volume relief valves in machinery spaces, up the outer stack to the atmosphere.

ATMOSPHERIC PRESSURE—The pressure exerted by the atmosphere in all directions, as indicated by a barometer. Standard atmospheric pressure is considered to be 14.7 pounds per square inch, which is equivalent to 29.92 inches of mercury.

ATOMIZATION—The spraying of a liquid through a nozzle so that the liquid is broken into tiny droplets or particles.

AUTOMATIC BUS TRANSFER—*See* ABT.

AUTOMATIC CONTROLLER—An instrument or device that operates automatically to regulate a controlled variable in response to a set point and/or input signal.

AUTOMATIC CONTROL SYSTEMS—A combination of instruments or devices arranged systematically to control a process or operation at a set point without assistance from operating personnel.

AUTOMATIC OPERATION—Operation of a control system and the process under control without assistance from the operator.

AUXILIARIES—Propulsion plant equipment not powered by main steam.

AUXILIARY—Systems or components functioning in a secondary capacity to the main boilers and propulsion turbines (such as pumps, air ejectors, blowers, and so forth).

AUXILIARY MACHINERY—Any system or unit of machinery that supports the main propulsion units or helps support the ship and the crew. Example: Pump, evaporator, steering engine, air—conditioning and refrigeration equipment, laundry and galley equipment, deck winch, and so forth.

AXIAL—In a direction parallel to the axis.

B

BABBITTED—Lined with a babbitt metal (containing tin, copper, and antimony).

BACK PRESSURE—(l) Refers to the resistance to the flow of exhaust fluids through the exhaust system. (2) The pressure exerted on the exhaust side of a pump or engine.

BAFFLE—A plate installed to disperse (scatter) motion and/or change direction of flow of fluids.

BALLASTING—The process of filling empty tanks with salt water to protect the ship from underwater damage and to increase its stability. See DEBALLASTING.

BDC (BOTTOM DEAD CENTER)—The position of a reciprocating piston at its lowest point of travel.

BEARING—A mechanical component that supports and guides the location of another rotating or sliding member.

BELL BOOK—An official record of engine orders received and answered.

BIAS OR BIASING—The act of adding to or subtracting from a control system signal.

BIMETALLIC—Two dissimilar metals with different rates of expansion when subjected to temperature changes.

BLEEDER—A small cock, valve, or plug that drains off small quantities of air or fluids from a container or system.

BLOCK DIAGRAM—A drawing of a system using blocks for components to show the relationship of components.

BLOWING OF TUBES—A procedure that uses steam to remove soot and carbon from the tubes of steaming boilers.

BLUEPRINT—Reproduced copy of drawing (usually having white lines on a blue background).

BOILER—A strong metal tank or vessel composed of tubes, drums, and headers, in which water is heated by the gases of combustion to form steam.

BOILER BLOW PIPING—Piping from the individual boiler blow valves to the overboard connection at the skin of the ship.

BOILER CENTRAL CONTROL STATION—A centrally located station for directing the control of all boilers in the fireroom.

BOILER DESIGN PRESSURE—Pressure specified by the manufacturer, usually about 103 percent of normal steam drum operating pressure.

BOILER EFFICIENCY—The efficiency of a boiler is the ratio of the Btu per pound of fuel absorbed by the water and steam to the Btu per pound of fuel fired. In other words, boiler efficiency is output divided by input, or heat utilized divided by heat available. Boiler efficiency is expressed as a percentage.

BOILER FEEDWATER—Deaerated water in the piping system between the deaerating feed tank and the boiler.

BOILER FULL-POWER CAPACITY—The total quantity of design steam flow required to develop specified horsepower of the ship, divided by the number of boilers installed in the ship. Also expressed as the number of pounds of steam generated per hour at a specified pressure and temperature.

BOILER INTERNAL FITTINGS—All parts inside the boiler which control the flow of steam and water.

BOILER LOAD—The steam output demanded from a boiler, generally expressed in pounds per hour (lb/hr).

BOILER MASTER—A steam pressure controller.

BOILER OPERATING PRESSURE—The pressure required to be maintained in a boiler while in service.

BOILER OPERATING STATION—A location from which boilers are operated.

BOILER OVERLOAD CAPACITY—As specified in design of a boiler, usually 120 percent of boiler full-power capacity, either in steaming or firing rate as specified for the individual installation.

BOILER RECORD SHEET—A NAVSHIPS form maintained for each boiler, which serves as a monthly summary of operation.

BOILER REFRACTORY—Materials used in the boiler furnace to protect the boiler from heat of combustion.

BOILER ROOM—A compartment containing boilers but not containing a station for operating or firing the boilers. Refers specifically to bulkhead enclosed boiler installations.

BOILER TUBE CLEANER—A cylindrical brush that is used to clean the insides of boiler tubes.

BOILER WATER—The water actually contained in the boiler.

BONNET—A cover used to guide and enclose the tail end of a valve spindle.

BOTTOM BLOW—A procedure used to remove suspended solids and sludge from a boiler.

BOURDON TUBE—A C-shaped hollow metal tube that is used in a gauge for measuring pressures of 15 psi and above. One end of the C is welded or silver-brazed to a stationary base. Pressure on the hollow section forces the tube to try to straighten. The free end moves a needle on the gauge face.

BRAZING—A method of joining two metals at high temperature with a molten alloy.

BRINE—Any water in which the concentration of chemical salts is higher than seawater.

BRITISH THERMAL UNIT (Btu)—A unit of heat used to measure the efficiency of combustion. It is equal to the quantity of heat required to raise 1 pound of water 1°F.

BRITTLENESS—That property of a material which causes it to break or snap suddenly with little or no prior sign of deformation.

BUCKET WHEEL—The steel wheel or disc, fitted to a turbine shaft, to which the blading is attached.

BULL GEAR—The largest gear in a reduction gear train-the main gear, as in a geared turbine drive.

BURNERMAN—Person in the fireroom who tends the burners in the boilers.

BUS—The common connection between a group of line cutout switches. The bus may be in one single piece or it may be divided; may be free or directly connected to a jack outlet.

BUSHING—A renewable lining for a hole through which a moving part passes.

BUS TRANSFER—A device for selecting either of two available sources of electrical power. It may be accomplished either manually or automatically.

BUTTERFLY VALVE—A light-weight, relatively quick acting, positive shutoff valve.

BYPASS—To divert the flow of gas or liquid. Also, the line that diverts the flow.

C

CALIBRATION—The procedure required to adjust an instrument or device to produce a standardized output with a given input. The amount of deviation from the standard must first be determined in order to ascertain the proper correction requirements.

CAPILLARY TUBE—A slender, thinwalled, small-bored tube used with remote-reading indicators.

CARBON MONOXIDE—A deadly, colorless, odorless, and tasteless gas formed by incomplete burning of hydrocarbons.

CARBON PACKING—Pressed segments of graphite used to prevent steam leakage around shafts.

CARRYOVER—(1) Boiler water entrained with the steam (by foaming or priming). (2) Particles of seawater trapped in vapor in a distilling plant and carried into the condensate.

CASING—A housing that encloses the rotating element (rotor) of a pump or turbine.

CASING THROAT—An opening in a turbine or pump casing through which the shaft protrudes.

CASUALTY—An event or series of events in progress during which equipment damage and/or personnel injury has already occurred. The nature and speed of these events are such that proper and correct procedural steps will serve only to limit equipment damage and/or personnel injury.

CASUALTY POWER SYSTEM—Portable cables that are rigged to transmit power to vital equipment in an emergency.

CELSIUS—Thermometer scale on which the boiling point of water is 100° and the freezing point is O°.

CENTIGRADE—*See* CELSIUS.

CENTRIFUGAL FORCE—The outward force on a rotating body.

CHARACTERIZER—A control system component that acts to alter a signal in a predetermined manner to match a nonlinear parameter in the process under control.

CHECK VALVE—A valve that permits a flow of liquid in one direction only.

CHEMICAL ENERGY—Energy stored in chemicals (fuel) and released during combustion of the chemicals.

CHILL SHOCKING—A method that uses steam and cold water to remove scale from the tubes of a distilling plant.

CHLORIDE—A compound of the chemical element chlorine with another element or radical.

CHLORINE—A heavy, greenish-yellow gas used in water purification, sewage disposal, and in the preparation of bleaching solutions. Poisonous in concentrated form.

CIRCUIT BREAKER—An electrical switching device that provides circuit overload protection.

CIRCULATING WATER—Water circulated through a heat exchanger (condenser or cooler) to transmit heat away from an operating component.

CLARIFIER—A water tank containing baffles that slow the rate of water flow sufficiently to allow heavy particles to settle to the bottom and light particles to rise to the surface. This separation permits easy removal, thus leaving the clarified water. The clarifier is sometimes referred to as a settling tank or sedimentation basin.

CLASSIFICATION AND/OR TYPE—A method of identifying and sorting various equipment and materials. For example:

a. Check valves-swing, stop, and so forth.

b. Valve-solenoid, manual, and so forth.

CLUTCH—A form of coupling that is designed to connect or disconnect a driving or driven member.

COLD IRON CONDITION—An idle plant as in a destroyer when all port services are received from an external source, such as shore or tender.

COMBINING TUBES—Short open-ended tubes in which the inner surfaces are paralleled, or nearly so, and used to combine two inlets into a single outlet.

COMBUSTIBLE—A material that can burn.

COMBUSTION—The burning of fuel in a chemical process accompanied by the evolution of light and heat.

COMBUSTION CONTROL SYSTEM—A system that regulates fuel rate and combustion air flow to a boiler so that steam is produced at a constant pressure and fuel is burned with optimum combustion efficiency.

COMBUSTION EFFICIENCY—The ratio of the energy in the combustion gases, theoretically available for absorption by the boiler under actual operating conditions, to the energy available had the fuel been burned with the minimum theoretical combustion air.

COMPONENT—Individual unit, or part, of a system; also, the major units which, when suitably connected, comprise a system.

COMPONENT PART—The integral parts of a component.

CONDENSATE—Water produced in the cooling system of the steam cycle from steam that has returned from the turbine or from steam that has returned from various heat exchangers. The water is used over again to generate steam in the boiler for an endless repetitive cycle.

CONDENSATE DEPRESSION—The difference between the temperature of condensate in the condenser hot well and the saturation temperature corresponding to the vacuum maintained in the condenser.

CONDENSATION—The process of cooling the vapors to produce a denser form (vapor to liquid).

CONDENSER—A heat transfer device in which vapor is condensed to liquid.

CONDUCTANCE—The ability of a substance to pass an electrical current.

CONDUCTIVITY (of water)—The ability of water to conduct an electric current. It is expressed in micromhos/cm. Generally, the amount of dissolved solids is directly proportional to the conductivity.

CONSOLE—A panel equipped with remote manual controls and visual indicators of system performance.

CONSTANT-PRESSURE GOVERNOR—A device that maintains a constant pump discharge pressure under varying loads.

CONTROL ACTION—The nature of the change of the output of a control element or system affected by its input signal.

CONTROL AIR SUPPLY—Clean, dry air at proper pressure for operation of pneumatic control equipment.

CONTROLLER (AUTOMATIC)—A device or group of devices arranged to automatically regulate a controlled variable in accordance with a command or set point signal.

CONTROLLER (ELECTRICAL)—A device used to stop, start, and protect motors from overloads while they are running.

CONTROLLER (PNEUMATIC)—(1) A control system component or group of components arranged to sense two or more control system variables, which acts to provide a pneumatic (air) output signal, tending to reduce the difference between these signals to some predetermined value. (2) An arrangement of control system computing elements designed to perform a predetermined set of mathematical functions.

CONTROL POWER—Power that controls or operates a component or component part.

CONTROL SIGNAL (ELECTRICAL)—A signal that activates control circuitry or indicators; for example, the signal from a pressure switch.

CONTROL SIGNAL (PNEUMATIC)—A loading signal applied to a final control element.

CONVECTION—The transmission of heat by the circulation of a liquid or a gas, such as air. Convection may be forced by use of a pump or fan, or it may occur naturally due to heated air or liquid rising and forcing the colder air or liquid downward.

COOLANT—Liquid in the cooling system.

COOLER—Any device that removes heat. Some devices, such as oil coolers, remove heat to waste in over-board seawater discharge; other devices, such as ejector coolers, conserve heat by heating condensate for boiler feedwater.

COOLING SYSTEM—Heat removal process that uses mechanical means to remove heat to maintain the desired air temperature. The process may also result in dehumidification.

CORROSION—A gradual wearing away or alteration of metal by a chemical or electrochemical process. Essentially, it is an oxidizing process, such as the rusting of iron by the atmosphere.

COUNTERSINK—A cone-shaped tool used to enlarge and bevel one end of a drilled hole.

COUPLING—A device for securing together adjoining ends of piping, shafting, and so forth, in a manner to permit disassembly when necessary.

CRITICAL SPEED—The speed at which the centrifugal force of a rotating element tends to overcome the natural weight of the element, causing distortion and vibration.

CROSS-CONNECT—To align piping of systems to provide flow between machinery groups.

CROSS-CONNECTED PLANT—A method of operating two or more plants as one unit from a common steam supply.

CROSS PIPING (OR VALVES)—Piping that provides flow between port and starboard systems or between systems having different purposes.

CURTIS STAGE—A velocity-compounded impulse turbine stage having one pressure drop in the nozzles and two velocity drops in the blading.

CUTOUT VALVE—A valve that is intended normally to be fully open or fully closed.

D

DAMPER—A device for reducing the motion or oscillations of moving parts, air, or liquid.

DAMPING—A characteristic of a system that results in dissipation of energy and causes decay in oscillations. The negative feedback of an output rate of change.

DEAERATE—Process of removing dissolved oxygen.

DEAERATING FEED TANK (DFT)—A unit in the steam-water cycle used to (1) free the condensate of dissolved oxygen, (2) heat the feedwater, and (3) act as a reservoir for feedwater.

DEBALLASTING—The process by which salt water is emptied from tanks.

DEFORMATION—Permanent alteration of form or shape.

DEGREE OF SUPERHEAT—The amount by which the temperature of steam exceeds the saturation temperature.

DEHUMIDIFICATION—The mechanical process of removing water vapor from air.

DENTAL COUPLING—A flexible coupling assembly, consisting of a set of external/internal gear teeth that compensates for slight shaft misalignment between a driver and a driven machinery component.

DESIGN PRESSURE (BOILER)—The pressure specified by a manufacturer as a criterion in design. (In a boiler it is approximately 103 percent operating pressure.)

DESIGN TEMPERATURE (BOILER)—The intended operating steam temperature at the superheater outlet at some specified rate of operation. The specified rate of operation is normally full-power capacity.

DESUPERHEATED STEAM—Steam from which some of the superheat has been removed.

DIAL GAUGE OR INDICATOR—A precision micrometer-type instrument that indicates the reading via a needle moving across a dial face.

DIESEL ENGINE—An engine using the diesel cycle of operation; air alone is compressed and diesel fuel is injected at the end of the compression stroke. Heat of compression produces ignition.

DIFFUSER—A device that spreads a fluid out in all directions and increases fluid pressure while decreasing fluid velocity.

DIRECT CURRENT (dc)—Current that moves in one direction only.

DIRECT DRIVE—One in which the drive mechanism is coupled directly to the driven member.

DIRECT-DRIVEN—Driven at the same speed as the driver (not having reduction gears).

DISTILLATE—The product (freshwater) resulting from the condensation of vapors produced by the evaporation of seawater.

DISTILLATION—The process of evaporating seawater, then cooling and condensing the resulting vapors. Produces freshwater from seawater by separating the salt from the water.

DISTILLING PLANTS—Units commonly called evaporation used to convert seawater into freshwater.

DOUBLE REDUCTION—A reduction gear assembly that reduces the high input rpm to a lower output rpm in two stages.

DOUBLE SUCTION IMPELLER—An impeller with a suction inlet on each side.

DRUM WATER—A tank at the bottom of a boiler. Also called MUD DRUM.

DRY PIPE—A perforated pipe, at the highest point in a steam drum, that collects dry steam from steam separators.

DUPLEX PUMP—A pump that has two liquid cylinders and is referred to as double-acting.

DUPLEX STRAINER—A strainer containing two separate elements, independent of each other.

E

ECONOMIZER—A heat transfer device that uses the gases of combustion to preheat the feedwater in the boiler before it enters the steam drum.

EDUCTOR—A jet-type pump (no moving parts) used to empty flooded spaces.

EFFICIENCY—The ratio of the output to the input. Also, the degree of conversion of heat of steam to usable mechanical power output.

ELASTICITY—The ability of a material to return to its original size and shape.

ELECTRICAL ENERGY—Energy derived from the forced induction of electrodes from one atom to another.

ELECTROHYDRAULIC STEERING—A system having a motor-driven hydraulic pump that creates the force needed to actuate the rams to position the ship's rudder.

ELECTROLYSIS—A chemical action that takes place between unlike metals in systems using salt water.

EMERGENCY—An event or series of events in progress which will cause damage to equipment unless immediate, timely, and correct procedural steps are taken.

EMULSIFIED OIL—A chemical condition of oil in which the molecules of the oil have been broken up and suspended in a foreign substance (usually water).

ENERGY—The capacity for doing work.

ENGINEERING LOG—A legal record of important events and data concerning the machinery of a ship.

ENGINEER'S BELL BOOK—A legal record, maintained by the throttle watch, of all ordered main engine speed changes.

ENGINE ORDER TELEGRAPH—A device on the ship's bridge to give orders to the engineroom. Also called ANNUNCIATOR.

EPM (EQUIVALENT PER MILLION)—A term used to describe the chemical concentration of dissolved material; used in reporting sample test results. It expresses the chemical equivalent unit weight of material dissolved in a million unit weights of solution. (The chemical equivalent weight of chloride is 35.5. If 35.5 pounds of chloride were dissolved in 1,000,000 pounds of water, the water would contain 1.00 epm chloride.)

ERROR—The difference between a set point and a feedback signal.

EVAPORATION—The action that takes place when a liquid changes to a vapor or gas.

EVAPORATOR—A distilling device used to produce freshwater from seawater.

EXCESS FEED—Excess feedwater that is returned to storage tanks.

EXPANSION JOINT—A junction in a piping system which allows for expansion and contraction.

F

FAHRENHEIT—Thermometer scale on which the boiling point of water is 212°, and the freezing point is 32° above zero.

FAIL—(l) The loss of control signal or power to a component. (2) The breakage or breakdown of a component or component part.

FAIL POSITION—The operating or physical position to which a device will go upon loss of its actuating electrical, electronic, pneumatic, or hydraulic control signal.

FATIGUE—The tendency of a material to break under repeated strain.

FEEDBACK—Information about a process output which is communicated to the process input.

FEEDER—An electrical conductor or group of conductors between different generating or distributing units of a power system.

FEED HEATER—A heat transfer device that heats the feedwater before it goes to the boiler.

FEEDWATER—Water that meets the requirements of *Naval Ship's Technical* Manual, Chapter 220 (9560) for use in a boiler.

FEEDWATER SYSTEM—A system for storing, heating, and delivering feedwater to boilers.

FERROUS METAL—Metal with a high iron content.

FILTER—A device through which gas or liquid is passed; dirt, dust, and other impurities are removed by the separating action.

FIREBOX—The section of a ship's boiler where fuel oil combustion takes place.

FIRE MAIN—The salt water line that provides fire fighting and flushing water throughout the ship. Raw water is used at Great Lakes in lieu of salt water.

FIREROOM—A compartment containing boilers and stations for "firing" or operating same.

FIRE-TUBE BOILER—Boiler in which the gases of combustion pass through the tubes and heat the water surrounding them.

FLAMMABLE—A combustible material that burns easily, intensely or quickly.

FLAREBACK—A backfire of flame and hot gases into a ship's fireroom from the firebox, caused by a fuel oil explosion in the firebox.

FLASH POINT OF OIL—The temperature at which oil vapor will flash into fire although the main body of the oil will not ignite.

FLEXIBLE COUPLING—A coupling that transmitts rotary motion from one shaft to another while compensating for minor misalignment between the two units.

FLEXIBLE I-BEAM—An I-shaped steel beam on which the forward end of a turbine is mounted; it allows for longitudinal expansion and contraction.

FLOOR PLATES—The removable deck plating of a fireroom or engineroom aboard ship.

FLUID—A substance capable of flowing or conforming to the shape of its container (a liquid or gas).

FOAMING—Failure of steam bubbles to break, caused by either dissolved solids or light suspended solids in the boiler water, causing small amounts of continuous boiler water carryover with the steam.

FORCE—Anything that tends to produce or modify motion.

FORCED DRAFT—A term that describes the combustion air supplied under pressure to the burners in a ship's boiler by the forced draft blowers.

FREQUENCY—The number of vibrations, cycles, or changes in direction in a unit of time.

FRESHWATER—Water of relatively low dissolved solids content as compared to seawater. There are two types of shipboard feedwater (the low-pressure drains of the steam generator condensate system) and potable water (supplied from either a shore water source or a shipboard distilling plant).

FRESHWATER DRAINS—A collective term which refers to drainage from steam heating systems and warming-up drainage from other higher pressure steam systems. These drains are of feedwater quality and are returned to the boiler condensate system.

FRESHWATER SYSTEM—A piping system that supplies freshwater throughout the ship.

FRICTION—Resistance to relative motion between two bodies in contact with each other.

FUEL OIL MICROMETER VALVE—A valve, installed at the burner manifold, that controls the fuel oil pressure to the burners.

FUEL OIL SERVICE TANKS—Tanks from which the fuel oil service pumps take suction for supplying oil to the burners.

FUNCTION—To perform the normal or characteristic action of anything, or special duty or performance required of a person or thing in the course of work.

FUSE—A protective device that will open a circuit if the current flow exceeds a predetermined value.

G

GAIN—The ratio of the signal change, which occurs at the output of a device, to the change at the input.

GAS FREE—A term that describes a space which has been tested and found safe for entry.

GASKETS—(l) A class of material which provides a seal between two stationary parts. (2) Packing materials, by which air, water, oil, or steam tightness is secured in such places as on doors, hatches, cylinders, manhole covers, or in valves, between the flanges of pipes, etc. Such materials as rubber, canvas, asbestos, paper, short lead and copper, soft iron, and commercial products are extensively used.

GAUGE GLASS—A device for indicating the liquid level in a tank.

GAUGE PRESSURE—Pressure above atmospheric pressure.

GEARED TURBINE—A turbine coupled to its driven unit through a gear assembly.

GEARED-TURBINE DRIVE—A turbine that drives a pump, generator, or other machinery through reduction gears.

GENERATOR—A machine that converts mechanical energy into electrical energy.

GLAND SEAL REGULATOR—A device that automatically regulates the steam flow of the turbine glands to meet the flow requirements for the various operating conditions.

GLAND SEALING—Water piped to a pump casing stuffing box to maintain a seal against air entering the pump casing. Also, low pressure steam piped to the glands of steam turbines to prevent air leakage into turbines.

GOVERNOR—A speed-sensitive device designed to control or limit the speed of a turbine or engine.

GROUNDED PLUG—A three-pronged electrical plug used to ground portable tools to the ship's structure. It is a safety device which always must be checked prior to your using portable tools.

GUARDING VALVE—A valve installed upstream of the throttle valves. This valve permits stopping steam flow to the turbines if the throttle valves are leaking or damaged.

H

HANDHOLE—An opening large enough for the hand and arm to enter the boiler for making slight repairs and for inspection purposes.

HARDENING—The heating and rapid cooling (quenching) of metal to induce hardness.

HARDNESS—A quality exhibited by water containing various dissolved salts, principally calcium and magnesium. Can result in a heat transfer resistant scale on the steam generating surfaces.

HEADER—A chamber or tank located within a boiler, to which tubes are connected so that water or steam may pass freely from one tube to the other(s). Similar to, but smaller than, a water drum.

HEAT—A form of energy.

HEAT EXCHANGER—Any device that is designed to allow the transfer of heat from one fluid (liquid or gas) to another.

HEATING SURFACE—A system for adding heat to maintain the desired air temperature, as distinguished from heat added incidentally or unavoidably.

HERTZ (Hz)—Frequency per second of alternating current. Formerly referred to as "cycles per second."

HORSEPOWER (Hp)—A unit to indicate the time rate of doing work equal to 550 foot-pounds per second or 33,000 foot-pounds per minute.

HOT WELL—Reservoir attached to the bottom of a condenser for collecting condensate.

HUMIDITY—The vapor content of the atmosphere. Humidity can vary depending on air temperature; the higher the temperature, the more vapor the air can hold.

HUNTING—An undesirable oscillation, such as in the speed of a machine or in the position of an automatic valve, and so forth.

HYDRAULICS—The study of liquid in motion.

HYDROCARBON—Chemical compound of hydrogen and carbon; all petroleum fuels are composed of hydrocarbons.

HYDROGEN—A highly explosive, light, invisible, nonpoisonous gas used in underwater welding and cutting operations.

HYDROMETER—An instrument used to determine the specific gravity of liquids.

HYDROSTATIC—Static (nonmoving) pressure generated by pressurizing liquid.

HYDROSTATIC TEST—A test using pressurized water to detect leaks in a boiler or other closed systems.

I

IGNITION, COMPRESSION—When the heat generated by compression in an internal-combustion engine ignites the fuel (as in a diesel engine).

IGNITION, SPARK—When the mixture of air and fuel in an internal-combustion engine is ignited by an electric spark (as in a gasoline engine.)

IGNITION TEMPERATURE—The minimum temperature to which the substance (solid, liquid, or gas) must be heated to cause self-sustained combustion.

IMPELLER—An encased, rotating element provided with vanes which draw in fluid at the center and expel it at a high velocity at the outer edge.

IMPULSE LINES—Piping that connects a sensing element to the point at which it is desired to sense pressure, flow, temperature, and so forth.

IMPULSE TURBINE—A turbine in which the major part of the driving force is receivd from the impulse of incoming steam.

INDICATORS—Panel-mounted pressure gauges.

INDIRECT DRIVE—A drive mechanism coupled to the driven member by gears or belts.

INERT—Inactive.

INERTIA—The tendency of a stationary object to remain stationary and of moving objects to remain in motion.

INJECTOR—A device that uses a jet of steam to force water into the boiler. Injectors are also used in a diesel engine to force fuel into the cylinders.

INSULATION—A material that retards heat transfer.

INTERCOOLER—An intermediate heat transfer unit between two successive stages, as in an air compressor.

INTERFACE—Surface or area between two abutting parts usually of different materials or systems.

INTERLOCK—A feature or device in one system or component that affects the operation of another system or component. Generally, a safety device but it may be used to control the operating sequence of components.

J

JACK BOX—Receptacle, usually secured to a bulkhead, in which telephone jacks are mounted.

JACKING—Mechanically rotating a turbine at very low speed.

JOB ORDER—An order issued by a repair activity to its own subdivision to perform a repair job in response to a work request.

JOURNAL—That part of a shaft that is prepared to accept a bearing (connecting rod, main bearing).

JUMPER—Any connecting pipe, hose, or wire, normally used in emergencies aboard ship to bypass damaged sections of a pipe, a hose, or a wire. *See* BYPASS.

JURY RIG—Any temporary or makeshift device.

K

KEY—A parallel-sided piece inserted into a groove cut part way into each of two parts, which prevents slippage between the two parts.

KEYWAY—A slot cut in a shaft, pulley hub, wheel hub, and so forth. A square key is placed in the slot and engages a similar keyway in the mating piece. The key prevents slippage between the two parts.

KINETIC ENERGY—Energy in motion producing work.

L

LABYRINTH—A system of metal packing in which the inside diameter of a series of rings contacts the rotating surface of the turbine shaft. The passage of air or steam along the shaft is thereby reduced or inhibited.

LABYRINTH PACKING—A soft metal ring installed in the casing throat in such a manner that the lateral teeth of the inside diametrical surface will be presented to the surface of the rotating shaft. The teeth run either in close proximity to the shaft or in grooves machined in the shaft.

LAGGING—A protective and confining cover placed over insulating material.

LATENT HEAT—Heat that is given off or absorbed by a substance while it is changing its state.

LATENT HEAT OF CONDENSATION—The amount of heat (energy) required to change the state of a substance from a vapor to a liquid without a change in temperature.

LATENT HEAT OF VAPORIZATION—The amount of heat (energy) required to change the state of a substance from a liquid to vapor without a change in temperature.

LIFT CHECK VALVE—A valve having a guide-mounted, spring-loaded disc wherein a liquid exerting pressure on the bottom of the disc will lift the disc and pass through. Pressure exerted against the top of the disc shuts the disc and ensures only one direction of flow.

LIGHT OFF—Start. Literally, “to start a fire in,” as in “light off a boiler.”

LIMIT SWITCH—A switch that is actuated by the mechanical motion of an element.

LINE CUTOUT SWITCH—The device in a switchbox which disconnects an individual line from a group of circuits.

LOAD—Steam production demanded of a boiler by the operation of steam-driven equipment.

LOADING—The act of transferring energy into or out of a system.

LOADING SIGNAL—An input air signal to a control system element.

LOCAL MANUAL OPERATION—Direct manual positioning of a control valve or power operator by means of a handwheel or lever.

LOCKED TRAIN—A gear arrangement that has the high-speed pinions “locked” between the high-speed gears so that the only load on the pinion since the tooth loads cancel one another.

LOG BOOK—Any chronological record of events, such as an engineering watch log.

LOG ROOM—Engineer’s office aboard ship.

LOOP SEAL—A vertical U-bend in drain piping in which a water level is maintained to create an airtight seal.

LUBRICANT—Any material, usually of a petroleum nature such as grease, oil, and so forth, that is placed between two moving parts in an effort to reduce friction.

LUBRICATING OIL PURIFIER—A unit that removes water and sediment from lubricating oil by centrifugal force.

M

MACHINABILITY—The ease with which a metal may be turned, planed, milled, or otherwise shaped.

MACHINERY GROUP—One single self-contained steam plant consisting of one engine room and one fireroom.

MAIN CONDENSATE—Condensate from the main condenser. Although this is the principle source of feedwater, water from other drains as well as water from reserve makeup tanks and the SSTG condensers are also included in feedwater.

MAIN CONDENSER—A heat exchanger that converts exhaust steam to feedwater.

MAIN DRAIN SYSTEM—System used for pumping bilges; consists of pumps and associated piping.

MAIN INJECTION (SCOOP INJECTION)—An opening in the skin of a ship designed to deliver cooling water to the main condenser and main lubricating oil cooler by the forward motion of the ship.

MAIN STEAM—The major steam system which operates at boiler pressure.

MAKEUP FEED—Water from reserve feed tanks added to the condensate-feedwater system to make up for water losses from the steam generator system.

MALLEABILITY—That property of a material which enables it to be stamped, hammered, or rolled into thin sheets.

MANIFOLD—A fitting with numerous branches used to convey fluids between a large pipe and several smaller pipes.

MAXIMUM OPERATING PRESSURE—The highest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is determined by such influences as pump or compressor shutoff pressures, pressure regulating valve lockup (no-flow) pressure, and maximum chosen pressure at the system source.

MAXIMUM SYSTEM PRESSURE—The highest pressure that can exist in a system or subsystem during any condition. Normal, abnormal, and emergency operation and casualty conditions shall be considered in determining the maximum system pressure. In any system or subsystem with relief valve protection, the nominal setting of the relief valve shall be taken as the maximum system pressure (relief valve accumulation may be ignored).

MECHANICAL ADVANTAGE (MA)—The advantage (leverage) gained by the use of devices such as a wheel to open a large valve, chain falls and block and tackle to lift heavy weights, and wrenches to tighten nuts on bolts.

MECHANICAL CLEANING—A method of cleaning the firesides of boilers by scraping and wirebrushing.

MECHANICAL ENERGY—Energy derived from mechanical force or impact.

MICROMHO—Electrical unit used with salinity indicators for measuring the conductivity of water. Is equivalent to the quantity of one divided by the resistance of the water to electrical conductivity.

MONITORING POINT—The physical location at which any indicating device displays the value of a parameter at some control station. *See* PARAMETER.

MORPHOLINE—A chemical that prevents sludge in boilers by neutralizing the acidic quality of condensate, thereby reducing corrosion in condensate and feedwater piping, which forms as sludge in boilers.

MOTIVE STEAM—Steam that performs work in the turbine steam path.

MOTOR CONTROLLER—A device or group of devices that governs, in some predetermined manner, the operation of the motor to which it is connected.

MOTOR GENERATOR SET—A machine that consists of a motor mechanically coupled to a generator and usually mounted on the same base.

N

NAVAL STANDARDS (NAVSTDs)—Requirements for advancement for all ratings including military conduct, naval organization, military justice, security, and watch standing.

NAVY BOILER COMPOUND—A powdered chemical mixture used in boiler water treatment to convert scale-forming salts into sludge.

NAVY DISTILLATE FUEL—Navy distillate (ND) fuel is used in steam-powered ships of the Navy. ND is a fuel of the middle to higher distillation range. Military specification MIL-F-24397 (ships), NATO Symbol F85 covers the requirements for Navy distillate fuel.

NAVY SPECIAL FUEL OIL—Navy Special fuel oil (NSFO) is used in steam-powered ships of the Navy. NSFO is a blend of heavy residuum and heavy distillates (both cracked and virgin) with cutter stock distillate, used to adjust viscosity. The blend is made at the refinery in proper proportions to comply with Military specification MIL-F-859 NATO Symbol F77.

NEEDLE VALVE—Type of valve with rod-shaped, needle-pointed valve body which works into a valve seat so shaped that the needle-point fits into it and closes the passage. Suitable for precise control of flow.

NIGHT ORDER BOOK—A notebook containing standing and special instructions from the engineer officer to the night engineering officer of the watch.

NITROGEN—An inert gas that will not support life or combustion. Used in' recoil systems and other spaces that require an inert atmosphere.

NOMINAL OPERATING PRESSURE—The approximate pressure at which an essentially constant-pressure system operates when performing its normal function. The pressure is used for the system basic pressure identification.

NONFERROUS METAL—Metals that are composed primarily of some element or elements other than iron.

NOZZLE—That portion of a turbine that converts heat energy of steam into a directed steam and sets the amount of steam flow.

NOZZLE AREA—Smallest opening (area) of a nozzle that is at right angles to the direction of steam flow.

NOZZLE-BLOCK—Turbine part that takes steam from the turbine chest and directs it into the first stage of the turbine.

NOZZLE DIAPHRAGM—A removable metal ring inserted in the casing between the stages of the turbine. This ring contains the nozzles by which steam flows from one stage to another.

OOCCUPATIONAL STANDARDS (OCCSTDs)—Requirements that are directly related to the work of each rating.

OFFICER OF THE WATCH (OOW)—Officer on duty in the engineering spaces.

OIL KING—A petty officer who receives transfers, discharges, and tests fuel oil and maintains fuel oil records.

OIL POLLUTION ACTS—The Oil Pollution Act of 1924 (as amended), the Oil Pollution Act of 1961, and the Water Quality Improvement Act of 1970 prohibit the overboard discharge of oil or water that contains oil, in port, in any sea area within 12 miles of land, and in special prohibited zones.

OIL STRAINER—A strainer placed at the inlet end of the oil pump to prevent dirt and other particles from getting into moving parts.

ONE-LINE SCHEMATIC DIAGRAM—A drawing of a system using only one line to show the tie-in of various components; for example, the three conductors needed to transmit three-phase power are represented by a single line.

OPERATING CHARACTERISTICS—The combination of a parameter and its set points. *See* PARAMETER.

OPERATING PRESSURE—The constant pressure at which a component is designed to operate in service.

OPERATING TEMPERATURE—The actual temperature of a component during operation.

ORIFICE—A circular opening in a flow passage which acts as a flow restriction.

ORIFICE PLATE—A place with an opening fitted between flanges in piping systems to reduce velocity and pressure in steam traps and steam supply to distilling plants.

OVERLOAD RELAY—An electrical protective device which automatically trips when a circuit draws excessive current.

OXIDATION—The process of various elements and compounds combining with oxygen. The corrosion of metals is generally a form of oxidation; rust on iron, for example, is iron oxide, or oxidation.

OXYGEN-FREE FEEDWATER—Water in which dissolved oxygen has been removed.

P

PANT, PANTING—A series of pulsations caused by minor, recurrent explosions in the firebox of a ship's boiler. Usually caused by a shortage of air.

PARALLEL CIRCUIT—An electrical circuit with two or more resistance units wired to permit current flow through both units at the same time. Unlike the series circuit, the current in the parallel circuit does not have to pass through one unit to reach the other.

PARALLEL OPERATION—Two or more units operating simultaneously and connected so their output forms a common supply, as opposed to series or independent operation.

PARAMETER—A variable, such as temperature, pressure, flow rate, voltage, current, frequency, and so forth, that may be indicated, monitored, checked or sensed in any way during operation or testing.

PARTICULATE—Minute particles or quantities of matter resulting from incomplete combustion. Carbon, sulphur, ash, and various other compounds are all referred to as particulate, either collectively or individually, when discharged into a flue or into the atmosphere.

PERIPHERY—The curved line which forms the boundry of a circle (circumference), ellipse, or similar figure. Also, the outer bounds of something as distinguished from the center or internal regions.

pH—A chemistry term that denotes the degree of acidity or alkalinity of a solution. The pH of water solution may have any value between 0 and 14. A solution with a pH of 7 is neutral. Above 7, it is alkaline. Below 7, it is acidic.

PILOT VALVE—A small valve disk and seat, usually located within a larger disk, which opens to reduce the steam pressure across, and therefore reduce the effort required to unseat the main disk.

PINION—A gear that meshes with a larger mating gear.

PIPING—An assembly of pipe or tubing, valves, fittings, and related components that forms a whole or a part of a system for transferring fluids.

PIPING MAIN—The larger or primary piping, extending throughout the boundaries of a system, to which components or subsystems are interconnected by smaller branch lines.

PITOMETER LOG—Device that indicates the speed of a ship and the distance traveled by measuring water pressure on a tube projected outside the ship's hull.

PLUG-COCK—A valve that has a rotating plug which is drilled for passage of flushes.

PNEUMATIC—Driven or operated by air pressure.

PNEUMERCATOR—A type of manometer that measures the volume of liquid in tanks.

POSITIONER—That part of a control drive, loaded by a control signal, which supplies energy to an actuator in such a manner that the final control element is positioned in accordance with the control signal.

POTENTIAL ENERGY—Energy at rest; stored energy.

POTABLE WATER—Water that is suitable for drinking. The potable water system supplies scuttlebutts, sinks, showers, sculleries, and galleys and provides makeup water for various freshwater cooling systems.

POWER—The time rate of doing work.

PPM (PARTS PER MILLION)—Concentration of the number of parts of a substance dissolved in a million parts of another substance. Used to measure the salt content of water. If 1 pound of sea salt were dissolved in 1,000,000 pounds of water, the sea salt concentration would be 1.00 ppm.

PREHEATING—The application of heat to the base metal before it is welded or cut.

PRESSURE—The amount of force distributed over each unit of area. Pressure is expressed in pounds per square inch (psi), atmospheric units, or kilograms per square contractor, inches of mercury, and other ways.

PRESSURE FEED SYSTEM—A system in which pressure (rather gravity) is used to maintain flow.

PRESSURE RELIEF VALVE—A valve designed to open when pressure in the system exceeds a certain limit.

PRESSURE SWITCH—An electrical switch operated by the increase or decrease of pressure.

PRIMARY ELEMENT—That part of a measuring device that affects, or is affected by, the quantity being measured to produce a signal capable of being sensed by a transmitter or indicator.

PRIMARY SENSING ELEMENT—The control component that transforms energy from the controlled medium to produce a signal which is a function of the value of the controlled variable.

PRIME MOVER—The source of motion, such as a turbine, automobile engine, and so forth.

PRIMING—Unevaporated boiler water carried out of the steam drum with the steam. It is caused by malfunctioning steam drum internals, high water level, sudden steam demand, or rough weather.

PROPELLER—A propulsion device consisting of a boss or hub carrying two or more radial blades. Also called a sensor.

PROPULSION OR STEAM PLANT—The entire steam propulsion plant.

PROTECTIVE FEATURE—A feature of a component or component part designed to protect a component or system from damage.

PULSATION—A rhythmical throbbing or vibrating.

PUMP—A device that raises, transfers, or compresses fluids or gases.

PUMP CAPACITY—The amount of fluid a pump can move in a given period of time, usually stated in gallons per minute (gpm).

PUMP RISER—The section of piping from the pump discharge valve to the piping main.

PUNCHING TUBES—Process for cleaning the interiors of boiler tubes.

PURGE—To make free of an unwanted substance; as to bleed air out of a fuel system.

PURPLE-K-POWDER (PKP)—A purple powder composed of potassium bicarbonate that is used on class B fires. Can be used on class C fires; however, $C0_2$ is a better agent for such electrical fires because it leaves no residue.

Q

QUILL SHAFT—A reduction gear shaft that connects the first reduction gear to the second reduction pinion.

R

RABBET—A machined joint that fits a protruding part of one joint into a groove in another joint.

RACE (BEARING)—The inner or outer ring that provides a contact surface for the balls or rollers in a bearing.

RADIAL BEARINGS—Bearings designed to carry loads applied in a plane perpendicular to the axis of the shaft and used to prevent movement in a radial direction.

RADIAL THRUST BEARINGS—Bearings designed to carry a combination of radial and thrust loads. The loads are applied both radially and axially with a resultant angular component.

RADIATION—Transfer of heat in the form of waves similar to light and radio waves, without physical contact between the emitting and the receiving regions.

RADIATION, HEAT—Heat emitted in the form of heat waves.

RAW WATER—City water used in lieu of salt water.

REACH ROD—A length of pipe or bar stock used as an extension on valve stems.

REACTION TURBINE—A turbine in which the major part of the driving force is received from the reactive force of steam as it leaves the blading.

RECEIVER INDICATORS—Pressure sensitive instruments indicating the loading pressure signals in percentage.

RECIPROCATING—Moving back and forth, as a piston reciprocating in a cylinder.

RECIRCULATION SYSTEM—The process of removing heat and moisture with cooled air by means of mechanical or natural distribution ductwork. The process may include filtering, heating, and dehumidifying.

RECTIFIER—A device for converting alternating current into direct current.

RECTIFY—To make an alternating current flow in one direction only.

REDUCER—(l) Any coupling or fitting that connects a large opening to a smaller pipe or hose. (2) A device that reduces pressure in a fluid (gas or liquid) system.

REDUCING STATION—An assembly consisting of a reducing valve, isolation valves, and bypass valves for the reducer.

REDUCING VALVES—Automatic valves that provide a steady pressure lower than the supply pressure.

REDUCTION GEARS—Combination of gears and shafting that reduce the speed of the input shaft to the output shaft.

REFRACTORY—Various types of heat resistant, insulating material used to line the insides of boiler furnaces.

REFRIGERATION TON—Unit of measure for the amount of heat removed. (12,000 Btu per hour).

REGULATOR (GAS)—An instrument that controls the flow of gases from a compressed gas cylinder.

RELATIVE HUMIDITY (RH)—The ratio of the weight of water vapor in a quantity of air to the weight of water vapor which that quantity of air would hold if saturated at the existing temperature. Usually expressed as a percentage; for example, if air is holding half the moisture it is capable of holding at the existing temperature, the RH is 50 percent.

RELAY—A magnetically operated switch that makes and breaks the flow of current in a circuit. Also called *cutout* and *circuit breaker.*

RELAY SENDER—A control system component that provides a means for manually setting a signal.

REMOTE MANUAL OPERATION—Human operation of a process by manual manipulation of loading signals to the final control elements.

REMOTE OPERATING GEAR—Rods or flexible cables attached to valve wheels so the valves can be operated from another compartment or level.

RESERVE FEEDWATER—Water stored in tanks for use in the boiler feedwater system as needed.

RISER—A vertical pipe leading off a large one; for example, fire main riser.

ROOT VALVE—A valve located where a branch line comes off the main line.

ROTARY SWITCH—An electrical switch that closes or opens the circuit by a rotating motion.

ROTOR—The rotating element of a motor, pump, or turbine.

S

SAFETY VALVE—An automatic, quick opening and closing valve that has a reset pressure lower than the lift pressure.

SALINE/SALINITY—(1) constituting, or characteristic of salt. (2) Relative salt content of water.

SALINOMETER—A hydrometer that measures the concentration of salt in a solution.

SATURATED AIR—Air that contains the maximum amount of moisture it can hold at a specified temperature.

SATURATED STEAM—Steam at the saturation temperature.

SATURATION PRESSURE—The pressure corresponding to the saturation temperature.

SATURATION TEMPERATURE—The temperature at which a liquid boils under a given pressure. For a given pressure there is a corresponding saturation temperature.

SAYBOLT VISCOMETER—An instrument that determines the fluidity or viscosity (resistance to flow) of an oil.

SCALE—Undesirable deposit, mostly calcium sulfate, which forms in the tubes of boilers.

SEA CHEST—An arrangement for supplying seawater to engines, condensers, and pumps and for discharging waste water from the ship to the sea. It is a cast fitting or a built-up structure located below the waterline of the vessel and having means for attachment of the piping. Suction sea chests are fitted with strainers or gratings.

SEAWATER—Seawater is an aqueous solution of various minerals and salts (chlorides). In suspension also, but not dissolved in the water, may be various types of vegetable and animal growths, including, in many cases, bacteria and organisms harmful or actually dangerous to health.

SECURE—(l) To make fast or safe. (2) The order given on completion of a drill or exercise. (3) The procedure followed with any piece of equipment that is to be shut down.

SEDIMENT—An accumulation of matter which settles to the bottom of a liquid.

SELECTOR SWITCH—Usually a rotary-type switch with more than two line connections. The selector switch permits the connection of a permanently connected handset to any other circuit selected; that is, wired in, by means of a jack outlet. In some stations, where only two circuits are involved, a double-throw toggle switch is sufficient.

SENSIBLE HEAT—Heat that is given off or absorbed by a substance without changing its state.

SENSING POINT—The physical and/or functional point in a system at which a signal may be detected and monitored or may cause some automatic operation to result.

SENTINEL VALVE—A relief valve designed to emit an audible sound; does not have substantial pressure-relieving capacity.

SEPARATOR—A trap for removing oil and water from compressed gas before it can collect in the lines or interfere with the efficient operation of pneumatic systems.

SERIES CIRCUIT—A circuit with two or more resistance units so wired that the current must pass through one unit before reaching the other.

SERIES-PARALLEL CIRCUIT—A circuit of three or more resistance units in which a series and a parallel circuit are combined.

SERVICE TANKS—Tanks in which fluids for use in the service systems are stored.

SET POINT—The level or value at which a controlled variable is to be maintained.

SHAFT ALLEY—The long compartment of a ship in which the propeller shafts revolve.

SHAFT GLANDS AND PACKING—Used to minimize steam leakage from the turbine casing and/or the entrance of air into the turbine casing.

SHELL INSERT BEARING—A bearing in which the wearing surface is installed on a thin shell. This shell is removable from the bearing body.

SHORE WATER—A broad term for classifying water originating from a source ashore.

SHRINK—In a boiler, a short-term decrease in drum water level which results from a change in the firing rate or steam flow without any corresponding change in the feeding rate. Since flow of water into the boiler must correspond to the outflow of steam, the feeding rate must be decreased when shrink occurs.

SIMPLE SKETCH—A simplified pictorial illustration of a system.

SIMPLEX PUMP—A pump that has only one liquid cylinder.

SKETCH—A rough drawing indicating major features of an object to be constructed.

SLIDING FEET—A mounting for turbines and boilers to allow for expansion and contraction.

SLUDGE—(l) The sediment in the lower portion of a secured boiler resulting from the settling of suspended solids in the boiler water. The sediment may include, besides the suspended solids, oil and other contaminants. (2) The sediment left in fuel oil tanks.

SOLID COUPLING—A device that joins two shafts rigidly.

SOOT BLOWER—A soot removal device using a steam jet to clean the firesides of a boiler.

SPECIAL FUNCTION—A unique service performed by a system usually above and beyond the intended design of the system. Special functions are usually provided by small modifications to a simple system as opposed to making a separate system to perform a single operation.

SPECIFIC GRAVITY—The relative weight of a given volume of a specific material as compared to the weight of an equal volume of water.

SPECIFIC HEAT—The amount of heat required to raise the temperature of 1 pound of a substance 1°F. All substances are compared to water which has a specific heat of 1 Btu/lb/°F.

SPEED-LIMITING GOVERNOR—A device for limiting the rotational speed of a prime mover.

SPEED-REGULATING GOVERNOR—A device that maintains a constant speed on a piece of machinery that is operating under varying load conditions.

SPLIT PLANT—A method of operating propulsion plants so that they are divided into two or more separate and complete units.

SPRING BEARINGS—Bearings positioned at varying intervals along a propulsion shaft to help keep it in alignment and to support its weight.

STANDING CASING—The half of a split casing that is bolted to the foundation, as opposed to the half, or cover, which can be removed with minimum disturbance to other elements of the equipment.

STANDARD PRINT—A standard drawing, schematic, or blueprint produced in the applicable technical manual, or other official technical publication.

STANDBY EQUIPMENT—Two identical auxilaries that perform one function. When one auxiliary is running, the standby is so connected that it may be started if the first fails.

STATIC—A force exerted by reason of weight alone as related to bodies at rest or in balance.

STATIC FORCE—A balanced force characteristic of bodies at rest.

STATOR—The stationary element of a motor or generator.

STEAM—Vapor of water, invisible, odorless, tasteless, and expansive.

STEAM DRUM—The large tank in which the steam collects in the boiler.

STEAM DRUM PRESSURE—The actual steam pressure in the boilers steam drum.

STEAM LANCE—A device for using low-pressure steam inside boilers to remove soot and carbon from boiler tubes.

STEAMING WATCH—Watches stood when the main engines are in use and the ship is under way.

STEP-TOOTHED LABYRINTH—Labyrinth type packing having each alternate tooth ring installed on the shaft and running in close proximity to the fixed packing ring.

STEERING ENGINE—The machinery that turns the rudder.

STERN TUBE—A watertight enclosure for the propeller shaft.

STERN TUBE FLUSHING WATER—Water circulated through the stern tubes from inboard to prevent accumulation of debris in the stem tube while the ship is at rest or backing down.

STRAIN—The deformation, or change in shape, of a material which results from the weight of the applied load.

STRENGTH—The ability of material to resist strain.

STRESS—A force which produces, or tends to produce, deformation in a metal.

STRIPPING SYSTEM—A system provided to strip all oil tanks and service systems of water and sediment.

STUFFING BOX—A device to prevent fluid leakage between a moving and a fixed part in a steam engineering plant.

STUFFING TUBE—A packed tube that makes a watertight fitting for a cable or small pipe passing through a bulkhead.

SUMP—A container, compartment, or reservoir used as a drain or receptacle for fluids.

SUPERHEAT—Amount of heat applied to steam to raise its temperature above the saturation temperature while maintaining constant pressure.

SUPERHEATED STEAM—Steam heated to a temperature above the saturated temperature of the given pressure.

SUPERHEATER—That part of the boiler specifically designed to raise the temperature of the steam to a predetermined figure above the saturation point for a design pressure of the boiler.

SUPERHEAT TEMPERATURE—Temperature of steam heated above the saturated temperature of the given pressure.

SUPPLY AIR—Compressed air required for the proper operation of pneumatic control components.

SWASH PLATES—Metal plates in the lower part of the steam drum that prevent the surging of boiler water with the motion of the ship.

SWELL—A short-term increase in boiler drum water level which results from a change in the firing rate or steam flow without any corresponding change in the feeding rate. Since flow of water into the boiler must correspond to the outflow of steam, the feeding rate must be increased when swell occurs.

SWING-CHECK VALVE—A valve having a guide-mounted disc swung from the top by a horizontal pin. A liquid exerting pressure against the disc will cause it to open, allowing a flow. Pressure exerted in the opposite direction will close the valve, ensuring only one direction of flow.

SWITCHBOARD—A panel or group of panels with automatic protective devices, used to distribute the electrical power throughout the ship.

SWITCHGEAR GROUP—Two or more switchboards in close proximity, mechanically independent but electrically connected, to form a designated unit.

SYNCHRO—An electromagnetic device for the transmission of mechanical motions to a remote location.

SYNTHRON SEAL—A rubber strip seal installed on the shaft to prevent seawater from leaking into the ship along the shaft.

SYSTEM—A grouping of components or equipment joined to serve a common purpose.

SYSTEM ALIGNMENT—The operation or adjustment of components within a system to route flow to a designated point.

SYSTEM DESIGN PRESSURE—The pressure used in the calculation of minimum section thickness of piping and piping components.

SYSTEM DESIGN TEMPERATURE—The temperature for which all equipment in the system or subsystem is intended.

SYSTEM INTERRELATION—Specific individual operations in one system affecting the operation in another system under normal conditions which are not fully described in emergency or casualty procedures or in the functional discussion of the system.

T

TAKE LEADS—A method of determining bearing clearance.

TANK TOP—Top side of tank section of double bottom of a ship.

TDC (TOP DEAD CENTER)—The position of a reciprocating piston at its uppermost point of travel.

TEFLON®—A plastic with excellent selflubricating bearing properties.

TEMPERING—The heating and controlled cooling of a metal to produce the desired hardness.

THERMAL CYCLE—The cycle in which the water is formed into steam, back to water and back to steam again by the addition or removal of heat.

THERMAL ENERGY—Energy contained in, or derived from, heat.

THIEF SAMPLE—A sample of oil or water taken from a ship's tank for analysis.

THREE-ELEMENT FEEDWATER CONTROL—An automatic feedwater flow control system which senses steam flow, feedwater flow and drum water level, and acts to maintain boiler drum water level at a constant set point.

THROAT—Openings in the cylinder block through which the crankshaft ends are extended.

THROTTLEMAN—Person in the engine room who operates the throttles to control the main engines.

THROTTLE VALVE—A type of valve especially designed to control rate of flow.

THROTTLING—Operating a valve partially open such as to produce a pressure drop with flow.

THRUST BEARINGS—Bearings that serve to limit the axial (longitudinal) movement of the rotor within the casing and to absorb the thrust imparted to the rotor by the steam.

TIE CUTOUT SWITCH—Normally closed, the tie cutout switch is opened to disconnect a tie line, usually under casualty conditions.

TIE LINES—The connection between the tie and the tie cutout switches.

TIE SWITCH—Connects two circuits when closed.

TOP OFF—To fill up, as a ship tops off, with fuel oil before leaving port.

TOUGHNESS—The property of a material which enables it to withstand shock as well as to be deformed without breaking.

TRANSFER SWITCH—(1) Used to transfer the connections of individual lines from one group of circuits to another group. Used primarily in fire control telephone circuits. (2) When used with a sound-powered telephone amplifier, the transfer switch selects a single line from two or more lines for amplification. Communications on the remaining lines continue at normal level of volume.

TRANSFER VALVE—Manually operated valve used to switch automatic control systems from automatic to manual operation and vice versa.

TRANSFORMER—An electrical device used to step up or down an ac voltage.

TRANSMITTER—A device that produces an output signal proportional to the measured variable.

TUBE EXPANDER—A tool that expands replacement tubes into their seats in boiler drums and headers.

TURBINE—A multibladed rotor, driven by steam, hot gas, or water.

TURBINE AHEAD ELEMENT—Bladed section of turbine that provides torque or power to drive the ship ahead (fwd).

TURBINE ASTERN ELEMENT—Bladed section of turbine that provides torque or power to drive the ship aft (astern).

TURBINE CASING—Shell that houses blading and other internals.

TURBINE JACKING GEAR—A motor-driven gear arrangement that slowly rotates idle propulsion shafts and turbines.

TURBINE STAGE—The term applied to one set of nozzles and the succeeding row or rows of moving blades.

U

UNBURNABLE OIL—That quantity of oil below the stripping suction in storage tanks and below the service suction in service tanks.

UNSTABLE—That action of an automatic control system and controller process that is characterized by a continuous cycling of one or more system variables to a degree greater than a specified maximum.

UPTAKES (EXHAUST TRUNKS)—Large enclosed passages for exhaust gases from boilers to the stacks.

V

VACUUM—Pressures lower than atmospheric; in steam plant, a mixture of very little air and low density steam.

VALVE—A mechanism that can be opened or closed to control or stop the flow of a liquid, gas, or vapor from one to another place.

VALVE SEAT—The surface, normally curved, against which the valve disc operating face comes to rest to provide a seal against leakage of liquid, gas or vapor.

VALVE SEAT INSERT—Metal ring inserted into valve seat; made of special metal that can withstand operating temperatures satisfactorily.

VALVE SPRING—The compression-type spring that closes the valve when the valve-operating cam assumes a closed-valve position.

VANE—A thin plate that is affixed to a rotatable unit either to throw off air or liquid (in a pump) or to receive the thrust imparted by moving air or liquid striking the vane (in a turbine).

VAPOR—The gaseous state of a substance that is usually a liquid or solid at atmospheric temperature and pressure.

VELOCITY—Speed in a definite direction.

VENT—A valve in a tank or compartment used primarily to permit air to escape.

VENTILATION SYSTEM—The process of removing heat and stale air and providing fresh air by means of mechanical or natural distribution ductwork. The process may also include filtering and heating.

VENTURI—That part of a tube, channel, pipe, and so forth, tapered to form a smaller or constricted area. A liquid or a gas moving through this constricted area will speed up and, as it passes the narrowest point, a partial vacuum will be formed. The taper facing the flow of air is much steeper than the taper facing away from the flow of air.

VENTURI INJECTOR—A device used to wash the firesides of boilers.

VISCOSIMETER—A device that determines the viscosity of a given sample of oil. The oil is heated to a specific temperature and then allowed to flow through a set orifice. The length of time required for a certain amount to flow determines the oil's viscosity.

VITAL CIRCUITS—Electrical circuits that provide power or lighting to equipment and spaces necessary for propulsion, ship, control, and communications.

VOID—A small empty compartment below decks.

VOLATILE—The term that describes a liquid that vaporizes quickly.

VOLTAGE TESTER—A portable instrument that detects electricity.

VOLUTE—A gradually widening spiral.

W

WATCH STATION—Duties, assignments, or responsibilities that an individual or group of individuals may be called upon to carry out. Not necessarily a normally manned position with a "watchbill" assignment.

WATER DRUM—A tank at the bottom of a boiler, sometimes called MUD DRUM, that equalizes distribution of water to the generating tubes and collects loose scale and other solids in boiler water.

WATER JACKET—Internal passages and cavities cast into the cylinder block of engines or air compressors through which water is circulated around and adjacent to friction (heat) areas.

WATER LEG—The water that condenses in a dead-end pressure gauge line.

WATER TUBE BOILER—Boilers in which the water flows through the tubes where it is heated by the gases of combustion.

WATER WASHING—A method of cleaning the firesides of boilers to remove soot and carbon.

WIPED BEARINGS—A bearing in which the babbitt has melted because of excess heat.

WIREWAYS—Passageways between decks and on the overheads of compartments that contain electric cables.

WORK—The result of force moving through distance.

WORK REQUEST—Request issued to naval shipyard, tender, or repair ship for repairs.

WYE GATE—A fitting with two separately controlled hose fittings, designed to connect to an outlet.

Z

ZERK FITTING—A small fitting to which a grease gun can be applied to force lubricating grease into bearings or moving parts of machinery.

ZINC—A metal placed in salt water systems to counteract the effects of electrolysis.

APPENDIX II

REFERENCES

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 or revised methods, practices, or procedures; therefore, you need to ensure that you are studying the latest references.

CHAPTER 1

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INDEX

ASSIGNMENT 1

Textbook Assignment: "Introduction to the Machinist's Mate (Surface) Rate" and "Steam Turbines," chapters 1 and 2, pages 1-1 through 2-32.

1-1. If you are assigned to the M division, which of the following terms best describes your rating?

1. General
2. Special
3. Selective
4. Standard

1-2. A Machinist's Mate (MM) (Surface) in the M division will most likely maintain which of the following equipment?

1. Steering engine(s)
2. Laundry equipment
3. Refrigeration equipment
4. Propulsion machinery

1-3. As you move up the promotion ladder to MM3 and then to MM2, your technical leadership responsibilities will change in what way?

1. They will be more directly related to your work
2. They will be more general in nature
3. They will include more military responsibilities
4. They will require only that you tell others what to do

1-4. You can best demonstrate technical leadership in which of the following ways?

1. Develop military leadership
2. Work with integrity and increase your knowledge
3. Complete the NRTCs for the MM rate
4. Pass the Navywide Advancement Examination for your rate

1-5. What is the purpose of the Navy Enlisted Classification Codes (NECs)?

1. To identify skills and training required for specific types of operations or equipment
2. To recruit Navy men and women
3. To determine who will advance
4. To classify information about ships

1-6. Which of the following offices details personnel with special NECs?

1. Chief of Naval Operations
2. Chief of Naval Personnel
3. Naval Sea Systems Command
4. Naval Weapons Command

1-7. Which of the following subjects is covered by the Naval Standards?

1. Security
2. Pump operation
3. Boiler operation
4. 3-M

1-8. Before you can take the Navywide Advancement Examination for MM2, you must be aware of which of the following types of information?

1. Military conduct
2. Naval organization
3. Military justice
4. Each of the above

1-9. The PQS program has which of the following functions?

1. To describe the knowledge and skills you need to perform your duties correctly
2. To describe the steps to be taken for advancement
3. To acquaint you with your military duties
4. To eliminate the need for examinations

1-10. What person is responsible for the safekeeping of your qualification records?

1. The commanding officer
2. The engineer officer
3. Your supervisor
4. Yourself

1-11. What is the most useful thing to know about a piece of equipment?

1. Clearances
2. Pressures
3. Where to find the name plate data
4. Where to find the necessary information on the equipment

1-12. The required and recommended training courses to study for advancement in rating can be found in what publication?

1. *Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068
2. *Bibliography for Advancement Study,* NAVEDTRA 12061
3. Guide for Enlisted Classification
4. Shipboard Training Manual

1-13. If extensive changes occur in the qualifications for a rating between annual revisions of NAVEDTRA 12061, where can you find a list of current study material?

1. NAVSEA notices
2. BUPERS notices
3. NAVEDTRA 12061 supplements
4. *Naval Ships' Technical Manual (NSTM)*

1-14. Which of the following hints for studying should help you get the most from your Navy training course?

1. Devote your time exclusively to important military topics
2. Try not to cover a complete unit in any one study period
3. Omit easy material; study only the most difficult and the unfamiliar
4. Make notes as you study, putting the main ideas in your own words; then review your notes

1-15. As you study a Navy training course, which of the following study practices should you follow?

1. Set up a fixed number of pages to study in each and every study period
2. Prepare notes exactly as stated in the TRAMAN
3. Memorize as much as you can from a chapter and repeat it to a shipmate
4. Skip over the illustrations and save them until the end of your course

1-16. You should find useful articles about shipboard engineering and new developments each month in which of the following publications?

1. Changes to the *NSTM*
2. NAVSEA's *Deckplate*
3. Supplements to the applicable Navy training course
4. Bibliography for Advancement Study

1-17. Aboard ship, blueprints are filed according to

1. month and year of issue
2. SHIP/ALT number
3. numerical sequence in the SDI
4. revision number or letter

1-18. You will most likely find the *NSTM* in what space in the engineering department?

1. The engine room
2. The fireroom
3. The pump room
4. The log room

THIS SPACE LEFT BLANK INTENTIONALLY.

A. ENERGY
B. POWER
C. WORK
D. KINETIC ENERGY
E. ENTHALPY
F. POTENTIAL ENERGY
G. STORED ENERGY

Figure 1A

IN ANSWERING QUESTIONS 1-19 THROUGH 1-24, REFER TO FIGURE 1A AND SELECT THE TERM DEFINED BY THE QUESTION.

1-19. The ability to do work.

1. A
2. B only
3. B and C
4. E, F, and G

1-20. Work done within a specified period of time.

1. A
2. B
3. C
4. D

1-21. A force that acts on matter and moves it.

1. A and B
2. C only
3. C and D
4. F and G

1-22. Energy that has been released.

1. A and C
2. D
3. E and F only
4. E, F, and G

1-23. Stored energy within steam.

1. B, C, and F
2. A, B, and C
3. C, D, F, and G
4. E

1-24. Stored energy in an object.

1. D
2. E
3. F
4. G

1-25. What type of energy is found in the water of an operating boiler?

1. Chemical
2. Thermal
3. Mechanical
4. Specific

IN ANSWERING QUESTIONS 1-26 AND 1-27, REFER TO FIGURE 2-1 IN THE TEXTBOOK.

1-26. Chemical energy is converted to thermal energy in what component?

1. The furnace
2. The superheater
3. The steam drum
4. The economizer

1-27. Thermal energy of steam is converted to mechanical energy in which of the following components?

1. The condensate pump
2. The main feed pump
3. The feed booster pump
4. Each of the above

IN ANSWERING QUESTIONS 1-28 AND 1-29, REFER TO FIGURE 2-2 IN THE TEXTBOOK.

1-28. If you are operating at 30 percent speed, you are using what percentage of rated horsepower?

1. 1%
2. 10%
3. 40%
4. 4%

1-29. If you increase the percentage of speed to 60 percent, you are using what percentage of rated horsepower?

1. 10%
2. 20%
3. 30%
4. 40%

1-30. What parts of a reaction turbine serve the same purpose as the nozzle of an impulse turbine?

1. Fixed nozzles
2. Fixed blades only
3. Moving blades only
4. Fixed blades and moving blades

1-31. As the steam passes across the moving blades in a reaction turbine, what happens to the pressure and velocity?

1. They increase
2. They decrease
3. They remain constant
4. The velocity increases and the pressure decreases

1-32. In the impulse turbine, what device converts thermal energy to kinetic energy?

1. Moving blades
2. Fixed blades
3. Nozzles
4. Valves

1-33. Convergent-divergent nozzles are used in high-pressure turbine applications for which of the following reasons?

1. They are easy to manufacture
2. They are less susceptible to steam erosion than other types because of their shape
3. They produce a larger pressure drop and therefore are more efficient than other types
4. They direct the steam flow more efficiently than other types

1-34. What is a Rateau stage on a turbine?

1. One set of nozzles and two rows of moving blades
2. One set of nozzles and one row of moving blades
3. Two sets of nozzles and two rows of moving blades
4. Two sets of nozzles and one row of moving blades

1-35. What is the cause of large temperature and pressure drops in the first-stage nozzles of a combination impulse and reaction turbine?

1. Two rows of moving blades
2. Steam passing through a single row of blades more than once
3. Using a dummy piston cylinder to offset axial thrust
4. A velocity-compounded impulse stage at the high-pressure end of the turbine followed by reaction blading

1-36. The turbine wheel uses the steam more than once in which of the following turbines?

1. Helical flow only
2. Axial flow only
3. Helical and axial flow
4. Axial and radial flow

1-37. Double-flow reaction turbines have very little axial thrust for which of the following reasons?

1. No axial thrust develops
2. Partially expanded steam is exhausted to a low-pressure turbine where the expansion is completed
3. The axial thrusts developed at each end counterbalance each other
4. Equalizing holes are provided in the turbine wheel

1-38. The after end of most main engine turbines are rigidly mounted for which of the following reasons?

1. Because of the steam line connection
2. Because of the drain line connection
3. Because of the blading and casing alignment
4. Because of the turbine and reduction gear alignment

1-39. Because of the pressure drop existing across each diaphragm in a turbine, the flow of steam between the nozzle diaphragm and the rotor is held to a minimum by what means?

1. A fluid seal
2. A deflector ring
3. A babbitt liner
4. A labyrinth packing ring

1-40. The labyrinth packing in a turbine serves which of the following purposes?

1. It maintains rotor alignment
2. It relieves excessive pressure along the rotor
3. It assists in sealing the area where the rotor passes through the casing
4. It allows for rotor expansion

1-41. What is the purpose of gland sealing steam?

1. To stop air from entering a turbine casing operating under a vacuum
2. To cool the packing gland
3. To assist turbine warmup
4. To preheat the packing gland before the ship gets under way

1-42. What causes the gland leak-off steam in a propulsion turbine to pass through the gland exhaust condenser?

1. Steam pressure from the low-pressure turbine
2. Steam pressure from the high-pressure turbine
3. Compressed air in the air pilot
4. The gland exhauster

IN ANSWERING QUESTION 1-43, REFER TO FIGURE 2-24 IN THE TEXTBOOK.

1-43. The poppet valves in nozzle control valves are held closed by what means?

1. The lifting beam
2. Springs
3. Steam pressure
4. Oil pressure

IN ANSWERING QUESTIONS 1-44 AND 1-45, REFER TO FIGURE 2-25 IN THE TEXTBOOK.

1-44. When valves #1 and #2 are wide open, what should be the steam pressure in the steam chest?

1. About the same as the line pressure
2. In excess of the line pressure
3. Increasing in intensity
4. Sufficient for maximum turbine speed and power

1-45. Of the following cam-operated valves, which one admits steam directly into the sixth stage?

1. No. 5
2. No. 2
3. No. 3
4. No. 4

1-46. What is the range of economic operation for turbine-driven ships?

1. 5 to 10 Kt
2. 10 to 26 Kt
3. 12 to 20 Kt
4. 20 to 25 Kt

1-47. In a main engine using a double-flow low-pressure turbine, where are the astern elements located?

1. In the forward end of the high-pressure turbine only
2. In the after end of the high-pressure turbine only
3. In the forward and after ends of the low-pressure turbine
4. In the forward and after ends of the high-pressure turbine

1-48. Astern turbines are normally made up of what type of staging?

1. Reversing
2. Reaction
3. Velocity-compounded impulse
4. Pressure-compounded impulse

1-49. Auxiliary turbines improve overall plant efficiency by supplying steam to which of the following components?

1. The main air ejector
2. The fuel oil service pump
3. The DFT
4. The fuel oil heater

1-50. The efficiency is increased in some auxiliary turbines by using which of the following devices?

1. Reduction gears
2. Speed-limiting governors
3. Convergent nozzles
4. Divergent nozzles

1-51. Auxiliary turbines are classified according to which of the following characteristics?

1. Weight displacement
2. Length and height
3. Number of blades
4. Number of stages

1-52. Which of the following pieces of equipment is most likely to be driven by an auxiliary turbine?

1. A low-pressure air compressor
2. A cooling water pump
3. A force draft blower
4. An exhaust fan

1-53. What type of turbine is most often used to drive the main lube oil pump?

1. Single stage
2. Multistage
3. Condensing
4. Noncondensing

1-54. Which of the following factors is a means used to classify turbogenerator turbines?

1. Condensing
2. Noncondensing
3. Both 1 and 2 above
4. Kilowatts per hour

1-55. If a turbogenerator is in operation with a faulty safety device, you should take which of the following actions?

1. Secure the generator
2. Place an out-of-commission sign on the safety device and continue to operate the generator
3. Place a caution tag on the safety device and continue to operate the generator
4. Bypass the safety device and continue to operate the generator

1-56. On a turbogenerator, what type of governor ensures a steady frequency output?

1. Constant-pressure
2. Constant-speed
3. Speed-limiting
4. Overspeed

1-57. When the electrical load is increased on a turbogenerator equipped with a centrifugal governor, the flyweights initially move in what direction?

1. Inward
2. Outward
3. Downward
4. Upward

1-58. On the turbogenerator, what safety device will cause the trip throttle valve to close when it reaches its set point?

1. The overspeed trip
2. The low lube oil pressure trip
3. The back-pressure trip
4. The constant-speed trip

1-59. If a turbogenerator operates at 1,200 rpm, what should be the setting of the overspeed trip?

1. 1,220 rpm
2. 1,320 rpm
3. 1,440 rpm
4. 1,520 rpm

1-60. The quickest way to determine bearing wear on the main turbines is to take what type of reading?

1. Crown thickness
2. Lead gauge
3. Depth gauge
4. Bridge gauge

1-61. When you use inside and outside micrometers to measure bearing wear, you are actually taking what measurement?

1. The oil clearance
2. The crown thickness
3. The amount of babbitt remaining
4. The amount of shaft wear

1-62. When using a Kingsbury thrust bearing to axially position the turbine rotor, you should make adjustments by adjusting the thickness of what part(s)?

1. The thrust shoes
2. The base roughness
3. The filler piece
4. The thrust collar

1-63. The thrust measurement on a turbine should be taken with what instrument?

1. A dial indicator
2. A feeler gauge
3. A depth micrometer
4. An outside micrometer

1-64. You should use which of the following tools to repair labyrinth packing?

1. A chisel bar and a hand chisel
2. Files and stones
3. A hammer and files
4. Stones and emery paper

1-65. Which of the following suggestions will help you recognize the symptoms of a casualty more readily?

1. Be familiar with the normal pressures, temperatures, and operating speeds of the equipment
2. Know your casualty control procedures
3. Study the ship's organization manual
4. Study the damage control manual

ASSIGNMENT 2

Textbook Assignment: "Reduction Gears and Related Equipment" and "Lubrication and Associated Equipment," chapters 3 and 4, pages 3-1 through 4-8.

2-1. What is the purpose of reduction gears?

1. To change rotary motion into linear action
2. To reduce high speed to low speed
3. To minimize thrust on the main turbines
4. To transmit thrust from the main shaft to the ship's hull

2-2. What is the purpose of double helical gears in reduction gears?

1. To produce smoother action and eliminate tooth shock
2. To produce double reduction
3. To eliminate misalignment
4. To eliminate radial stress

2-3. In reference to reduction gears, the term *axial float* has what meaning?

1. The gears aren't subject to excessive tooth loads due to mismatch of the journal bearing halves
2. The gears are double-helical and axial thrust is eliminated
3. The gears are capable of free motion, neither supporting nor supported by other gears radially
4. The gears are capable of free motion, neither supporting nor supported by other gears axially

2-4. The first reduction gear and the second reduction pinion each have two bearings and are connected by a quill shaft and flexible coupling. They are known as what type of gearing?

1. Double-reduction
2. Single-reduction
3. Nested
4. Articulated

2-5. What is the meaning of the term *lock-train?*

1. The main shaft can be locked
2. The main turbines can be locked
3. The two first reduction pinions are locked between the two first reduction gears
4. The second reduction gear is locked between the two first reduction pinions

2-6. In a main reduction gear, the gear case covers are bolted and securely locked to the upper casings. What mean(s) is/are provided to inspect the rotating pairs?

1. Inspection plates
2. Bullseye covers
3. RTE junction boxes
4. A tachometer drive

2-7. In an articulated, double-reduction, divided-power path gear set, the first and second reduction gears are usually of fabricated construction. The teeth are cut in a temperature-controlled room for what reason?

1. To prevent stress buildup
2. To prevent the effects of temperature and humidity
3. To control the size of the journals
4. To control stress in the webbing

2-8. In propulsion systems, the shaft for a main reduction gear may be made from what type of material?

1. Aluminum-bronze
2. Forged steel
3. Aluminum
4. Monel

2-9. The type of construction for gear wheels used in reduction gear mechanisms aboard ship is determined by which of the following factors?

1. The size of the gear wheel
2. The type of the reduction gear
3. The type of ship in which they will be used
4. The type of gear to be driven

2-10. What type of flexible couplings are used in most turbine reduction gear installations?

1. Friction clutch
2. Gear tooth
3. Bend
4. Flange

2-11. The expansion and minor misalignments that occur between the main turbines and the reduction gears are compensated by what device?

1. A sleeve
2. A flexible coupling
3. An expansion gear
4. A pinion gear

2-12. Failure to use the turning gear during turbine startup may result in which of the following casualties?

1. A hot condenser
2. A hot bearing
3. A bowed rotor
4. Bowed reduction shafts

2-13. Geared turbine installations are equipped with turning mechanisms for which of the following reasons?

1. To jack the main engine periodically when it is secured
2. To turn the main engine during routine inspections
3. To turn the main engine during warmup and securing periods
4. Each of the above

2-14. In the type of turning gear discussed in the text, what component connects the turning gear to the high-pressure pinion?

1. A manually operated hand brake
2. A manually operated jaw clutch
3. A sleeve coupling
4. A quill shaft

2-15. What type of reduction gearing is used for turbogenerators?

1. External spur
2. Bevel
3. Helix
4. Screw

2-16. In the reduction gearing for a typical ship's turbogenerator, the gear that drives the oil pump and governor is mounted on the turbine end of what component?

1. The pinion shaft
2. The turbine shaft
3. The generator shaft
4. The gear wheel shaft

2-17. The reduction gears on the turbine-driven main circulating pump are lubricated by what type of pump?

1. Gear
2. Centrifugal
3. Hand
4. Screw

2-18. To keep the reduction gear operating properly, what should be your principle concern?

1. Keeping a constant reduction ratio between the speed of the turbine and the speed of the driven unit
2. Keeping the upper half of the gear casing secured to the lower half of the casing
3. Keeping the gear supplied with pure oil at the proper pressure and temperature
4. Keeping the drive gear aligned with the drive shaft

2-19. Dirt and/or metallic particles in a reduction gear lubrication system may cause which of the following problems?

1. Scored journals
2. Clogged spray journals
3. Eroded gear teeth
4. All of the above

2-20. On a reduction gear unit, the main sump is located directly below the gears. When adding lube oil, you must take which of the following precautions?

1. Don't use 2190-TEP oil
2. Don't raise the oil level to the point where it will come in contact with the bull gear
3. Don't add oil using the lube-oil purifier
4. Don't strike down oil from the storage tank

2-21. Which of the following casualties indicates that oil is churning in the main sump?

1. High bearing temperatures
2. Water in the lube oil
3. A low sump level
4. A hot line shaft bearing

2-22. What person is required to be present when the reduction gear casing is opened?

1. The division officer
2. The officer of the deck
3. The damage control officer
4. The engineer officer

2-23. Which of the following precautions is/are required when you are working on reduction gears?

1. Work in a T-shirt
2. Work in clothes with all buttons and pockets taped
3. Secure tools to your person with a lanyard
4. All of the above

2-24. Thrust bearings provide free shaft movement in the direction of the shaft axis.

1. True
2. False

2-25. Turbine bearings and reduction gear bearings have separate lubrication systems.

1. True
2. False

2-26. In the main engine installations, the main reduction gear bearings and other bearings have which of the following characteristics in common?

1. They are of the single-casting type
2. They are babbitt lined
3. They are self aligning
4. They are spherically seated

2-27. Reduction gear bearings are mounted rigidly in their housings by what means?

1. Keyways and keys
2. Spherical housings
3. Dowels or locking screws and washers
4. Notched construction

2-28. The splits in the main reduction gear bearings are mounted at an angle to the horizontal to prevent which of the following problems?

1. Oil loss
2. Steam loss
3. Axial stress
4. Wiping

2-29. A main thrust bearing of a ship's propulsion plant located in the reduction gear casing has which of the following purposes?

1. To support the weight of the reduction gears
2. To absorb the radial thrust developed when power is transmitted
3. To absorb the axial thrust transmitted through the shaft from the propeller
4. To allow for shaft misalignment

QUESTIONS 2-30 THROUGH 2-33 REFER TO SEGMENTAL PIVOTED-SHOE-TYPE THRUST BEARINGS.

2-30. Which of the following is the principle of operation of these bearings?

1. A flat film of oil is more readily formed and maintained than a wedge-shaped film
2. A flat film of oil can carry heavier loads than a wedge-shaped film
3. A wedge-shaped film of oil absorbs less heat than does a flat film
4. A wedge-shaped film of oil is more readily formed and maintained than a flat film

2-31. Which of the following parts equalizes the thrust load between the shoes?

1. The leveling plates
2. The thrust collar
3. The base ring
4. The oil wedge

2-32. Which of the following parts transmits the thrust to the ship's structure?

1. The thrust collar
2. The leveling plates
3. The base ring
4. The oil wedge

2-33. What base ring feature prevents it from turning and secures it to its housing?

1. The pin only
2. The dowel only
3. The combination of pin and dowel
4. The keyed construction

2-34. Most main line shaft bearings have which of the following features?

1. Ring-oiled or disc-oiled
2. Nonself-aligning
3. Segmental-pivoted shoe
4. Rigidly mounted sleeve

2-35. In the disc-oiled spring bearing, the oil is removed from the disc by what means?

1. Shaft rotation
2. A scraper
3. The oil ring
4. Disc guides

2-36. While underway, the temperature and oil levels of spring bearings should be checked at what specified interval?

1. Hourly
2. Daily
3. Weekly
4. Monthly

2-37. Water is prevented from entering the ship's hull via the propulsion shaft by which of the following devices?

1. Stem tube packing or automatic shaft seal
2. A deflector ring and drain
3. Spring bearings
4. Oiler rings

2-38. Water flowing through the stem tube stuffing box serves which of the following purposes?

1. Cools
2. Lubricates
3. Flushes
4. All of the above

2-39. When the ship is in port and cold iron, what should be the condition of the stern-tube packing gland?

1. Tight
2. Loose
3. Disassembled
4. Tagged out

2-40. When packing is added to the stern tube. what means should you use to ensure that the gland is taken up evenly?

1. Listen for a smooth, regular sound
2. Measure the distance between the gland and stuffing box with a rule
3. Judge by, the feel of the gland as it is being tightened
4. Open the drain connection to let seawater flow in and make the distance even

2-41. The automatic shaft sealing system has which of the following advantages over the stuffing box and backing gland method?

1. It eliminates the repairing or renewing of the shaft sleeve
2. It is fully automatic in operation
3. It allows for removal and reinstallation of ail parts without dismantling the shafts
4. Each of the above

2-42. In most cases, what is the first indication of bearing trouble?

1. White looking lube oil
2. Abnormal or rapid temperature rise
3. Excessive lube oil pressure
4. Misalignment of the turbine rotor

2-43. Normally, what method is used to connect the sections of line shafting?

1. Banding
2. Unions
3. Welding
4. Couplings

2-44. The exposed portion of the outboard shaft is protected against seawater corrosion by which of the following means?

1. A heavy lubricant
2. A covering of plastic or rubber
3. A bronze sleeve
4. A strut tube

2-45. Which of the following statements describes ship propellers?

1. The number of blades varies from two to four
2. The number of blades varies from three to seven
3. Controllable pitch propellers are of the single- casting type
4. Left-hand helices as viewed from astern turning counterclockwise to move the ship forward

2-46. Which of the following is a description of controllable pitch propellers?

1. They give excellent maneuverability
2. They can develop maximum thrust at any given rpm
3. They stop the ship in a shorter distance
4. All of the above

2-47. The controllable pitch propeller controls the position of which of the following units?

1. Propeller blades
2. Propeller
3. Propeller hub assembly
4. Propeller and shafting

2-18. Which of the following components provides passage for the prairie air tubing?

1. The hydraulic oil power module
2. The manifold block assembly
3. The OD box
4. The valve rod assembly

2-49. Which of the following components prevent(s) seawater from entering the hub assembly?

1. The piston rod assembly
2. The blade port cover
3. The blade seal ring
4. Both 2 and 3 above

2-50. What is kinetic friction?

1. Friction between two bodies at rest
2. Friction that must be overcome to generate motion
3. Friction between moving bodies or between a moving body and a stationary surface
4. Friction that must be overcome to stop a body in motion

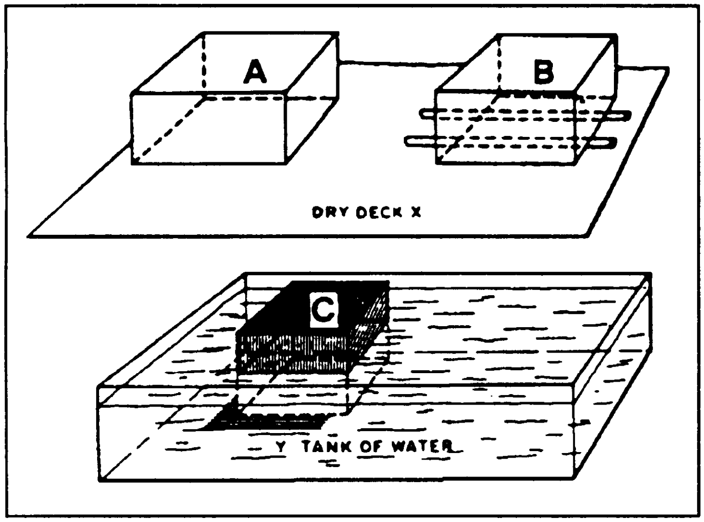

Figure 2A

IN ANSWERING QUESTIONS 2-51 THROUGH 2-56, REFER TO FIGURE 2A.

2-51. What type of friction must be overcome to put boxes A and B in motion?

1. Fluid
2. Rolling
3. Sliding
4. Static

2-52. What type of friction exists between the deck and the bottom of box A as the box is dragged to point X?

1. Fluid
2. Rolling
3. Sliding
4. Static

2-53. What type of friction exists between the deck and the pipes under box B as the box is pushed to point X?

1. Fluid
2. Rolling
3. Sliding
4. Static

2-54. What type of friction exists between the water and the sides and bottom of box C as the box is floated to point Y?

1. Fluid
2. Rolling
3. Sliding
4. Static

2-55. Friction exists between the water and the sides and bottom of floating box C. This friction is created by the forces that cause molecules of water to have which of the following characteristics?

1. Attract one another
2. Stick to the box
3. Both 1 and 2 above
4. Repel one another

2-56. Boxes A and B are identical in every respect. Compare the amounts of power consumed and heat produced to overcome friction in moving box A with the corresponding amounts for overcoming friction in moving box B. What conclusion should you draw from the comparison?

1. More power is consumed and more heat is produced in moving box A
2. More power is consumed and more heat is produced in moving box B
3. More power is consumed and less heat is produced in moving box A
4. More power is consumed and less heat is produced in moving box B

2-57. By introducing an unbroken film of oil between two moving parts that are making metal-to-metal contact, you reduce the friction between them. Theoretically, what kinds of friction are exchanged?

1. Sliding to rolling
2. Rolling to sliding
3. Sliding or rolling to fluid
4. Fluid to sliding or rolling

2-58. According to the Langmuir theory, which of the following statements best describes the effects of lubricating oil on two moving surfaces?

1. The outside layers adhere to the moving surfaces and the inside layer(s) slide between the outside layers and force the moving surface apart
2. One layer slides on the other and each layer clings to one of the moving surfaces
3. One layer prevents metal-to-metal contact and acts as a roller between the two moving surfaces
4. A flat-shaped layer forces the moving surfaces apart in the same way as a solid wedge

2-59. Temperature has what effect on lubricating oil?

1. The oil changes viscosity
2. The oil absorbs more condensation
3. The oil turns milky in color
4. The oil erodes the component parts

2-60. A water-based glycol hydraulic fluid is chiefly used in which of the following components?

1. Catapult retracting gears
2. Deck-edge elevators
3. Refrigerator compressors
4. Machinery reduction gears

2-61. What does the digit 2 in the lube oil symbol 2190T represent?

1. The principal synthetic additive in the oil
2. The class of the oil according to type and use
3. The diameter, in centimeters, of the standard orifice used to measure the oil's viscosity
4. The number of minutes it takes a 60-mL sample of the oil to flow through a standard orifice at a specified temperature

2-62. What part of the lube oil symbol 2190T represents the viscosity of the oil?

1. 19
2. 90
3. 190
4. 219

2-63. What minimum flashpoint temperature is allowed for Navy lube oils?

1. 315°F
2. 400°F
3. 500°F
4. 600°F

2-64. What term describes the lowest temperature at which the vapors of an oil will bum in the absence of a spark or flame?

1. Fire point
2. Flashpoint
3. Combustion point
4. Autoignition point

2-65. What type of content is shown by the precipitation number of an oil?

1. Acid
2. Additive
3. Moisture
4. Asphalt or carbon residue

2-66. When a lubrication system aboard ship has three lube oil service pumps, the electrical- and turbine-driven-pumps are used in what way?

1. As lube oil service pumps all the time
2. Secured when the shaft-driven pump has the load
3. As standbys, at normal speeds, for the shaft-driven pumps
4. To supply the auxiliary

2-67. The sensing point for the low-pressure alarm is located in what part of a lube oil system?

1. The lube oil pump suction
2. Between the lube oil pump and the lube oil cooler
3. At or near the most remote bearing
4. At or near the lube oil pump discharge

2-68. What device in the main lube oil system maintains the desired pressure to the most remote bearing?

1. A needle valve
2. An orifice
3. An unloading valve
4. A check valve

2-69. In a force-feed lubrication system, what device controls the amount of oil to each individual bearing?

1. A pump
2. An unloading valve
3. A needle or orifice valve
4. An expansion valve

2-70. What type of lube oil pump is normally used on a turbine-driven pump?

1. Screw
2. Simple gear
3. Lobe
4. Jet

2-71. What type of strainer is normally used in the main lube oil system?

1. Duplex
2. Single-wire mesh
3. V
4. Y

2-72. On a turbine-driven pump, what device in the cooling water line leaving the cooler prevents air pockets in the cooler?

1. A needle valve
2. A check valve
3. An orifice
4. A vent

ASSIGNMENT 3

Textbook Assignment: "Lubrication and Associated Equipment" and "Pumps," chapters 4 and 5, pages 4-8 through 5-17.

3-1. Pressure fittings should NOT be used to lubricate which of the following types of bearing applications?

1. Low-speed
2. Electric generator
3. Sleeve
4. Fire flushing pump

3-2. If you apply excessive pressure to lubricate bearings fitted with felt while using pressure fittings, which of the following problems may occur?

1. Broken rotors
2. Broken seals
3. Excessive wearing ring clearance
4. Excessive water bearing wear

3-3. What is the principle source of lube oil contamination?

1. Dirt
2. Sludge
3. Water
4. Carbon

A. THE OIL IS HEATED
B. WATER AND OTHER IMPURITIES ARE REMOVED FROM THE SETTLING TANK
C. LUBRICATION OIL IS TRANSFERRED FROM THE SUMP TO THE SETTLING TANKS
D. OIL IS CENTRIFUGED AND RETURNED TO THE SUMP

Figure 3A

IN ANSWERING QUESTION 3-4, REFER TO FIGURE 3A.

3-4. Batch oil purifying is performed in what sequence?

1. A, B, C, D
2. B, C, A, D
3. C, B, A, D
4. C, A B, D

3-5. A lube-oil purifier is referred to as a separator when it is used to remove what substance from the oil?

1. Water
2. Sludge
3. Metal particles
4. Sediment of any nature

3-6. The disk-type purifier differs from the tubular type in which of the following ways?

1. The capacity
2. The principle of operation
3. The position assumed by the separated oil
4. The design of the rotating unit

IN ANSWERING QUESTION 3-7, REFER TO FIGURE 4-7 IN THE TEXTBOOK.

3-7. Dirty oil flows from the bottom of the regulating tube through the inside of a tubular shaft in to a

1. bowl shell
2. centrifugal tube
3. stack of disks
4. discharge ring

3-8. When a disk purifier is used, the clean oil passes through which of the following processes?

1. Clean oil is discharged through the discharge ring; water mixes with sludge and dirt flows upward and is discharged from the neck of the top disk; and most of the dirt and sludge collects on the vertical surface of the bowl shell
2. Water and most dirt and sludge are discharged through the drains; some dirt collects on the vertical surface of the bowl; and clean oil is discharged through the discharge ring
3. Water mixed with dirt and sludge passes through the discharge ring; most of the dirt and sludge is collected on the vertical walls of the bowl shell; and purified oil flows inward and upward through the disk and is discharged through the neck of the top disk
4. Clean oil flows inward and upward and is discharged through the top disk; and water, dirt, and sludge are discharged through the drains

3-9. What is the function of the three-wing device in the tubular-type centrifugal purifier?

1. To maintain a constant oil pressure
2. To restrain movement of the bottom of the bowl
3. To cause the liquid to rotate at bowl speed
4. To accelerate emulsification

3-10. A tubular-type purifier is being used as a lube-oil clarifier. You should change which, if any, of the following devices to make a clarifier?

1. The bowl
2. The three-wing device
3. The drag bushing
4. None of the above

3-11. Oil purifiers give maximum efficiency when operating at their rated capacity and at what speed?

1. The maximum design speed
2. A speed between minimum and maximum
3. The minimum speed
4. A speed determined by prevailing conditions

3-12. When a purifier is operated as a separator, what essential action precedes the admittance of oil?

1. The bowl is primed with fresh water to prevent losing the oil
2. The bowl is primed with air to prevent water from entering the oil
3. Condensate is removed from the bowl to prevent contamination of the oil
4. The bowl is vented to the atmosphere to ensure free flow of oil into the bowl

3-13. The amount of time required to purify a lube oil depends on which of the following conditions of the oil?

1. Density
2. Specific gravity
3. Viscosity
4. All of the above

3-14. What action tends to occur if oil is overheated during purification?

1. It oxidizes
2. It emulsifies
3. It evaporates excessively
4. It clarifies

3-15. When heating oil for purification, you should add enough heat to decrease its viscosity to what specified level?

1. 60 SSU
2. 75 SSU
3. 90 SSU
4. 120 SSU

3-16. The size of the discharge ring for the oil in use fails to give satisfactory purification. What action should you take to correct this problem?

1. Use the largest possible size ring that will produce oil-free water discharge
2. Use the smallest possible size ring that will produce oil-free water discharge
3. Use the next smaller size
4. Use the next larger size

3-17. Which of the following statements does NOT apply to the operation of a pump?

1. To be pumped, a substance must be made to flow
2. To be pumped, a substance must be cold
3. The kinetic energy transformed by the pump can be used to force a substance through a hydraulic system
4. A pump must receive its energy from an external source

3-18. Which of the following terms is/are common to all kinds of pumps?

1. Power end and fluid end
2. Propeller and eductor
3. Volute vane impeller
4. Turbine and piston

A.	HEAD
B.	PUMP HEAD
C.	SUCTION HEAD
D.	DISCHARGE HEAD
E.	NET POSITIVE SUCTION HEAD

Figure 3B

IN ANSWERING QUESTIONS 3-19 THROUGH 3-21, REFER TO FIGURE 3B.

3-19. Subtract the vapor pressure from the suction pressure at the pump suction, and you obtain this pressure.

1. B
2. C
3. D
4. E

3-20. What term indicates the total pressure of liquid entering a pump?

1. B
2. C
3. D
4. E

3-21. The pressure of liquid leaving a pump.

1. A
2. C
3. D
4. E

3-22. What unit of measurement is used to express the (a) positive and (b) negative suction heads?

1. (a) In.Hg (b) feet of water
2. (a) Feet of water (b) in.Hg
3. (a) In.Hg (b) in.Hg
4. (a) Feet of water (b) feet of water

3-23. Which of the following problems will prevent a shipboard pump from achieving its maximum suction lift?

1. A jammed suction valve
2. Friction in the pipes
3. An open vent valve
4. Excessive pump speed

3-24. A centrifugal pump is used for which of the following purposes?

1. Lube-oil service
2. Main feed pump
3. Air ejector
4. Bilge pump

3-25. With respect to impellers, centrifugal pumps have which of the following classifications?

1. Single stage
2. Multistage
3. Both 1 and 2 above
4. Horizontal or vertical

3-26. Which of the following functions applies to closed impellers?

1. They allow liquid to enter the eye from one direction
2. They have side walls that extend from the eye to the outer edge of the vane tips
3. They have small impeller eyes
4. They are not vented above the impeller eye

3-27. Centrifugal pumps have the following construction features for which of the following reasons?

1. They are carefully machined to minimize friction
2. They are balanced to prevent vibration
3. The close radial clearance between the outer hub of the impeller and the part of the pump casing in which the hub rotates minimizes leakage from the discharge side of the pump casing to the suction side
4. All of the above

3-28. What centrifugal pump feature reduces the need to renew worn impellers and pump casings?

1. The close radial clearance between the impeller hub and casing
2. The rotational speed of the impeller
3. The removable end plate
4. The replaceable wearing ring

3-29. Removable sleeves are put on a centrifugal pump shaft for what reason?

1. To make it easier to maintain the pump
2. To make replacements more economical
3. To lighten the weight of the pump, when needed
4. To increase the strength of the shaft

3-30. Air leakage between the shaft and stuffing box packing in a pump is prevented by what means?

1. Compressed packing glands
2. Lantern rings between the packing rings
3. Liquid seal
4. Stuffing box glands

3-31. The seal piping takes liquid from the discharge side of the pump and delivers it to which of the following components?

1. The flinger ring
2. The wearing ring
3. The shaft sleeve
4. The lantern ring

3-32. In mechanical seals, a snug fit is maintained between the rotating and stationary seal by what means?

1. A notch and keyway
2. Spring pressure and system pressure
3. A bellows
4. A seal retaining ring

3-33. What type of material is used in the mechanical seal of most centrifugal water pumps?

1. Mild steel
2. Copper
3. Carbon
4. Bronze

3-34. Turbine-driven centrifugal pumps used in Navy ships are usually powered by which of the following kinds of turbine?

1. Two-stage
2. Single-stage
3. Reaction
4. Combination impulse and reaction

3-35. The pump stuffing box packing is lubricated by which of the following means?

1. Gravity and feed oil cups
2. Grease cups
3. The land during installation
4. The liquid being pumped

3-36. Mechanical seals are ideal for use in pumps in closed systems for which of the following reasons?

1. There is no excessive loss of fluid
2. The pumps can be run slower
3. The pumps can be run faster
4. Both 2 and 3 above

3-37. Water from leaking stuffing box glands is kept out of the bearing housing by which of the following devices?

1. Shaft sleeves
2. Lantern rings
3. Water flingers
4. Water seals

3-38. Before checking the shaft alignment of a centrifugal pump, you must be sure that which of the following conditions exists?

1. Spare parts for the pump are available
2. The shaft sleeve fits snugly
3. Some water is leaking between the shaft and sleeve
4. Each of the above

3-39. Assume that the coupling flanges are not aligned. What action should you take to make the necessary adjustments?

1. Raise or lower the pump with shims
2. Raise or lower the motor with shims
3. Move the two units in the direction necessary by means of the jacks welded on the foundation
4. Raise or lower either unit with shims and shift them horizontally by means of the jacks welded to the foundation

3-40. What instrument should you use to check pump shaft alignment?

1. A strobotac
2. A thickness gauge
3. A strobe light
4. A reed tachometer

3-41. The misalignment of shafts of a pump and its prime mover can cause which of the following problems?

1. A cracked casing
2. Improper wear of a throat bushing
3. A broken impeller
4. A warped pump foundation

3-42. What instruments are used to measure wearing ring clearances?

1. Inside and outside micrometers
2. A dial indicator and an outside micrometer
3. A dial indicator and an inside micrometer
4. Inside and depth micrometers

3-43. Which of the following problems can cause a pump to fail to deliver liquid?

1. Wrong direction of rotation
2. A ruptured suction line
3. Insufficient priming
4. Each of the above

3-44. A centrifugal pump is operating at a lower capacity than it should and sometimes fails to deliver any liquid. What condition is the probable cause of this trouble?

1. A shaft is bent
2. The stuffing box is packed too tightly
3. The discharge pressure is too low
4. There is air leakage

3-45. Which of the following conditions indicates that a motor-driven centrifugal pump is using too much power?

1. The speed of the pump decreases
2. The viscosity of the liquid being pumped decreases
3. The motor overheats
4. The stuffing box packing is loose

3-46. A vibrating and noisy pump could indicate a loss of suction. Which of the following actions should help you eliminate this possibility?

1. Checking the alignment
2. Priming the pump
3. Checking the foundation bolts
4. Checking the lubrication of the bearings

3-47. A constant-pressure pump governor on a turbine-driven pump has (a) what function that is accomplished in (b) what way?

1. (a) Controls the amount of steam discharged from the driving turbine
   (b) by regulating the pressure
2. (a) Controls the pump discharge pressure
   (b) by regulating the pressure
3. (a) Controls the pump discharge pressure
   (b) by controlling the amount of steam admitted to the driving turbine
4. (a) Controls the amount of steam discharged from the driving turbine
   (b) by controlling the amount of steam admitted to the driving turbine

3-48. Constant-pressure governors differ mainly by the size of what components?

1. The crosshead connecting rods
2. The operating pistons
3. The indicator plates
4. The upper diaphragms

3-49. The speed of the driving turbine increases under which of the following conditions?

1. The governor operating piston moves up
2. The lower diaphragm moves down
3. The fluid pressure against the upper diaphragm increases
4. The steam to the controlling valve decreases

3-50. As the speed of the turbine increases, what force initiates the action to reduce the steam supply to the operating turbine?

1. The discharge pressure
2. The operating piston movement
3. The intermediate diaphragm
4. The steam chamber pressure

3-51. The top of the intermediate diaphragm of the pump governor will function at the required pressure because of a continuous supply of steam at the required pressure that is supplied by which of the following components?

1. The turbine
2. The crosshead
3. The controlled valve
4. The steam chamber

3-52. The automatic shutdown device is essentially a constant-pressure governor equipped with which of the following devices?

1. A steam chamber
2. A crosshead
3. A pull open device
4. A special top cap

3-53. Steam is supplied to the controlling valve of the automatic shutdown device through what component?

1. A port
2. An auxiliary pilot valve
3. A needle valve
4. A main feed valve

3-54. Aboard ship, which of the following pumps will most likely be a propeller-type pump?

1. A hydraulic transmission pump
2. A main condenser circulating pump
3. A steering engine pump
4. A fuel booster pump

3-55. Propeller pumps are used primarily where there is a large volume of liquid, but their use is usually limited to what total amount of head?

1. 50 to 70 feet
2. 20 to 30 feet
3. 30 to 50 feet
4. 40 to 60 feet

3-56. Which of the following terms is/are used to classify reciprocating pumps?

1. High or low pressure
2. Direct or indirect drive
3. Steam or electric driven
4. Direction of rotation

3-57. In a reciprocating pump, the term *direct acting* indicates that the pump has which of the following characteristics?

1. A cam between the piston and the pump plunger
2. A single pump rod connecting the piston and the pump plunger
3. A water chest directly mounted to the pump
4. A one-piece piston and pump plunger

3-58. A reciprocating pump designated as a 14 x 12 x 18-inch pump has which of the following characteristics?

1. An 18-inch diameter piston
2. A 12-inch diameter plunger
3. A high-pressure pump
4. A low-pressure pump

3-59. What component of a reciprocating pump admits steam to the cylinder?

1. The valve operating assembly
2. The crosshead arm
3. The pump rod
4. The pilot valve operating rod

3-60. What part of a reciprocating pump controls the position of the pilot valve?

1. The moving tappet
2. The adjustable tappet collar
3. The stay rod
4. The main piston in the steam cylinder

3-61. On a reciprocating pump, the moving tappet slides down the pilot valve operating rod until it comes in contact with what component?

1. The link
2. The adjustable tappet collar
3. The moving tappet
4. The crosshead

3-62. Before examining or repairing a reciprocating pump, you should first take which of the following actions?

1. Mark the piston stroke adjustment
2. Take micrometer and caliper measurements of the valve cylinders
3. Study all available data on the pump including blueprints and drawings
4. Dismantle the suction end of the pump

ASSIGNMENT 4

Textbook Assignment: "Pumps (continued)" and "Heat Exchangers and Air Ejectors," chapters 5 and 6, pages 5-18 through 6-19.

4-1. Variable stroke pumps are commonly used as part of electrohydraulic transmissions and in which of the following systems?

1. Lube oil
2. Steering gear
3. Fuel oil
4. Salt water

4-2. Normally, a variable-stroke axial-piston pump has what total number of single-acting pistons?

1. 3 or 5
2. 5 or 7
3. 7 or 9
4. 9 or 11

4-3. An odd number of pistons are used in most variable-stroke axial-piston pumps for which of the following reasons?

1. To keep down the size of the pump
2. To maintain axial alignment
3. To prevent pulsations in the discharge flow
4. To prevent the pump from becoming air bound

4-4. The tilting box of a variable-stroke axial-piston pump is at right angles to the shaft while the pump is rotating. Which of the following conditions exists?

1. The pistons are reciprocating
2. The B-end cylinder barrel is rotating
3. No liquid is being pumped
4. Power is being transmitted hydraulically

IN ANSWERING QUESTION 4-5, REFER TO FIGURE 5-14 IN THE TEXTBOOK.

4-5. The tilting box on the B-end is installed in what configuration?

1. Free to tilt in one direction only
2. Free to tilt in either direction
3. In a fixed position vertical to the shaft
4. In a permanent fixed angle to the shaft

4-6. In variable-stroke radial-piston pumps, both the direction and amount of fluid flow are determined by the relative position of which of the following parts?

1. The pump shaft relative to the central valve
2. The horizontal ports
3. The pump shaft and couplings
4. The cylinder body relative to the float ring

4-7. A variable-stroke radial-piston pump functions when what part is moved off center?

1. The nonrevolving ring
2. The floating ring
3. The cylinder body
4. The central cylindrical valve

4-8. Increasing the speed of rotary pumps above the rated speed will cause which of the following effects?

1. Loss of suction
2. Increased clearances
3. Decreased clearances
4. Decreased slippage

4-9. What characteristic of a herringbone pump makes the discharge pressure steadier than that of a simple gear pump?

1. The clearance between the gear teeth and the casing is smaller
2. The gear teeth are smaller
3. One discharge phase starts before the previous discharge phase is completed
4. It has four spur gears while the simple gear pump has two

4-10. The helical gear pump has what advantage over the simple gear pump?

1. It maintains a steadier speed
2. It delivers liquids over greater distances
3. It operates for longer periods of time
4. It produces an increased capacity without sacrificing a smoother discharge flow

4-11. Liquid is kept from leaking at the shaft of a helical gear pump by which of the following features?

1. Overlapping spaces between gear teeth
2. A roller bearing
3. A stuffing box
4. Large gear teeth

4-12. In a lobe-type rotary pump, which of the following parts prevent wear on the lobe ends?

1. Gibs
2. Spur gears
3. Casing seals
4. Liner plates

4-13. What is the main difference in the various types of screw pumps?

1. The thickness of the screws
2. The pitch of the screws only
3. The number and pitch of the screws
4. The material of the screws

4-14. The liquid is discharged from which of the following parts of a screw pump?

1. The top
2. The bottom
3. Both 1 and 2 above
4. The middle

4-15. What unique feature does an eductor pump have?

1. A discharge end that is larger than the suction end
2. A retractable crank handle
3. A lack of moving parts
4. A rotating plunger

4-16. In modern ships, what type of pump is the primary means of dewatering spaces?

1. Main circulating
2. Eductor
3. Fire and bilge
4. P-500

4-17. The operation of an eductor is basically the same as which of the following components?

1. An air ejector nozzle assembly
2. A main engine loop seal
3. A gland exhauster
4. A centrifugal pump

4-18. Labyrinth steam seals are used on turbines and the annular space between the two sealing elements in each packing gland is connected to the leak-off connection. What total number of spring-loaded sections are used to form a steam seal?

1. One
2. Two
3. Three
4. Four

4-19. The combined exhaust and relief valve functions with an inlet pressure up to 50 psig and an outlet pressure up to 35 psig. What is the maximum designed steam pressure for this valve?

1. 600°F
2. 700°F
3. 800°F
4. 900°F

4-20. Blower governors control the blower speed by throttling the turbine inlet steam valve. What type of governor is used for this purpose?

1. Centrifugal ball weight
2. Horizontal bucket
3. Centrifugal flyweight
4. Horizontal flyweight

4-21. The rate of heat transfer is fastest per unit of time between which of the following objects or substances?

1. Iron at 200°F and a metal sheet at 150°F
2. A brick at 200°F and a block of ice at 32°F
3. Ice and salt water at 35°F
4. Boiling water and a steel rod at 230°F

4-22. Heat exchangers are classified by which of the following factors?

1. Construction features
2. Path of heat flow
3. Relative direction of fluid flow
4. Each of the above

4-23. Which of the following is a direct-contact heat exchanger?

1. A deaerating feed tank
2. A lube oil cooler
3. An air ejector condenser
4. An air cooler

4-24. The return band type of heat exchanger has which of the following distinctive features?

1. Coils of tubing
2. Pairs of flat oblong strips
3. One tube inside another
4. U-shaped tubes in one tube sheet

4-25. The helical tube-type heat exchanger has which of the following distinctive features?

1. Pairs of flat oblong strips
2. Coils of tubing
3. One tube inside another
4. U-shaped tubes in one tube sheet

4-26. The double-tube type of heat exchanger has which of the following features?

1. U-shaped tubes in one tube sheet
2. One tube inside another
3. Pairs of oblong strips
4. Coils of tubing

4-27. A condenser changes a gas to a liquid by causing the gas to

1. gain sensible heat
2. lose its latent heat
3. gain latent heat
4. lower the rate of heat flow

4-28. After leaving the bottom of the main condenser, the condensate flows into which of the following components?

1. The circulating pump
2. The auxiliary cooling water pump
3. The hot well
4. The overboard discharge valve

4-29. In a main condenser that is operating on scoop injection, the flow rate of the cooling water is controlled by what means?

1. The main circulating pump
2. The auxiliary cooling water pump
3. The forward speed of the ship
4. The flow rate valve

4-30. When the circulating pump is operating, what is the function of the large swing-check valve on the main injection line?

1. To permit water to flow through the pump
2. To permit water to flow through the main injection line
3. To prevent backflow of water through the pump
4. To prevent backflow of water through the main injection line

4-31. Main condensers equipped with scoop injection are of what type?

1. Curved-tube, single-pass
2. Straight-tube, single-pass
3. Straight-tube, double-pass
4. Curved-tube, double-pass

4-32. What part of a main condenser serves as a divider between the saltwater circuit and the vapor-condenser circuit?

1. The baffle arrangement
2. The strainer bars
3. The tube sheet
4. The Monel metal plates

4-33. What part of a main condenser collects the condensate as the steam condenses on the tube?

1. The receiving tray
2. The hot well
3. The air baffles
4. The condensate pump

4-34. Air and steam mixtures are separated in main condensers by what component(s)?

1. Air ejectors
2. Baffle arrangements
3. A receiving tray
4. Strainer bars

4-35. In a properly operating single-pass main condenser, the overboard temperature should have what relationship to the injection temperature?

1. Higher
2. Lower
3. Alternately higher and lower
4. Approximately the same

4-36. Which of the following problems may cause a condenser to function improperly?

1. Air is not being properly removed from the condenser
2. An air leakage exists in the condenser
3. The condensate level remains excessively high
4. Each of the above

4-37. If the condensate level in the main condenser is allowed to rise to the bottom row of tubes, which of the following problems will occur?

1. A gradual loss of vacuum
2. A rapid loss of vacuum
3. A loss of condensate pressure
4. A clogging of the air ejector nozzle

4-38. For a temporary repair of air leakage at a flange joint of a condenser, which of the following methods should you use?

1. Apply shellac to the flange
2. Apply Devcon to the flange
3. Drive a soft wood wedge into the flange at the point where the air is entering
4. Wrap the faulty flange with rags

4-39. Although a lighted candle is sometimes a satisfactory device for locating air leaks in a condenser, a more reliable method is to coat the suspected area with (a) what substance while the condenser is under (b) what vacuum or pressure?

1. (a) Shellac (b) vacuum
2. (a) Shellac (b) pressure
3. (a) Soapsuds (b) pressure
4. (a) Soapsuds (b) vacuum

4-40. Boiling out the steam side of a condenser to remove grease and dirt is usually done at what minimum interval?

1. 1 to 2 years
2. 6 to 9 weeks
3. 3 to 6 weeks
4. Each overhaul cycle

4-41. The seawater side of the condenser tubes may be cleaned by which of the following methods?

1. Force soft rubber plugs through the tubes by means of compressed air
2. Scrub the tubes with a rotating bristle brush
3. Push an air lance through the tubes
4. Each of the above

4-42. If the seawater side of a main condenser is not layed up properly, which of the following problems may result?

1. Oxidized turbine blading
2. Reduced heat transfer of the tubes
3. Increased heat transfer of the tubes
4. A bowed turbine rotor

4-43. A chloride buildup in the steam generator of a newly constructed conventional propulsion plant indicates what condition?

1. Poor ventilation of the seawater side of the condenser
2. Excessive foreign matter deposits on the condenser tube walls
3. Poor water circulation in the steam side of the condenser
4. Seawater leakage in the active condenser tube lengths between the tube sheet

4-44. In the interest of safety when a loss of vacuum occurs in a hot condenser, you should take which of the following actions?

1. Increase the pressure in the seawater chest
2. Close all sea connections
3. Partly close the sea suction-line valve
4. Secure exhausting to the engine

4-45. Which of the following safety precautions applies to steam condensers in the engineering plant?

1. Keep at least 15 psig pressure in the seawater chest
2. Avoid metal contact with the zincs
3. Keep air pressure in the saltwater sides of the condensers that are in use
4. Ensure that no open flame or sparking object is near a freshly opened condenser

4-46. Personnel may enter the seawater side of a newly opened condenser only after which of the following safety precautions have been taken?

1. It must be inspected by the engineer officer
2. It must be tested and certified safe by the gas free engineer
3. It must be washed out with fresh water
4. It must be blown out with steam or air

4-47. The DFT serves which of the following purposes?

1. To cool the feedwater
2. To store the feedwater
3. To remove the chloride from the feedwater
4. To add oxygen to the feed water

4-48. What is the purpose of the spring-loaded poppet valves in the DFT?

1. To form the condensate into a conical spray
2. To form the steam into a conical spray
3. To remove gas from the steam
4. To remove gas from the condensate

4-49. Water is removed from the collection cone of the DFT by what means?

1. Eductor action
2. Gravity
3. Booster pump suction
4. Condensate pump suction

4-50. Initial deaeration takes place in what part of the DFT?

1. The gas collection chamber
2. The baffle section
3. The storage compartment
4. The spray chamber

4-51. During DFT operation, you should maintain the proper water level for which of the following reasons?

1. Steam and water will not mix properly unless the tank is at least 3/4 full
2. Excessive water will prevent the efficient removal of air
3. With insufficient water, damage to the main feed pumps and boilers may result
4. Both 2 and 3 above

4-52. The check valve installed in the auxiliary exhaust supply to the DFT serves which of the following purposes?

1. To meter the flow of exhaust
2. To prevent water from entering the exhaust line
3. To prevent exhaust from entering the condensate
4. To allow for a quick securing of the DFT

4-53. Normally, the main lube oil cooler is a counterflow type. The term *counterflow* refers to which of the following functions?

1. The oil and the cooling water flow in opposite directions
2. The oil and the cooling water flow in the same direction
3. The oil flows horizontally
4. The oil flows vertically

4-54. The three-way valve in the oil line of a turbogenerator oil cooler acts as a bypass for what component?

1. The strainer
2. The heater
3. The cooler
4. The pump

4-55. Which of the following heat exchangers has tubes with fins?

1. A main condenser
2. A turbogenerator lube oil cooler
3. A pump lube oil cooler
4. A generator air cooler

4-56. What is the purpose of the main air ejector?

1. To remove air and noncondensable gases from the condensate
2. To remove air and noncondensable gases from the main condenser
3. To cool the condensate before it enters the DFT
4. To control the temperature of the condensate going to the DFT

4-57. An air ejector is what type of pump?

1. Centrifugal
2. Reciprocating
3. Jet
4. Propeller

4-58. Two sets of nozzles and diffusers are installed in a main air ejector for what reason?

1. To have a standby set
2. To allow for efficient operation
3. To maintain vacuum
4. To preheat the condensate

4-59. Condensate formed in the intercondenser is discharged to (a) what component through (b) what part of the unit?

1. (a) The aftercondenser (b) the second stage
2. (a) The main condenser (b) the loop seal line
3. (a) The aftercondenser (b) the loop seal line
4. (a) The main condenser (b) the second stage

4-60. When the ship is cruising at low speeds, what means is used to provide adequate cooling?

1. The condensate is recirculated
2. The condensate pump is energized
3. The auxiliary steam-air mixture is pumped to the main condenser
4. The seawater is cut into the air ejector

4-61. A loss of vacuum in the main condenser is indicated by which of the following conditions?

1. The vacuum is equalized between the main condenser and the air ejector intercondenser
2. The vacuum is equalized between the intercondenser and the aftercondenser of the air ejector
3. The condensate has lost suction
4. The condenser hot well is dry

4-62. If an air ejector is not operating properly, which of the following problems is a probable cause?

1. The DFT is low on water
2. The air ejector has a fouled nozzle
3. The intercondenser is draining to the main condenser
4. The aftercondenser is draining to the low-pressure drain system

4-63. Before admitting steam to a nozzle of an air ejector, you should take which of the following actions?

1. Open the suction valve
2. Close the discharge valve
3. Open the discharge valve
4. Close the loop seal valve

4-64. After making major repairs to an air ejector unit, you should take which of the following actions?

1. Wash it down with hot soapy water
2. Perform a hydrostatic test
3. Operate it for 2 hours before taking a suction on the condenser
4. Boil out the intercondensers and aftercondensers

4-65. Which of the following devices helps to deliver pure water to the boiler?

1. The economizer
2. The condenser
3. The water drum
4. The morpholine injection pump

4-66. A low pH in the condensate causes which of the following problems in the piping?

1. Corrosion
2. Leaking
3. Stretching
4. Flexing

4-67. Which of the following is a purpose of the demineralizer unit?

1. To treat the condensate
2. To treat the makeup feedwater
3. To clean the condenser
4. To clean the boiler

4-68. Which of the following is a purpose of the demineralizer unit?

1. To reduce sludge buildup in the boiler water
2. To eliminate the use of blowdowns
3. To reduce the chance of low boiler water
4. To eliminate the need for boiler water testing

4-69. In the demineralizer, the resin must be changed when what condition occurs?

1. The low-pressure drains back up
2. The main condenser loses vacuum
3. The makeup feedwater conductivity quicklyrises above 1.0 micromho/cm
4. The condensate's conductivity quickly rises above 1.0 micromho/cm

ASSIGNMENT 5

Textbook Assignment: "Engineering Operations" and "Engineering Administration," chapters 7 and 8, pages 7-1 through 8-20.

5-1. Which of the following statements describes the EOSS?

1. It is a group of general procedures that covers all ships of the same class
2. It details the sequential operational functions for the complete cycle of plant evolutions in a specific ship
3. It includes PMS and PQS
4. It improves everything except watch standing

5-2. Which of the following information is contained in the Engineering Operational Casualty Control (EOCC)?

1. Watch qualifications
2. Casualty symptoms
3. Casualty reporting to the type commander
4. Casualty reports to BUMED

5-3. Which of the following is part of your engine room watch duties?

1. Read or interpret measuring instruments
2. Find out the night orders after relieving the watch
3. Operate a defective piece of equipment
4. Make notes of gear adrift

5-4. Before you are relieved of your watch, your relief has which of the following responsibilities?

1. To be in the proper uniform
2. To know the general orders
3. To know the ship's destination
4. To know the status of the plant

5-5. When preparing a steam propulsion plant for light-off, you will normally take what step first?

1. Open the funnel drains in the main steam line
2. Measure the cold turbine rotor positions
3. Reseat the throttle valves slightly
4. Open the hand-operated nozzles

5-6. Before turning the main engine with steam, you must ensure that the lube oil has reached what minimum temperature?

1. 50°F
2. 70°F
3. 90°F
4. 100°F

5-7. You must put the turning gear in operation before you take which of the following actions?

1. Admit steam to the sealing glands
2. Admit oil to the bearings
3. Check the axial clearance of the rotor
4. Unseat the throttle valves for the first time

5-8. Admitting steam to the turbine casing or glands when the rotor is stationary is likely to cause which of the following problems?

1. Distortion of the rotor
2. Damage to the gland packing
3. Contamination of the lubricating oil
4. Water hammer in the steam lines

5-9. What person must give permission to spin the main engines?

1. The commanding officer
2. The operations officer
3. The officer of the deck
4. The damage control officer

5-10. When standing by with the jacking gear engaged, which of the following actions should you take?

1. Open the guarding valve five turns
2. Spin the main engines every 3 minutes
3. Secure the first stage of the main air ejector
4. Secure the lube oil service pump

5-11. When a turbine is in operation, 1/2 to 2 psi of steam pressure is maintained on the glands for what reason?

1. To eliminate the need for a vacuum
2. To keep air from leaking into the turbine
3. To increase the pressure and/or vacuum within the turbine
4. To prevent steam leakage at the astern throttle

5-12. When a ship is under way, the temperature of the lube oil cooler should be maintained within what range?

1. 90°F to 100°F
2. 100°F to 110°F
3. 110°F to 120°F
4. 120°F to 130°F

5-13. If the rotor's axial movement is allowed to exceed the safe limits, damage will occur to which of the following parts?

1. The stationary blades
2. The main thrust bearing
3. The quill shaft
4. The convergent nozzles

5-14. Which of the following conditions indicates that water is entering a lube-oil system?

1. An increase in oil pressure
2. A decrease in oil temperature
3. A rise in the oil sump level
4. A drop in the oil sump level

5-15. Large quantities of cold water in the deaerating feed tank may cause which of the following casualties?

1. A temporary loss of a main engine
2. A gain of pressure in the tank
3. A loss of main feed pressure
4. A sudden demand for feedwater for the boilers

5-16. After the plant is secured, the main circulating pump is normally left running until which of the following conditions has been met?

1. The turbine bearing temperature is near ambient
2. The exhaust trunk temperature is near ambient
3. The rotor position indicator returns to normal
4. It is no longer needed to condense turbine steam

5-17. If vacuum is broken on the main engine by securing the gland seal, which of the following parts may be damaged?

1. The condenser tubes
2. The turbine bearings
3. The relief valve
4. The turbine glands

5-18. What is the best form of casualty control?

1. Casualty prevention
2. Effective organization
3. Minimizing the casualty
4. Restoring the casualty

5-19. Which of the following sources is best for studying casualty control?

1. The training manual
2. The Watch, Quarter, and Station Bill
3. The EOCC
4. The *NSTM*

5-20. What is one of the major problems in dealing with casualty control?

1. Communications
2. Combating the casualty
3. Cross-connecting the plant
4. Changing equipment

5-21. Under normal steaming conditions, you will stop and lock the shaft immediately for which of the following conditions?

1. A loss of vacuum
2. A hot bearing
3. An uncontrollable hot bearing
4. A turbine vibration

5-22. You can reduce the chance of an engine room fire by taking which of the following precautions?

1. Keep flange shielding properly installed
2. Replace oil-soaked lagging
3. Keep the bilge oil free
4. All of the above

5-23. Which of the following types of checks should you perform before the boiler is lit off?

1. Boiler water high and low alarm checks
2. Steam drum pressure gauge checks
3. Hot plant checks
4. Cold plant prelight-off checks

5-24. Cold plant checks are conducted according to the EOP and should include which of the following items?

1. Safety walkthroughs
2. Safety valve hand-easing gear
3. Remote-operating gear for valves
4. Each of the above

5-25. What device should you use to verify that the boiler deck is clear of unburned fuel before inserting a torch?

1. A BOD
2. A BID
3. A DIB
4. A BED

5-26. To accomplish a boiler purge, you are required to make what total number of volumetric air changes of the boiler furnace, uptake, and smoke pipe?

1. Six
2. Five
3. Three
4. Four

5-27. After completion of a purge, you must purge the boiler again if fires are not lit off within what specified number of minutes?

1. 5
2. 2
3. 3
4. 4

5-28. What total number of persons are required during a burner light off?

1. One
2. Two
3. Three
4. Four

5-29. During initial burner light off, the torch man should wear which of the following equipment?

1. Fire-retardant engineering coveralls
2. Eye shields
3. Gloves
4. All of the above

5-30. You have shut the burner fuel oil supply manifold valve and safety shutoff device because the ignition failed to occur within 3 seconds after burner light off. What step, if any, should you take next?

1. Make sure the fuel-oil recirculating valve is closed
2. Determine the reason for the unsuccessful ignition and correct it
3. Increase the fuel-oil manifold pressure
4. None; you do not have to take corrective action until the burner fails to ignite three times

5-31. Unless authorized, the boiler firing rate should not exceed what percentage of full power until the boiler is on line?

1. 1%
2. 5%
3. 3%
4. 10%

QUESTIONS 5-32 THROUGH 5-34 REFER TO PLACING A BOILER ON LINE.

5-32. What action should you perform when the steam drum pressure reaches 50 psi?

1. Open the main and auxiliary steam stop
2. Blow down the gauge glass
3. Shift the superheater from the low-pressure drain to the high-pressure drain
4. Bring the boiler on line

5-33. When the drum pressure reaches 200 psi, what action should you take?

1. Blow down the gauge glass
2. Shift the main and auxiliary drains to HP
3. Open the main bypass
4. Open the auxiliary bypass

5-34. The steam drum pressure is between 200 and 400 psi. What action should you take next?

1. Blow down the gauge glass
2. Bring the boiler on line
3. Open the main bypass
4. Open the auxiliary bypass

5-35. If a boiler casualty has occurred, you may be required to perform which of the following tasks?

1. Cross-connect the plant
2. Split the plant
3. Drain the steam lines
4. Each of the above

5-36. Properly maintained operating logs can provide which of the following information?

1. Information on a piece of equipment that is not operating properly
2. The ship's schedule
3. Your PQS requirements
4. The requirements for general quarters

5-37. If an operating log has one of the readings out of limits, which of the following actions should you take?

1. Circle the reading in red
2. Call the commanding officer
3. Mark through the reading
4. Circle the reading in black

5-38. What records in the engineering department are considered to be legal records?

1. The evaporator and ac logs
2. The main engine and boiler logs
3. The air compressor and generator logs
4. The Engineering Log and Engineer's Bell Book

5-39. The Engineering Log and the Engineer's Bell Book should be retained on board a ship for what minimum number of years?

1. 1
2. 2
3. 3
4. 4

5-40. A ship has been placed on inactive status. What is done with the Engineering Log and Engineer's Bell Book sheets that are less than 3 years old?

1. They are destroyed
2. They are retained on board the ship
3. They are sent to the Naval Records Management Center
4. They are sent to the Naval Sea Data Support Activity

5-41. Which of the following information is entered in the Engineering Log?

1. The ship's horsepower
2. The miles steamed during each watch
3. The amount of fuel on board before getting underway
4. The equipment out of commission in the engineering department

5-42. Injuries to engineering department personnel should be recorded in which of the following logs?

1. The fireroom operating log
2. The Engineering Log
3. The Engineer's Bell Book
4. The rough log

5-43. Entries in the Engineering Log should be made according to instructions contained in what *NSTM* chapter?

1. 220
2. 221
3. 090
4. 041

5-44. Which of the following officers approves and signs the Engineering Log on the last day of each month?

1. The commanding officer
2. The executive officer
3. The engineer officer
4. The engineer duty officer

5-45. Orders received by the throttleman for movement of the ship's propellers are recorded in which of the following logs?

1. The Engineering Log
2. The Engineer's Bell Book
3. The Engine Room Operating Log
4. The Fireroom Operating Log

5-46. The time that an order was received is recorded in what column of the Engineer's Bell Book?

1. 1
2. 2
3. 3
4. 4

5-47. The EOOW signs the Engineer's Bell Book before going off watch. What person signs the Engineer's Bell Book in machinery spaces where an EOOW is not stationed?

1. The commanding officer
2. The executive officer
3. The engineer officer
4. The watch supervisor

5-48. If there is an incorrect entry in the Engineer's Bell Book, what action is taken to correct it?

1. A single line is drawn through the incorrect entry and the correct entry is recorded on the following line
2. Two lines are drawn through the incorrect entry and the correct entry is recorded above the incorrect entry
3. The incorrect entry is erased and the correct entry is recorded on the same line
4. The correct entry is written on top of the incorrect entry

5-49. Which of the following information is contained in the steaming orders?

1. The time to light off the condensate pump
2. The time to light off boilers
3. The name of the commanding officer
4. The name of the lower-level watch

5-50. The engineer's night order book is filled out according to whose instructions?

1. The CNO
2. The TYCOM
3. The commanding officer
4. The operations officer

5-51. A piece of equipment is put out of commission. What action should be taken before repair of the equipment can begin?

1. Isolate and tag out the piece of equipment
2. Notify the commanding officer
3. Submit OPNAV Form 4790/20
4. Request permission from the OOD to begin work

5-52. Equipment tagged with a CAUTION tag may be operated as long as there is no danger to personnel.

1. True
2. False

5-53. Equipment tagged with a DANGER tag may be operated as long as there is no danger to personnel.

1. True
2. False

5-54. What person specifies the number of tag-out logs needed and their location?

1. The CNO
2. The individual force commander
3. The commanding officer
4. The engineer officer

5-55. Before starting the tag-out procedure, the authorizing officer must get permission from what person?

1. The type commander
2. The commanding officer
3. The chief in charge of the space
4. The supervisor of the space

5-56. When repairs have been completed on a piece of equipment that was tagged with a DANGER tag, which of the following actions must be taken before it can be tested?

1. The work request must be completed
2. The tag must be properly cleared and removed
3. Clear the piece of equipment from the out-of-commission log
4. Warm up the system

5-57. What two systems basically make up the 3-M Systems?

1. The Planned Maintenance System (PMS) and the Maintenance Data System
2. The EOSS and propulsion operating systems
3. The PQS and the PMSsystems
4. The EOSS and the PMS

5-58. What does PMS dictate?

1. The maximum required maintenance to keep a piece of equipment in a fully operational condition within specifications
2. The minimum required maintenance to keep a piece of equipment in a fully operational condition within specifications
3. The Q-1 can only be performed once a quarter
4. The amount of time required to complete a repair

5-59. PMS is what type of maintenance?

1. Corrective
2. Preventive
3. Calculated
4. Instructional

5-60. Ship's force personnel may make which of the following changes to the MRC without submitting a feedback report?

1. The man-hours required to do the job
2. The rate required to do the job
3. The safety precautions related to the job
4. The tools required to do the job

5-61. In order for PMS to produce good results, which of the following actions must be taken?

1. Continuous direction at each echelon must be maintained
2. The machinery must be corrected when time permits
3. All personnel must make the required changes to the quarterly board
4. All casualties must be corrected immediately

5-62. What OPNAV form is used to request PMS software?

1. 4790/2K
2. 4790/2Q
3. 4790/7B

5-63. Where does OPNAV Form 4790/2K originate?

1. The captain's office
2. The engineer's office
3. The work center
4. The 3-M coordinator's office

5-64. What is the purpose of the current ship's maintenance project (CSMP)?

1. To provide a consolidated list of deferred corrective maintenance
2. To provide a list for preparing the ship bills
3. To serve as a management tool for PMS
4. To serve as a management tool for PQS

5-65. The QA Program organization (Navy) begins with which of the following officers?

1. Type commanders
2. Commander in chief of the fleet
3. Commanding officers
4. QA officer

5-66. Which of the following officers provide instruction, policy, and overall direction for the implementation and operation of the force QA Program?

1. Commander in chief of the fleets
2. Commanding officers
3. Type commanders
4. Both 2 and 3 above

5-67. The QA officer is responsible to which of the following officers for the organization, administration, and execution of the ship's QA Program?

1. Type commander
2. Commander in chief of the fleets
3. Commanding officer
4. Each of the above

5-68. Which of the following is a responsibility of the QA officer?

1. Coordinating the ship's QA training program
2. Maintaining ship's records and for test and inspection reports
3. Conducting QA audits as required
4. Each of the above

5-69. Which of the following persons is/are assigned as the ship's quality control inspectors (SQCIs)?

1. The division officer
2. The engineer officer
3. The work center supervisor and two others
4. The 3-M coordinator

5-70. Level A assurance provides which of the following levels of assurance?

1. The most stringent restrictive verification
2. The least verification
3. Limited verification
4. Minimum verification

5-71. Level B assurance provides which of the following levels of assurance?

1. Minimum verification
2. Most restrictive verification
3. No verification
4. Adequate verification

5-72. Level C assurance provides for which of the following levels of assurance?

1. Minimum verification
2. Limited verification
3. No verification
4. Most stringent verification

5-73. Which of the following devices are included in the MEASURE program?

1. HP cutout switches
2. Motor controllers
3. Gauges
4. Bearings

5-74. Which of the following actions is/are reported by a meter card?

1. Bearing readings
2. Gauge calibration
3. Pump test
4. Trials

5-75. In the MEASURE program, what is the purpose of the Format 802?

1. To report out-of-commission gauges
2. To record gauge calibrations
3. To recall gauges for calibration
4. To report gauge serial number changes

ASSIGNMENT 6

Textbook Assignment: "Engineering Administration" and "Steam Operated Distilling Plants," chapters 8 and 9, pages 8-20 through 9-25.

6-1. Heat stress can be controlled somewhat by taking which of the following actions?

1. Running exhaust vents on low
2. Repairing steam and hot water leaks
3. Closing all exterior hatches
4. Soaking the lagging with cold water

6-2. Hearing protection must be worn where the noise level is above what minimum number of decibels?

1. 55 dB
2. 64 dB
3. 78 dB
4. 84 dB

6-3. Lube-oil management procedures are outlined in what *NSTM* chapter?

1. 262
2. 505
3. 541
4. 543

6-4. Samples of lube oil should be representative of the oil to be tested. The most representative samples are obtained from what source?

1. The outlet side of the lube-oil cooler
2. The lube-oil purifier
3. An operating system
4. An idle system

6-5. You have just taken an oil sample. To prevent contamination, what action should you promptly take with all the containers?

1. Cap or close them
2. Empty them into other containers
3. Place them in a dust-free space
4. Heat them

6-6. What information should be recorded on lube-oil sample bottles?

1. Equipment, oil type, date, and time
2. Equipment, oil type, date, and test results
3. Oil type, test results, date, and time
4. Time, equipment. date, and lube-oil temperature

6-7. What is the purpose of visually inspecting a lube-oil sample?

1. To determine the presence of carbon
2. To determine the percentage of free water
3. To determine the presence of free water and solid particulate matter
4. To determine the presence of salt water

6-8. The transparency test is conducted only on auxiliary machinery oil samples that have failed what criteria?

1. Clean and water-free
2. Water-free and bright
3. Clear and bright
4. Bright and smooth

6-9. Which of the following procedures must be conducted on all lube-oil samples that fail the transparency test run on auxiliary machines?

1. BS&W test
2. Hot oil bath
3. Dilution test
4. API gravity test

6-10. If lube oil is contaminated with salt water, you should take what action?

1. Renovate it
2. Transfer it to a settling tank
3. Dispose of it
4. Pump it overboard

6-11. Which of the following statements describes the term *viscosity*?

1. The highest temperature at which a fluid will flow
2. The lowest temperature at which a fluid will flow
3. The velocity at which a fluid will flow
4. The measure of resistance to flow

6-12. What is the most accurate method you can use to measure viscosity?

1. Observe the color of the liquid
2. Observe the slow flow of liquid through capillary tubes
3. Conduct an API gravity test
4. Conduct a BS&W test

6-13. A fuel will not form a flammable vapor-air mixture by evaporation if its temperature is below which of the following points?

1. Burn point
2. Conduction point
3. Flash point
4. Thermal energy point

6-14. What is the minimum flash point required for F-76 and JP-5 fuel?

1. 70°C
2. 60°C
3. 50°C
4. 40°C

6-15. The gravity of a petroleum oil is an index of the weight of a given volume of the material at what temperature?

1. 60°F
2. 55°F
3. 50°F
4. 40°F

6-16. What scales are used with petroleum products?

1. PHEL curves and specific gravity
2. API gravity and PHEL curves
3. SAE and API gravity
4. API gravity and specific gravity

6-17. Although water is slightly soluble in fuels, only water in mechanical suspension in the fuel is of practical interest to the engineer. This suspended water is referred to by which of the following terms?

1. Excess water
2. Insoluble water
3. Contaminated water
4. Free water

6-18. When a ship is receiving fuel, what person is responsible for ensuring that the stability of the ship isn't impaired?

1. The gas free engineer
2. The oil king
3. The senior damage controlman
4. The senior burnerman

6-19. If a sound rod is being used when oil is being received, the fuel oil tanks should be sounded every 3 or 4 minutes. After the tank is nearly three-fourths full, the soundings should be made at what specified interval?

1. Every minute
2. Every 2 minutes
3. Every 30 seconds
4. Continuously

6-20. Fuel oil tanks should be filled to what maximum level?

1. 65%
2. 75%
3. 85%
4. 95%

6-21. Where is the Fuel Oil Management Log prepared?

1. NETPDTC
2. NAVSUPSYSCOM
3. NAVPERS
4. Locally

6-22. The Fuel Oil Management Log should contain which of the following information?

1. A sequential listing of sample analyses
2. An operational procedure check-off list
3. Tank inspections and findings
4. All of the above

6-23. Fuel in ship stowage and service tanks must be tested according to the requirements in what *NSTM* chapter?

1. 220
2. 221
3. 503
4. 541

6-24. A steam-operated distilling plant produces distilled water from seawater by which of the following means?

1. By boiling the seawater and condensing the vapors
2. By boiling the fresh water and condensing the vapors
3. By filtering the seawater
4. By filtering the fresh water

6-25. Which of the following contaminants is NOT contained in fresh water produced by Navy distilling plants?

1. Vegetable and animal growths
2. Bacteria
3. Both 1 and 2 above
4. Slight traces of chemical salts

6-26. Distilling plants can separate volatile gases from distillate.

1. True
2. False

6-27. If there is salt water in the distillate from carryover, which of the following is the probable cause?

1. Faulty salinity cells
2. Leaks in the tube nests
3. Leaks in the basket
4. Improper plant operation

6-28. Carryover is undesirable for which of the following reasons?

1. The chemical salts will cause corrosion of the boiler tubes
2. Coliform bacteria may be present
3. The distillate is not sterilized
4. All of the above

6-29. Navy distillate plants are operated at low pressure and low boiling temperatures for which of the following reasons?

1. To prevent carryover
2. To increase efficiency
3. To sterilize the distillate
4. To keep down the size of the unit

6-30. Which of the following terms defines the first half of the distillation process?

1. Condensation
2. Evaporation
3. Feed
4. Distillate

6-31. Which of the following terms best describes the product of the separation of seawater into vapor?

1. Distillation
2. Evaporation
3. Feed
4. Distillate

6-32. Which of the following terms best describes the measure of the concentration of chemical salts?

1. Brine
2. Salinity
3. Effect
4. Evaporator feed

6-33. Which of the following terms describes any water in which the salt content is higher than it is in seawater?

1. Brine
2. Salinity
3. Effect
4. Evaporator feed

6-34. A stage in the distilling process where distillation actually occurs is known as

1. brine
2. salinity
3. effect
4. evaporator feed

6-35. Low-pressure distilling plants are termed *low pressure* for what reason?

1. They use low pressure only
2. They operate below atmospheric pressure
3. They use low-pressure steam, and their operating shell pressure is less than atmospheric pressure
4. There is low pressure on the feed

QUESTIONS 6-36 THROUGH 6-45 REFER TO SUBMERGED TUBE DISTILLING PLANTS.

6-36. What substance is contained in the evaporator?

1. Feed
2. Low-pressure steam
3. Brine
4. Distillate

6-37. In the soloshell evaporator, what device(s) control(s) the amount of steam admitted to the tubes?

1. Relief valves
2. A reducing valve
3. A drain regulator
4. An orifice

6-38. You can increase the output capacity by using which of the following means?

1. Install a bigger vapor condenser
2. Install a bigger vapor-feed heater
3. Increase the size of the weight-loaded reducer
4. Increase the size of the orifice plate

6-39. Before passing into the first-effect tube nest, low-pressure steam is subjected to what process?

1. Heating by steam from the 150-psi system
2. Superheating by a spray of water
3. Desuperheating by a spray of water
4. Volume reducing by increased steam pressure

6-40. Before entering the second-effect evaporator, vapor from the first-effect separator passes into what component(s)?

1. The first-effect drain regulator
2. The vapor feed heater
3. The boiler feed system
4. The freshwater tanks

6-41. What change takes place in the first-effect vapor that reaches the tube nests of the second-effect evaporator?

1. It gains latent heat of vaporization from the second-effect feed
2. It gains latent heat of vaporization from a second-effect steam supply
3. It loses its latent heat of vaporization to the second-effect feed
4. It loses its latent heat of vaporization to a second-effect steam supply

6-42. Vapor produced in the shell of the second effect passes through which of the following equipment?

1. Baffles
2. Demisters
3. Flash towers
4. Distillate tray

6-43. The first-effect vapor boils and vaporizes the seawater feed in the second-effect shell through which of the following actions?

1. Higher pressure in the first-effect shell than in the second-effect shell
2. Lower pressure in the first-effect shell than in the second-effect shell
3. Superheating vapor and distillate on entering the second-effect shell
4. Desuperheating vapor and distillate on entering the second-effect shell

6-44. After entering the first-effect shell, some of the feedwater is evaporated. The rest of the feedwater (brine) is forced into the second-effect shell by which of the following means?

1. Gravity
2. The condenser circulating pump
3. The pressure difference between the first effect and second effect
4. A tube nest drain pump

6-45. Vacuum in the shell of the second effect is maintained by what means?

1. The air ejector
2. The condensation of steam in the vapor feed
3. The cooling effect of carbon dioxide
4. The steam condensed by the evaporator feed

QUESTIONS 6-46 THROUGH 6-54 REFER TO FLASH-TYPE DISTILLING PLANTS.

6-46. The flash distilling plant has which of the following advantages over the submerged-tube distilling plant?

1. It can run with a lower vacuum; therefore, scale formation is reduced
2. It has no submerged heat transfer surfaces; therefore, scale formation is reduced
3. It requires less space
4. No operator is required

6-47. Feedwater for the distilling plant is preheated before it reaches the feedwater heater by passing through what component?

1. The distillate cooler
2. The first-effect tube nest
3. The first-stage distilling condenser
4. The second-effect tube nest

6-48. As feedwater passes through the evaporator feedwater heater, final heating occurs by which of the following means?

1. An electric heater
2. Auxiliary exhaust steam
3. High-pressure steam
4. Brine overflow

6-49. Heated feedwater enters the first-stage shell through the spray pipes in which of the following components?

1. The stage distilling condenser
2. The stage vapor separators
3. The bottom of the first-stage shell
4. The second-stage internal feed box

6-50. The moisture removed by the demisters of the first stage drains to what part of the unit?

1. The distillate of the first stage
2. The feed section of the first stage
3. The feed section of the second stage
4. The hotwell

6-51. In a two-stage flash evaporator, the two three-way solenoid trip valves are located at the

1. loop seal and the distillate pump
2. loop seal and the air ejector drain
3. distillate pump outlet and the air ejector drain
4. seawater heater drain and loop seal

6-52. If the maximum allowable salinity (usually 0.65 epm) of the distillate is exceeded, a salinity cell automatically trips the solenoid valve, dumping the contaminated water to the bilge. What is the location of the salinity cell?

1. In the inlet to the distillate pump
2. In the outlet from the distillate pump
3. In the inlet to the first-stage drain regulator
4. In the outlet to the feedwater heater drain pump

6-53. What is the maximum design feedwater temperature?

1. 75°F
2. 85°F
3. 165°F
4. 175°F

6-54. What means can be used to increase the capacity of a flash-type evaporator?

1. Increasing the volume of the feed to the first stage
2. Increasing the heat of the seawater by the feedwater heater
3. Decreasing the vacuum in the first stage
4. Decreasing the heat of the feedwater

QUESTIONS 6-55 THROUGH 6-59 REFER TO VERTICAL BASKET DISTILLING PLANTS.

6-55. Vertical basket distilling plants have what approximate capacity?

1. 4,000 gpd
2. 6,000 gpd
3. 8,000 gpd
4. 10,000 gpd

A. BASKET
B. DISTILLER CONDENSER
C. DISTILLATE OUTLET
D. DISTILLATE TROUGH
E. MAIN CONDENSER
F. MIST ELIMINATOR
G. PERFORATED PLATE

Figure 6A

IN ANSWERING QUESTIONS 6-56 THROUGH 6-58, REFER TO FIGURE 6A AND SELECT THE COMPONENT THAT IS DESCRIBED BY THE QUESTION.

6-56. The condensed steam in the bottom of the basket flows into this component.

1. C
2. D
3. E
4. F

6-57. This device acts as the first stage of moisture separation.

1. G
2. F
3. E
4. D

6-58. This device changes the vapor to distillate.

1. A
2. B
3. C
4. D

6-59. The steam condensed in the air ejector condenser drains into which of the following locations?

1. The main condenser or the LP drain tank
2. The LP drain tank or the condensate system
3. The condensate system or the feed system
4. The brine tank or the bilge

6-60. The evaporator distillate should be monitored by a salinity indicator at what minimum interval?

1. Hourly
2. Daily
3. Weekly
4. Continuously

6-61. What characteristic of water is actually measured by a salinity cell?

1. Density
2. Purity
3. Conductivity
4. Brine

6-62. If a distilling plant is operated with a high brine density, which of the following problems will occur?

1. Loss of vacuum in the unit
2. Excessive scale formation in the unit
3. Excessive brine pump discharge pressure
4. Excessive heat loss

6-63. What device should you use to measure brine density?

1. A salinity cell
2. A flow meter
3. A salinometer
4. A psychrometer

6-64. You should check a salinometer at what minimum interval?

1. Daily
2. Weekly
3. Monthly
4. Semiannually

6-65. Scale deposits on the evaporator tubes of a submerged-tube distilling plant will cause a reduction in output. This reduction becomes measurable when the deposits reduce the first-effect tube-nest vacuum to what amount?

1. 1 to 2 in.Hg
2. 4 to 6 in.Hg
3. 8 to 10 in.Hg
4. 12 to 14 in.Hg

6-66. A distilling plant uses seawater as feed. To keep the formation of hard scale to a minimum, which of the following conditions should be maintained?

1. Steam pressure above the orifice should not exceed 5 psi
2. A high vacuum
3. The brine density doesn't exceed 1.5 thirty-seconds
4. All of the above

6-67. Evaporator feed water is treated with Ameroyal to reduce what condition?

1. The rate of tube scaling
2. The amount of insoluble suspended matter
3. The quantity of soluble carbonates
4. The salt content of the feed

6-68. What is the correct injection rate for Ameroyal?

1. 1 pint per 4,000 gpd output
2. 1 pint per 10,000 gpd output
3. 1 pint per 12,000 gpd output
4. 2 pints per 12,000 gpd output

6-69. A duplex pump may be used to inject chemicals into two separate distilling plants when the plants meet which of the following conditions?

1. They are in different compartments
2. They vary in output by no more than 4,000 gpd
3. They are in separate compartments but have equal distilling capacity
4. They are equal in distilling capacity and are in the same compartment

6-70. If the proportioner pump fails, the operator feeds a chemical solution into the evaporator with a vacuum injection line and controls the flow by using which of the following components?

1. A standby pump
2. A feed control valve
3. An adjusting screw
4. A needle valve

6-71. After the tube nest has been removed from a submerged-tube evaporator, the tubes are cleaned mechanically by which of the following devices?

1. An electric torch
2. A feed control valve
3. An adjusting screw
4. A needle gun

6-72. Under what condition may the ship's force use hydrochloric acid to clean the evaporator?

1. When supervised by the engineer officer
2. When supervised by qualified shipyard personnel
3. When the plant is badly scaled
4. When the plant has been operated in contaminated waters

ASSIGNMENT 7

Textbook Assignment: "Piping Systems," chapter 10, pages 10-1 through 10-34.

7-1. Which of the following dimensions is important in the classification of tubular products?

1. Inside diameter (ID)
2. Outside diameter (OD)
3. Wall thickness
4. Each of the above

7-2. In the Navy, there is a distinction made between pipe and tubing based on dimensions. Under what condition is a tubular product known as tubing?

1. When identified by actual measured OD only
2. When identified by actual measured wall thickness only
3. When identified by actual measured OD and actual measured wall thickness
4. When identified by a nominal dimension

7-3. Which of the following measurements represents a nominal pipe size (NPS)?

1. 14.000 in.
2. 3.550 in.
3. 2.750 in.
4. 2.225 in.

7-4. Under what condition does the wall thickness schedule identify any one particular wall thickness?

1. When NPS is not specified
2. When the NPS is also specified
3. When the wall thickness is identified
4. When the wall thickness is not identified

7-5. Unions are used in piping systems for which of the following reasons?

1. To join two pipes so that they can be taken down for repairs or alterations
2. To join two pipes of unequal size
3. To provide a joint that will expand or contract with changes in temperature
4. To provide a joint that can withstand high pressure and heavy expansion strains

A. BOLTED FLANGE JOINTS

B. EXPANSION JOINTS

C. SILVER-BRAZED JOINTS

D. THREADED UNIONS

E. WELDED JOINTS

Figure 7A

IN ANSWERING QUESTIONS 7-6 THROUGH 7-9, REFER TO FIGURE 7A AND SELECT THE TERM DEFINED BY THE QUESTION.

7-6. These joints are used in subassemblies of piping systems, especially in high-pressure piping.

1. A
2. C
3. D
4. E

7-7. These joints are used because metal contracts and expands during changes in temperature.

1. A
2. B
3. C
4. D

7-8. These joints are the simplest pipe fitting and are not widely used except in low-pressure water piping systems.

1. A
2. B
3. C
4. D

7-9. One type of this type of joint is used extensively where piping is subject to high pressures and heavy expansion strains.

1. A
2. B
3. D
4. E

7-10. The expansion-contraction movement in the corrugated joints or bellows joints is absorbed by what means?

1. Installed expansion plates
2. The foundation bolts
3. The changing curvature of the corrugations or bellows
4. The foundation sliding feet

7-11. Expansion bends are used in which of the following types of steam piping?

1. High-pressure, high-temperature
2. High-pressure, low-temperature
3. Low-pressure, high-temperature
4. Low-pressure, low-temperature

7-12. What is the purpose of flange safety shields?

1. To reduce the possibility of a leak at a lube-oil pipe connection only
2. To reduce the possibility of a leak at a fuel-oil pipe connection only
3. To reduce the possibility of engine room fires casued by a leak at a fuel-oil or lube-oil pipe-flange connection
4. To reduce the possibility of a fire at the lube-oil connection

7-13. Valves used in high-pressure systems and suitable for temperatures above 550°F are made from what metal?

1. Steel
2. Cast iron
3. Copper
4. Brass

7-14. Normally, valves used in systems that carry salt water are made from what metal?

1. Steel
2. Copper
3. Bronze
4. Brass

A. GLOBE VALVE
B. GATE VALVE
C. BUTTERFLY VALVE
D. BALL VALVE

Figure 7B

IN ANSWERING QUESTIONS 7-15 THROUGH 7-18, REFER TO FIGURE 7B AND SELECT THE VALVE DEFINED BY THE QUESTION.

7-15. The common types of this valve include the straight-flow, angle-flow, and cross-flow.

1. A
2. B
3. C
4. D

7-16. These valves can be used in fresh water, sea water, JP-5 fuel, diesel fuel, and marine lube oil, and chill water systems aboard ship.

1. A
2. B
3. C
4. D

7-17. These valves are used when a straight line flow of fluid and minimum flow restriction are needed.

1. A
2. B
3. C
4. D

7-18. DELETED

7-19. Gate valves are suitable as throttling valves because they close in small increments.

1. True
2. False

7-20. Gate valves are classified as either rising stem or nonrising stem. Which of the following is a description of a nonrising-stem gate valve?

1. The gate is connected to the stem and moves with it
2. The gate is free floating
3. The gate travels up or down the stem on threads while the stem remains vertically stationary

7-21. Which of the following is a description of a butterfly valve?

1. This valve is recomended for throttling use
2. This valve is light-weight, relatively small, and relatively quick acting
3. This valve is heavy and has a slow reactance time
4. This valve is recommended for use in steam systems

7-22. The use of what type of gear to operate a ball valve allows the use of a relatively small hand-wheel and operating force to operate a fairly large valve?

1. Helical gear
2. Planetary gear
3. Worm gear
4. Herringbone gear

7-23. What type of spring-loaded valve is installed in some systems to warn of dangerous pressures?

1. Sentinel valves
2. Spring-loaded reducing valves
3. Pressure-reducing valves
4. Air-operated valves

7-24. Reducing valves used in reduced pressures lines aboard ship are designed for what purpose?

1. To prevent damage to the lines due to excessive pressure
2. To keep the operating pressure equal to the supply pressure
3. To vary the operating pressure according to the demand
4. To provide a steady pressure lower than the supply pressure

A.	AIR-PILOT OPERATED DIAPHRAGM REDUCING VALVE
B.	PNEUMATIC-PRESSURE-CONTROL REDUCING VALVE
C.	SPRING-LOADED REDUCING VALVE

Figure 7C

IN ANSWERING QUESTIONS 7-25 THROUGH 7-27, REFER TO FIGURE 7C AND SELECT THE TYPE OF VALVE DESCRIBED IN THE QUESTION.

7-25. In this valve, the main valve is opened by the operating piston and closed by the main valve spring.

1. A
2. B
3. C

7-26. Applications include low-pressure air reducers, distilling plant seawater reducers, and some reduced-steam system reducers.

1. A
2. B
3. C

7-27. One type of this valve is used to regulate low-temperature fluids, such as air, water, or oil.

1. A
2. B
3. C

7-28. Which of the following types of valves is a basic pressure-reducing valve?

1. Spring-loaded
2. Hydraulic-loaded
3. Hydraulic-diaphragm
4. Floating-disk

7-29. A spring-loaded reducing valve fails to close after the outlet pressure is at the desired value. What is the most likely cause?

1. A ruptured diaphragm
2. A broken adjustment screw
3. A spring that has lost tensile strength
4. A backseated handwheel

7-30. What type of pressure-reducing valve uses a pilot valve to control the main valve to control the flow of upstream fluid?

1. A spring-loaded valve
2. A floating disk valve
3. An internal pilot-actuated pressure-reducing valve
4. A hydraulically loaded valve

7-31. What is the principle of operation of an air-controlled regulator?

1. The pressure of an enclosed gas is directly proportional to its temperature
2. The pressure of an enclosed gas varies inversely to its temperature
3. The pressure of an enclosed gas is directly proportional to its volume
4. The pressure of an enclosed gas varies inversely to its volume

7-32. Diaphragm control valves with air-operated control pilots may be used for which of the following purposes?

1. Air pressure control
2. Liquid level control
3. Temperature control
4. Each of the above

7-33. In an air-pilot-operated diaphragm control valve, the air-operated control pilot may be either direct acting to reverse acting. Which of the following statements describes the way a direct-acting pilot works?

1. The controlled pressure acts on the bottom of the diaphragm
2. The pressure is controlled by an adjusting spring
3. The controlled pressure acts on the top of the diaphragm
4. Each of the above

7-34. During normal operation, the thermostatic recirculating valves are actuated by the temperature of the condensate from which of the following components?

1. The main condensate pumps
2. The main condenser
3. The air ejector aftercondenser
4. A hand-controlled valve

7-35. Which of the following is/are types of remote-operated valves?

1. Mechanical
2. Hydraulic
3. Electric
4. All of the above

7-36. What is the approximate range of adjustment of the thermostatically controlled recirculating valve?

1. 10°F
2. 20°F
3. 30°F
4. 40°F

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A. IMPULSE
B. BIMETALLIC
C. ORIFICE-TYPE
D. THERMOSTATIC

Figure 7D

IN ANSWERING QUESTIONS 7-37 THROUGH 7-40, REFER TO FIGURE 7D.

7-37. What type of steam trap is best described as operating on the principle that hot water under pressure flashes into steam when the pressure is reduced?

1. A
2. B
3. C
4. D

7-38. What type of steam trap is made of material that reacts to close the trap when steam is present and to open the trap when condensate is present?

1. A
2. B
3. C
4. D

7-39. What type of trap has no moving parts and is suitable only for service in which the condensate formation is continuous?

1. A
2. B
3. C
4. D

7-40. What type of steam trap depends on the expansion of a sealed bellows for its operation?

1. A
2. B
3. C
4. D

7-41. When installing a valve, you should be sure you know which of the following information?

1. The material the valve shaft is made from
2. The length of the stem
3. The size of the valve disk
4. The function the valve is to perform

7-42. What method should you use to visually determine whether a valve seat and disk are making good contact?

1. Die tapping
2. Spotting-in
3. Prussian bluing
4. Machine marking

7-43. As part of the process when grinding in a valve, you apply grinding compound to the valve disk. At what interval should you apply the NEBU compound?

1. At 1-minute intervals
2. At 2-minute intervals
3. At 3-minute intervals
4. At 4-minute intervals

7-44. What is the difference between the processs of grinding in and lapping in valve seats?

1. Grinding in requires special tools
2. Lapping in requires special tools
3. Grinding in is done on a lathe
4. Lapping in is done on a lathe

7-45. Which of the following machines should you use to reface all valve disks and hard-surfaced valve seats?

1. A power grinder
2. A reseating machine
3. A lapping-in tool
4. A lathe

7-46. What digits of the packing gland identification symbol will help you make the proper selection with respect to the type of joint and type of packing material, respectively?

1. First and second digits only
2. First and third digits only
3. Second and third digits only
4. Second, third, and fourth digits

7-47. Carbon ribbon packing (CRP) is highly resilient, flexible, may be wrapped around valves stems of any size, and will not shrink at any temperature.

1. True
2. False

7-48. When repacking a valve, you can ignore a scored or damaged shaft because CRP will fill grooves in the shaft.

1. True
2. False

7-49. Which of the following gaskets is being used by the Navy in high-temperature, high-pressure installations?

1. Corrugated copper
2. Teflon®
3. Spiral-bound metallic-asbestos
4. Plastic nonmetallic asbestos

7-50. Lagging for piping insulation serves what purpose?

1. It resists the flow of heat
2. It secures the insulation material to the pipe
3. It repels water
4. It protects and confines the heat-resistant material

7-51. Sheet metal pipe covering is kept unpainted for what reason?

1. To increase heat radiation
2. To decrease heat radiation
3. To reduce the danger of fire
4. To avoid condensation

7-52. Aboard ship, lagging of the fire main piping system serves what purpose?

1. It keeps the heat in
2. It keeps the heat out
3. It prevents moisture of condensation on the outside of the pipes
4. It protects the pipes against accidental damage

ASSIGNMENT 8

Textbook Assignment: "Refrigeration," chapter 11, pages 11-1 through 11-29.

8-1. Refrigeration functions on which of the following principles?

1. Heat flows in its natural direction from warmer material to colder material
2. Heat is removed from spaces, objects, and material
3. Both 1 and 2 above
4. Heat is converted into work

8-2. A refrigeration unit cools water in what way?

1. It reduces the pressure of the water
2. It adds coolness to the water
3. It increases the pressure of the water
4. It removes heat from the water

8-3. What standard unit is used to measure the amount of heat energy in a substance?

1. A refrigeration ton
2. A British thermal unit (Btu)
3. Total heat
4. Sensible heat

8-4. What is the latent heat of fusion of a pound of ice?

1. 288 Btu
2. 144 Btu
3. 72 Btu
4. 36 Btu

8-5. To change 1 ton of water at 32°F to ice, approximately what amount of heat must be removed?

1. 288,000 Btu
2. 12,000 Btu
3. 72 Btu
4. 36 Btu

8-6. Water will boil under which of the following conditions?

1. At 80°F under a vacuum of 29 in.Hg
2. At 100°F at a pressure of 14.7 psig
3. At 350°F at a pressure of 600 psig
4. At 50°F under a vacuum of 10 in.Hg

8-7. A vapor can be superheated only under which of the following conditions?

1. When allowed to decrease in volume
2. When held at a constant pressure
3. When remaining in contact with the boiling liquid
4. When separating from the liquid from which it was generated.

8-8. When the temperature of a gas is increased, in what way will its (a) volume and (b) pressure react?

1. (a) Increase (b) decrease
2. (a) Decrease (b) increase
3. (a) Decrease (b) decrease
4. (a) Increase (b) increase

8-9. When the volume of a gas is held constant, an increase in the temperature of the gas causes what reaction in the (a) pressure; and, a decrease in temperature causes the pressure to react in (b) what way?

1. (a) Decrease (b) increase
2. (a) Increase (b) decrease
3. (a) Decrease (b) decrease
4. (a) Increase (b) increase

8-10. Which of the following refrigeration systems is generally used for shipboard refrigeration?

1. Vapor compression cycle with centrifugal compressors
2. Vapor compression cycle with reciprocating compressors
3. Steam-jet with reciprocating compressors
4. Steam-jet with centrifugal compressors

IN ANSWERING QUESTIONS 8-11 THROUGH 8-13 REFER TO FIGURE 11-1 OF THE TEXTBOOK.

8-11. Refrigeration flows through parts of the system in which of the following sequences?

1. Receiver, evaporator, expansion valve, condenser, compressor, receiver
2. Receiver, expansion valve, evaporator, compressor, condenser, receiver
3. Receiver, condenser, compressor, evaporator, expansion valve, receiver
4. Receiver, expansion valve, compressor, condenser, evaporator, receiver

8-12. Heat is absorbed by the R-12 refrigerant in what component?

1. Thermostatic expansion valve (TXV)
2. Receiver
3. Condenser
4. Evaporator

8-13. The low-pressure side of the refrigeration system is located between what components?

1. The TXV up to and including the intake side of the compressor cylinders
2. The suction side of the compressor and the receiver
3. The suction side of the compressor and the condenser
4. The discharge valve of the compressor to the TXV

8-14. What change occurs in the physical state of the R-12 as it passes through the evaporator?

1. It changes from a superheated vapor to a boiling liquid
2. It changes from a boiling liquid to a superheated vapor
3. It changes from a cool liquid to a hot vapor
4. It changes from a hot vapor to a cool liquid

8-15. What component pumps heat, absorbed by the refrigerant, from the evaporator to the condenser?

1. Receiver
2. Condenser
3. Suction side of the compressor
4. Evaporator

8-16. What is the primary function of a compressor?

1. To raise the temperature of liquid R-12 to the point where it will boil and vaporize completely before entering the condenser
2. To raise the pressure of liquid R-12 to the point where its temperature at this pressure is high enough to cause it to boil and vaporize completely before entering the condenser
3. To raise the pressure of vaporized R-12 to the point where its temperature at this pressure is high enough above the temperature to use seawater as a cooling medium
4. To raise the pressure of vaporized R-12 to the point where its superheat amounts to 10°F

8-17. What change takes place in the R-12 as it passes through the condenser?

1. It condenses and gives up its latent heat of condensation only
2. It condenses and gives up its superheat only
3. It condenses and gives up its superheat and its latent heat of condensation
4. It gives up its sensible heat, then it condenses and gives off its latent heat

8-18. What type of lubrication is used on high-speed compressors?

1. Gravity feed lubrication
2. Splash lubrication
3. Self-lubrication
4. Pressure lubrication

IN ANSWERING QUESTION 8-19, REFER TO FIGURE 11-8 IN THE TEXTBOOK.

8-19. The surfaces between the removable shaft seal shoulder and the crankcase are sealed by what means?

1. The shaft seal clamping nut
2. The neoprene gasket
3. The lapped surface
4. The mitralloy collar

8-20. Of the forces listed below, which one is used to load compressors?

1. Refrigerant pressure
2. Oil pressure
3. Refrigerant suction
4. Water pressure

8-21. The compressor has reached full speed. At what point does the capacity control system start to unload the compressor?

1. When the shaft seal bursts
2. When the system is overcharged
3. When the pulldown period begins
4. When the pulldown period is complete

8-22. Which of the following components governs the capacity control system?

1. The capacity control valve
2. The unloader power element
3. The hydraulic relay
4. The suction pressure

A.	SPRING-LOADED RELIEF VALVE
B.	WATER REGULATING VALVE
C.	LOW-PRESSURE CUTOUT SWITCH
D.	EVAPORATOR PRESSURE REGULATING VALVE
E.	HIGH-PRESSURE CUTOUT SWITCH
F.	WATER FAILURE SWITCH
G.	OIL FAILURE SWITCH

Figure 8A

IN ANSWERING QUESTIONS 8-23 THROUGH 8-28, REFER TO FIGURE 8A AND SELECT THE DEVICE DESCRIBED BY THE QUESTION.

8-23. The water in a water cooler will freeze if the pressure setting is too low.

1. B
2. D
3. E
4. F

8-24. Under normal conditions, this device controls the operation of the compressor.

1. C
2. D
3. E
4. G

8-25. Provided you correctly set this device, the compressor will stop when the pressure reaches the cutout point and start when the pressure drops to the reset point.

1. B
2. C
3. D
4. E

8-26. The function of this device depends on the failure of the high-pressure cutout switch.

1. A
2. B
3. D
4. G

8-27. This device maintains the proper rate of cooling water flow through the condenser.

1. A
2. B
3. D
4. F

8-28. If device F fails to function, this device will perform its intended function.

1. A
2. B
3. C
4. E

8-29. The solenoid valve and the thermostatic expansion valves are protected from foreign matter by what means?

1. A TXV
2. A liquid strainer
3. A dehydrator
4. A thermometer

8-30. Although intervals between plant inspections vary, you should check the refrigeration system's temperature and pressure at what minimum interval?

1. Each hour
2. Every 2 hours
3. Once a watch
4. Daily

8-31. A refrigeration compressor may be left unattended in the manual mode of operation.

1. True
2. False

8-32. An R-12 refrigeration plant is supplied with cooling water from either a centrifugal pump or from a fire and flushing main. When, if ever, is the pump controller switch of this plant opened manually?

1. When the cooling water is from the centrifugal pump only
2. When cooling water is from the fire and flushing main only
3. When cooling water is from the centrifugal pump or the fire and flushing main
4. Never

8-33. Refrigeration systems that are equipped with water-regulating valves should be maintained at what condensing pressure?

1. 50 to 60 psi
2. 100 to 110 psi
3. 125 psi
4. 175 psi

8-34. If an R-12 compressor is idle, it should be operated at what minimum interval?

1. Monthly
2. Every 2 weeks
3. Weekly
4. Daily

8-35. Two compressors serving the same cooling system should not be operated at the same time for which of the following reasons?

1. Because oil may be transferred from one compressor to another and cause serious damage
2. Because of the compressor discharge differential pressure
3. Because of the compressor motor electrical interlock
4. All of the above

8-36. An MM3 or MM2 is responsible for which of the following maintenance jobs on R-12 systems?

1. Pumping down refrigeration systems
2. Testing for refrigerant leaks
3. Adjusting refrigeration systems controls
4. All of the above

8-37. During hot gas defrosting, the hot gas enters the refrigeration system through which of the following components?

1. The compressor discharge valve
2. The compressor suction valve
3. The liquid line
4. The tail coil

8-38. What action must be taken before repairs are made to the receiver of a refrigeration system?

1. The entire system must be drained into spare refrigerant drums
2. The receiver must be pumped down to return all refrigerant to the condenser
3. All valves in the lines leading to the receiver must be opened
4. Line valves must be closed and the refrigerant in the receiver must be released to the atmosphere

8-39. You are pumping down a system to make minor repairs on lines between the receiver and cooling coils. Which of the following precautions should you observe before making repairs?

1. Blow out all R-12 gas from the isolated section that has been opened
2. Allow the lines to return to normal temperature after pumping them down and before opening them
3. Pump the lines down to a pressure slightly above atmospheric pressure before opening them
4. Cap removed sections of lines to prevent loss of refrigerant

8-40. When a refrigerant system is opened, the free ends of the refrigerant lines should be temporarily plugged to prevent the entrance of air and dirt.

1. True
2. False

8-41. After a line in the refrigerant system has been opened, it must be purged with gas from a cylinder.

1. True
2. False

8-42. When you must pump down an entire refrigeration system for major repairs, what valve is used to interrupt the flow of R-12 to begin the purging operations?

1. The suction line stop valve
2. The discharge line stop valve
3. The main liquid-line shut-off valve
4. The cooling coil solenoid valve

8-43. You are draining the refrigerant charge from a refrigeration system. What action should you take after the compressor has been stopped by the low-pressure control switch?

1. Close the compressor discharge line valve
2. Close all liquid valves at the cooling coil
3. Connect an empty R-12 service drum to the refrigerant drain valve
4. Restart the compressor manually and continue pumping down until suction pressure reaches approximately 2 psig

8-44. Before connecting an R-12 service drum to the refrigerant drain valve, you should take which of the following steps?

1. Cool the drum to expedite draining
2. Weigh the drum to determine its capacity
3. Adjust the temperature of the drum to that of the refrigerant
4. Vent the drum to the atmosphere

8-45. Which of the following conditions may indicate loss of refrigerant from a refrigeration system?

1. Short cycling
2. Frosting of the compressor suction line
3. Excessive lubrication oil pressure
4. Relatively low crankcase temperature

8-46. When using the soap test to search for leaks, you should wait for what minimum period of time for bubbles to form from a small leak?

1. 1 minute
2. 15 seconds
3. 30 seconds
4. 45 seconds

8-47. A mixture of air and R-12 containing 20 percent or more refrigerant has an odor resembling what gas?

1. Chloride
2. Ammonia
3. Carbon tetrachloride
4. Methane

8-48. Oil was added to a force-lubricated compressor, which has been inoperative for several weeks. What procedure should you use to check the actual oil level?

1. Observe the oil level in the sight glass before starting the compressor
2. Operate the compressor on manual control for 1 hour or more and observe the oil level in the sight glass immediately after stopping the compressor
3. Stop the compressor and check the oil level with the crankshaft and connecting rod ends immersed in the lubricating oil
4. Stop the compressor and check the oil level with the crankshaft and connecting rod ends out of the lubricating oil

8-49. Which of the following means should you use to remove oil from a compressor that doesn't contain a drain valve?

1. Stop the compressor and close the suction and discharge line valves
2. Reduce crankcase pressure to about 1 psi by slowly closing the suction line stop valve
3. Loosen the drain plug just enough for oil to seep out
4. All of the above

8-50. A refrigeration system has steel connections. You should check the compressor crankcase oil for contamination at what minimum interval?

1. Once a year
2. Once each 6-month period
3. Once each 3-month period
4. Once each week

8-51. A compressor V-belt is tightened correctly when you can use one finger to depress the belt midway between the flywheel and motor pulleys what distance?

1. 1/8 inch
2. 3/8 inch
3. 1/2 to 3/4 inch
4. 7/8 to 1 inch

8-52. When one belt in a multiple-V-belt drive is stretched excessively, what means should you use to correct the problem?

1. Replace the defective belt
2. Replace all the belts
3. Tighten the defective belt
4. Treat the defective belt with belt dressing

8-53. What adjustment in the high-pressure switch will raise the cutout point without affecting the cut-in point?

1. Turn the range adjusting screw clockwise
2. Turn the range adjusting screw counterclockwise
3. Turn the differential adjusting screw counterclockwise
4. Turn the differential adjusting screw clockwise

8-54. You are adjusting the high-pressure switch of a refrigeration plant. You have raised the compressor discharge to 10 psig above the desired cut-in pressure. What action should you take immediately?

1. Turn the range screw counterclockwise until the contactor opens
2. Turn the range screw clockwise until the contacts close
3. Turn the differential screw counterclockwise all the way
4. Turn the differential screw clockwise all the way

8-55. When setting the high-pressure switch of a refrigeration plant, you should turn the differential switch in what sequence?

1. Counterclockwise, then clockwise only
2. Clockwise, then counterclockwise only
3. Counterclockwise, clockwise, and counterclockwise
4. Clockwise, counterclockwise, and clockwise

8-56. You want to set the low-pressure switch of a refrigeration plant so that it will cut out at 50 psig. With the compressor operation you should (a) set what suction pressure and (b) turn the differential screw to what position?

1. (a) 30 psig
   (b) clockwise until the switch contacts close
2. (a) 40 psig
   (b) counterclockwise until the switch contacts open
3. (a) 40 psig
   (b) clockwise, then counterclockwise
4. (a) 30 psig
   (b) clockwise until the switch contacts open

8-57. What is the most likely result of an expansion valve adjusted for a too low degree of superheat?

1. A coil operating at reduced capacity
2. A damaged expansion valve
3. A damaged compressor
4. An excessive amount of refrigerant in the coil

8-58. Pressure changes that are brought about by a change in the temperature in the refrigerator compartment cause a reaction in which of the following control/safety devices?

1. The thermostatic switch
2. The water failure switch
3. The thermal expansion valve
4. The automatic reducing valve

8-59. The refrigeration plant is not operating satisfactorily. Normally, what step should you take first when checking the system?

1. Test the discharge valves
2. Test the suction valves
3. Short cycle the compressor
4. Shift the compressors

8-60. You are testing for a leaking discharge valve. What procedure should you conduct (a) first and (b) last?

1. (a) Pump the compressor down to 2 psig
   (b) check the discharge pressure drop rate
2. (a) Stop the compressor
   (b) close the suction valves
3. (a) Pump the compressor down to 2 psig
   (b) close the suction valves
4. (a) Stop the compressor
   (b) check the discharge pressure drop rate

8-61. You have pumped a vacuum to approximately 20 in.Hg, and the compressor stops. The vacuum can't be maintained for which of the following reasons?

1. The discharge valve leaks
2. The suction valve leaks
3. The shaft seals leak releasing R-12 to the atmosphere
4. The R-12 being released from the crank-case oil causes the pressure to rise

8-62. You have replaced a shaft seal on a compressor. What action should you take to check for leaks?

1. Pump down the compressor and look for oil
2. Run the compressor and look for oil
3. Open the suction and discharge valves and check with an electronic leak detector
4. Fill the crankcase and look for oil

8-63. In excessive concentrations, gaseous R-12 causes which of the following health hazards?

1. It poisons on contact any food that contains milk or eggs
2. It irritates the eyes unless it is diluted with at least an equal amount of air
3. It explodes when it comes in direct contact with a high-temperature open flame
4. It will not support respiration

8-64. An R-12 cylinder should be filled to what maximum percentage of capacity?

1. 90%
2. 85%
3. 80%
4. 75%

8-65. Which of the following safety gear must be worn when you work with R-12?

1. Apron and gloves
2. Goggles
3. Mouthpiece
4. Safety shoes

8-66. When R-12 touches your skin, you should administer what first-aid treatment?

1. Rub or massage the affected area
2. Immerse the affected part in a warm bath
3. Apply nonirritating oil to the affected area
4. Bathe the affected area with strong soap and water

ASSIGNMENT 9

Textbook Assignment: "Air Conditioning" and "Compressed Air Systems," chapters 12 and 13, pages 12-1 through 13-24.

9-1. Which of the following is a function of air conditioning?

1. It prevents deterioration of ammunition in storage spaces
2. It maintains temperatures at specified levels in electrical and electronic equipment spaces
3. It prevents excessive pressure buildup in containers in gas storage spaces
4. All of the above

9-2. Which of the following is a definition of the term *dew point* of air?

1. The temperature at which the specific humidity is 100 grains per pound of dry air
2. The temperature at which the air is saturated with moisture
3. The temperature at which any increase in temperature will cause moisture to vaporize
4. The temperature at which dew vaporizes into the air

9-3 The relative humidity of air is the ratio between the actual amount of water vapor in a sample of air and

1. the weight of the sample
2. the volume of the sample
3. the amount of water vapor the sample would hold if it were saturated
4. the dew point of the sample

9-4. The deciding factor in human comfort is the relative humidity.

1. True
2. False

9-5. It is possible to feel more comfortable at 90°F than at 70°F

1. True
2. False

9-6. What is your body's continuous source of heat?

1. Surroundings that radiate heat
2. Currents of heated air
3. Physiological processes within the body
4. Objects your body comes into contact with

9-7. What is the best overall range of relative humidity for human comfort and health?

1. 15% to 50%
2. 30% to 40%
3. 40% to 60%
4. 30% to 70%

9-8. In the duct systems of Navy ships, axial-flow fans are used instead of centrifugal fans for what reason?

1. They require less installation space
2. They blow more air
3. They are less complicated
4. They tend to decrease humidity

9-9. Onboard Navy ships, which of the following fans are used primarily to exhaust explosive or hot gases?

1. Tube-axial
2. Centrifugal
3. Valve-axial
4. Bracket

9-10. Vane-axial ventilating fans are operated with the air ducts open for which of the following reasons?

1. Less electrical current will be used
2. A larger volume of air can be moved
3. The motor will not overheat
4. The air distribution can be limited

9-11. Excess water accumulated in heavy seas is automatically sealed out of waterproof ventilators by what means?

1. Sump valves
2. Drain tubes
3. The weight of the water in the bucket
4. Scupper valves draining onto the deck

9-12. In chilled water circulating systems, the type of primary refrigerant depends on the size and type of the compressor.

1. True
2. False

9-13. Where is the heat removed from the secondary refrigerant of a vapor compression unit?

1. In the water chiller
2. In the condenser
3. In the refrigerant receivers
4. In the float chambers

9-14. In a centrifugal refrigeration plant, what valve releases the refrigerant to the chiller?

1. Compressor
2. Suction
3. Float
4. Differential compression

9-15. The lithium bromide unit operates on the absorption cycle. What is used as the primary refrigerant?

1. R-11
2. R-12
3. R-114
4. Water

9-16. When there is a 29.9-inch vacuum in the container of a lithium bromide absorption unit, what is the lowest temperature at which water will boil?

1. 212°F
2. 100°F
3. 35°F
4. 10°F

9-17. In a lithium bromide absorption unit, the regeneration heat exchanger performs what function on the lithium bromide?

1. It cools both the weak and the strong solutions
2. It cools the weak and heats the strong solutions
3. It preheats the weak and cools the strong solutions
4. It preheats both the weak and the strong solutions

9-18. Which of the following is the purpose of the collection tray on the spot cooler?

1. To collect water from the vent cock
2. To collect condensation from the air around the cooling coils
3. To allow condensate to evaporate
4. To collect impurities from condensation

9-19. Dirt should be kept out of a ventilation system for which of the following reasons?

1. It restricts airflow
2. It creates a fire hazard
3. Both 1 and 2 above
4. It damages the filters

9-20. Which of the following maintenance actions is proper for air-conditioning equipment?

1. Periodically oil flame arresters and grease filters
2. Wash, steam, and then rinse dirty air filters
3. After washing, oil the filters with filter oil
4. Both 2 and 3 above

9-21. Aboard Navy ships, compressed air is used for which of the following purposes?

1. Starting diesel engines
2. Charging and firing torpedoes
3. Operating pneumatic tools
4. All of the above

9-22. A reciprocating air compressor is generally selected for which of the following capacity requirements?

1. 8,800 cfm and 20 psi
2. 5,000 cfm and 100 psi
3. 2,100 cfm and 125 psi
4. 800 cfm and 5,000 psi

9-23. What is the usual source of power for operating air compressors aboard ship?

1. Steam turbines only
2. Electrical motors only
3. Steam turbines and electric motors
4. Internal combustion engines

9-24. What device is generally used to connect the source of power to an air compressor when the speed of the driving unit and compressor is the same?

1. A flexible coupling
2. A rigid coupling
3. A V-belt
4. A reduction gear

9-25. Which of the following is the classification of a medium-pressure air compressor?

1. Two-stage, vertical, duplex single-acting with a discharge pressure of 151 psi to 1,000 psi
2. Two-stage, vertical V-type with a discharge pressure of 150 psi or less
3. Three-stage, vertical, single-acting with a discharge pressure of 1,500 psi or higher
4. Three-stage, vertical, double-acting with a discharge pressure of 1,500 psi to 10,000 psi

9-26. What cylinder arrangement is used in two-stage, W-type air compressors?

1. One cylinder per stage
2. Two cylinders per stage
3. Two cylinders for the first stage and one cylinder for the second stage
4. One cylinder for the first stage and two cylinders for the second stage

9-27. A piston makes what total number of strokes during each operating cycle of a single-acting air compressor?

1. One
2. Two
3. Three
4. Four

9-28. Which of the following parts is NOT included in the compressing elements of an air compressor?

1. Cylinder
2. Piston
3. Unloader
4. Air valve

9-29. The operation of the automatic valves of an air compressor is initiated by what means?

1. A lack of air pressure
2. An air pressure differential
3. A high air pressure
4. A camming action

9-30. What device is used to lubricate the high-pressure air compressor cylinders?

1. A cylinder splash lubricator
2. A compressor oil pump
3. A sight-glass oil-flow indicator
4. An adjustable mechanical force-fed lubricator

9-31. Which of the following means is/are used to cool most high- and medium-pressure air compressors?

1. Oil
2. Fresh water or sea water
3. Air
4. Distilled water

9-32. The cylinders and heads of some shipboard air compressors are made from bronze alloy for what reason?

1. To provide cooling
2. To minimize friction
3. To reduce wear
4. To minimize corrosion

9-33. What is the function of the intercoolers of an air compressor?

1. To remove heat generated during compression and to condense existing vapor
2. To remove heat from the incoming water and to condense existing vapor
3. To cool air before compression
4. To cool the air after the final stage of compression

9-34. The quantity of water that passes through the oil cooler can't be regulated without changing the quantity that passes through the intercoolers.

1. True
2. False

9-35. What is the purpose of using baffles in tube-type water-cooled intercoolers?

1. To remove oil contaminants from the air
2. To deflect air or water passing through the cooler
3. To prevent the tube nest from expanding
4. To prevent the tube nest from contracting

9-36. The control system for an electrically driven reciprocating air compressor will automatically stop the compressor when the pressure in the receiver causes what action?

1. The governor valve to open
2. The governor valve to close
3. The pressure switch to open
4. The pressure switch to close

9-37. The automatic temperature shutdown device of a high-pressure reciprocating air compressor stops the compressor under which of the following conditions?

1. When the accumulator temperature rises a predetermined amount
2. When the accumulator temperature drops a predetermined amount
3. When the cooling water temperature rises above a preset limit
4. When the cooling water temperature drops below a preset limit

9-38. In rotary-type centrifugal compressors, air is compressed by which of the following forces?

1. Water
2. Centrifugal force
3. An impeller
4. A piston

9-39. Which of the following is the purpose of the air receiver in an air compressor?

1. To cool the air
2. To minimize pressure variations
3. To remove foreign matter
4. To filter moisture and oil from the air

9-40. Which of the following systems is supplied by nonvital air?

1. Automatic boiler control
2. Water level control
3. Air pilot-operated control valves
4. Laundry equipment

9-41. What type of compressor supplies air to the prairie-masker system?

1. A turbocompressor
2. A multistage compressor
3. An angle compressor
4. A vertical compressor

9-42. When very high-pressure air is throttled to low pressure at a high flow rate, the throttling valve freezes. Which of the following is the reason for the valves freezing?

1. Charles' effect
2. Venturi effect
3. Herbst effect
4. Boyle's effect

9-43. What is the cooling medium for the oil-free compressor?

1. Seawater
2. Air
3. Fresh water
4. Oil

9-44. What device controls the movement of the A-end of an electrohydraulic speed gear?

1. A throttle
2. A tilt box
3. A piston
4. A hydraulic ram

9-45. The A-end hydraulic pump and B-end hydraulic motor combination provides rotary motion. What change is made in the hydraulic system to provide reciprocating motion?

1. The angle of tilt of the socket ring is reversed
2. The tilt box is placed in a neutral position
3. The A-end is replaced by a piston or a ram
4. The B-end is replaced by a piston or a ram

IN ANSWERING QUESTION 9-46, REFER TO FIGURE 14-2 IN THE TEXTBOOK.

9-46. When the ram is moving, oil is forced into one ram cylinder and out of the other cylinder to what destination?

1. The operating tank
2. The output side of the main pump
3. The suction side of the auxiliary pump
4. The suction side of the main hydraulic pump

9-47. Which of the following devices maintains hydraulic pressure in the ram-type electrohydrualic steering gear?

1. Centrifugal pumps
2. A rudder yoke
3. A variable-stroke pump
4. A hydraulic ram

9-48. If the remote steering system fails, what device is used for local hydraulic control of the steering gear?

1. A hand pump
2. An auxiliary pump
3. A trick wheel
4. A differential control box

9-49. If electrical power is lost to the hydraulic pump motor, what device can be used to control the steering gear?

1. A hand pump
2. An auxiliary pump
3. A trick wheel
4. A differential control box

9-50. Some electrohydraulic anchor windlasses have two motors. One motor drives each of the pumps, which normally drives one wildcat. However, each pump can drive either wildcat with the use of what device?

1. A locking head
2. A three-way plug, cock-type valve
3. A multiple-spur gearing
4. A special coupling

9-51. A windlass has been idle for several months. Before operating this windlass, which of the following maintenance actions should you perform?

1. Replace the friction shoes
2. Adjust the brake
3. Remove, clean, and lubricate the locking head only
4. Lubricate the equipment

9-52. What type of winch is normally used to hoist aircraft aboard the ship?

1. Steam
2. Electric
3. Electrohydraulic
4. Land

9-53. The horizontally mounted drum of an electrohydraulic winch is connected to the shaft by what device?

1. A chin drive
2. A key
3. A ratchet lock
4. A clutch

9-54. Electric capstans are usually reversible. Those powered by dc motors usually have what total number of speeds in either direction of rotation?

1. One to three
2. Two to four
3. Three to five
4. Four to six

9-55. The boom of a crane is controlled by what means?

1. A king post
2. Blocks
3. A rotating gear
4. Sheaves

9-56. Fouling of the hoisting ropes is prevented by what means?

1. Fair-lead sheaves
2. Blocks
3. A king post
4. A grooved drum

9-57. The delicate control often required to handle loads with a crane is usually provided by what means?

1. An electric motor for rotating the crane
2. Reduction gearing in the crane rotating mechanism
3. Hydraulic variable-speed gears for driving the hoisting whips and topping lifts
4. Electric motors for driving the hoisting whips and topping lifts

9-58. On a crane, what device is provided to hold the load when electric power fails?

1. An A-end hydraulic pump
2. A hydraulic torque motor
3. A hand brake
4. An electric brake

9-59. What device finds and retains the neutral position of the A-end hydraulic pump on a crane?

1. A B-end hydraulic motor
2. A centering device
3. An electric torque motor
4. A slack, take-up device

9-60. When a crane is used to raise light loads, the cable has a tendency to develop slack when hoisting is started. What means is used to prevent slack?

1. An electric torque motor
2. A hydraulic torque motor
3. A high-hook paying-out device
4. A pressure stroke control device

9-61. CV class aircraft carriers are equipped with airplane elevators that have what maximum lifting capacity?

1. 135,000 lb
2. 125,000 lb
3. 115,000 lb
4. 105,000 lb

9-62. In the closed hydraulic system of an electrohydraulic power plant, nitrogen is used with oil instead of air for which of the following reasons?

1. To increase the efficiency of the oil
2. To prevent a possible explosive mixture
3. To ensure a constant pressure within the system
4. To eliminate contamination of the oil usually caused by air

9-63. An electrohydraulic elevator is raised by high-pressure oil acting directly against what component?

1. A hydraulic engine valve piston
2. A high-pressure tank baffle plate
3. A ram
4. A platform

9-64. On modem deck-edge elevators, what built-in safety feature limits the damage caused by the possible breaking of all hoisting cables on one side of the elevator?

1. An electrical stopping device, which will block the platform
2. Serrated safety shoes, which will wedge the platform between the guide rails
3. Pressure-actuated switches, which will disconnect the electrical power source
4. A high-pressure tank, which will cushion the platform as it is lowered

9-65. Power conveyors are configured either vertically or horizontally.

1. True
2. False

9-66. Conveyors are used to handle which of the following supplies?

1. Dry provisions
2. Chilled and frozen food
3. Both 1 and 2 above
4. Ammunition

9-67. While loading a vertical conveyor, what is the position of the load-unload device?

1. At a 30° incline
2. Vertical
3. Horizontal
4. At a 45° incline

9-68. What is the purpose of the interlock switch on a vertical conveyor?

1. To prevent upward operation of the conveyor when the load-unload device is in the load position
2. To ensure that the trunk door won't open
3. To prevent downward operation of the conveyor when the load-unload device is in the load position
4. To allow the truck door to be opened while the conveyor is in operation

9-69. Which of the following safety precautions must you take to ensure accident-free operation of horizontal conveyors?

1. Establish positive communications between all operating control stations using sound-powered telephones or intercom systems
2. Use the two-man rule at all times while operating the conveyor
3. Do not use the conveyor trunk as a voice tube
4. All of the above

9-70. The final rinse in a double-tank dishwasher is activated by what means?

1. A manual control
2. A thermostat control
3. The movement of dish racks
4. A can on the conveyor belt

9-71. In the double-tank dishwashing machine, the final rinse is controlled by an adjustable automatic steam-mixing valve that maintains which of the following temperature ranges?

1. 170°F to 175°F
2. 180°F to 185°F only
3. 180°F to 190°F
4. 190°F to 195°F

9-72. The rinse tank of a double-tank dishwashing machine contains a thermostatically operated switch that prevents machine operation if the rinse water drops below what temperature?

1. 180°F
2. 190°F
3. 200°F
4. 210°F

ASSIGNMENT 10

Textbook Assignment: "Propulsion Boilers," chapter 15, pages 15-1 through 15-13.

10-1. For information about boilers, you should refer to which of the following references?

1. *NSTM,* chapter 221
2. *NSTM,* chapter 593
3. NAVEDTRA 12077
4. NAVEDTRA 12097

10-2. To what publication should you refer to find your ship's boiler full-power capacity?

1. *NSTM,* chapter 221
2. Manufacturer's technical manual
3. Boiler repair manual
4. PMS card

10-3. Boiler overload is specified in the design of the boiler. Depending on its installation, boiler overload capacity is given as either the firing rate or the

1. operating pressure
2. steaming rate
3. design pressure
4. design rate of full power

10-4. The boiler overload capacity is usually what percentage of boiler full-power capacity?

1. 150%
2. 140%
3. 130%
4. 120%

10-5. What term describes the actual pressure in the boiler steam drum at any given time?

1. Operating pressure
2. Steam drum pressure
3. Superheater outlet pressure
4. Superheater inlet pressure

10-6. The constant pressure at which a boiler is being operated is known as the

1. actual pressure
2. operating pressure
3. outlet pressure
4. inlet pressure

10-7. Which of the following statements defines the design pressure of a boiler?

1. The design pressure is the same as the operating pressure
2. The design pressure is the normal full-power capacity
3. The design pressure is lower than the operating pressure
4. The design pressure is specified by the boiler manufacturer as a criteria for boiler design

10-8. The amount of Btu per pound of fuel absorbed by the water and steam divided by the Btu per pound of fuel is known as

1. the operating temperature
2. the design temperature
3. the design pressure
4. boiler efficiency

10-9. If you were to state the efficiency of a boiler, you would use which of the following expressions?

1. 90%
2. 90:1
3. 90 is equal to 1
4. 0.90

10-10. Which of the following terms defines the statement: "The time during which the boiler has fires lighted for raising steam and the time during which it is generating steam"?

1. Operating period
2. Steaming hours
3. Cruising time
4. Generating time

10-11. The total heating surface equals the sum of the generating, superheater. and economizer surfaces, You measure the total heating surface of a steam-generating unit on the side that is exposed to the

1. steam being heated
2. water
3. gases of combustion
4. firebox

10-12. At the maximum steam drum pressure point, what boiler safety valve lifts?

1. The first
2. The second
3. The third
4. The fourth

10-13. Minimum steam drum pressure is usually what percentage of the boiler operating pressure?

1. 70%
2. 75%
3. 80%
4. 85%

10-14. Naval boilers can be classified in several ways. One way is to divide them into two classes, auxiliary boilers and what other class?

1. Propulsion
2. Heat and steam
3. Fire tube
4. Water tube

10-15. Boilers can be classified according to their location relative to the fire and water spaces. In this type of classification, what class of boiler pertains to all propulsion spaces?

1. Forced natural circulation
2. Fire tube
3. Water tube
4. Forced circulation

10-16. Boilers whose tubes slope steeply from the steam drum to the water drum will have what type of circulation?

1. Natural circulation only
2. Accelerated natural circulation
3. Forced natural circulation
4. Forced circulation

10-17. What factor determines the classification of natural-circulation water-tube boilers as either a header- or drum-type boiler?

1. The number of downcomers
2. The arrangement of the steam and water spaces
3. The arrangement of the superheater
4. The arrangement of the desuperheater

10-18. Which of the following statements is a description of a header?

1. It is a type of drum
2. It is a type of collection point
3. It is a type of manifold
4. Both 2 and 3 above

10-19. What is the only distinction between a header and a drum?

1. Shape
2. Number of tubes
3. Number of downcomers
4. Size

10-20. For what reason are single furnace boilers known as D-type boilers?

1. The tubes form a shape that looks like the letter D
2. They serve a dual purpose
3. They have double-acting tubes

10-21. Because of the shape or arrangement of its tubes, a double-furnace boiler is known as what type of boiler?

1. A
2. B
3. D
4. M

10-22. On most boilers, superheater tubes are protected from radiant heat by what means?

1. Baffle plates, which prevent the radiant heat from escaping
2. Water screen tubes, which absorb the intense radiant heat of the furnace
3. Heat deflectors, which deflect the heat away from the superheater
4. Radiant heat suppressors, which prevent radiant heat from leaving the boiler

10-23. To be considered a high-pressure boiler, it must be operated at what minimum pressure?

1. 450 psi
2. 600 psi
3. 700 psi
4. 751 psi

10-24. What is the purpose of the steam drum located at the top of the boiler?

1. To receive feedwater and as a place where saturated steam (generated in the tube) is accumulated
2. To separate the water from the steam
3. To equalize the distribution of water to the generating tubes
4. To provide a place for loose scale to accumulate

10-25. On a steam drum, tube sheets are required to be thicker than the wrapper sheet for which of the following reasons?

1. Because the extra thickness provides better insulation
2. Because the extra thickness provides better heat transfer
3. To form a continuous loop of the steam drum
4. To ensure adequate strength after the holes for the generating tubes are drilled

10-26. The steam drum is located on the top of the boiler. Where are the water drums and headers located?

1. At the top of the boiler
2. On the sides of the boiler
3. At the bottom of the boiler
4. On the front of the boiler

10-27. Which of the following are types of generating and circulating tubes?

1. Main generating tube bank tubes
2. Water wall and water screen tubes
3. Downcomers
4. Each of the above

10-28. What is the function of water wall tubes?

1. To strengthen the furnace walls
2. To protect the furnace refractories
3. To transmit fuel oil
4. To protect the economizer

10-29. A modem boiler contains approximately what number of tubes?

1. Between 1,000 and 2,000 tubes
2. Between 2,000 and 3,000 tubes
3. Between 3,000 and 4,000 tubes
4. Between 4,000 and 5,000 tubes

10-30. In relation to the boiler, tube rows run in what sequence?

1. From the front to the rear of the boiler
2. From the rear to the front of the boiler
3. From the left side to the right side of the boiler
4. From the right side to the left side of the boiler

10-31. Which of the following is a source of information you can use to identify boiler tubes?

1. Manufacturer's technical manuals
2. Boiler tube renewal sheets
3. Boiler plans
4. Each of the above

THIS SPACE LEFT BLANK INTENTIONALLY.

A. H-SHAPED SUPERHEATER TUBE

B. T-SHAPED SUPERHEATER TUBE

C. U-SHAPED SUPERHEATER TUBE

D. W-SHAPED SUPERHEATER TUBE

Figure 10A

IN ANSWERING QUESTIONS 10-32 AND 10-33, REFER TO FIGURE 10A AND SELECT THE TYPE OF SUPERHEATER TUBE DESCRIBED IN THE QUESTION.

10-32. Used with convection-type vertical superheaters.

1. A
2. B
3. C
4. D

10-33. Used with convection-type horizontal superheaters.

1. A
2. B
3. C
4. D

10-34. What boiler component uses heat from combustion gases to heat the feedwater before it enters the steam drum?

1. Air preheater
2. Deaerating feed heater
3. Economizer
4. Superheater

10-35. What is the purpose of the projections on the outer tube surface of an economizer?

1. To strengthen the tube
2. To extend the heat transfer area of the tube
3. To protect the tube from radiant heat
4. To direct the flow of combustion gases to the atmosphere

10-36. Which of the following are factors that affect refractory service life?

1. Shock and vibration
2. Panting
3. Sustained high furnace temperature
4. All of the above

10-37. To withstand shock and vibration, all areas of refractory must be anchored or held in place by one of three methods-by anchor strips, by boiler tubes, and by what other method?

1. By cutting back the sides of adjacent brickwork
2. By nichrome wire
3. By brick bolts
4. By plastic settings

10-38. Which of the following problems contributes to undue panting of a boiler?

1. Poor air-oil intermixture
2. Deficiency of air
3. Excessive oil temperature
4. Each of the above

A. FIREBRICK

B. INSULATING BRICK

C. INSULATION BLOCK

D. REFRACTORY MORTAR

E. BURNER TILE

F. CASTABLE FIRECLAY REFRACTORY

G. PLASTIC FIRECLAY REFRACTORY

H. BAFFLE TILE

I. CASTABLE INSULATION

J. PLASTIC CHROME ORE

K. CHROME CASTABLE

L. INSULATING CEMENT

Figure 10B

IN ANSWERING QUESTIONS 10-39 THROUGH 10-44, REFER TO FIGURE 10B AND SELECT THE TYPE OF REFRACTORY MATERIAL DESCRIBED BY THE QUESTION.

10-39. Can only be used with specific burner types.

1. E
2. F
3. G
4. H

10-40. Used to provide structural stability and to protect backup insulation.

1. K
2. F
3. D
4. A

10-41. Its advantage is the speed and economy of insulation because handcutting insulation or brick bolts is eliminated.

1. H
2. I
3. J
4. K

10-42. Used as an insulating space filler between insulation block and the casing in some boilers.

1. B
2. C
3. K
4. L

10-43. Used primarily on studded tubes in divided furnace boilers.

1. A
2. C
3. E
4. J

10-44. In D-type burners, used in superheater cavities?

1. A
2. B
3. C
4. D

10-45. When used, castable firelay refractory should be air-cured for what minimum period of time before it is baked out?

1. 5 days
2. 2 days
3. 3 days
4. 4 days

10-46. Which of the following types of refractory mortar develop(s) its strength after drying without being heated?

1. Nonair-setting mortar
2. Class 1
3. Class 2
4. Both 2 and 3 above

10-47. Baffle tile is made from what material?

1. Copper
2. Plastic
3. Steel
4. Silicon carbide

10-48. Styrofoam expansion joints must be cut to what uniform thickness?

1. 1/3 inch
2. 1/4 inch
3. 1/5 inch
4. 1/8 inch

10-49. The majority of propulsion boilers have what total number of furnaces?

1. One
2. Two
3. Three
4. Four

10-50. What steam drum fitting dispersers feedwater evenly in the steam drum?

1. Water separators
2. Internal feed pipe
3. Baffle plates
4. Blowdown piping

ASSIGNMENT 11

Textbook Assignment: "Propulsion Boilers" and "Boiler Fittings and Instruments," chapters 15 and 16, pages 15-14 through 16-28.

11-1. Unless a different criteria is shown in an applicable refractory arrangement drawing, what should the width of the expansion joints in the firebrick layer be?

1. 1/4 in.
2. 1/3 in.
3. 1/2 in.
4. 3/4 in.

11-2. Expansion joints are constructed of what two materials?

1. Metal or wood
2. Styrofoam or plastic
3. Styrofoam or metal
4. Plastic or metal

11-3. In modem boiler installations, each boiler is enclosed in two steel casings. The inner casing is lined with refractory materials, and the outer casing extends around most of the inner casing. What is between the inner and out casings?

1. Air space
2. Styrofoam fill
3. Fireclay
4. Baffle tile

11-4. As a rule, the uptakes from two or more boilers in the same space connect with what total number of smokepipes?

1. One
2. Two
3. Three
4. Four

11-5. Which of the following boiler components supports each water drum and water header?

1. Beams built up from the structure
2. Saddles
3. Sliding feet
4. I-beams

11-6. Desuperheaters are referred to as what type of fitting?

1. Indirect
2. Direct
3. External
4. Internal

11-7. In most single-furnace propulsion boilers, what total number of forced draft blowers are there per boiler?

1. One
2. Two
3. Three
4. Four

11-8. When the burner is in operation, the register doors should be in what position to permit unrestricted airflow?

1. Closed tightly
2. Quarter-way open
3. Halfway open
4. Wide open

11-9. What component lets air flow to the boiler but prevents reverse flow and windmilling of the idle blower?

1. Automatic shutters
2. Check valve
3. Ductwork
4. Uptakes

11-10. Combustion gases leave the furnace through the screen tubes. What is the purpose of the screen tubes during boiler operation?

1. To protect the furnace refractories
2. To support the water drum
3. To reduce direct flame impingement on the superheater tubes
4. To direct the gas flow into the uptakes

11-11. During full power conditions, feedwater temperature is increased approximately what amount?

1. 190°F
2. 200°F
3. 210°F
4. 220°F

IN ANSWERING QUESTION 11-12, REFER TO FIGURE 15-13 IN THE TEXTBOOK.

11-12. Feedwater travels through a series of tubes and back through another set of finned tubes by U-bends. Each plane of 13 tubes is known as a row of

1. economizer tubes
2. generating tubes
3. superheater tubes
4. screen tubes

11-13. What components ensure a positive flow of water to the lower parts of the boiler?

1. Feedwater pipes
2. Economizers
3. Downcomers
4. Generating tubes

11-14. In order to be heated to superheat temperature, steam must make what number of passes through the superheater tubes?

1. One
2. Two
3. Three
4. Four

11-15. When steam leaves the superheater via the inlet/outlet header, it is split in two directions. The majority of steam leaving the superheater is directed to what component?

1. The desuperheater
2. The FEB
3. The SSTG
4. The main engines

11-16. The chemical feedpipe is used to inject chemicals into the boiler. This pipe extends through approximately what percentage of the length of the steam drum?

1. 50%
2. 75%
3. 90%
4. 100%

11-17. What is the purpose of the holes located on top of the dry pipe in a boiler?

1. To inject chemicals into the boiler
2. To prevent moisture from entering the pipe
3. To prevent chemicals from entering the superheater
4. To carry off scum and foam

11-18. On the boiler discussed in the text, the surface blow pipe is located just below the normal water level of the drum. This pipe extends for the full length of the drum. What total number of rows of holes is drilled into the top of the pipe?

1. One
2. Two
3. Three
4. Four

11-19. Which of the following steam drum internals is designed to reduce the swirling motion of water as it enters the downcomers?

1. The economizer
2. The desuperheater
3. The vortex eliminator
4. The separator

11-20. What is the purpose of the desuperheater?

1. To reduce the temperature of a portion of the superheated steam
2. To turn the superheated steam back into saturated steam
3. To supply steam to the SSTGs
4. To lower the steam pressure for the FDBs

11-21. In a single-furnace boiler, the desuperheater is located in the

1. superheater tube bank
2. steam drum or water drum
3. economizer
4. furnace

11-22. When the boiler is being emptied, what component lets air enter the steam drum?

1. The vent valve
2. The header drain valve
3. The aircock
4. The superheater drain

11-23. The aircock is used to vent the boiler. At what point on a steam drum is it located?

1. At the highest point
2. At the three-quarter point
3. At the midpoint
4. At the lowest point

11-24. What component(s) allow(s) the superheater to be vented and drained with each pass?

1. Blow valves
2. Air cock only
3. Vent valves and aircock
4. Superheater vents and drains

11-25. At what point should you obtain a sample of boiler water that has the greatest possibility of being representative?

1. Superheater drains
2. Gauge glass
3. Steam drum
4. Water drum

11-26. Stop-check valves are used throughout the engineering plant. One of the most familiar stop-check valves is also known as the

1. boiler steam-stop valve
2. boiler feed-check valve
3. check valve

11-27. What is the purpose of steam-stop valves?

1. To disconnect boilers to the main steam line only
2. To connect boilers to the main steam line only
3. To connect and disconnect boilers to the main steam line
4. To connect and disconnect boilers to the secondary steam lines

11-28. What is the required number of valve protections for each boiler on ships built to US. Navy specifications?

1. One
2. Two
3. Three
4. Four

11-29. What is the purpose of the soot blowers installed on boilers?

1. To remove soot from the superheater while the boiler is steaming
2. To remove soot from the superheater while the boiler is not steaming
3. To remove soot from the firesides while the boiler is steaming
4. To remove soot from the firesides while the boiler is not steaming

11-30. Soot blowers should be used in the proper sequence for which of the following reasons?

1. To prevent fire hazards
2. To prevent heavy smoke
3. So the soot will be swept progressively toward the uptakes
4. So the soot will be swept progressively toward the firebox

11-31. Before tubes are blown, the EOOW must obtain permission from what individual before giving the order to blow tubes?

1. CO
2. XO
3. OOD
4. DCA

11-32. Each steaming boiler uses its own steam to supply its own soot blowers. To what pressure is the steam used in the blowing tubes reduced?

1. 100 psi
2. 200 psi
3. 300 psi
4. 400 psi

11-33. What is the purpose of the surface and bottom blow valves?

1. To remove solid matter from the superheater
2. To remove solid matter from the boiler
3. To remove liquid impurities from the boiler water
4. To remove liquid-waste buildup from the superheater

11-34. Each boiler should be equipped with what minimum number of indicating devices?

1. One
2. Two
3. Three
4. Four

11-35. What is the purpose of remote-water-level indicators?

1. To monitor the boiler water level from the lower level of the fireroom or operating station
2. To provide a control station
3. For use during a casualty
4. For use aboard auxiliary ships

11-36. In firerooms, which of the following is/are the most commonly used temperature gauges?

1. Direct-reading
2. Distant-reading
3. Both 1 and 2 above

11-37. What number of smoke periscopes are required to be installed in the uptake for a single-furnace boiler?

1. One
2. Two
3. Three
4. Four

11-38. What force causes the huddling-chamber safety valve to lift?

1. The static pressure of the steam
2. The amount of compression on the spring
3. The set pressure of the nozzle
4. The pressure on the disk

11-39. What factor determines the amount of blowdown in a huddling-chamber safety valve?

1. The position of the adjusting ring
2. The compression on the spring
3. The shape of the nozzle
4. The shape of the huddling chamber

11-40. The superheater safety valve is set to pop at approximately what percentage higher than the drum pilot valve?

1. 1%
2. 2%
3. 3%
4. 4%

11-41. Which of the following is a type of atomizer?

1. Steam-assist
2. Vented-plunger
3. Straight-through
4. Each of the above

11-42. The three-valve superheater outlet safety valve assembly consists of a pilot valve, a piston actuator, and an unloading valve. This valve is used on which of the following types of boilers?

1. 450 psi
2. 750 psi
3. 1,200 psi
4. 1,500 psi

11-43. A spring-loaded pilot valve is mounted on the top center line of the steam drum. What causes the safety valve in this assembly to lift?

1. Excessive pressure in the steam drum
2. Excessive pressure in the superheater
3. Excessive pressure in the economizer
4. Excessive pressure in the downcomers

11-44. What is the principle of operation of the vented-plunger atomizer?

1. Steam is used to project the oil mass
2. Steam is used to break up the oil mass
3. The straight mechanical pressure atomization principle
4. The straight-through-flow atomizer principle

A. VENTED-PLUNGER ATOMIZER
B. STRAIGHT-THROUGH-FLOW ATOMIZER
C. STEAM-ASSIST ATOMIZER

Figure 11A

IN ANSWERING QUESTIONS 11-45 AND 11-46, REFER TO FIGURE 11A.

11-45. In this type of atomizer, all oil is sprayed into the furnace.

1. A
2. B
3. C

11-46. In this type of atomizer, steam is supplied through the inner tube of the atomizer to the steam ports of the sprayer plate.

1. A
2. B
3. C

11-47. If steam is not available, the steam atomization burner systems can use which of the following substitutes for the 150 psi auxiliary steam for cold plant light off?

1. Low-pressure compressed air
2. Shore steam
3. High-pressure compressed air
4. Medium-pressure compressed air

11-48. Which of the following factors affect the character of atomization?

1. The size and relative passage proportions in the atomizer parts
2. The fuel-oil viscosity
3. The size of the orifice of a sprayer plate
4. Each of the above

11-49. In what position will the atomizer root valve be on a secured burner?

1. Halfway open
2. Fully open
3. Fully closed

11-50. Which of the following phrases describes the function(s) of the burner/atomizer safety shutoff device?

1. To admit fuel to the atomizer
2. To prevent uncoupling a fuel-pressurized atomizer
3. To prevent personnel from accidentally cutting-in fuel to a burner without an atomizer
4. Both 2 and 3 above

ASSIGNMENT 12

Textbook Assignment: "Automatic Boiler Controls" chapter 17, pages 17-1 through 17-26.

12-1. Which of the following types of combustion and feedwater control systems are installed on most naval ships?

1. Automatic
2. Manual
3. Local-manual
4. Remote-manual

12-2. To find detailed information about each boiler control system, you should refer to which of the following publications?

1. *NSTM,* chapter 553
2. *NSTM,* chapter 220
3. Manufacturer's training manual
4. Each of the above

12-3. Which of the following is a purpose of control systems?

1. To measure a value on the output side of a process
2. To compare the measured value with the desired value and compute the amount of required change
3. To correct the value on the input side of a process so the output side is back to the desired value
4. Each of the above

12-4. What term defines a quantity or condition that is measured and controlled by a control system?

1. Controlled variable only
2. Variable
3. Controlled medium only
4. Medium

12-5. What term defines any quantity or condition that is varied by a control system to affect the value of a controlled variable?

1. An open loop
2. A closed loop
3. A manipulated variable only
4. A variable

12-6. What term defines the slowing down effect that is associated with capacity and resistance?

1. Dead time
2. Transfer time
3. Lag
4. Flow

12-7. What is the difference, if any, between dead time and lag time?

1. Dead time is resistance time, while lag time is travel time
2. Dead time is the time from the input to the output, while lag time is resistance time
3. Dead time is travel time, while lag time is related to the capacity and resistance of equipment
4. None; dead time and lag time are the same

12-8. An operable arrangement of one or more automatic controllers connected to function as a closed loop and used with one or more processes is known as a/an

1. automatic controller
2. automatic control system
3. manual controller
4. manual control system

12-9. What type of device measures the value of a variable and operates to correct or limit deviation of this measured value from a selected reference?

1. An automatic closed loop
2. An automatic controller
3. A control agent
4. A closed loop

12-10. The elements of an automatic controller that find and communicate the value of the controlled variable to the controller are known as the

1. measuring means
2. primary element
3. automatic controller
4. automatic control system

12-11. What part of the measuring means first uses or transforms energy from the controlled medium?

1. The final control element
2. The controlling means
3. The set point
4. The primary element

12-12. Refer to figure 17-3 in your text. The primary element of the automatic controller uses or transforms energy from the controlled medium to produce a desired change in the controlled variable. What is the primary element in this system?

1. The motor operator
2. A Bourdon tube
3. The capillary tubing
4. A thermometer bulb

12-13. The controlling means of an automatic controller produce what type of action?

1. Correcting
2. Measuring
3. Computing
4. Controlling

12-14. Refer to figures 17-2 and 17-3 in your text. The final control element of a control means changes the value of the manipulated variable. Which of the following is an example of a final control element?

1. The motor operator
2. The Bourdon tube
3. The steam valve
4. The thermometer bulb

12-15. What part of the controlling means applies power to operate the control element?

1. The motor operator
2. The relay-operated controller
3. The automatic controller
4. The self-operated controller

12-16. In an automatic control system, what type of signal represents the desired value of the controlled variable?

1. The output signal
2. The input signal
3. The feedback signal
4. The secondary feedback signal

12-17. Which of the following types of signals is an example of a primary feedback signal?

1. The input signal used as a reference
2. The output signal used as a reference
3. The input signal that represents the actual measured value of the controlled variable
4. The output signal that represents the actual measured value of the controlled variable

12-18. The comparison between the reference input and the primary feedback produces which of the following signals?

1. The reference input signal
2. The feedback signal
3. The actuating signal
4. The primary feedback signal

12-19. The position to which the control-point setting mechanism is set to provide a reference input is known as the

1. controlling means
2. control point
3. controller
4. set point

12-20. What term defines the instantaneous difference between the actual value of the controlled variable and the value of the controlled variable corresponding to the set point?

1. Deviation
2. Control point
3. Set point
4. Feedback

12-21. The purpose of the automatic controller is to maintain what component?

1. The set point
2. The controller
3. The control point
4. The controlling means

12-22. What is meant by the term *cycling*?

1. The ratio of a signal change between the control point and set point
2. A difference between the control point and set point
3. The oscillation of an automatic control system
4. A continuous changing of the controlled variable

12-23. Whenever a controlled variable reaches a certain value, a final control element is moved from one of two fixed positions to the other. What type of positioning action is taking place?

1. Two-position, differential-gap action
2. Two-position action
3. Two-position, single-point action
4. Two-position, two-point action

12-24. A two-position, single-point controller is not capable of making an exact correction. What correction action does this controller always make?

1. Undercorrects
2. Overcorrects
3. Creates dead time
4. Cycles

12-25. In what type of positioning action does the controlled variable have a range of values instead of a single value to reach?

1. Two-position, differential-gap
2. Two-position, single-point
3. Two-position, double-point
4. One-position, single-point

12-26. A controlled variable is required to produce a specified change in the position of the final control element. Which of the following terms defines this change?

1. Proportional band
2. Ratio
3. Actuating signal
4. Reference input

12-27. Which of the following is a description of a rate action?

1. An action that produces an approximate correction
2. An action that gives control without offset
3. The action in which there is a continuous linear relationship between the control variable and the position of the final control element
4. The action in which two or more types of controller action are combined

12-28. What action combines two or more types of controller action?

1. Rate action
2. Floating-rate action
3. Proportional action
4. Multiple action

12-29. What type of action gives control without offset under all load conditions?

1. Rate
2. Proportional only
3. Proportional plus reset
4. Floating rate

12-30. What action combines proportional-position action and rate action?

1. Rate
2. Proportional only
3. Proportional plus rate
4. Floating rate

12-31. The time that it takes the rate action to advance the effect of the proportional-position action on the final control element is known as what type of time?

1. Reset time
2. Lag time
3. Dead time
4. Rate time

12-32. One part of a boiler control system consists of the combustion control. What is the other part?

1. Fuel
2. Air
3. Feedwater
4. Air lock

12-33. The components of the two control systems for each boiler are designed for what total number of methods of control operation?

1. One
2. Two
3. Three
4. Four

12-34. If there is a diaphragm failure in the feedwater regulating valve, the valve will go to which, if any, of the following positions?

1. Full open
2. Full close
3. Set point
4. None of the above

12-35. If there is a diaphragm failure of the fuel-oil control valve, the valve will go to which, if any, of the following positions?

1. Full open
2. Close
3. Set point
4. None of the above

12-36. What is the controlling or balancing force for the operation of pneumatic units?

1. Sea water
2. Oil
3. High-pressure air
4. Compressed air

A. CONTROL PRESSURE
B. LOADING PRESSURE
C. SUPPLY AIR PRESSURE
D. VARIABLE AIR PRESSURE

Figure 12A

IN ANSWERING QUESTIONS 12-37 THROUGH 12-39, SELECT FROM FIGURE 12A THE TYPES OF PRESSURES DEFINED IN THE QUESTION.

12-37. This compressed air pressure is supplied to each pneumatic unit to develop pneumatic messages or signals.

1. A
2. B
3. C
4. D

12-38. This compressed air pressure goes from one pneumatic unit to another, unless the pressure is imposed on a motor operator of a final control element.

1. A
2. B
3. C
4. D

12-39. This compressed air pressure goes from a pneumatic unit to a motor operator of a final control element.

1. A
2. B
3. C
4. D

12-40. The output signals from the direct-acting steam pressure transmitter is transmitted by what device?

1. The steam pressure control
2. The steam pressure transmitter
3. The high signal selector
4. The boiler master

12-41. The high signal selector selects the higher of the pressures, then this signal is sent to what device?

1. The boiler master
2. The steam pressure transmitter
3. The steam pressure controller
4. The low signal selector

12-42. Of the following components, which one measures the differential between the wind box and the fire box?

1. The forced draft blower A/M station
2. The F/A ratio signal generator
3. The range modifier
4. The airflow transmitter

12-43. Because of an adverse condition, you need to readjust the airflow to restore combustion to an acceptable state until excess air can be adjusted. By what means can you modify the airflow signal?

1. The airflow transmitter
2. The signal range modifier
3. The F/A ratio signal generator
4. The ratio fuel relay

12-44. The airflow feedback signal goes to which of the following components?

1. The airflow rate relay
2. The low signal selector
3. The airflow transmitter
4. The steam flow transmitter

12-45. Which of the following actions describes the purpose of the airflow controller?

1. To compare the master demand signal and the airflow signal
2. To apply proportional pulse reset action to correct differences between the master demand and airflow signals
3. Both 1 and 2 above
4. To measure the differential between the wind box and the fire box

12-46. The output of the steam flow rate relay goes to what component?

1. The range modifier
2. The airflow rate relay
3. The two-way, forced draft blower master A/M
4. The proportional band

12-47. The signal range modifier sends out an increased signal that is transmitted through the forced draft blower A/M stations to what component(s)?

1. The final control elements
2. The range modifier
3. The airflow transmitters
4. The airflow rate relay

12-48. What is the input of the first component in the fuel control loop low signal selector?

1. The master demand signal only
2. The airflow feedback signal only
3. The master demand and airflow feed back signals
4. The differential signal

12-49. What is the purpose of the low signal selector?

1. To compare the feedback signal and the demand signal
2. To ensure that the fuel flow never exceeds airflow, preventing black smoke
3. To send a signal to the characterizing relay
4. To control fuel-oil pressure below 50%

12-50. Depending on need, what is the output range of the steam pressure controller?

1. Between 0 and 60 psig
2. Between 20 and 80 psig
3. Between 50 and 100 psig
4. Between 60 and 120 psig

12-51. In the air loop, the airflow controller signal is transmitted to what component?

1. The steam flow rate relay
2. The fuel flow rate relay
3. The master A/M station
4. The signal range modifier

12-52. An increase in signal for the airflow controller and the input from the steam flow transmitter causes the steam flow rate relay output to increase. This output is transmitted to what component?

1. The airflow master signal
2. The master demand signal
3. The signal range modifier
4. The master A/M control

12-53. In the fuel control loop, the airflow signal is still at which of the following values?

1. The value it had before the steam pressure dropped
2. The value is the same as the primary feedback
3. The value is the same as the reference input
4. The value is the same as the controlled variable

12-54. The output of the characterizing relay goes directly to what component?

1. The fuel-oil A/M station
2. The low signal selector
3. The fuel pressure control valve final control element
4. The master control

12-55. In the pressure-sensing group, what force opposes the tendency of the beam to move upward on an increase in header pressure?

1. Bellows
2. Proportional band
3. Signal gain
4. Steam pressure transmitter

12-56. Which of the following are components of the airflow loop?

1. Steam flow rate relay, high signal selector, and airflow controller
2. Signal range modifier, high signal selector, and steam flow rate relay
3. Airflow transmitter, signal range modifier, and high signal selector
4. Airflow controller, airflow transmitter, and steam flow rate relay

12-57. The fulcrum of the signal range modifier is properly adjusted. If the airflow controller output is less than 9 psi, what is the signal to the final control element of the forced draft blower?

1. 15 psi
2. 12 psi
3. 9 psi
4. 6 psi

12-58. From what component does the fuel-oil control valve receive its signal?

1. The high signal selector
2. The low signal selector
3. The master selector
4. The characterizing relay

12-59. The oil control valve is fitted with a handjack operated by a handwheel that serves which of the following purposes?

1. To manually position the valve piston
2. To automatically position the valve
3. To maintain the set point
4. To select the mode of operation

12-60. From which of the following positions can biasing be done?

1. A two-way transfer station
2. A four-way transfer station
3. A boiler master
4. A forced draft blower control station

12-61. Biasing can only be accomplished when the boiler is in which of the following modes?

1. Remote-manual
2. Local-manual
3. Manual
4. Automatic

12-62. A system is completely automatic when it is operating in which of the following ways?

1. Biasing
2. Hunting
3. With human assistance
4. Without human assistance

ASSIGNMENT 13

Textbook Assignment: "Automatic Boiler Controls" and "Boiler Water/Feedwater Test and Treatment," chapters 17 and 18, pages 17-26 through 18-34.

13-1. Throughout the engineering plant, what system automatically monitors and controls the operation of the main boilers and supporting auxiliaries?

1. The automatic boiler control
2. The automatic combustion control
3. The automatic control

13-2. The value of a control condition is compared with a desired value. The corrective action that is taken depends on the difference. What term describes this type of operation?

1. Automatic
2. Control agent
3. Automatic control
4. Automatic controller

A. AUTOMATIC CONTROL
B. AUTOMATIC CONTROLLER
C. ACTUATOR

Figure 13A

IN ANSWERING QUESTIONS 13-3 AND 13-4, REFER TO FIGURE 13A AND SELECT THE TERM DESCRIBED IN THE QUESTION.

13-3. The component part of the final control element that converts energy into a mechanical position change.

1. A
2. B
3. C

13-4. The device that operates automatically to regulate a controlled variable in response to a feedback signal.

1. A
2. B
3. C

A. CYCLING
B. DEAD TIME
C. DEVIATION
D. HUNTING

Figure 13B

IN ANSWERING QUESTIONS 13-5 THROUGH 13-8, REFER TO FIGURE 13B AND SELECT THE TERM DESCRIBED IN THE QUESTION.

13-5. The undesirable oscillation of an automatic control system.

1. A
2. B
3. C
4. D

13-6. A periodic change in a controlled variable.

1. A
2. B
3. C
4. D

13-7. The time interval between initiation of an input change and the start of the response.

1. A
2. B
3. C
4. D

13-8. The difference between the instantaneous value of the controlled variable and the value of the controlled variable corresponding to the set point.

1. A
2. B
3. C
4. D

13-9. Which of the following is a definition of the term *differential* ?

1. The difference between a value that results from a measurement and the corresponding true value
2. The difference between the signal generated by one component of a control system and another component of the same system
3. The difference of two or more motions or forces
4. The difference of the periodic changes of the controlled variable

13-10. A signal is returned to the input of the system, where it is compared with the reference signal to get the actuating signal. The actuating signal returns the controlled variable to the desired value. What signal performs these actions?

1. A final control element signal
2. A feedback signal
3. A gain signal
4. A hunting signal

13-11. What term defines the ratio of the signal change at the output of a device to the change at the input of the device?

1. Gain
2. Hunting
3. Feedback
4. Demand

13-12. The property of any material to resist a change in its state or motion is known as

1. the lag time
2. inertia
3. mass
4. the loading effect

13-13. What term describes the steady state difference between the control point and the value of the controlled variable that corresponds to the set point?

1. Parameter
2. Positioner
3. Process
4. Offset

13-14. What type of equipment is run by air or uses compressed air?

1. Pneumatic
2. Hydraulic
3. Manual
4. Mechanical

13-15. Which of the following statements defines the term process?

1. A collection of functions performed in and by the equipment in which a variable is controlled
2. The function that serves to position the final control element in proportion to the loading pressure
3. The respective values that distinguish a specific system
4. A quantity that controls the controlled variables in a system

13-16. What component/system positions the final control element in proportion to the loading pressure?

1. The demand system
2. The pneumatic system
3. The positioner
4. The processor

13-17. The amount of deviation of the controlled variable from the set point required to move the final control element through the full range is known as the

1. range
2. relay
3. proportional band
4. process

13-18. What term describes the difference between the maximum and minimum values of physical output over which an instrument is designed to operate normally?

1. Ratio
2. Relay
3. Reset
4. Range

13-19. On an instrument whose scale starts at zero with the span equal to the range, the difference between the top and bottom scale values of the instrument is known as the

1. variable
2. span
3. ratio
4. relay

13-20. Which of the following terms defines the time rate of linear motion in a given direction?

1. Speed
2. Acceleration
3. Vector
4. Velocity

13-21. Service steam and freshwater drains affect condensate and feedwater in what way?

1. They are subject to pressure from the freshwater drain-collecting tank
2. They are subject to shore water and other types of contamination
3. They will increase the chloride by 10 epm in 4 days while steaming
4. They contain a higher concentration of solids

13-22. Because its solvent strength is great enough to dissolve everything it touches, which of the following substances is known as the *universal solvent?*

1. Liquid wrench
2. Oil
3. Water

13-23. If a boiler is producing steam at about 50 percent of its capacity, the amount of dissolved and suspended materials brought into the boiler with the feedwater will be concentrated in the boiler at what rate?

1. 5 times per hour
2. 2 times per hour
3. 10 times per hour
4. 20 times per hour

13-24. Boiler water quality depends directly on what factor?

1. The quality of the feedwater
2. The quality of the boiler water
3. Effective feedwater control
4. Effective shore water control

13-25. In a boiler, a microscopically thin layer of what material protects the iron it covers from corrosion?

1. Magnetite
2. Electrons
3. Scale
4. Carfan

A. SILICA IN SHORE SOURCE FEEDWATER

B. DISSOLVED OXYGEN IN BOILER WATER AND WATER HAS LOW pH

C. CHLORIDE ON STAINLESS STEEL TUBES OF A SUPERHEATER

D. HIGH CONDUCTIVITY WATER CAUSING INEFFECTIVE SEPARATION OF CONTAMINATED WATER FROM STEAM

E. SUSPENDED SOLIDS IN THE BOILER WATER

F. LUBRICATION OIL THAT ACCUMULATES IN THE STEAM DRUM

Figure 13C

IN ANSWERING QUESTIONS 13-26 THROUGH 13-31, SELECT FROM FIGURE 13C THE CAUSE FOR THE CONDITION LISTED IN THE QUESTION.

13-26. Stress corrosion.

1. B
2. C
3. D
4. E

13-27. Baked on carbon deposits.

1. A
2. B
3. D
4. F

13-28. Pitting corrosion.

1. B
2. C
3. D
4. E

13-29. Scale formation.

1. A
2. B
3. C
4. D

13-30. Sludge formation.

1. A
2. C
3. D
4. E

13-31. Carryover.

1. A
2. C
3. D
4. F

13-32. By what means is water acidity or alkalinity determined?

1. pH
2. Chloride
3. Phosphate
4. Silica

13-33. Which of the following is a description of the term *priming*?

1. Failure of the steam bubbles to break
2. Water bubbles are carried into the dry pipe
3. Slugs of boiler water are carried into the dry pipe and reach as far as the turbine
4. High water when it reaches the superheater

13-34. Which of the following are the major feedwater contaminants?

1. Fuel, ion exchange resin, shore water, and seawater
2. Preservatives, fuel, seawater, and lubricating oil
3. Shore water, suspended solids, seawater, and metal corrosion products
4. Metal corrosion products, dirt, shore water, and debris

13-35. By what means can you tell if feedwater has been contaminated with ion exchange resin?

1. Chloride in the water
2. The water smells fishy
3. The water feels gritty
4. Yellowish water

13-36. Which of the following is an amine that, when added to freshwater drain-collecting tanks, raises pH and reduces corrosion in the condensate and deareated feedwater lines of the preboiler system?

1. Morpholine
2. Caustic soda
3. Trisodium phosphate
4. Disodium phosphate

13-37. What is the purpose of the Navy treatment of boiler water known as *coordinated phosphate control*?

1. Maintaining pH and phosphate levels so caustic corrosion cannot occur
2. Maintaining a phosphate residual in the water causes calcium and magnesium phosphate sludges
3. Maintaining pH high enough to limit boiler metal corrosion
4. All of the above

13-38. During idle boiler maintenance, one goal is to prevent oxygen corrosion of the boiler metal. To prepare the boiler for dry layup, sodium nitrite is injected into a boiler. The sodium nitrite forms a passivating film that remains on the watersides. By what means does this protect the boiler?

1. It retards iron oxidation
2. It keeps the watersides dry
3. It keeps air out of the boiler
4. It speeds up water evaporation

A. FUEL OIL
B. DISSOLVED OXYGEN
C. SEAWATER
D. SHORE WATER
E. PRESERVATIVES

Figure 13D

IN ANSWERING QUESTIONS 13-39 THROUGH 13-42, REFER TO FIGURE 13D AND SELECT THE CAUSE DESCRIBED BY THE RESULT USED AS THE QUESTION.

13-39. Boiler tube blistering and failure.

1. A
2. B
3. D
4. E

13-40. Generating and superheater tube failure.

1. A only
2. B only
3. C only
4. A, B, and C

13-41. Salinity cell malfunction.

1. A
2. B
3. C
4. D

13-42. Localized corrosion of the boiler metal.

1. B
2. C
3. D
4. E

13-43. Because shore water contains relatively large amounts of calcium in comparison to magnesium, what is the first chemical reaction?

1. A conductivity increase
2. Phosphate
3. Chloride
4. A pH increase

13-44. Which of the following is an indication of chemical hideout?

1. A diminishing level of phosphate as the boiler steaming rate increases
2. A diminishing level of phosphate as the boiler steaming rate decreases
3. An increasing level of phosphate as the boiler steaming rate increases
4. An increasing level of pH as the boiler steaming rate decreases

A. A STEAM BLANKET IS APPLIED
B. A NITROGEN BLANKET IS APPLIED
C. BOILERS ARE BACKFILLED THROUGH THE SUPERHEATER WITH HOT DEAREATED FEEDWATER
D. AFTER THE DFT IS SECURED, THE LAST BOILER IS BACKFILLED WITH RESERVE FEEDWATER

Figure 13E

IN ANSWERING QUESTION 13-45, REFER TO FIGURE 13E.

13-45. What layup methods may be used for all propulsion boilers?

1. A and B
2. C only
3. D only
4. C and D

13-46. What record should be retained for a minimum period of 2 years?

1. The Fuel and Water Report
2. The Reserve/Makeup Feedwater Test Log
3. The Machinery Plant Water Treatment Log Package
4. The Fireroom Operating Log

13-47. For what minimum period of time should the daily fuel and water report be retained?

1. 1 month
2. 2 months
3. 3 months
4. 4 months

13-48. What is the purpose of surface blowdown?

1. To provide control of boiler water solids, both suspended and dissolved
2. To increase the materials dissolved in the water
3. To decrease materials that have dissolved in the water
4. To reduce the amount of sludge in the water

13-49. What is the purpose of a bottom blowdown?

1. To reduce the amount of sludge in the boiler
2. To decrease materials that have dissolved in the water
3. To increase materials that have dissolved in the water
4. To complete an overhaul

13-50. What chemicals are added to a boiler during a complete wet layup of a propulsion boiler?

1. Morpholine only
2. Hydrazine only
3. Morpholine and hydrazine
4. Magnetite

13-51. When a chemical test is performed for chloride, what code is entered in the code column of the Feedwater Chemical Tests section of the Feedwater Chemistry Worksheet Log?

1. SI
2. ML
3. EPM
4. CH

13-52. Which of the following documents contains a section for pH meter standardization?

1. The Feedwater Chemistry Worksheet Log
2. The Daily Fuel and Water Report
3. The Boiler Water Chemistry Worksheet Log
4. The Monthly Cover sheet

13-53. If you find an error on the Boiler Water Chemistry Worksheet Log, what method should you use to correct it?

1. Erase the error, then make the correct entry
2. Write the correct entry over the error
3. Line through the error, initial it, and make the correct entry
4. Recopy the entire log

13-54. What type of test indicates the effectiveness of the DFT?

1. Dissolved oxygen test
2. pH test
3. Chemical chloride test
4. Salinity indicator comparison

13-55. If you suspect that there is shore water contamination, you should test the affected component for what property?

1. pH
2. Conductivity
3. Hardness
4. Salinity

13-56. What information is reflected in the Reserve Makeup Feedwater Test Log?

1. Quality of the reserve feedwater actually being used
2. Comparison test
3. Conductivity test
4. Silica test

13-57. By what means can you determine the integrity of an unused reserve feedwater tank?

1. Daily silica value
2. Daily hardness value only
3. Daily chloride value only
4. Daily hardness and/or chloride value