

NONRESIDENT TRAINING COURSE

September 1999



Utilitiesman Basic Volume 2

NAVEDTRA 14279

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Although the words "he," "him," and "his" are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

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PREFACE

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

COURSE OVERVIEW: In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following subjects:

Boilers	Galley and Laundry Equipment
Boiler Maintenance	Refrigeration
Steam Distribution Systems	Air Conditioning
Heating Systems	

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

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

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

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Sailor's Creed

"I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all."

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SUMMARY OF UTILITIESMAN BASIC

VOLUME 1

Utilitiesman Basic, Volume 1, NAVEDTRA 11019, consists of chapters on Construction Plans, Specifications, Color Coding: Advanced Base Functional Components (ABFC); Plumbing; Plumbing Valves and Accessories; Plumbing Fixtures and Plumbing Repairs; Pumps and Compressors; Water Treatment; and Maintenance of Water Treatment Equipment.

VOLUME 2

Utilitiesman Basic, Volume 2, NAVEDTRA 11020, consists of chapters on Boilers; Boiler Maintenance; Steam Distribution Systems; Heating Systems; Galley and Laundry Equipment; Refrigeration; and Air Conditioning.

SAFETY PRECAUTIONS

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

During equipment operation and preventive or corrective maintenance, the procedures may call for personal protective equipment (PPE), such as goggles, gloves, safety shoes, hard hats, 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 you 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 eyewash station must be installed.

All lubricating agents, oil, cleaning material, and chemicals used in maintenance and repair are hazardous materials. Examples of hazardous materials are gasoline, coal distillates, and asphalt. Gasoline contains a small amount of lead and other toxic compounds. Ingestion of gasoline can cause lead poisoning. Coal distillates, such as benzene or naphthalene in benzol, are suspected carcinogens. Avoid all skin contact and do not inhale the vapors and gases from these distillates. Asphalt contains components suspected of causing cancer. Anyone handling asphalt must be trained to handle it in a safe manner.

Hazardous materials require careful handling, storage, and disposal. PMS documentation provides hazard warnings or refers the maintenance man to the Hazardous Materials User's Guide. Material Safety Data Sheets (MSDS) 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 you command's *Hazardous Material Coordinator.* OPNAVINST 4110.2 (series), *Hazardous Material Control and Management,* contains detailed information on the hazardous material program.

Recent legislation and updated Navy directives implemented tighter constraints on environmental pollution and hazardous waste disposal. OPNAVINST 5090.1 (series), *Environmental and Natural Resources Program Manual,* provides detailed information. Your command must comply with federal, state, and local environmental regulations during any type of construction and demolition. Your supervisor will provide training on environmental compliance.

Cautions and warnings of potentially hazardous situations or conditions are highlighted, where needed, in each chapter of this TRAMAN. Remember to be safety conscious at all times.

INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

Grading on the Internet: Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the assignments. To submit your assignment answers via the Internet, go to:

http://courses.cnet.navy.mil

Grading by Mail: When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

COMMANDING OFFICER
NETPDTC N331
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32559-5000

Answer Sheets: All courses include one "scannable" answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

Do not use answer sheet reproductions: Use only the original answer sheets that we provide—reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

PASS/FAIL ASSIGNMENT PROCEDURES

If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once.** Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

COMPLETION CONFIRMATION

After successfully completing this course, you will receive a letter of completion.

ERRATA

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

http://www.advancement.cnet.navy.mil

STUDENT FEEDBACK QUESTIONS

We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

For subject matter questions:

E-mail: n314.products@cnet.navy.mil
Phone: Comm: (850) 452-1001, Ext. 1826
DSN: 922-1001, Ext. 1826
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC N314
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32509-5237

For enrollment, shipping, grading, or completion letter questions

E-mail: fleetservices@cnet.navy.mil
Phone: Toll Free: 877-264-8583
Comm: (850) 452-1511/1181/1859
DSN: 922-1511/1181/1859
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC N331
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32559-5000

NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you may earn retirement points for successfully completing this course, if authorized under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 12 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty,* BUPERSINST 1001.39, for more information about retirement points.)

Student Comments

Course Title: *Utilitiesman Basic, Volume 2*

NAVEDTRA: 14279 **Date**: _____

We need some information about you:

Rate/Rank and Name: _____ SSN: _____ Command/Unit _____

Street Address: _____ City: _____ State/FPO: _____ Zip _____

Your comments, suggestions, etc.:

Privacy Act Statement: Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This information will not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.

NETPDTC 1550/41 (Rev 4-00

CHAPTER 1

BOILERS

Learning Objectives: Describe the principles and theory of steam generation. Identify different types of boilers and the design requirements for boilers. Describe the purpose and operation of the different types of boilers and their fittings and accessories. Describe the methods and procedures for the testing and treatment of boiler water. Describe methods and procedures involved in fireside and waterside cleaning.

A boiler is an enclosed vessel in which water is heated and circulated, either as hot water or steam, to produce a source for either heat or power. A central heating plant may have one or more boilers that use gas, oil, or coal as fuel. The steam generated is used to heat buildings, provide hot water, and provide steam for cleaning, sterilizing, cooking, and laundering operations. Small package boilers also provide steam and hot water for small buildings.

A careful study of this chapter can help you acquire useful knowledge of steam generation, types of boilers pertinent to Seabee operations, various fittings commonly found on boilers, and so on. The primary objective of this chapter is to lay the foundation for you to develop skill in the operation, maintenance, and repair of boilers.

STEAM GENERATION THEORY

Learning Objective: Describe the principles and theory of steam generation.

To acquaint you with some of the fundamentals underlying the process of steam operation, suppose that you set an open pan of water on the stove and turn on the heat. You find that the heat causes the temperature of the water to increase and, at the same time, to expand in volume. When the temperature reaches the BOILING POINT (212°F or 100°C at sea level). a physical change occurs in the water; the water starts vaporizing. When you hold the temperature at the boiling point long enough, the water continues to vaporize until the pan is dry. A point to remember is that THE TEMPERATURE OF WATER DOES NOT INCREASE BEYOND THE BOILING POINT. Even if you add more heat after the water starts to boil, the water cannot get any hotter as long as it remains at the same pressure.

Now suppose you place a tightly fitting lid on the pan of boiling water. The lid prevents the steam from escaping from the pan and this results in a buildup of pressure inside the container. However, when you make an opening in the lid, the steam escapes at the same rate it is generated. As long as water remains in the pan and as long as the pressure remains constant, the temperature of the water and steam remains constant and equal.

The steam boiler operates on the same basic principle as a closed container of boiling water. By way of comparison, it is as true with the boiler as with the closed container that steam formed during boiling tends to push against the water and sides of the vessel. Because of this downward pressure on the surface of the water, a temperature in excess of 212°F is required for boiling. The higher temperature is obtained simply by increasing the supply of heat; therefore, the rules you should remember are as follows:

1. All of the water in a vessel, when held at the boiling point long enough, will change into steam. AS LONG AS THE PRESSURE IS HELD CONSTANT, THE TEMPERATURE OF THE STEAM AND BOILING WATER REMAINS THE SAME.

2. AN INCREASE IN PRESSURE RESULTS IN AN INCREASE IN THE BOILING POINT TEMPERATURE OF WATER.

A handy formula with a couple of fixed factors will prove this theory. The square root of steam pressure multiplied by 14 plus 198 will give you the steam temperature. When you have 1 psig of steam pressure, the square root is one times 14 plus 198 which equals 212°F which is the temperature that the water will boil at 1 psig.

There are a number of technical terms used in connection with steam generation. Some of these commonly used terms you should know are as follows:

- "Degree" is defined as a measure of heat intensity.
- "Temperature" is defined as a measure in degrees of sensible heat. The term *sensible heat* refers to heat that can be measured with a thermometer.
- "HEAT" is a form of energy measured in British thermal units (Btu). One Btu is the amount of heat required to raise 1 pound of water 1 degree Fahrenheit at sea level.
- "Steam" means water in a vapor state. DRY SATURATED STEAM is steam at the saturation temperature corresponding to pressure, and it contains no water in suspension. WET SATURATED STEAM is steam at the saturation temperature corresponding to pressure, and it contains water particles in suspension.
- The "QUALITY" of steam is expressed in terms of percent. For instance, if a quantity of wet steam consists of 90 percent steam and 10 percent moisture, the quality of the mixture is 90 percent.
- "SUPERHEATED STEAM" is steam at a temperature higher than the saturation temperature corresponding to pressure. For example, a boiler may operate at 415 psig (pounds per square inch gauge). The corresponding saturation temperature for this pressure is 483°F, and this will be the temperature of the water in the boiler and the steam in the drum. (Charts and graphs are available for computing this pressure-temperature relationship.) This steam can be passed through a superheater where the pressure remains about the same, but the temperature will be increased to some higher figure.

Q1. When heat is applied to water, what physical change occurs?

Q2. How is a "degree" of heat defined?

Q3. As long as the pressure in a boiler is held constant, what factor remains the same in the boiler?

BOILER DESIGN REQUIREMENTS

Learning Objective: Describe the design requirements for boilers.

A boiler must meet certain requirements before it is considered satisfactory for operation. Three important requirements for a boiler are as follows:

1. The boiler must be safe to operate.
2. The boiler must be able to generate steam at the desired rate and pressure.
3. The boiler must be economical to operate.

NOTE

Make it a point to familiarize yourself with the boiler code and other requirements applicable to the area in which you are located.

Design rules for boilers are established by the ASME (American Society of Mechanical Engineers). These rules are general guidelines used by engineers when designing boilers. These rules require that for economy of operation and to generate steam at the desired rate and pressure, a boiler must have the following attributes:

- Adequate water and steam capacity
- Rapid and positive water circulation
- A large steam generating surface
- Heating surfaces that are easy to clean on both water and gas sides
- Parts accessible for inspection
- A correct amount and proper arrangement of heating surface
- A firebox for efficient combustion of fuel

Q4. What three requirements must a boiler meet before being considered satisfactory for operation?

Q5. What organization has established guidelines for designing boilers?

TYPES OF BOILERS

Learning Objective: Identify the different types of boilers and describe the operation of each.

The Utilitiesman is concerned primarily with the FIRE-TUBE type of boiler, since it is the type generally used in Seabee operations. However, the WATER-TUBE type of boiler may occasionally be used at some activities. The information in this chapter primarily concerns the different designs and construction feature: of fire-tube boilers.

concerns the different designs and construction features of fire-tube boilers.

The basis for identifying the two types is as follows:

- WATER-TUBE BOILERS are those in which the products ofcombustion surround the tubes through which the water flows.
- FIRE-TUBE BOILERS are those in which the products of combustion pass through the tubes and the water surrounds them.

WATER-TUBE BOILERS

Water-tube boilers may be classified in a number of ways. For our purpose, they are classified as either straight tube or bent tube. These classes are discussed separately in succeeding sections. To avoid confusion, make sure you study carefully each illustration referred to throughout the discussion.

Straight Tube

The STRAIGHT-TUBE class of water-tube boilers includes three types:

1. Sectional-header cross drum
2. Box-header cross drum
3. Box-header longitudinal drum

In the SECTIONAL-HEADER CROSS DRUM boiler with vertical headers, the headers are steel boxes into which the tubes are rolled. Feedwater enters and passes down through the downcomers (pipes) into the rear sectional headers from which the tubes are supplied. The water is heated and some of it changes into steam as it flows through the tubes to the front headers. The steam-water mixture returns to the steam drum through the circulating tubes and is discharged in front of the steam-drum baffle that helps to separate the water and steam.

Steam is removed from the top of the drum through the dry pipe. This pipe extends along the length of the drum and has holes or slots in the top half for steam to enter.

Headers, the distinguishing feature of this boiler. are usually made of forged steel and are connected to the drums with tubes. Headers may be vertical or at right angles to the tubes. The tubes are rolled and flared into the header. A handhold is located opposite the ends of each tube to facilitate inspection and cleaning. Its purpose is to collect sediment that is removed by blowing down the boiler.

Baffles are usually arranged so gases are directed across the tubes three times before being discharged from the boiler below the drum.

BOX-HEADER CROSS DRUM boilers are shallow boxes made of two plates—a tube-sheet plate that is bent to form the sides of the box, and a plate containing the handholds that is riveted to the tube-sheet plate. Some are designed so that the front plate can be removed for access to tubes. Tubes enter at right angles to the box header and are expanded and flared in the same manner as the sectional-header boiler. The boiler is usually built with the drum in front. It is supported by lugs fastened to the box headers. This boiler has either cross or longitudinal baffling arranged to divide the boiler into three passes. Water enters the bottom of the drum, flows through connecting tubes to the box header, through the tubes to the rear box header, and back to the drum.

BOX-HEADER LONGITUDINAL DRUM boilers have either a horizontal or inclined drum. Box headers are fastened directly to the drum when the drum is inclined. When the drum is horizontal, the front box header is connected to it at an angle greater than 90 degrees. The rear box header is connected to the drum by tubes. Longitudinal or cross baffles can be used with either type.

Bent Tube

Bent tube boilers usually have three drums. The drums are usually of the same diameter and positioned at different levels with each other. The uppermost or highest positioned drum is referred to as the STEAM DRUM, while the middle drum is referred to as the WATER DRUM, and the lowest, the MUD DRUM. Tube banks connect the drums. The tubes are bent at the ends to enter the drums radially.

Water enters the top rear drum, passes through the tubes to the bottom drum, and then moves up through the tubes to the top front drum. A mixture of steam and water is discharged into this drum. The steam returns to the top rear drum through the upper row of tubes, while the water travels through the tubes in the lower rear drum by tubes extending across the drum and enters a small collecting header above the front drum.

Many types of baffle arrangements are used with bent-tube boilers. Usually, they are installed so that the inclined tubes between the lower drum and the top front drum absorb 70 to 80 percent of the heat. The water-tube boilers discussed above offer a number of worthwhile advantages. For one thing, they afford flexibility in starting up. They also have a high productive capacity

ranging from 100.000 to 1,000,000 pounds of steam per hour. In case of tube failure, there is little danger of a disastrous explosion of the water-tube boiler. The furnace not only can carry a high overload, it can also be modified for tiring by oil or coal. Still another advantage is that it is easy to get into sections inside the furnace to clean and repair them. There are also several disadvantages common to water-tube boilers. One of the main drawbacks of water-tube boilers is their high construction cost. The large assortment of tubes required of this boiler and the excessive weight per unit weight of steam generated are other unfavorable factors.

FIRE-TUBE BOILERS

There are four types of fire-tube boilers—the Scotch marine boiler. the vertical-tube boiler, the horizontal return tubular boiler. and the firebox boiler. These four types of boilers are discussed in this section.

Scotch Marine Boiler

The Scotch marine tire-tube boiler is especially suited to Seabee needs. Figure 1-1 is a portable Scotch marine tire-tube boiler. The portable unit can be moved easily and requires only a minimal amount of foundation work. As a complete self-contained unit. its design includes automatic controls. a steel boiler. and burner equipment. These features are a big advantage because no disassembly is required when you must move the boiler into the field for an emergency.

The Scotch marine boiler has a two-pass (or more) arrangement of tubes that run horizontally to allow the heat inside the tubes to travel back and forth. It also has an internally fired furnace with a cylindrical combustion chamber. Oil is the primary fuel used to fire the boiler; however. it can also be fired with wood, coal, or gas. A major advantage of the Scotch marine boiler is that it requires less space than a water-tube boiler and can be placed in a room that has a low ceiling.

The Scotch marine boiler also has disadvantages. The shell of the boiler runs from 6 to 8 feet in diameter, a detail of construction that makes a large amount of reinforcing necessary. The fixed dimensions of the internal surface cause some difficulty in cleaning the sections below the combustion chamber. Another drawback is the limited capacity and pressure of the Scotch marine boiler.

An important safety device sometimes used is the fusible plug that provides added protection against low-water conditions. In case of a low-water condition. the fusible plug core melts, allowing steam to escape, and a loud noise is emitted which provides a warning to the operator. On the Scotch boiler the plug is located in the crown sheet, but sometimes it is placed in the upper back of the combustion chamber. Fusible plugs are discussed in more detail later in this chapter.

Access for cleaning, inspection, and repair of the boiler watersides is provided through a manhole in the top of the boiler shell and a handhold in the water leg. The manhole opening is large enough for a man to enter the

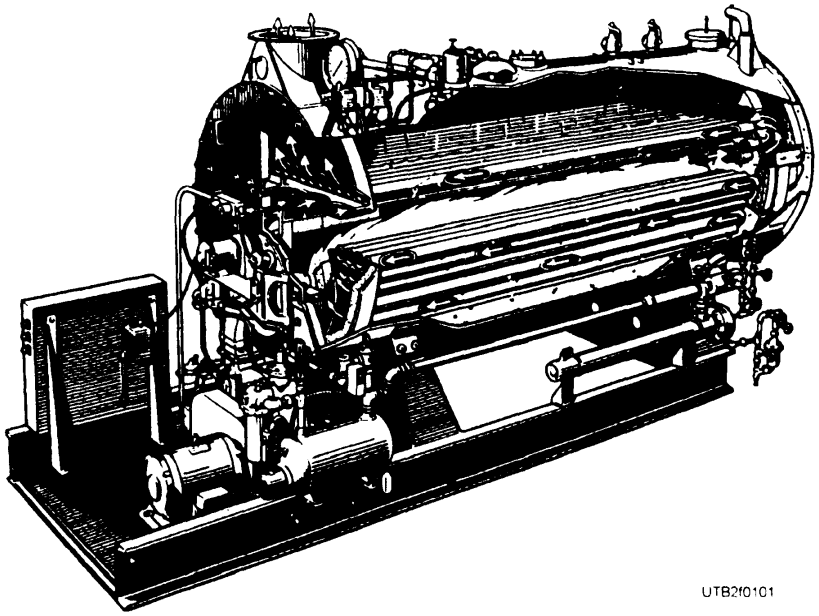
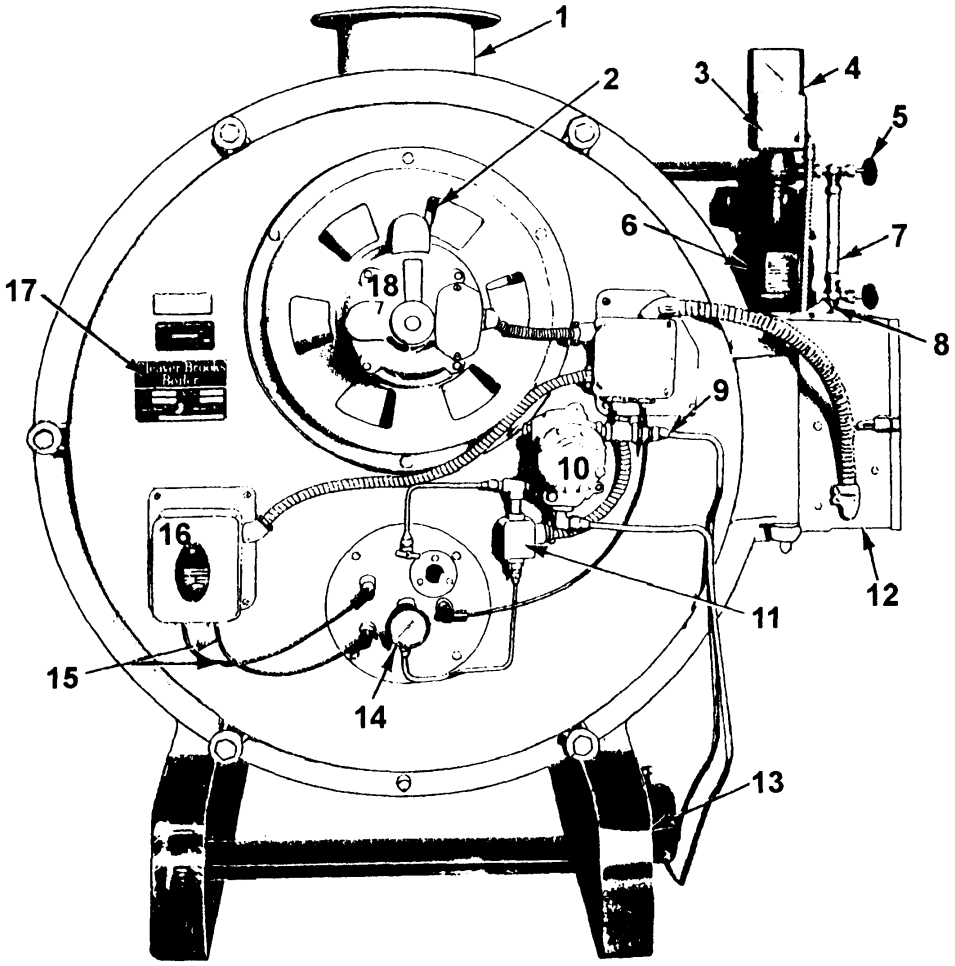


Figure 1-1.—Scotch marine type of fire-tube boiler.

boiler shell for inspection, cleaning, and repairs. On such occasions, always ensure that all valves are secured, locked, tagged, and that the person in charge knows you are going to enter the boiler. Additionally, always have a person located outside of the boiler standing by to aid you in case of an incident occurring that would require you to need assistance. The handholds are openings large enough to permit hand entry for cleaning, inspection, and repairs to tubes and headers. Figure 1-2 shows a horizontal fire-tube boiler used in low-pressure applications. Personnel in the Utilitiesman rating are assigned to operate and maintain this type of boiler more often than any other type of boiler.

Vertical-Tube Boiler

In some fire-tube boilers, the tubes run vertically, as opposed to the horizontal arrangement in the Scotch boiler. The VERTICAL-TUBE boiler sits in an upright position, as shown in figure 1-3. Therefore, the products of combustion (gases) make a single pass, traveling straight up through the tubes and out the stack. The vertical fire-tube boiler is similar to the horizontal fire-tube boiler in that it is a portable, self-contained unit requiring a minimum of floor space. Handholds are also provided for cleaning and repairing. Though self-supporting in its setting (no brickwork or foundation being necessary), it MUST be level. The vertical



1. VENTS
2. AIR DAMPER
3. HIGH-LIMIT PRESSURE CONTROL
4. STEAM PRESSURE GAUGE
5. GAUGE GLASS SHUTOFF COCK
6. LOW-WATER CONTROL
7. WATER LEVEL GAUGE
8. BURNER SWITCH
9. PRIMING TEE
10. OIL UNIT, TWO STAGE
11. SOLENOID OIL VALVE (Maintenance)
12. SERVICE CONNECTION BOX
13. FUEL OIL SUPPLY CONNECTION
14. FUEL OIL PRESSURE GAUGE
15. IGNITION CABLE
16 IGNITION CABLE
17. NAMEPLATE
18. BLOWER MOTOR

UTB2f0102

Figure 1-2.—Horizontal fire-tube boiler used in low-pressure applications.

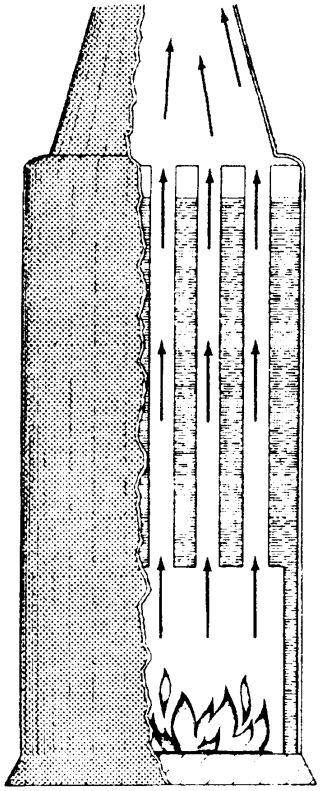


Figure 1-3.—Cutaway view of a vertical fire-tube boiler.

fire-tube boiler has the same disadvantages as that of the horizontal-tube design—limited capacity and furnace volume.

Before selecting a vertical fire-tube boiler, you must know how much overhead space is in the building where it will be used. Since this boiler sits in an upright position, a room with a high ceiling is necessary for its installation.

The blowdown pipe of the vertical tire-tube boiler is attached to the lowest part of the water leg. and the feedwater inlet opens through the top of the shell. The boiler fusible plug is installed either (1) in the bottom tube sheet or crown sheet or (2) on the outside row of tubes, one third of the height of the tube from the bottom.

Horizontal Return Tubular Boiler

In addition to operating portable boilers, such as the Scotch marine and vertical fire-tube boilers. the Utilitiesman must also be able to operate stationary boilers, both in the plant and in the field. A STATIONARY BOILER can be defined as one having a permanent foundation and not easily moved or relocated. A popular type of stationary fire-tube boiler is the HORIZONTAL RETURN TUBULAR (HRT) boiler shown in figure 1-4.

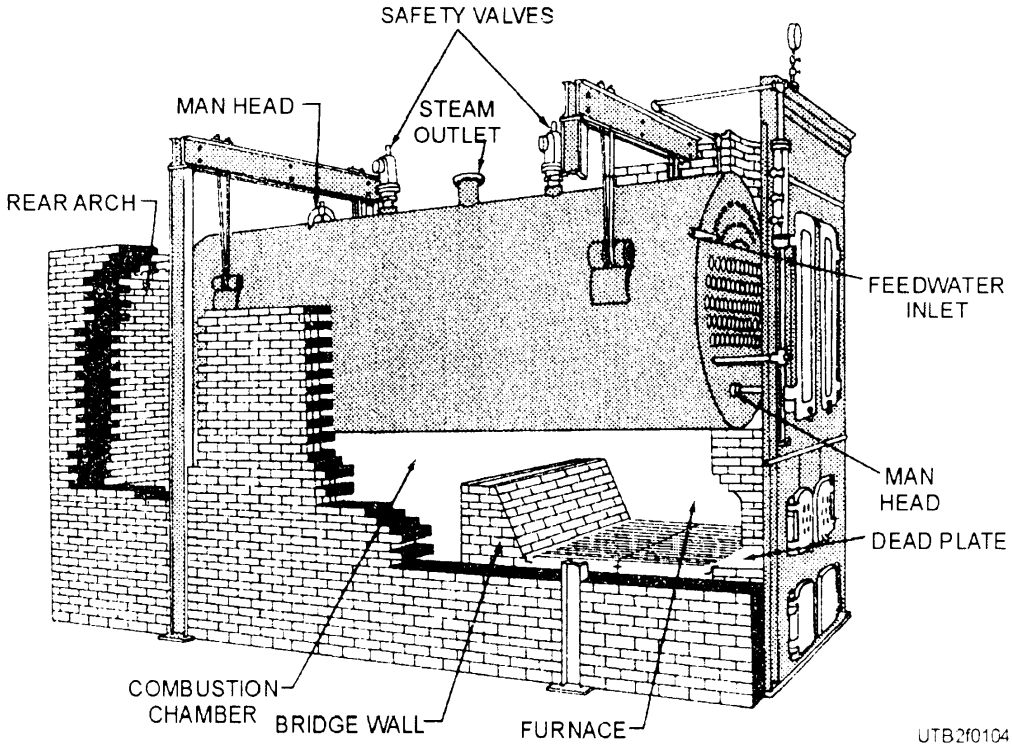


Figure 1-4.—Horizontal return tubular (HRT) fire-tube boiler.

The initial cost of the HRT boiler is relatively low and installing it is not too difficult. The boiler setting can be readily changed to meet different fuel requirements—coal, oil, wood, or gas. Tube replacement is also a comparatively easy task since all tubes in the HRT boiler are the same in size, length, and diameter.

The gas flows in the HRT boiler from the firebox to the rear of the boiler. It then returns through the tubes to the front where it is discharged to the breaching and out the stack.

The HRT boiler has a pitch of 1 to 2 inches to the rear to allow sediment to settle toward the rear near the bottom blowdown connection. The fusible plug is located 2 inches above the top row of tubes. Boilers over 40 inches in diameter require a manhole in the upperpart of the shell. Those over 48 inches in diameter must have a manhole in the lower, as well as in the upper, part of the shell. Do not fail to familiarize yourself with the location of these and other essential parts of the HRT boiler. The knowledge you acquire will definitely help in the performance of your duties with boilers.

Firebox Boiler

Another type of fire-tube boiler is the FIREBOX boiler that is usually used for stationary purposes. A split section of a small firebox boiler is shown in figure 1-5. Gases in the firebox boiler make two passes through the tubes. Firebox boilers require no setting except possibly an ash pit for coal fuel. As a result, they can be quickly installed and placed in service. Gases travel from the firebox through a group of tubes to a reversing chamber. They return through a second set of tubes to the flue connection on the front of the boiler and are then discharged up the stack.

Q6. What are the two types of boilers?

Q7. What are the four types office-tube boilers?

Q8. What is the primary factor that allows the firebox boiler to be quickly installed and placed into service?

BOILER FITTINGS AND ACCESSORIES

Learning Objective: Describe the function and operation of the different types of boiler fittings and accessories.

Now that the basic structure of a boiler has been explained, boiler fittings (fig. 1-6) and the operation or function of various devices, such as controls, valves, and try cocks, must be presented. A sufficient number of essential boiler fittings and accessories are discussed in this section to provide a background for further study. As a reminder, and in case you should run across some unit

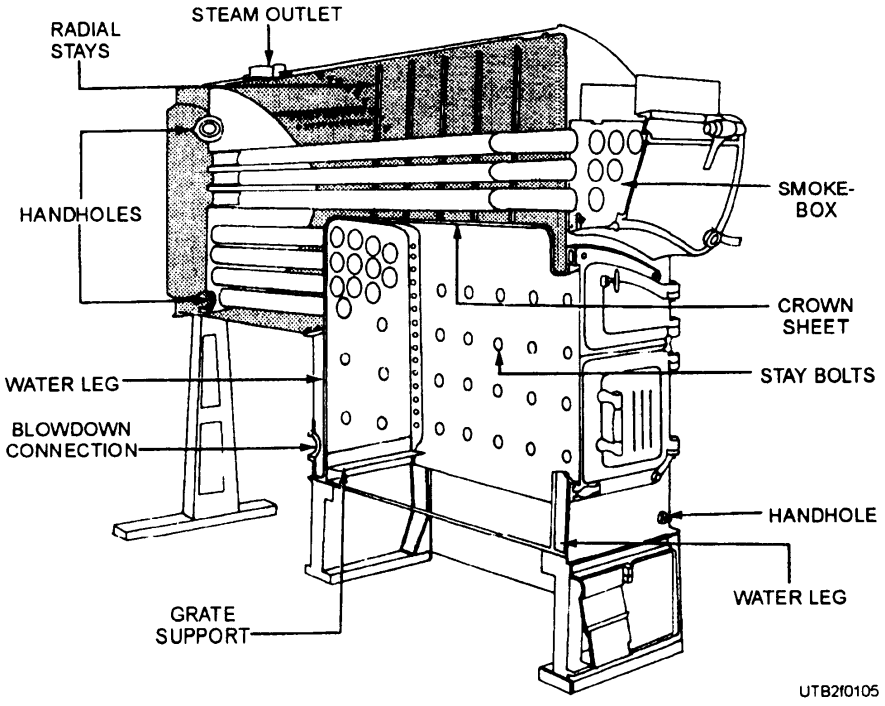


Figure 1-5.—Split section of a small firebox boiler.

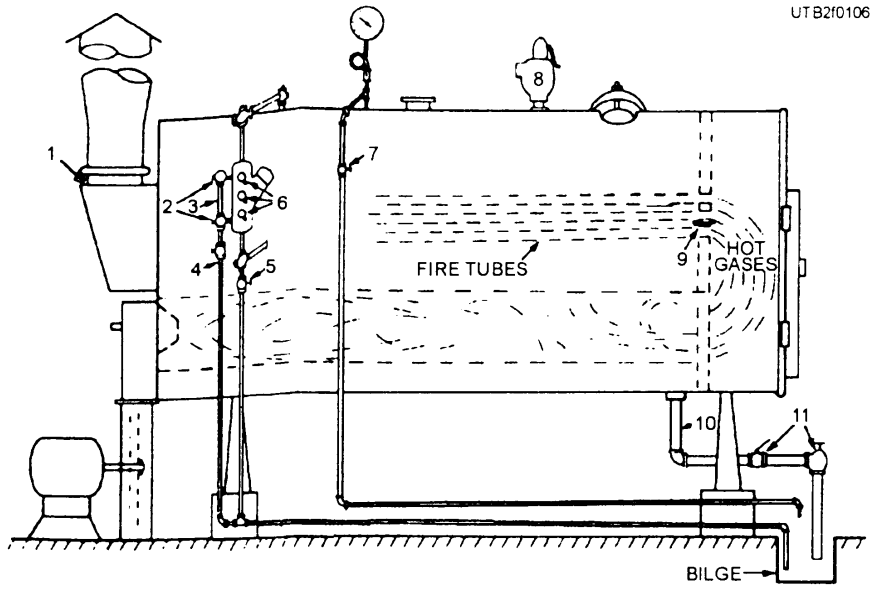


Figure 1-6.—Boiler fittings.

or device not covered in this text, check the manufacturer's manual for information on details of its construction and method of operation.

The term *fittings* include various control devices on the boiler. Fittings are vitally important to the economy of operation and safety of personnel and equipment. You must understand fittings if you are to acquire skill in the installation, operation, and servicing of steam boilers.

All boilers require boiler fittings to operate safely. The American Society of Mechanical Engineers (ASME) requires all boiler fittings to be made of materials that withstand the pressure and temperatures that boilers are subject to. All of the boiler fittings discussed are important and must be operated and maintained properly to operate a boiler safely.

AIR COCK

An air cock is located in the uppermost steam space of a boiler, as shown in item 7 in figure 1-6. This design allows for air to enter and escape during filling and draining of the boiler. Before firing a cold boiler with no steam pressure, the air cock is opened to allow air to escape during the heating of the water. When steam begins to come out of the air cock piping, close the valve.

CHIMNEYS, DRAFT FANS, AND BREECHINGS

Chimneys are necessary for discharging the products of combustion at an elevation high enough to comply with health requirements and to prevent a nuisance because of low-flying smoke, soot, and ash. A boiler needs a draft to mix air correctly with the fuel supply and to conduct the flue gases through the complete setting. The air necessary for combustion of fuel cannot be supplied normally by a natural draft. Therefore, draft fans may be used to ensure that the air requirements are properly attained. Two types of draft fans used on boilers are forced-draft and induced-draft fans. They are damper controlled and usually are driven by an electric motor.

The FORCED-DRAFT fan forces air through the fuel bed, or fuel oil burner, and into the furnace to supply air for combustion. The INDUCED-DRAFT fan draws gases through the setting, thus facilitating their removal through the stack. Breechings (see item 1 in fig. 1-6) are used to connect the boiler to the stack. They are usually made of sheet steel with provision for expansion and contraction. The breaching may be carried over the boilers, in back of the setting, or even under the boiler room floor. Keep breechings as short as possible and free from sharp bends and abrupt changes in area. The cross-sectional area should be approximately 20 percent greater than that of the stack to keep draft loss to a minimum. A breaching with a circular cross section causes less draft loss than one with a rectangular or square cross section.

BLOWDOWN VALVES

Blowdown valves on boilers are located on the water column and on the lowest point of the water spaces of the boiler (see items 2, 5, 10, and 11 in fig. 1-6). The blowdown valves on a boiler installed at the bottom of each water

drum and header are used to remove scale and other foreign matter that have settled in the lowest part of the water spaces. Boilers are also blown down to control concentration ofdissolved and suspended solids in boiler water. The water column blowdown permits removal of scale and sediments from the water column. Additionally, some boilers have what is called a surface blowdown. The surface blowdown is located at the approximate water level so as to discharge partial steam and water. The surface blowdown removes foaming on the top of the water surface and any impurities that are on the surface of the water.

FUSIBLE PLUGS

FUSIBLE PLUGS are used on some boilers to provide added protection against low water. They are constructed of bronze or brass with a tapered hole drilled lengthwise through the plug. They have an even taper from end to end. This tapered hole is filled with a low-melting alloy. consisting mostly of tin. There are two types of fusible plugs—fire actuated and steam actuated.

The FIRE-ACTUATED plug is filled with an alloy of tin, copper. and lead with a melting point of 445°F to 450°F. It is screwed into the shell at the lowest permissible water level. One side of the plug is in contact with the tire or hot gases, and the other side is in contact with the water (see item 9). As long as the plug is covered with water, the tin does not melt. When the water level drops below the plug, the tin melts and blows out. Once the core is blown out, a whistling noise will warn the operator. The boiler then must be taken out of service to replace the plug.

The STEAM-ACTUATED plug is installed on the end of a pipe outside the drum. The other end of the pipe. which is open, is at the lowest permissible water level in the steam drum. A valve is usually installed between the plug and the drum. The metal in the plug melts at a temperature below that of the steam in the boiler. The pipe is small enough to prevent water from circulating in it. The water around the plug is much cooler than the water in the boiler as long as the end of the pipe is below the water level. However, when the water level drops below the open end of the pipe, the cool water runs out of the pipe and steam heats the plug. The hot steam melts and blows the tin out, allowing steam to escape from the boiler warning the operator. This type of plug can be replaced by closing the valve in the piping. It is not necessary to take the boiler out of service to replace the plug.

Fusible plugs should be renewed regularly once a year. Do NOT refill old casings with new tin alloy and use again. ALWAYS USE A NEW PLUG.

WATER COLUMN

A WATER COLUMN (fig. 1-7) is a hollow vessel having two connections to the boiler. Water columns come in many more designs than the two shown in figure 1-7; however, they all operate to accomplish the same principle. The top connection enters the steam drum of the boiler through the top of the shell or drum. The water connection enters the shell or head at least 6 inches below the lowest permissible water level. The purpose of the water column is to steady the water level in the gauge glass through the reservoir capacity of the column. Also, the column may eliminate the obstruction on small diameter, gauge-glass connections by serving as a sediment chamber.

The water columns shown are equipped with high- and low-water alarms that sound a whistle to warn the operator. The whistle is operated by either of the two floats or the solid weights shown in figure 1-7.

Water Level Control

The water level control not only automatically operates the boiler feed pump but also safeguards the boiler against low water by stopping the burner. Various types of water level controls are used on boilers. At Seabee activities, boilers frequently are equipped with a float-operated type, a combination float and mercury switch type, or an electrode probe type ofautomatic water level control. Each of these types is described below.

The FLOAT-OPERATED TYPE of feedwater control, similar in design to the feedwater control shown in figure 1-8, is attached to the water column. This control uses a float, an arm, and a set of electrical contacts. As a low-water cutoff, the float rises or lowers with the water level in an enclosed chamber. The chamber is connected to the boiler by two lines, which allow the water and steam to have the same level in the float chamber as in the boiler. An arm and linkage connects the float to a set of electrical contacts that operate the feedwater pump when the water lowers the float. When the water supply fails or the pump becomes inoperative and allows the water level to continue to drop, another set of contacts operates an alarm bell, buzzer, or whistle, and secures the burners.

The COMBINATION FLOAT AND MERCURY SW ITCH TYPE of water level control shown in figure 1-8

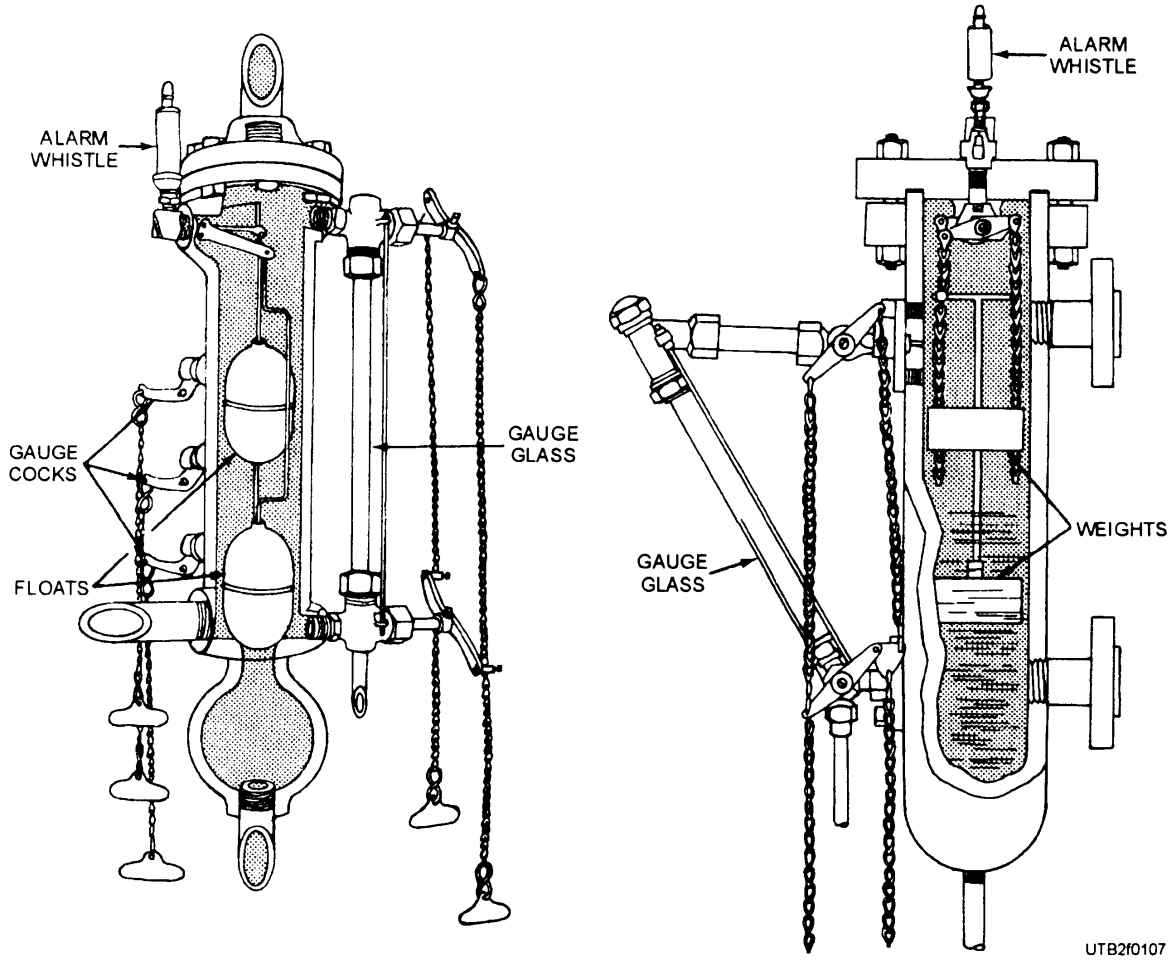


Figure 1-7.—Typical water columns.

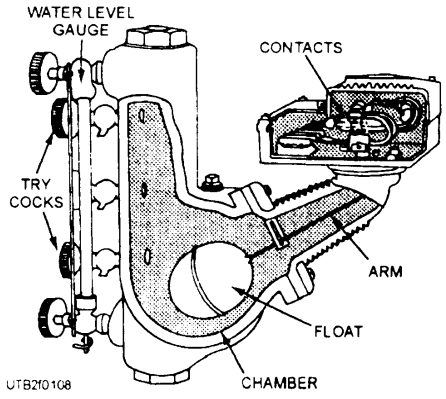


Figure 1-8.—Combination float and mercury switch type of feedwater control.

reacts to changes made within a maintained water level by breaking or making a complete control circuit to the feedwater pump. It is a simple two-position type control, having no modulation or differential adjustment or setting. As all water level controllers should be, it is wired independently from the programmer. The control is mounted at steaming water level and consists of a pressurized float, a pivoted rocker arm, and a cradle-attached mercury switch. The combination float and mercury switch type of water level control functions as follows: As the water level within the boiler tends to drop, the float lowers. As the float lowers, the position of the mercury switch changes. Once the float drops to a predetermined point, the mercury within the tube runs to its opposite end. This end contains two wire leads, and when the mercury covers both contacts, a circuit is completed to energize the feedwater pump. The pump, being energized, admits water to the boiler. As the water level within the boiler rises, the float rises. As the float rises, the position of the mercury switch changes. Once the float rises to a predetermined point, the mercury runs to the opposite end of its tube, breaking the circuit between the wire leads and securing the feedwater pump. The feedwater pump remains off until the water level again drops low enough to trip the mercury switch.

The ELECTRODE PROBE TYPE of feedwater control (fig. 1-9) and low-water cutoff consists of an electrode assembly and a water level relay. The electrode assembly contains three electrodes of different lengths correspondin g to high. low, and burner cutout in the boiler drum.

To understand the operation of a boiler circuit, refer to figures 1-9 and 1-10 as you read the information in table 1-1. Although this information is not complete. it is presented here to acquaint you with the operation of the electrode type of boiler water level control.

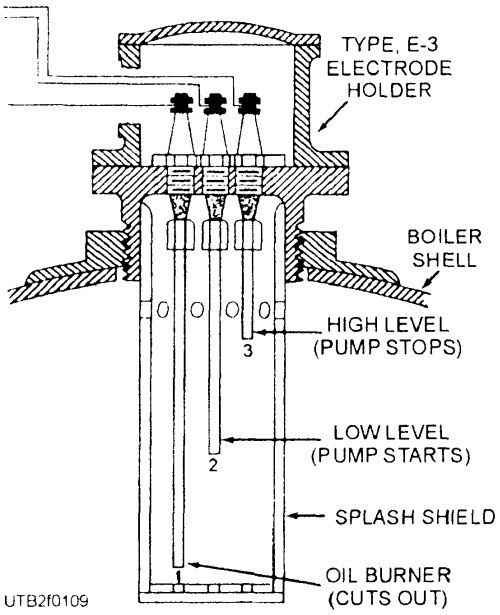


Figure 1-9.—Electrode type of water level control.

Try Cocks

The location of the try cocks is shown as item 6 in figure 1-6. The purpose of the try cocks is to prove the water level in the boiler. You may see water in the gauge glass. but that does not mean that the water level is at that position in the boiler. lf the gauge glass is clogged up. the water could stay in the glass giving a false reading. The try cocks, on the other hand, will blow water. steam. or a mixture of steam and water out of them when they are manually opened. When steam is discharged from the lowest try cock, you have a low-water condition.

Table 1-1.—Operation of a Boiler Circuit

Operation	Action	Results
When the feed pump switch is in the auto position.	The feed pump motor is energized.	The feed pump will operate under control of the water level relay (item #6 in fig. 1-10).
When the water level in the boiler reaches the level of electrode #3.	The circuit through the electrode is grounded and this completes the circuit.	All of the CONTACTS labeled #6 change position. The three feed pump contacts that are normally closed, i.e., 6-1, 6-2, and 6-3 open, and contact 6-4 closes which maintains the grounded circuit through electrode #2.
When the water level falls below electrode #2.	The circuit through relay #6 will no longer be grounded because the water is not in contact with the electrode.	This de-energizes relay #6, so all of the CONTACTS labeled #6 return to their normal positions. Contacts 6-1 through 6-3 close and 6-4 opens. The feedwater pump is energized and water is pumped into the boiler.
When the water level rises again to electrode #3.	Relay #6 will energize again.	The cycle continues and the water level in the boiler is maintained.
When the water level falls below electrode #1.	Relay #5 will be de-energized.	CONTACT 5-1 will open. This action de-energizes the entire control circuit. The boiler is now shut down and the low-water alarm is sounded.

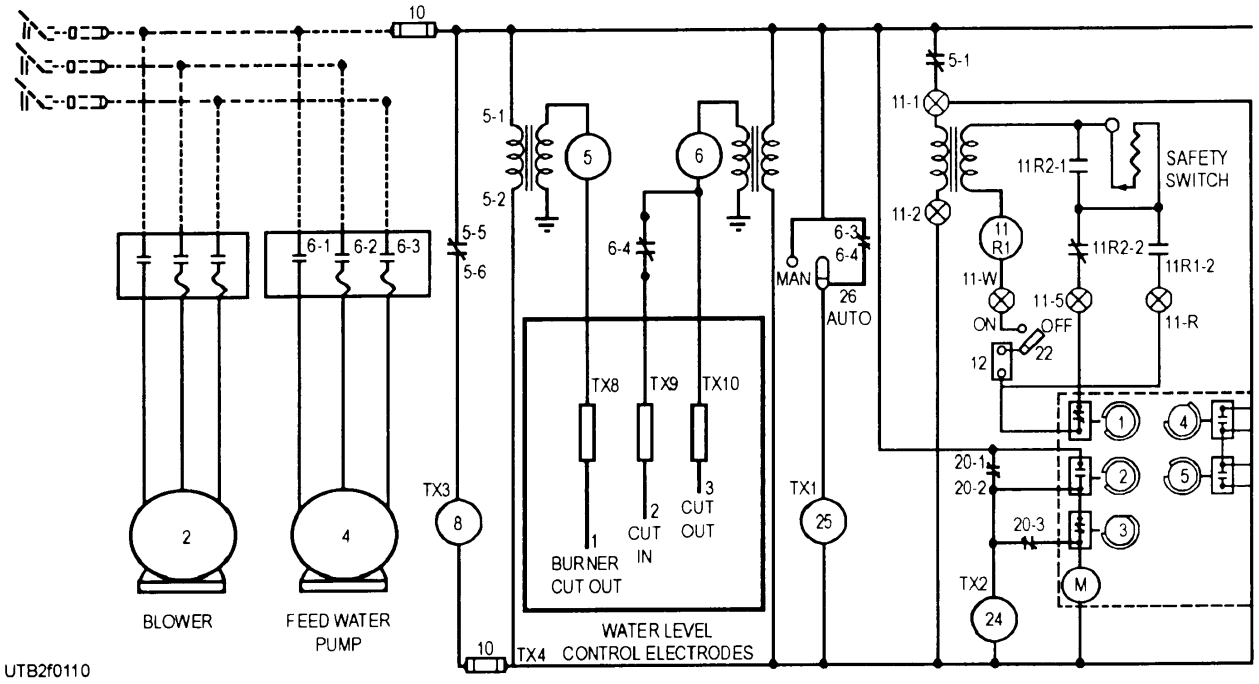


Figure 1-10.—A typical boiler circuit.

WARNING

When the water level is proved using the try cocks, personnel should stand off to the side of the try cocks away from the discharge. The discharged hot steam or very hot water can cause severe burns.

Gauge Glass

The gauge glass is located on the water column, as shown in figure 1-6, item 3. The gauge glass allows the boiler operator to see the water level in the boiler. Normally there are two valves associated with the gauge glass. One valve is located at the top and one is located at the bottom of the gauge glass. These two valves, named gauge cock valves (fig. 1-6, item 2). secure the boiler water and steam from the gauge glass. Another valve (fig. 1-6, item 4) located in line with the gauge glass, is used to blow the gauge glass down.

SAFETY VALVE

The SAFETY VALVE shown in figure 1-11 is the most important of boiler fittings. It is designed to open automatically to prevent pressure in the boiler from increasing beyond the safe operating limit. The safety valve is installed in a vertical position and attached directly to the steam space of the boiler. The location can be seen in figure 1-6, item 8. Each boiler has at least one safety valve; when the boiler has more than 500 square feet of heating surface, two or more valves are required.

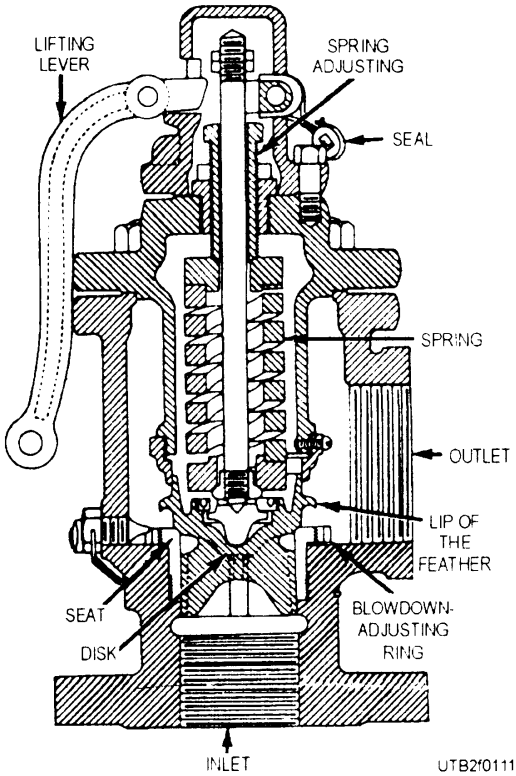


Figure 1-11.—A spring-loaded safety valve.

There are several different types of safety valves in use but all are designed to open completely (POP) at a specific pressure 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.

To understand the difference between boiler safety valves and ordinary relief valves is important, The amount ofpressure required to lift a reliefvalve increases as the valve lifts, because the resistance of the spring increases in proportion to the amount of compression. When a relief valve is installed on a steam drum, it opens slightly when the specified pressure was exceeded; a small amount of steam is discharged; and then the valve closes again. Thus a relief valve on a steam drum is constantly opening and closing; this repeated action pounds the seat and disk and causes early failure of the valve. Safety valves are designed to open completely at a specified pressure to overcome this difficulty.

Several different types of safety valves are used on boilers; however, they all lift on the same general principle. In each case, the initial lift of the valve disk, or feather, is caused by static pressure of the steam acting upon the disk. or feather. As soon as the valve begins to open, however, a projecting lip, or ring, of the larger area is exposed for the steam pressure to act upon. 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, the valve reseats at a lower pressure than that which caused it to lift originally.

Lifting levers are provided to lift the valve from its seat (when boiler pressure is at least 75 percent of that at which the valve is set to pop) to check the action and to blow away any dirt from the seat. When the lifting lever is used, raise the valve disk sufficiently to ensure that all foreign matter is blown from around the seat to prevent leakage after being closed.

The various types of safety valves differ chiefly as to the method of applying compression to the spring, the method of transmitting spring pressure to the feather, or disk, the shape of the feather. or disk, and the method of blowdown adjustment. Detailed information on the operation and maintenance of safety valves can be found in the instruction books furnished by the manufacturers of this equipment.

STEAM INJECTOR FEED SYSTEM

The STEAM INJECTOR (fig. 1- 12) is a boiler FEED PUMP that uses the velocity and condensation of a jet of steam from the boiler to lift and force a jet of water into the boiler. This injection of water is many times the weight of the original jet of steam.

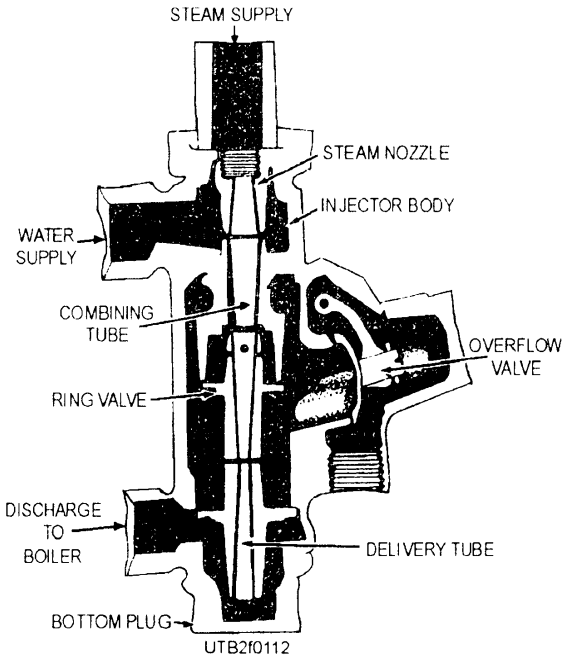


Figure 1-12.—A cross-sectional view of a steam injector.

The injector is used to some extent in boiler plants as an emergency or standby feed unit. It does not feed very hot water. Under the best conditions, it can lift a stream of water (that has a temperature of 120°F) about 14 feet.

The installation of an injector is not a difficult operation because the unit is mounted on the side of the boiler. The four connections (fig. 1-13) to the injector are as follows:

1. The discharge line to the boiler feedwater inlet

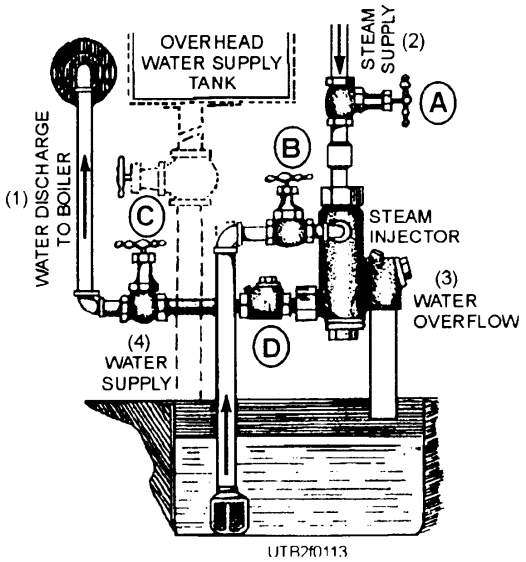


Figure 1-13.—Injector piping.

2. The steam supply line from the boiler

3. The water overflow line

4. The water supply line from the reservoir

The controls for the injector (fig. 1-13) include the following:

A. Steam supply valve

B. Water supply valve

C. Discharge valve to the boiler

D. Check valve in the discharge line

As you might expect. some degree of skill is needed to start the injector. After the injector begins to operate. however, it continues automatically until shutdown by the operator.

When starting the injector. first open the water supply valve (fig. 1-13B) about one full turn. Nest quickly turn the steam supply valve (fig. 1-13A) all the way open. At this point, steam rushes into the combining tube of the injector As the steam speeds past the water supply opening. it creates a suction that draws water through the opening into the combining tube. Water and steam are now mixed together inside the injector and the pressure opens a valve that leads to the boiler. Meanwhile. there is an excess of water in the injector; this excess is discharged through the overflow valve. As the nest step of the procedure, slowly turn the water supply valve (fig. 1-13B) toward the closed position until the overflow stops. The overflow valve has now closed and all of the water being picked up from the supply line is going into the boiler. Remember, this feedwater system is used on boilers only as a standby method for feeding water.

The water supply should not be hotter than 120°F for the injector to operate. When several unsuccessful attempts are made to operate the injector. it will become very hot and cannot be made to prime. When you should encounter this problem. pour cold water over the injector until it is cool enough to draw water from the supply when the steam valve is opened.

HANDHOLES AND MANHOLES

Handholds and manholes provide maintenance personnel access into a boiler to inspect and clean it internally as needed. These handholds and manholes will be covered in depth when boiler maintenance is discussed later in this volume.

BOILER ACCESSORIES

Figure 1-14 provides a graphic presentation of important boiler accessories. Refer to it as you study the table 1-2 which gives a brief description of each accessory, its location, and function.

Q9. Blowdown valves are installed at what location in a boiler?

Q10. How often should the fusible plugs in a boiler be renewed?

Q11. The two connections to the boiler of a water column are at what locations?

Q12. What are the three types of water level controls most often encountered by Seabees?

Q13. The electrode probe type of feedwater control has what total number of electrode sensors?

Q14. What boiler fitting is considered the most important?

Q15. What is the function of the guard valve on a boiler?

AUTOMATIC CONTROLS

Learning Objective: Identify the automatic controls commonly used on boilers and describe the function of each.

Automatic controls are a big asset since they reduce manual control of the furnace. boilers. and auxiliary equipment. For this reason. Utilitiesman personnel should be able to recognize and understand the basic operations of different types of boiler operating controls. The types of controls the Utilitiesman should become familiar with are as follows: float. pressure, combustion. flame failure. and operation controls.

FLOAT CONTROL

The float in a boiler control works on the same basic principle as the float in a flush-tank type of water closet. Float, or level, control depends on the level of fluid in a tank or boiler to indicate the balance between the flow out of and the flow into the equipment and to operate a controller to restore the balance.

A float is often used to measure the change in fluid level and to operate the controlled valve to restore the balance. It may be arranged to increase the flow when the fluid level drops. Figure 1-15 shows one of the methods used to accomplish this. Here, the float is connected to the control valve.

Table 1-2.—Boiler Accessories, Its Location, and Function

ITEM	ACCESSORY	LOCATION	PURPOSE
1	Boiler	Boiler room	Generate steam or hot water in a closed vessel
2	Main steam stop	On the steam outlet of a boiler	Place the boiler on line or off line
3	Guard valve	On the steam outlet of a boiler directly following the main steam-stop valve	Guard or backup to the main steam-stop valve
4	Daylight (drain) valve	Between the main steam-stop valve and the guard valve	Open only when the main steam and guard valves are closed. Indicates if one of the valves is leaking through
5	Main steam line	The line that conveys steam from a boiler to all branch or distribution lines. When a system is supplied by a bank of boilers connected into the same header, the line(s) conveying steam for the boiler(s) to the header	Carry steam from the boiler to the branches or distribution lines
6	Root valve	Installed in branch or distribution lines just off of the main steam line	Isolate a branch or distribution line (serves as an emergency shutoff)
7	Pressure regulating valve (PRV)	Installed as close as practical (after a reducing station) to the equipment or area it serves	Equipment that requires lower pressure than main steam line pressure (coppers, dishwashers, steam chest, turbines, etc.)
8	Steam trap	Installed on the discharge side of all steam heating or cooking equipment, dead ends, low points, or at regular intervals throughout a steam system (automatic drip legs)	Automatically drains condensate and prevents the passage of steam through equipment
9	Drip legs	Provided throughout a system where condensation is most likely to occur, such as low spots, bottom of risers, and dead ends	Remove condensate from a system manually

Table 1-2.—Boiler Accessories, Its Location, and Function—Continued

ITEM	ACCESSORY	LOCATION	PURPOSE
10	Temperature regulating valve (TRV)	Install in the steam supply line close to equipment needing temperature regulation (sensing element is installed at a point where the temperature is to be controlled, such as the hot- water discharge side of a heat exchanger	Control steam flow through a vessel or heating equipment
11	Heat exchanger	Locate as close as practical to the source for which it is going to supply heated water or oil	An unfired pressure vessel that contains a tube nest or electrical element. Used to heat oil or water
12	Strainer	Install in steam and water lines just ahead of PRVs, TRVs, steam traps, and pumps	Prevent malfunctions or costly repairs to equipment and com- ponents by trapping foreign matter, such as rust, scale, and dirt
13	Condensate line	Return line extends from the discharge side of steam traps to the condensate/makeup feedwater tank	Carry condensed steam back through piping for reuse in the boiler or heating vessel
14	Condensate/makeup tank	Close to the boiler as practical and at a higher level than the boiler feed-pump suction line	Provide storage space for condensate and makeup/feedwater and vent noncondensable gases to the atmosphere
15	Feed pump	Supplies water to the boiler as required	Installed between the condensate/ makeup/feedwater tank and the boiler sheall or steam drum
16	Feedwater pipe	This line extends from the discharge side of the feedwater pump to the boiler shell or drum (installed below the steaming water level)	Provide feedwater to the boiler when required
17	Relief valve	Between the feed pump and the nearest shutoff valve in the external feed line	Relieve excessive pressure should the external feed line be secured and the feed pump started accidently. A ruptured line or serious damage to the feed pump could occur if there were no relief valve
18	Feed check valve	Between the feed pump and the stop valve in the feed-water pipe	Prevent backflow from the boiler through the feedwater line into the condensate/feedwater tank during the off cycle of the pump
19	Feed stop valve	In the feedwater line as close to the boiler as possible between the boiler and feed check valve	Permit or prevent the flow of water to the boiler

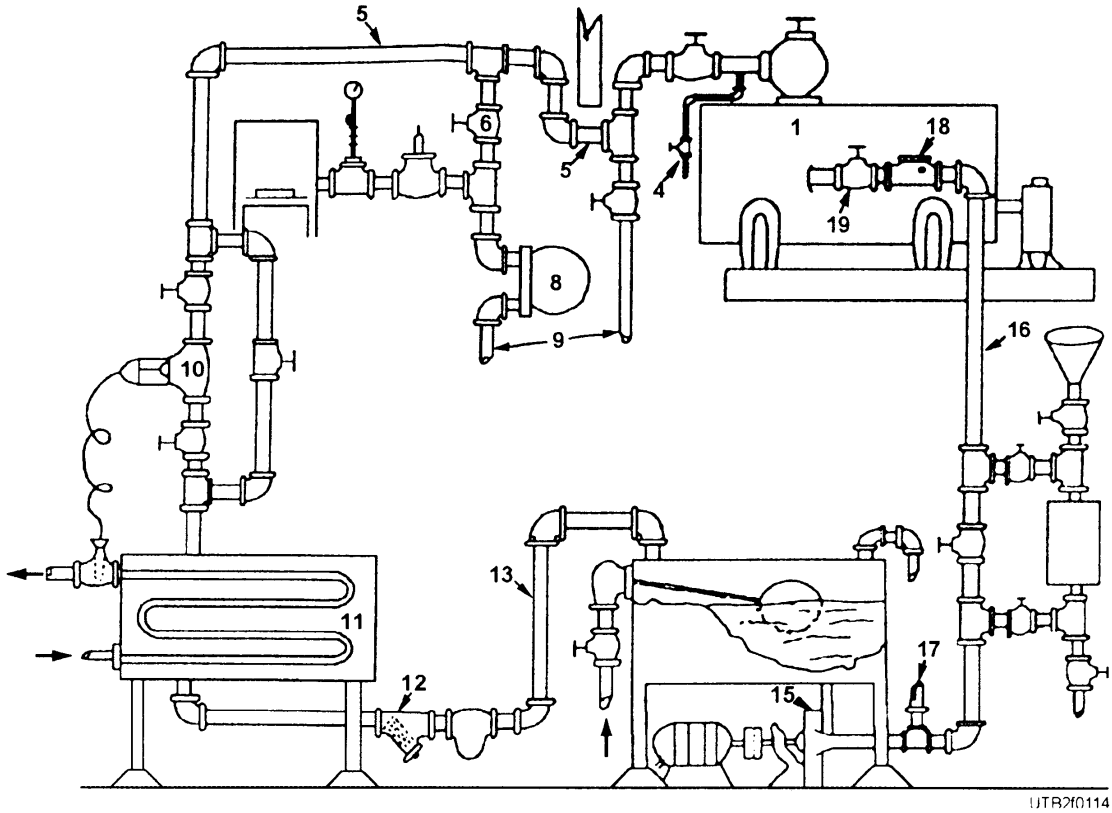


Figure 1-14.—Boiler accessory equipment.

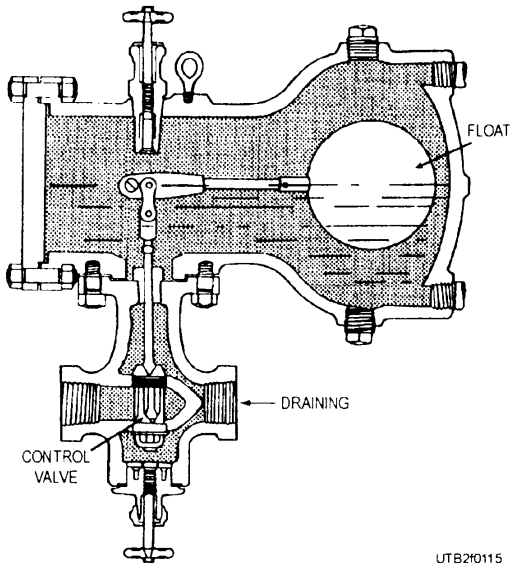


Figure 1-15.—Float controller.

PRESSURE-REGULATING CONTROL

Pressure regulating is the process of maintaining a difference of pressure between two points in a system. One type of pressure regulating maintains a definite pressure in one part of the system, while the other part fluctuates or changes within certain limits. An example of this type of control is a pressure-regulator valve (fig. 1-16) that maintains a definite pressure on the discharge side of the valve by controlling the flow of steam, air, or gas through the valve.

A second type of regulator maintains a definite difference in pressure between two points and also controls the flow. This type of regulator is often applied to a boiler feeding to maintain a fixed difference between the pressure of water supplied at the feed valve and the pressure in the boiler steam drum. The pressure regulator may consist of a self-contained device that operates the regulating valve directly, or it may consist of a pressure-measuring device, such as a Bourdon-tube gauge, that operates a pilot or relay valve. The valve positions the regulating valve or mechanism to maintain the desired conditions.

Pressure controls (fig. 1-17) are designed primarily for steam-heating systems but are also available for controlling air, liquids, or gases that are not chemically injurious to the control. The function of the pressure control is as follows:

- To control the pressure in the boiler

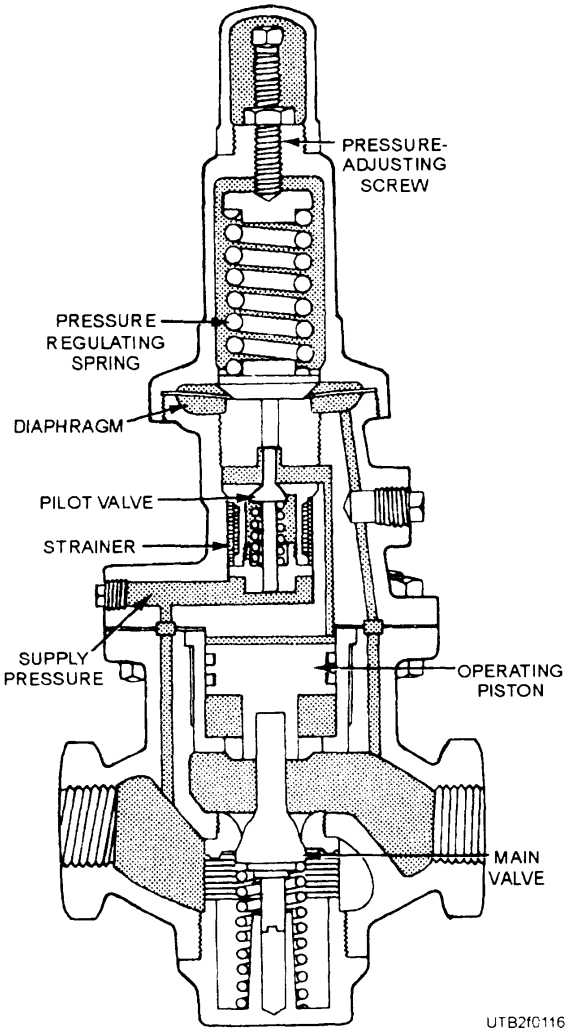


Figure 1-16.—Pressure regulator.

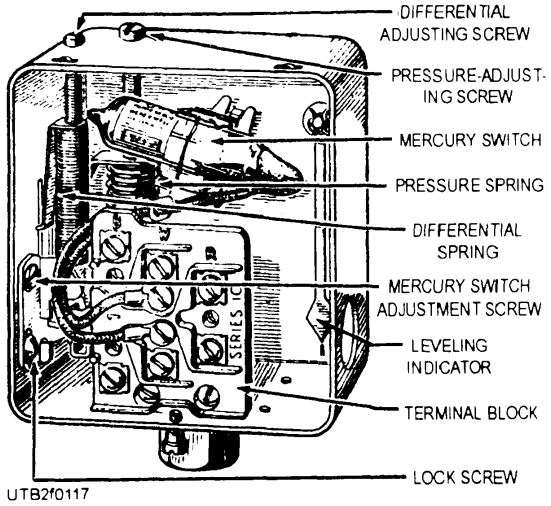


Figure 1-17.—Typical pressure control with a differential from 0 to 10 pounds.

- To secure the fuel-burning equipment when the pressure reaches a predetermined cutout
- To start the fuel-burning equipment when the pressure drops to the cut-in point

There are two settings on the pressure control—the cut-in point and the differential. To find the cut-out point, you add the differential to the cut-in pressure; for example, when you were operating a boiler with a cut-in pressure of 90 pounds and a differential of 13 pounds, the cut-out pressure should be 103 pounds. When excessive vibrations are encountered, you should mount the pressure control remotely from the boiler on a solid mounting with a suitable piping connection between them. When a mercury type of switch control is used, be sure that it is mounted level and that the siphon (pigtail) has the loop extending in the direction of the back of the control and at a 90-degree angle to the front, as shown in figure 1-18. This position prevents expansion and contraction of the siphon from affecting the mercury level and accuracy of the control. Additionally, when you install any pigtail, ensure the tube is filled with water. The water will prevent hot steam from contacting the control.

The pressure control can be mounted either on a tee along with the pressure gauge on the pressure-gauge tapping, as shown in figure 1-18, or it can be mounted on the low-water cutout provided by some manufacturers. In either case, be sure that the pipe dope does NOT enter the control. The procedure you should follow is to apply the dope to the male threads, leaving the first two threads bare.

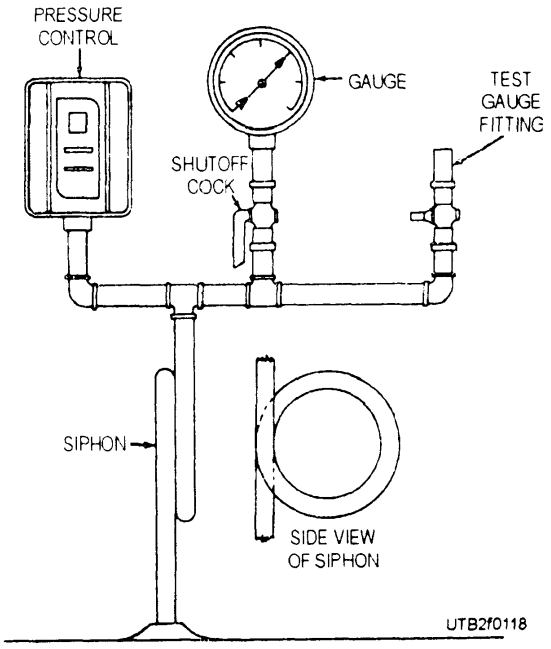


Figure 1-18.—A typical steam gauge installation.

COMBUSTION CONTROL

Combustion control is the process of regulating the mixed flow of air and fuel to a furnace as necessary to supply the demand for steam. A modulating pressuretrol controls the movement of the modutrol motor which, in turn. opens or closes the oil valve and air shutters to adjust the rate of firing to suit the demands of the boiler.

A modulating motor (fig. 1-19) consists of the motor windings, a balancing relay, and a balancing potentiometer, The loading is transmitted to the winding through an oil-immersed gear train from the crank arm. The crankshaft is the double-ended type, and the crank arm may be mounted on either end of the motor. The motor works with the potentiometer coil in the modulating pressuretrol. An electrical imbalance is created by pressure change signals to the pressuretrol. This causes the motor to rotate in an attempt to rebalance the circuit. The crank arm, through linkage, positions the burner air louvers and the oil regulating valve, maintaining a balanced flow of air and oil throughout the burner firing range.

Another process of controlling, combustion air is to use a manually adjusted air damper. A centrifugal blower, mounted on the boiler head and driven by the blower motor, furnishes combustion air. A definite amount of air must be forced into the combustion chamber to mix with the atomized oil to obtain efficient combustion. In operation, a pressure is built up in the entire head and the secondary air is forced through a diffuser to mix thoroughly with the atomized oil as combustion takes place.

The combustion airflow diagram in figure 1-20 shows a cutaway view of those components that influence most the path of the air through the burner assembly. Air is drawn into the motor-driven blower through the adjustable air damper at (A) and forced through openings (B) into the air box. Sufficient pressure is built up to force the air through openings (C) and the diffusor (D). In the area immediately beyond the diffusor (D), combustion is completed. The hot gaseous products of combustion are forced on through the remaining three passes where they give up a large portion of the heat contained to the water which completely envelopes the passes.

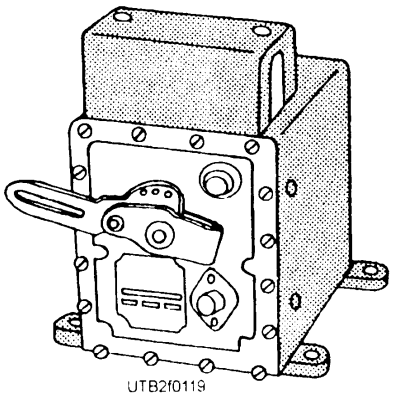


Figure 1-19.—A modulating motor.

The rate at which combustion air is delivered can be changed by throttling the intake to the blower by opening or closing the air damper to obtain the exact rate of airflow required for complete combustion. Since the rate at which fuel is delivered is predetermined by the design and is not readily adjustable, setting of the air damper is the only means of obtaining the correct ratio of fuel to air to ensure the most efficient combustion.

A pressure-regulating valve is built into the pump that controls the fuel. The fuel pump (fig. 1-21) contains a two-stage gear-type pump, a suction strainer, a pressure-regulating valve, and a nozzle cutoff valve, all assembled in a single housing. Knowledge of the functional relationship of the component parts can be gained by studying the internal oil flow diagram shown in figure 1-22. Observe that the two-stage fuel unit consists essentially of two pumps operating in tandem and arranged in a common housing. The first stage develops a pressure below the atmospheric pressure level at its inlet that causes the oil to flow from storage or supply to the strainer chamber reservoir. All air drawn into the unit rises to the top of this chamber. This air and excess oil are drawn into the first-stage-pumping element and pumped back to the fuel oil storage tank. The second stage withdraws air-free oil from the strainer chamber reservoir and raises the oil pressure to that required for proper atomization at the burner nozzles. The second stage, operating against a combination pressure regulating and nozzle cutoff valve, develops atomizing pressure because of the flow restriction imposed by this valve. The pressure-regulating valve also bypasses excess second-stage oil back to the bottom of the strainer chamber reservoir. The atomizing pressure can be varied within a restricted range by adjustment of the spring-loaded pressure-regulating valve. Normal atomizing pressures generally range between 95 and 120 pounds per square inch.

An orifice is included in the fuel line to the main oil burner. as shown in figure 1-22. The orifice serves to keep the oil pressure from experiencing a sudden drop when the solenoid oil valve in that line opens. The orifice is commonly built into the solenoid oil valve (fig. 1-22, item 1). Included in the schematic diagram is a photocell

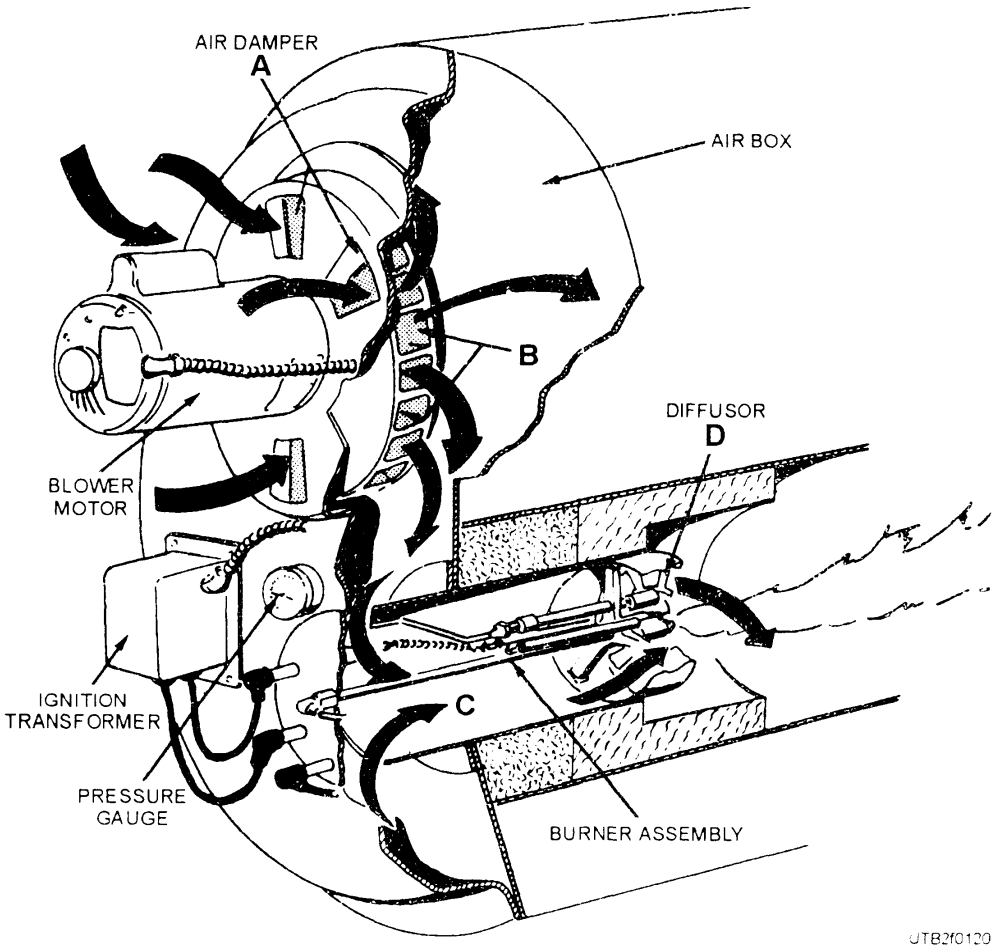


Figure 1-20.—Airflow diagram.

(3) which, if it sights no flame, reacts to cause a switching action that results in shutting down the burner.

FLAME FAILURE AND OPERATIONAL CONTROLS

Frequently on fully automatic boilers, you will find an electronic type of device provided for the control of flame failure. The device provides automatic start and operation of the main burner equipment. Some controls are designed to close all fuel valves, shut down the burner equipment within 4 seconds after a flame failure. and actuate an alarm. Some controls also create a safety shutdown within 4 seconds after de-energization of ignition equipment when the main burner flame is not properly established or fails during the normal starting sequence. These controls must create a safety shutdown when the pilot flame is not established and confirmed within 7 seconds after lighting. A safety shutdown requires manual reset before operation can be resumed and prevents recycling of the burner equipment.

Q16. What is the process of maintaining a difference of pressure between two points in a system called?

Q17. The flow of the air-fuel mixture supplied to the furnace is regulated by steam demand. What is this process called?

Q18. The rate at which combustion air is delivered to the blower can be changed by throttling what device?

Q19. Once a safety shutdown of a boiler has occurred, what action must be taken before operations can resume?

INSTRUMENTS AND METERS

Learning Objective: Identify the instruments and meters used on boilers and describe the function of each.

A pressure gauge is essential for safe operation of a boiler plant. However, the use of additional instruments.

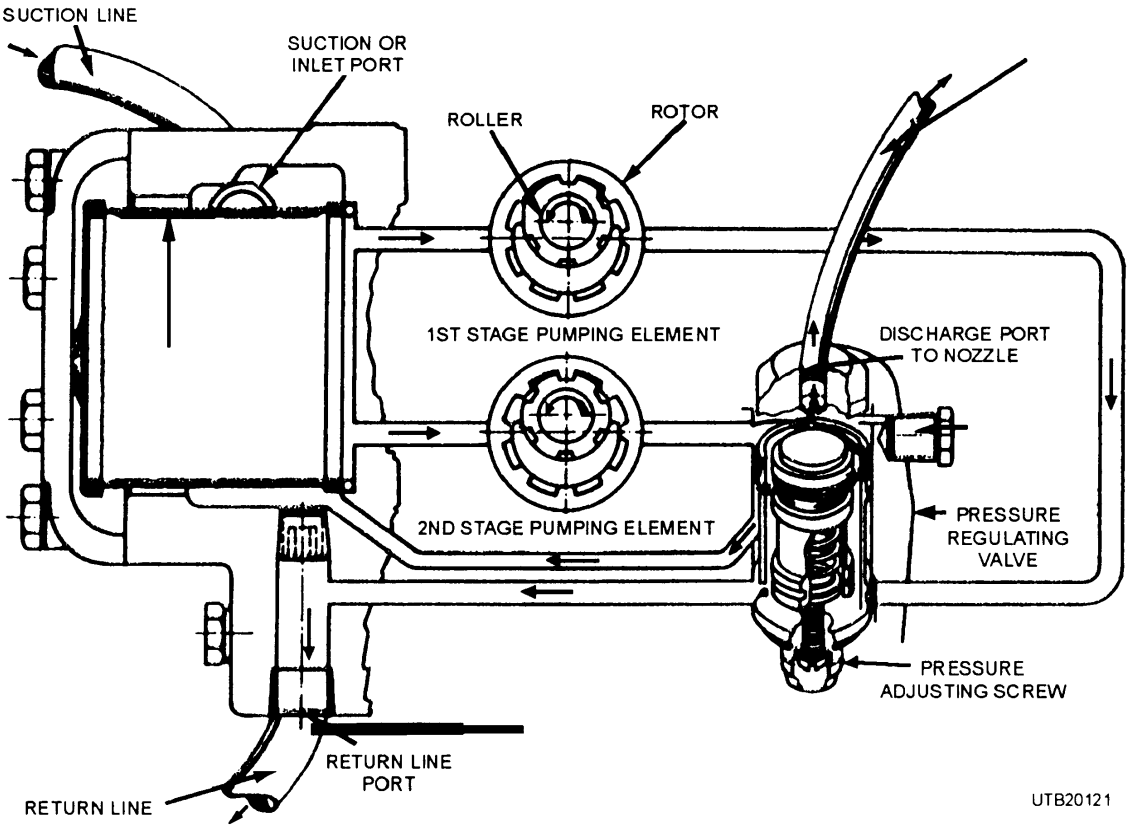


Figure 1-21.—Fuel oil pump.

such as flowmeters and draft gauges, increases safety and promotes efficiency. All of these instruments may be either indicating or recording.

STEAM FLOWMETERS

A Utilitiesman must be able to identify the different types of monitoring instruments and understand their operation and use. Meters used to measure quantities are divided into two general types:

1. Those indicating rate, such as flowmeters
2. Those indicating the total, such as scales

Many devices are designed to measure and indicate the pressure of steam flow. One of these devices is shown in figure 1-23. This meter uses a weighted inverted bell (called a Ledoux bell) sealed with mercury. The bell moves up and down as the rate of flow changes. The movement is transmitted to a pen that records the flow.

STEAM AND AIR FLOWMETERS

A combustion air and steam flowmeter is shown in figure 1-24. This meter is used as a guide in controlling the relationship between air required and air actually supplied to burn the fuel. The rate of steam generation is used as a measure of air necessary to burn the required amount of fuel. The flow of gases through the boiler setting is used as a measure of air supplied.

The essential parts of the meter are two airflow bells supported from knife-edges on a beam, which is supported by other knife-edges, and a mercury displacer assembly supported by a knife-edge on the beam. The bottoms of the bells are sealed with oil, and the spaces under the bells are connected to two points of the boiler setting.

DRAFT GAUGES

A draft gauge is a form of pressure gauge. In boiler practice, the term *draft* usually refers to the pressure difference producing the flow. Drafts are pressures below atmospheric pressure. They are measured in inches of water. A draft gauge is essential to boiler operation. Its use increases the safety of operation.

A simple type of draft gauge is the U-tube gauge. The source of draft is connected to one leg of the U and the other end is left open. The difference between the levels of the liquid in the two legs is a measure of the draft. Water is generally used in this type of gauge. Take

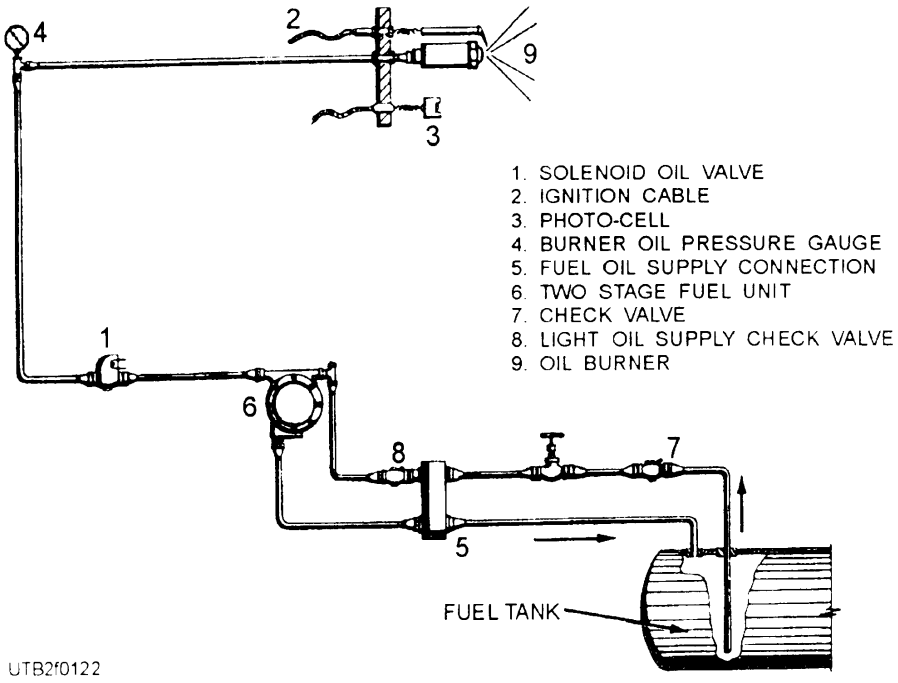


Figure 1-22.—The internal oil flow diagram.

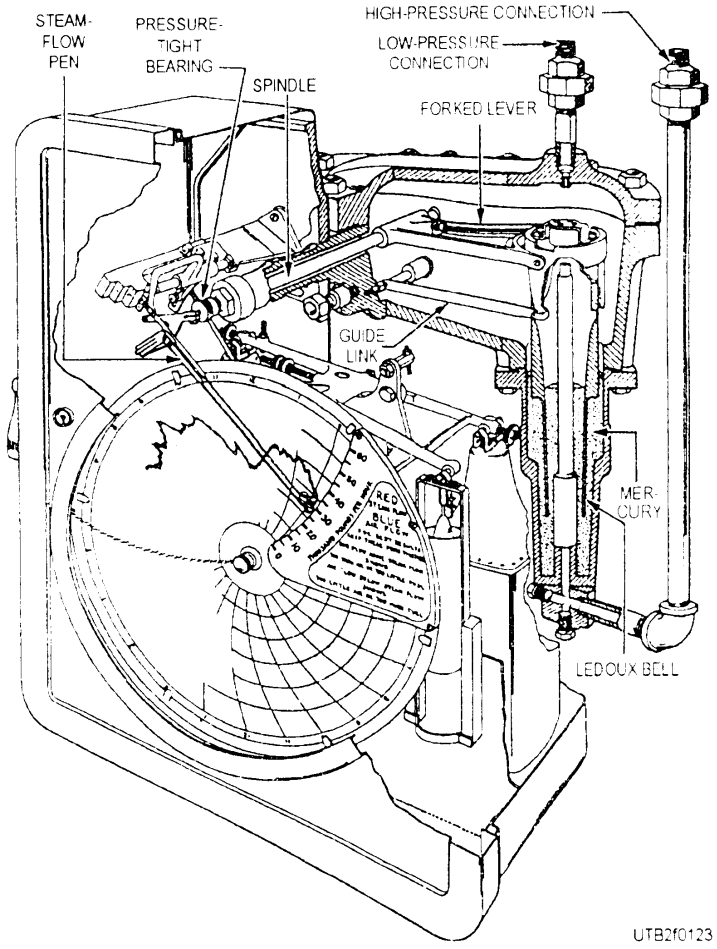


Figure 1-23.—Flowmeter.

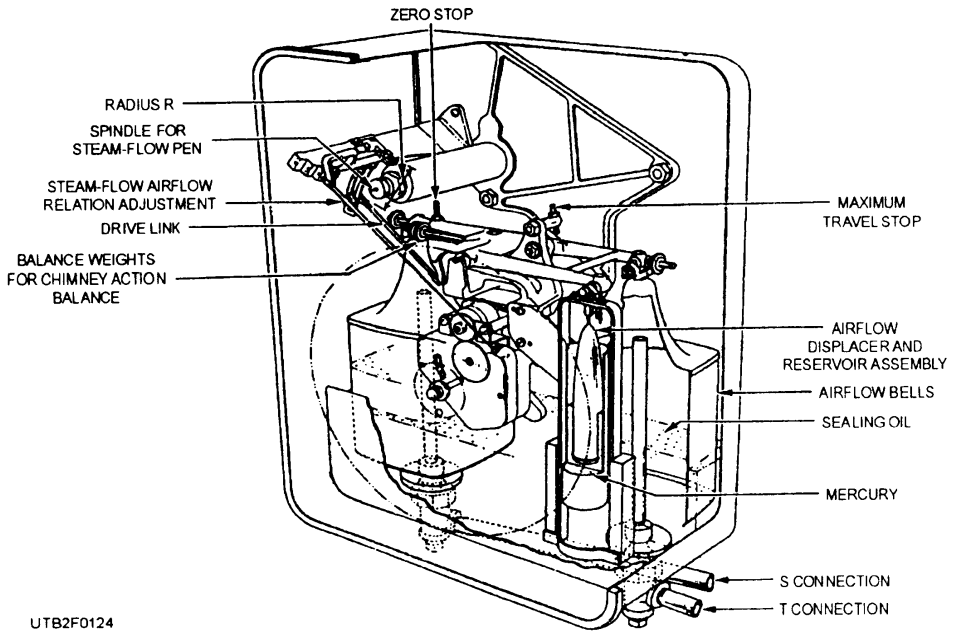


Figure 1-24.—Airflow mechanism of a boiler air flowmeter.

a close look at figure 1-25 that shows a comparison of an inclined-draft gauge and a U-tube gauge.

When one leg of the U tube is arranged on an incline, the distance moved by the liquid in the inclined portion is increased for a given draft change which makes more accurate reading possible.

Two or more draft gauges are required for economical boiler operation. The gauges inform the operator of the relative amount of air being supplied to burn the fuel and the condition of the gas passages. Draft gauges are made as indicators, recorders, or both. The measuring element uses a column of liquid, a diaphragm,

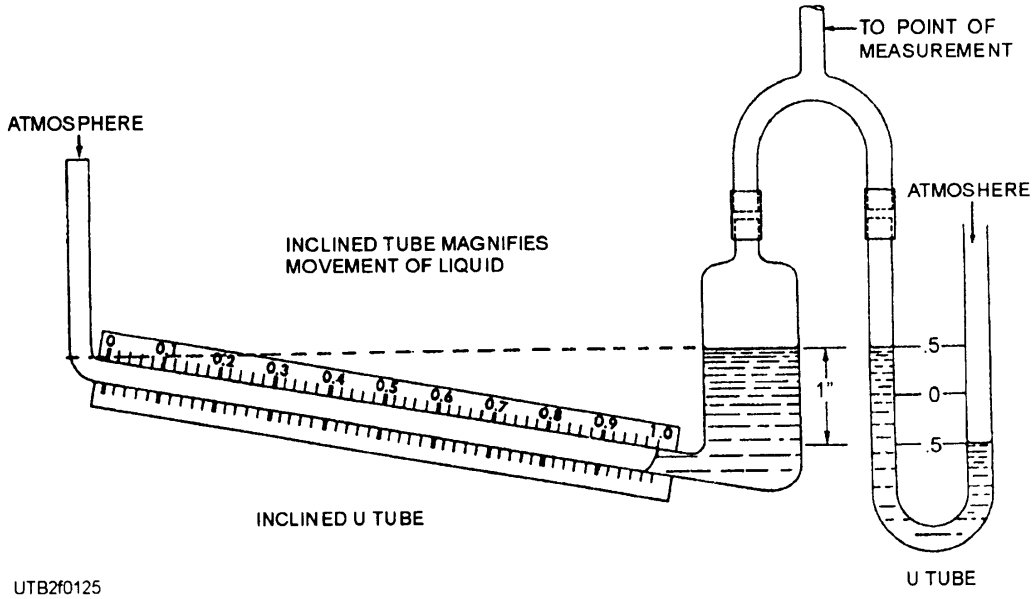


Figure 1-25.—Comparison of inclined-draft gauge and U-tube gauge.

or a bellows. The liquids used are oil, water, or mercury. The gauge shown in figure 1-26 is an indicating type that operates on the same principle as the U tube (difference between the levels of the liquid in the two legs is a measure of the draft).

The bottom of the inverted bell is sealed with oil or mercury, depending on the magnitude of the draft or pressure to be measured. It is supported by knife-edges on the beam to reduce friction as much as possible. The weights counterbalance the weight of the bell. and the pointer is returned to zero. The source of draft is connected to the tube, which projects into the inverted bell, so an increase in draft causes the pointer to move down.

CO_2 METERS (ANALYZERS)

Figure 1-27 shows one type of carbon dioxide meter. The meters are also known as analyzers and are designed for determining, indicating, and recording the percentage of CO_2 (carbon dioxide) in the products of combustion. The principle of this instrument is based on the fact that the specific weight of flue gas varies in proportion to its CO_2 content (CO_2 being considerably heavier than the remaining parts of the flue gas).

Q20. Meters are divided into what two general categories?

Q21. In reference to boiler operations, what does the term "draft" mean?

BOILER WATER TREATMENT AND CLEANING

Learning Objective: Describe the methods and procedures for the testing of and treatment of boiler water.

A Utilitiesman must understand the methods, tests, and safety precautions involved in boiler water treatment and the procedures for cleaning boiler firesides and watersides. To ensure a boiler operates at peak efficiency, you must treat and clean it. Water testing, treatment. and cleaning go hand-in-hand. The reason for this is because the effect of the impurities in the water on interior surfaces determines the method and frequency of boiler cleaning. In this section, we will discuss the relationships between water testing. treatment. and cleaning and the procedures for each.

WATER IMPURITIES

All natural waters contain acid materials and scale-forming compounds of calcium and magnesium that attack ferrous metals. Some water sources contain more scale-forming compounds than others; therefore, some waters are more corrosive than others. Subsurface or well waters are generally more scale-forming, while surface waters are usually more corrosive. To prevent scale formation on the internal water-contacted surfaces of a boiler and to prevent destruction of the boiler metal by corrosion, chemically treat feedwater and boiler

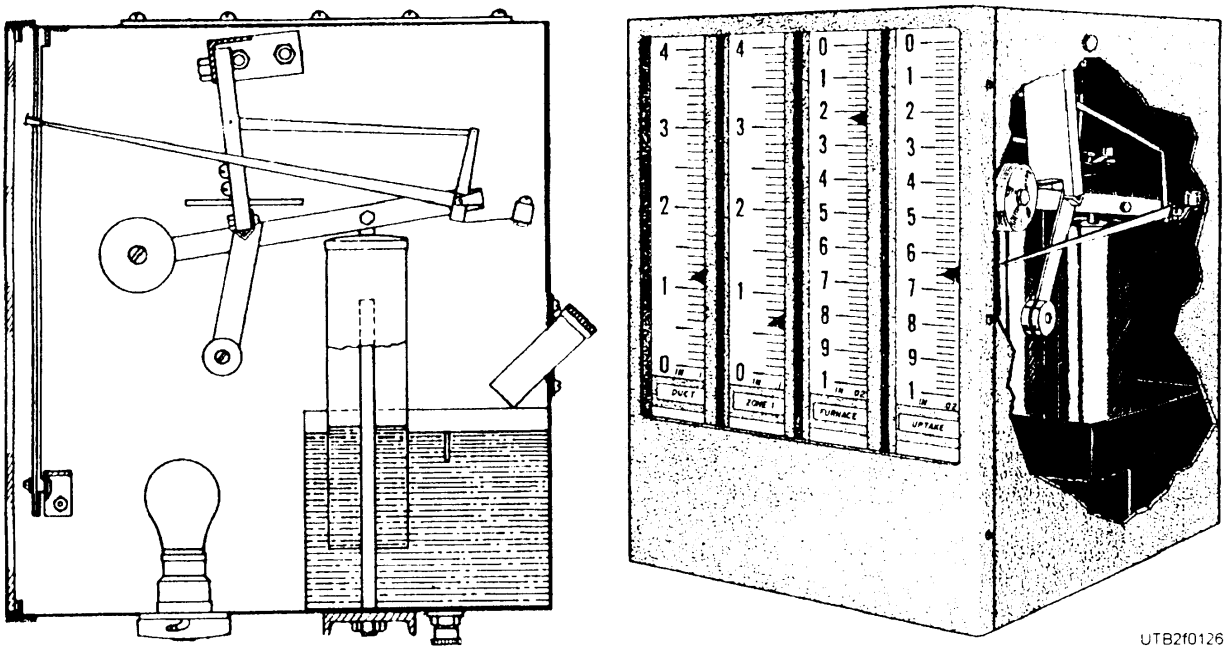
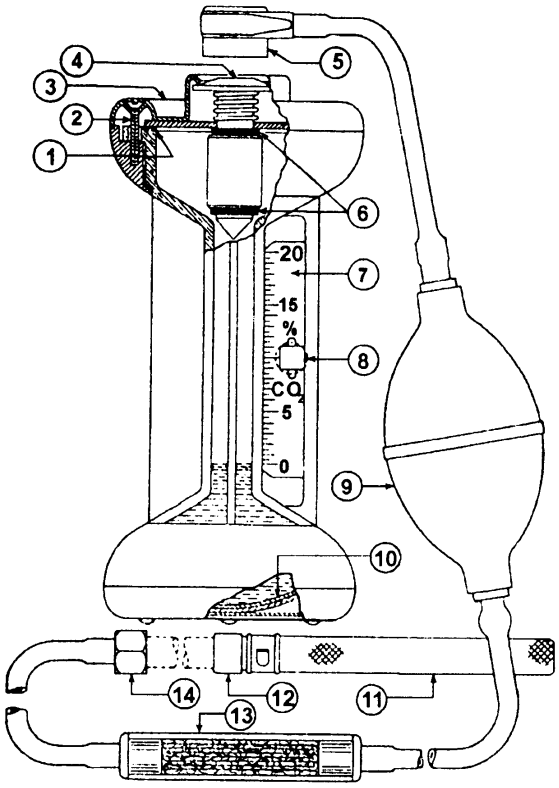


Figure 1-26.—Liquid-sealed draft gauge.



1. GASKET
2. TOP CAP HOLDING SCREW.
3. TOP CAP
4. PLUNGER CAP
5. CONNECTOR TIP.
6. PLUNGER SEATS.
7. CO_2 SCALE.
8 SCALE LOCKING SCREW.
9. RUBBER ASPIRATOR BULB
10. BOTTOM OF ANALYZER.
11. FILTER NIPPLE.
12. CONNECTION SAMPLING TUBE TO FILTER NIPPLE.
13 FILTER TUBE.
14. CONNECTION TUBING TO SAMPLING TUBE.

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Figure 1-27.—CO_2 meter (analyzer).

water. This chemical treatment prolongs the useful life of the boiler and results in appreciable savings in fuel, since maximum heat transfer is possible with no scale deposits.

SCALE

Crystal clear water, satisfactory for domestic use, may contain enough scale-forming elements to render it harmful and dangerous in boilers. Two such scale-forming elements are precipitates of hardness and silica.

Scale deposited on the metal surfaces of boilers and auxiliary water heat exchange equipment consists largely of precipitates of the HARDNESS ingredients—calcium and magnesium and their compounds. Calcium sulfate scale is, next to silica, the most adherent and difficult to remove. Calcium and magnesium carbonates are the most common. Their removal requires tedious hand scraping and internal cleaning by power-driven wire brushes. When deposits are thick and hard, the more costly and hazardous method of inhibited acid cleaning must be used. Scale deposits are prevented by the following: removal of calcium and magnesium in the feedwater to the boiler (external treatment); chemical treatment of boiler water (phosphate, organic extracts, etc.); and changing scale-forming compounds to form soft nonadherent sludge instead of scale that can be easily removed from the boiler by blowdown (internal treatment).

SILICA in boiler feedwater precipitates and forms a hard, glossy coating on the internal surfaces. In the feedwater of high-pressure boilers, such as those used in electric generating plants, a certain amount of silica vaporizes under the influence of high pressure and temperature. The vapor is carried over with steam and silica deposits on the intermediate and low-pressure blading of turbines. In boilers operating in the range of 10- to 125-psig pressure, the silica problem is not so troublesome. When the water is low in hardness, contains phosphate that prevents calcium silicate scale

from forming, or has enough alkalinity to keep the silica soluble. no great difficulty is encountered. The amount of soluble silica can be limited by continuous or routine boiler blowdown to prevent buildup of excessive concentrations.

CORROSION

Corrosion control occurs with the problem of scale control. Boilers, feedwater heaters, and associated piping must be protected against corrosion. Corrosion results from water that is acidic (contains dissolved oxygen and carbon dioxide). Corrosion is prevented by removing these dissolved gases by deaeration of feedwater, by neutralizing traces of dissolved gases in effluent of the deaerating heater by use of suitable chemicals. and by neutralizing acidity in water with an alkali.

METHODS OF TREATMENT

The specific method of chemical treatment used varies with the type of boiler and the specific properties of the water from which the boiler feed is derived. In general, however, the chemical treatment of feedwater and boiler water is divided into two broad types or methods-external treatment and internal treatment of makeup water for alkalinity control and for removal of scale-forming materials and dissolved gases (oxygen and carbon dioxide) before the water enters the boiler. "Internal treatment" means that chemicals are put directly into the boiler feedwater or the boiler water inside the boiler. Frequently, both external and internal chemical treatments are used.

External treatment. frequently followed by some internal treatment, often provides better boiler water conditions than internal treatment alone. However, external treatment requires the use of considerable equipment, such as chemical tanks, softening tanks, filters, or beds of minerals, and the installation costs are high. Such treatment is therefore used only when the makeup water is so hard or so high in dissolved minerals or when internal treatment by itself does not maintain the desired boiler water conditions. What is the dividing line between the hardness and the concentration of dissolved matter in water? What factors other than the dividing line determine the need for external treatment? These factors are the physical makeup of the plant. the type and design of the boilers used, the percentage of makeup water being used, the amount of sludge the boiler can handle, the space available, and the adaptability of the operators. Many methods of INTERNAL TREATMENT are in use. Most of these treatments use carefully controlled boiler water alkalinity, an alkaline phosphate, and organic material. One of the organic materials used is tannin. Tannin is a boiler water sludge dispersant; that is, it makes precipitates more fluid and prevents their jelling into masses that are difficult to remove by blowdown. Because of treatment costs and simplicity of chemical concentration control, the alkaline phosphate-tannin method of internal treatment is perhaps the most widely used. When properly applied and controlled, this treatment prevents formation of scale on internal boiler surfaces and prevents corrosion of the boiler tubes and shell.

BOILER WATER TESTING

As we have just seen. boiler water must be treated with chemicals to prevent the formation of scale on the internal surface of the boiler and to prevent deterioration of the boiler metal by corrosion. Boiler water must be tested to determine the sufficiency of chemical residuals to maintain clean boiler surfaces. As a Utilitiesman, you should be able to make various boiler water tests (fig. 1-28). The procedures for a few types of tests that you may have to make is given here—tests for hardness. phosphate. tannin. caustic alkalinity (with and without tannin), sodium sulfite, and pH. A test kit is provided for the different tests. Each test kit contains the equipment and materials for the specified test. If a kit is not available, you have to use the laboratory equipment (figs. 1-29 and 1-30) provided in the boiler or water treatment plants.

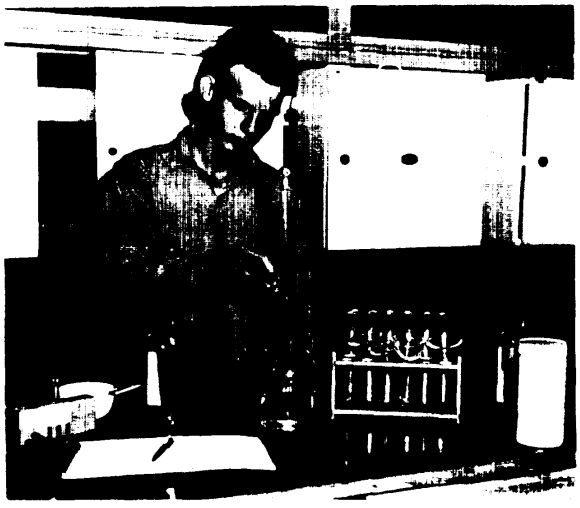


Figure 1-28.—Testing boiler water is an important job.

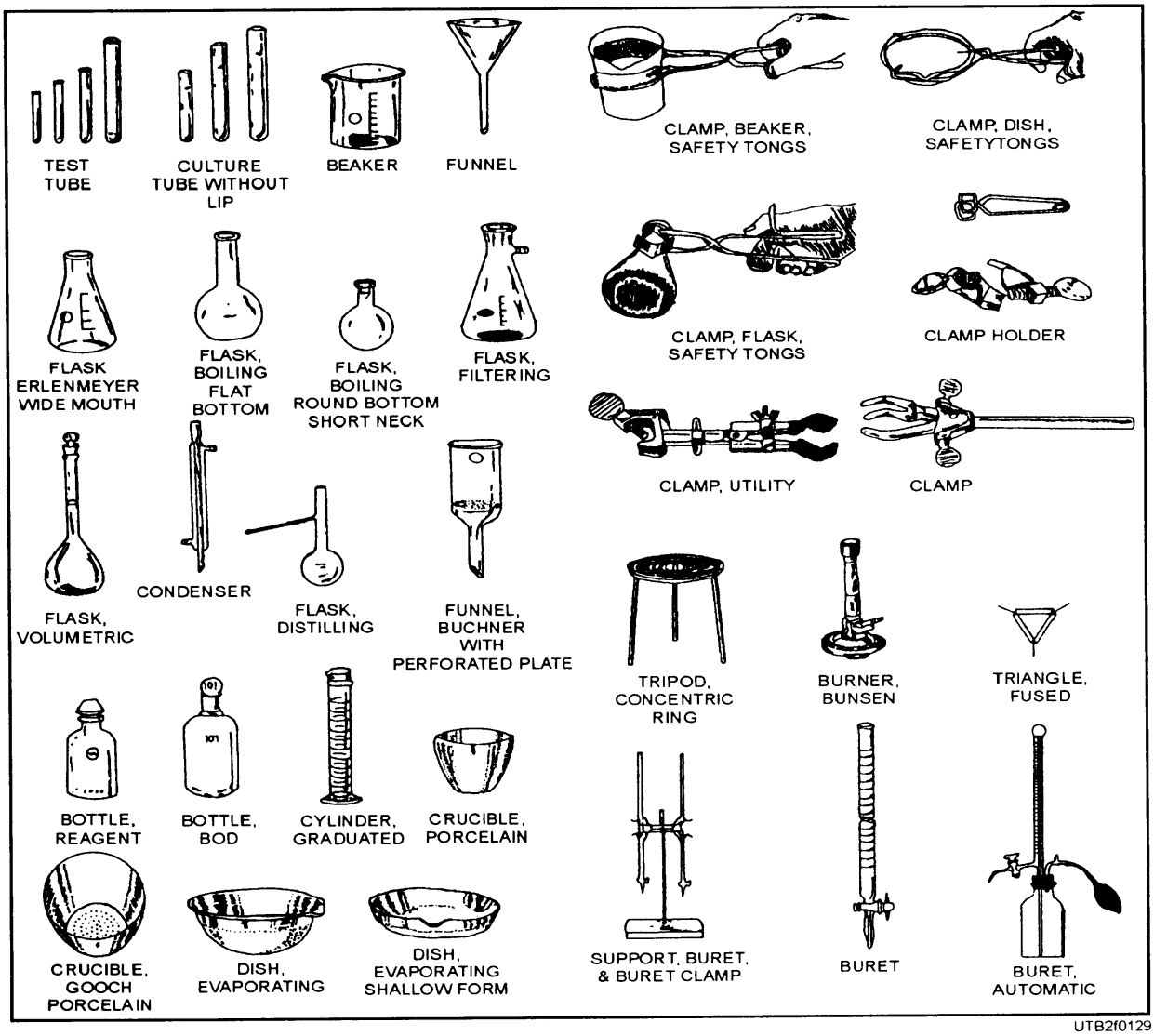


Figure 1-29.—General laboratory equipment.

CAUTION

The following caution applies to each test that is discussed: IF THE TESTING PROCEDURES OF THE EQUIPMENT AND/OR REAGENT SUPPLIER DIFFERS FROM THAT PRESCRIBED IN THIS TEXT, THE SUPPLIER'S PROCEDURE SHOULD BE USED.

Test for Hardness

Boilers operating at pressures of 15 psi and less are normally used for space heating and hot-water generation. Practically all the condensate is returned to the plant. Only a small amount of makeup is required, and secondary feedwater treatment usually is sufficient. When appreciable quantities of steam are used in process work and not returned as condensate to the plant, the problem of scaling and corrosion arises, and more

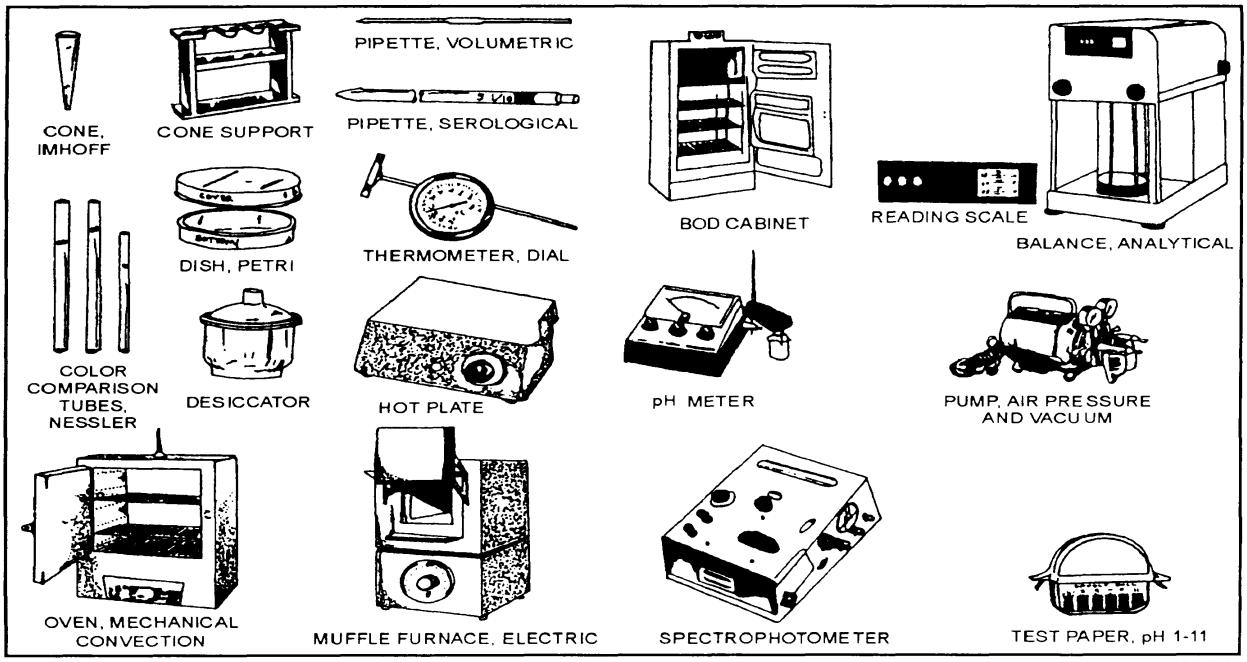


Figure 1-30.—General laboratory equipment.

complete treatment of feedwater must be considered. The ideal water for boilers does not form scale or deposits. does not pit feedwater systems and boiler surfaces, and does not generate appreciable CO_2 in steam. However. such raw makeup water is impossible to get in the natural state from wells or surface sources. Does the advantage of treatment make up for the cost of treatment?

Feedwater of 20- to 25-ppm hardness as calcium carbonate ($CaCO_3$) need not be treated externally to reduce hardness if enough alkalinity is present to precipitate the hardness in the boiler as $CaCO_3$, or if hardness reducers, such as phosphates, are introduced to combine with and precipitate the hardness. Precipitation of this hardness in a low- or medium-pressure boiler generally does not cause wasteful blowdown. When the mixture ofcondensate and makeup in a medium-pressure steam plant has a hardness greater than 20 to 25 ppm as $CaCO_3$, the hardness should be reduced to a level of 0 to 2 ppm as $CaCO_3$.

Feedwater of a hardness in excess of 2 ppm as $CaCO_3$ should be treated to bring it within the range of 0 to 2 ppm as $CaCO_3$. This small remaining hardness can be precipitated in the boiler by secondary treatment and removed by continuous blowoff equipment.

The test for hardness, as presented here, uses the calorimetric titration method. This test is based on finding the total calcium and magnesium content of a sample by titration with a sequestering agent in the presence of an organic dye sensitive to calcium and magnesium ions. The end point is a color change from red to blue, which occurs when all the calcium and magnesium ions are separated.

The following equipment is used for the hardness test:

- One 25-ml buret, automatic, complete
- One 210-ml casserole, porcelain
- One 50-ml cylinder, graduated
- One stirring rod, glass

The reagents for the test are as follows:

- Hardness indicator

- Hardness buffer
- Hardness titrating solution

The steps of the hardness test are as follows:

1. Measure 50 ml of the sample in the graduated cylinder and transfer it to the casserole.
2. With the calibrated dropper, add 0.5 ml of the hardness buffer reagent to the sample, and stir.
3. Add 4 to 6 drops of hardness indicator. If hardness is present, the sample will turn red.
4. Add the hardness titrating solution slowly from the burette, and stir continually. When approaching the end point, note that the sample begins to turn blue, although you can still see a definite reddish tinge. The end point is the final discharge of the reddish tinge. Adding more hardness titrate solution does not produce further color change.

In using this procedure, add the hardness titrating solution slowly because the end point is sharp and rapid. For routine hardness determination, measure 50 ml of the sample, but add only approximately 40 to 45 ml to the casserole at the start of the test. The hardness buffer reagent and the hardness indicator should then be added as directed and the mixture titrated rapidly to the end point. The remaining portion of the sample should then be added. The hardness in the remainder of the sample will turn the contents of the casserole red again. Titrating is continued slowly until the final end point is reached. A record should be kept of the total milliliters of hardness titrating solution used.

To calculate the results in ppm hardness, use the following equation:

ppm hardness = ml titrating solution x 1,000

($CaCO_3$) (ml sample)

With a 50-ml sample, the hardness in ppm as $CaCO_3$ is equal to the ml of titrating solution used, multiplied by 20.

Test for Phosphate

The calorimetric test for phosphate uses a decolorizing carbon to remove tannin. Carbon absorbs the tannin, and the carbon and tannin are then filtered out. When tannin is not present, carbon improves the test for residual phosphate by making the tricalcium phosphate sludge more filterable.

The equipment required for the phosphate test is as follows:

- One phosphate color comparator block of two standards—30 ppm and 60 ppm of phosphate as PO_4. (The Taylor high-phosphate slide comparator may be used instead.)
- Four combination comparator mixing tubes, each marked 5, 15, and 17.5 ml, with stoppers.
- One filter funnel, 65-mm diameter.
- One package of filter paper, 11 cm in diameter.
- One 20-ml bottle.
- One 0.5-ml dropper.
- One 1/4-tsp measuring spoon or spatula.
- Two plain test tubes, 22 mm by 175 mm (about 50 ml).
- Two rubber stoppers, No. 3 flask.
- One 250-ml glass-stoppered bottle or flask, labeled comparator molybdate reagent.

The reagents you need are as follows:

- One 32-oz comparator molybdate.
- One 2-oz concentrated stannous chloride.
- One 32-oz standard phosphate test solution (45 ppm of phosphate, PO_4).

One pound decolorizing carbon. (This is a special grade of decolorizing carbon tested to make sure it does not affect the phosphate concentration in the sample.)

For test purposes, the stannous chloride is supplied in concentrated form. The reagent must be diluted and should be prepared from the concentrated stannous chloride on the day it is to be used, because the diluted solution deteriorates too rapidly for supply by a central laboratory. If not fresh, diluted stannous chloride gives low test results. Concentrated stannous chloride also deteriorates and should not be used if more than 2 months old.

The procedure for making diluted stannous chloride is as follows:

1. Fill the 1/2-ml dropper up to the mark with the concentrated stannous chloride.
2. Transfer it to a clean 20-ml bottle.
3. Add distilled water up to the shoulder of the bottle, then stopper and mix by shaking.

CAUTION

Any diluted stannous chloride not used the day it is made should be discarded.

The following procedure is used to make the test for phosphate:

1. Without disturbing any settled sludge, transfer enough of the sample to the test tube to till it about half full.

2. Add 1/4 tsp of decolorizing carbon. Stopper the tube and shake vigorously for about 1 minute. The carbon absorbs the tannin so it can be filtered out.

3. Fold a filter paper and place it in the filter funnel. Do not wet down the filter paper with water. Filter the shaken sample, using a combination mixing tube as a receiver. The carbon absorbs tannin, and the tannin and sludge present are filtered out more rapidly. Avoid jiggling the funnel, as unfiltered boiler water may overflow the edge of the filter paper into the tube. You have to support the funnel.

4. After 5 ml of the sample has filtered through, as indicated by the level in the tube, discard it. Continue filtering to bring the level in the test tube again up to the 5-ml mark. The sample should come through clear and free, or nearly free, of any color from the tannin. If not nearly free of tannin color. repeat the test, using 1/2 tsp of carbon. adding it in two 1/4-tsp portions, shaking it for 1 minute after each addition.

5. Add the comparator molybdate reagent to bring the level up to the second mark (15 ml). Stopper and mix by inverting the tube several times.

6. Add fresh diluted stannous chloride up to the third mark (17.5 ml). Stopper and mix by inverting. If phosphate is present, the solution in the mixing tube turns blue.

7. Place the tube in the comparator block. Compare the color of the solution in the tube with the standard colors of the phosphate color block. Colors between the two standard colors may be estimated. Take the reading within 1 minute after adding the stannous chloride, because the color fades quickly.

8. Record the results as LOW, if below 30 ppm; HIGH, if above 60 ppm, or OK, if between 30 and 60 ppm.

Test for Tannin

The purpose of the TANNIN TEST is to determine the amount of tannin in the boiler water. Tannin holds sludge in suspension. In treating boiler water with tannin, control the dosage by the depth of brown formed in the boiler water by the tannin. To estimate the depth of the color, which is necessary in adjusting tannin dosages, compare a sample of the boiler water with a series of brown color standards of successively increased depths of color. A tannin color comparator, which is used for the comparison, has five glass color standards: No. 1, very light; No. 2, light: No. 3, medium; No. 4, dark; and No. 5, very dark.

The kit for the tannin test contains the following:

- One tannin color comparator
- Two square tubes, 13-mm viewing depth
- One plain test tube, 22 mm by 175 mm
- One filter funnel, 65 mm by 65 mm
- One package of filter paper, 11 cm in diameter

making this test, you first fill a plain test tube almost to the top with cool boiler water. Then place a square test tube in the slot of the comparator, and insert the filter funnel in it. Fold a filter paper and place it in the funnel without wetting it down. Filter water from the plain test tube into the square tube until the tube is neatly full. Remove the square tube from the comparator and hold it up to a good source of natural light. Note the appearance of the filtered boiler water. Is it free of suspended solids and sludge? If not, refilter the sample, using the same funnel and filter paper. Repeat, using a double filter paper if necessary, until the sample does come through free of suspended solids and sludge.

To complete the test, place the square tube of filtered sample in the middle slot of the comparator. Then compare the color of the sample with the five standards, viewing it against a good source of natural light. The color standard most closely matching the color of the filtered sample gives the tannin concentration of the boiler water. For a number of boiler water conditions, the tannin dosage is usually satisfactory if it maintains a medium (No. 3) tannin color. If the tannin color is too high, blow down; if too low, add tannin.

Test for Caustic Alkalinity (OH) without Tannin

The boiler water sample for this test is collected at a temperature of 70°F or below.

The equipment required is as follows:

- Two 8-in. droppers with bulbs
- Two 250-ml glass-stoppered bottles or flasks labeled causticity No. 1 and causticity No. 2
- Four marked test tubes, 22 mm by 185 mm
- Three plain test tubes, 22 mm by 175 mm
- Three rubber stoppers, No. 2
- One 14-in. test-tube brush
- One test-tube clamp
- Two 9-in. stirring rods
- One 1-oz indicator dropping bottle for phenolphthalein
- One test-tube rack
- The following reagents also are required:
- One 24-oz bottle or flask causticity reagent No. 1
- One 24-oz bottle or flask causticity reagent No. 2
- One 4-oz bottle phenolphthalein indicator

The following are the steps to follow in conducting a test for causticity when tannin is not used:

CAUTION

Avoid exposure of the sample to the air as much as possible to reduce absorption of the CO_2.

1. Without disturbing the settled sludge, fill a marked test tube exactly to the first mark (25 ml) with some of the original boiler water sample.

2. Shake causticity reagent No. 1 (barium chloride solution saturated with phenolphthalein) thoroughly and add enough to the graduated tube to bring the level exactly to the second, or long, mark (30 ml).

3. Stir the solution with the 9-inch stirring rod, which must be kept clean and reserved for the causticity test only. When the mixture remains colorless or does not turn pink, the causticity in the boiler water is zero and the test is finished. When the mixture turns pink, causticity is present. (If the pink color is not deep, intensify it by adding two drops of phenolphthalein indicator to the mixture in the tube.) Add causticity reagent No. 2 (standard one-thirtieth normal acid), using the 8-inch dropper, thatch must be kept clean and reserved for the causticity test only. Causticity reagent No. 2 is sucked from the reagent bottle into the dropper by its rubber bulb and added, drop by drop, to the test tube. After each addition, stir the mixture with a stirring rod. After sufficient reagent has been added, the pink color disappears; the change point is usually sharp. As soon as the pink color just fades out, stop adding the reagent.

4. The amount of causticity reagent No. 2 required to make the pink color disappear shows the concentration of hydroxide (OH) or causticity in the boiler water. The amount of reagent used is shown by the marks on the test tube above the long mark (30 ml). The distance between any two marks on the test tube equals 5 ml, and readings less than 5 ml can be estimated. For example, when only three fifths of the distance between the long mark and the next mark above were filled, then 3 ml was added. When the distance filled was past one mark plus three fifths of the distance to the next, then 5 + 3 = 8 ml was used. To obtain the actual ppm of hydroxide or causticity shown by the test, multiply the number of ml by 23. This constant number, 23, represents the amount of sodium hydroxide in the boiler water by volume. Thus, for 8 ml of causticity reagent No. 2, there are 8 x 23 = 184 ppm hydroxide or causticity in the water.

5. Record the results of the test in a boiler log or chemical log and adjust the range to meet requirements. When causticity is too high, blow down; if too low, add sodium hydroxide (caustic soda).

Test for Caustic Alkalinity (OH) with Tannin

For this test, start with a warm sample of about 160°F. It may be reheated by placing the sample-collecting container in a stream of hot boiler water drawn through the boiler water cooler connection. In a test for causticity when tannin is used, make sure you observe the same precautions as carefully as when tannin is not used.

CAUTION

Avoid exposure of the sample to the air as much as possible to reduce absorption of the CO_2.

The equipment and reagents required for this test are the same as those listed in the preceding section where tannin was not used.

The procedure for conducting a test for causticity with tannin is as follows:

1. Fill two test tubes to the first mark (25 ml) with some of the original boiler water sample, taking care not to disturb the settled sludge in the container. (Transfer as little sludge as possible from the sample-collecting container to the test tubes.)

2. Shake causticity reagent No. 1 thoroughly and add enough to each of the two marked tubes to bring the levels up to the second, or long, mark (30 ml). Stir both with the stirring rod, which must be kept clean and reserved for the causticity test only.

3. Stopper both tubes and let them stand until any sludge formed has settled to the bottom. The sludge carries down with it much of the tannin or other colored matter in the solution; settling takes a few minutes if the sample is warm.

4. Without disturbing the sludge at the bottom, pour enough solution from the tubes into the third marked tube to fill it to the second, or long, mark. Discard the mixture left in the first two. When the sample in the third tube is still warm, cool it by letting cold water run on the outside of the tube. It is sometimes possible to intensify the pink color by adding two drops of phenolphthalein from the indicator-dropping bottle to the sample in the tube. Stir the solution. When it is not pink, the causticity in the boiler water is zero.

5. When the sample is not pink, the test is finished. But if the mixture turns pink, proceed in the same manner as directed in Steps 3, 4, and 5 when no tannin is used.

Here is a brief explanation of an ALTERNATE PROCEDURE for making the test for causticity when tannin is used. In this procedure any glass container, such as a large test tube or graduated cylinder, marked for 50 to 60 ml can be used instead of the two standard marked test tubes used in Steps 1 and 2 above. With the large test tube or graduated cylinder, the warm (160°F) sample is added up to the 50-ml mark and causticity reagent No. 1 up to the 60-ml mark. Stir the mixture and stopper the tube, or graduate. After the sludge settles, pour off enough of the solution into one of the standard marked test tubes to fill it to the long mark (30 ml). When the sample is warm, cool it by letting cold water run on the outside of the tube. Adding two drops of phenolphthalein may intensify the pink color. When the solution is not pink, the causticity in the boiler water is zero. But if it turns pink, proceed in the same manner as in Steps 3, 4, and 5 when no tannin is used.

Test for Sodium Sulfite

The sample for this test should be cooled to 70°F, or below, and exposed to the air as little as possible, because oxygen in the air combines with sodium sulfite in the sample and causes low readings. Collect a separate sample, using the boiler water sample cooler, with the line reading to the bottom of the sampling bottle. Allow the boiler water to run until a few bottlefuls overflow to waste.

The equipment necessary to make the sodium sulfite test is as follows:

- Two marked test tubes
- Two plain test tubes
- One stopper for plain test tube
- One stirring rod
- One 8-in. dropper
- One 1/4-measuring tsp
- One 50-ml beaker
- One 150-ml beaker
- One 30-ml acid-dropping bottle, with dropper marked at 0.5 ml for hydrochloric acid 3N
- One 30-ml starch-dropping bottle, with dropper marked at 0.5 ml for starch indicator

The reagents required are as follows:

- One 2-oz bottle of potato, or arrowroot starch
- One 8-ml vial of thymol
- One 24-oz bottle of hydrochloric acid 3N
- One 1-pt amber bottle of standard potassium iodate-iodide reagent

The starch indicator for this test must be prepared locally. The procedure to adhere for good results is as follows:

1. Measure out a level one-fourth tsp of potato or arrowroot starch and transfer it to the 50-ml beaker.

2. Add a few milliliters of distilled water and stir the starch into a thick paste, using the end of the stirring rod.

3. Put 50 ml of distilled water into the 150-ml beaker. (It is convenient in this step to have the 150-ml beaker marked at the point where it holds 50 ml, or one of the marked test tubes can be used by filling it with distilled water to the fourth mark above the long mark.)

4. Bring the water in the 150-ml beaker to a boil by any convenient method.

5. Remove the source of heat and immediately pour the starch paste into the boiling water while stirring the solution.

6. Put a crystal of thymol into the starch solution and stir. After the solution has cooled, pour off any scum on the surface and transfer 30 ml to the indicator-dropping bottle.

7. The starch solution loses its sensitivity as an indicator after a time. Addition of the thymol preserves it for about 2 weeks. The starch should be dated when prepared.

In making the sodium sulfite test, proceed as follows:

1. Transfer 1 ml of hydrochloric acid 3N to a clean, marked test tube by measuring out 0.5-ml portions with the dropper of the acid-dropping bottle.

2. From the starch-dropping bottle, transfer 0.5 ml of starch to the marked test tube.

3. Without disturbing any settled sludge in the sample, pour enough of the sample into the marked test tube to bring the level up to the first mark (25-ml). Stir the mixture in the tube with the plunger end of the stirring rod.

4. To add the standard potassium iodate-iodide reagent to the mixture in the marked test tube, have the marked test tube supported and the stirring rod placed in the tube, so the reagent can be added with one hand while the mixture is stirred with the other. Fill the 8-inch dropper with standard potassium iodate-iodide reagent from the stock bottle by sucking it up with the rubber bulb. (The dropper must be kept clean and reserved for this test only.)

5. Add the reagent to the mixture in the marked test tube, one drop at a time, counting the number of drops and stirring after each is added until a permanent blue color, which is not removed by stirring, is obtained. The standard iodate-iodide reagent reacts with sodium sulfite in the mixture, and the formation of the permanent blue color from the action of excess reagent with the starch shows that the iodate-iodide reagent has consumed all the sodium sulfite in the mixture.

6. Each drop of iodate-iodide reagent used (except the last one) indicates 5 ppm of sodium sulfite in the boiler water sample. To figure the concentration of sodium sulfite in the boiler water, multiply the total number of drops of the standard iodate-iodide reagent used, less one, by 5. For example, when 5 drops were used, subtract 1 from 5 = 4, 5 x 4 = 20 ppm.

7. Record the results of the test as ppm.

Test for pH

The value of pH indicates the degree of acidity or alkalinity of a sample. A pH of 7.0 represents the neutral point; the lesser values denote acidity; the greater values denote alkalinity. The test is made as soon as possible after you take the sample. Avoid exposure to the air as much as possible to reduce absorption of CO_2.

The following equipment is used in making the pH test of boiler water:

- Two vials of indicator paper, hydrions pH 10 to 20
- Two vials of indicator paper, hydrions C pH 11 to 12
- One 50-ml beaker
- One 2-oz bottle

In conducting the test for pH of boiler water, remove a strip of pH 10 to 12 indicator paper from the vial and dip it into the sample in the beaker. Keep the paper immersed for 30 seconds; then remove it. When the sample does not change the color of the paper or colors it yellow or light orange, the pH of the sample is too low and the test is finished. When the paper turns orange or red, the pH is either satisfactory or too high.

In that case, remove a strip of paper of pH 11 to 12 from the vial and dip it into the sample in the beaker. Keep the paper immersed for 30 seconds; then remove it. When the sample does not change the color of the paper or colors it a light blue, the pH is satisfactory. When the paper turns deep blue, the pH is higher than necessary. Blow down or reduce the dosage of caustic soda (NaOH).

Test for pH of Treated Condensate

In making a test for pH of treated condensate, take the sample from a point in the return piping near which condensation takes place, such as after a trap, or preferably where the return-line corrosion is known to occur. The sample must represent water flowing in the return lines. Water taken from the return tank, especially of large installations, generally shows a higher pH. A sample should not be taken from a

collecting tank if other water, such as makeup, is received in the tank.

The equipment required for this test is as follows:

- One 4-oz brown bottle of condensate pH indicator
- One 1-oz indicator bottle, with dropper marked at 0.5 ml
- One 100-ml beaker, marked at 50 ml
- One 9-in. stirring rod, glass

In making a test for pH of treated condensate, proceed as follows:

1. Pour a freshly drawn sample into the testing beaker until it is filled to the 50-ml mark. You do not have to cool the sample.

2. Transfer 0.5 ml of indicator solution to the 50-ml testing beaker, using the marked dropper. Stir the solution in the beaker. If the color of the solution changes to light pink. the sample is NEUTRAL, or slightly alkaline; therefore, the condensate pH is satisfactory and the test is over.

3. Record in a log that the pH range is between 7 and 7.5.

4. When the color change is green, the sample is in the acid range and the boiler water must be treated with Amines. Treat the boiler water with Amines gradually (in small amounts at a time), and retest after each treatment. Amines are the only chemicals used to treat boiler water that will vaporize and leave with the steam and thereby protect the return system.

WARNING

Permission to treat with Amines must be obtained from your supervisor. Amines are volatile, poisonous, and in the alkaline range.

6. When the color change is red or purple, the sample is in an excessive alkaline (pH) range. In that case, reduce the Amines treatment gradually (in small amounts at a single time), and retest after each treatment. Remember, the condensate pH normal acceptable range is between 7 and 7.5.

Test for Total Dissolved Solids

The solu-bridge method is a simple and rapid way to determine the total dissolved solids (TDS) content. Ionizable solids in water make the solution conduct electricity. The higher the concentration of ionizable salts, the greater the conductance of the sample. Pure water, free from ionizable solids, has low conductance and thus high resistance. The solu-bridge instrument measures the total ionic concentration of a water sample, the value of which is then converted to parts per million. The solu-bridge test equipment and reagent are furnished by the supplier in a kit.

CAUTION

The model of the solu-bridge given below is not suitable for measuring solids in condensed steam samples or an effluent of the demineralizing process. A low-conductivity meter is necessary. because of the extremely low solids content of condensed steam and demineralized water.

The equipment and reagent are as follows:

- One solu-bridge, Model RD-P4 or equivalent, for a 105 to 120-volt, 50- to 60-cycle ac outlet. (This model has a range of 500 to 7,000 micromhos/cm.)
- One polystyrene dip cell, Model CEL-S2.
- One thermometer, 0°F to 200°F.
- One 0.1-g dipper for gallic acid.
- One cylinder, marked at the 50-ml level.
- Gallic acid powder, 1 lb.
- Calibration test solution. I qt.
- The test is made as follows:

Without shaking, pour 50 ml of the sample into the cylinder. Add 2 dippers of gallic acid powder and mix thoroughly with a stirring rod.

2. Connect the dip-cell leads to the terminals of the solu-bridge and plug the line cord into a 110-volt ac outlet. Turn the switch ON. and allow the instrument to warm up for 1 minute.

3. Clean the cell by moving it up and down several times in distilled water. Measure the temperature of the sample to be tested; then set the point of the solu-bridge temperature dial to correspond to the thermometer reading.

4. Place the cell in the cylinder containing the 50-ml sample. Move the cell up and down several times under the surface to remove air bubbles inside the cell shield. Immerse the cell until the air vents on the cell shield are submerged.

5. Turn the pointer of the solu-bridge upper dial until the dark segment of the tube reaches its widest opening.

6. Calculate the result in ppm by multiplying the dial reading either by 0.9 or by a factor recommended by local instructions. For example, when the dial reading is 4,000 micromhos and the factor used is 0.9, then 4,000 x 0.9 = 3,600 ppm.

7. Record the results of the test in ppm.

Q22. Scale deposited on metal surfaces of' boilers consists largely of what scale-forming element?

Q23. What are the two broad types or methods of chemical treatment of‘ boiler water?

Q24. Results of a phosphate test would need to be between what lower and higher ppm to be at an acceptable level?

Q25. In a causticity test without tannin, when the mixture turns pink, what does this mean?

Q26. A sample of boiler water for a sodium sulfite test should be cooled to what temperature before conducting the test?

CLEANING BOILER FIRESIDES AND WATERSIDES

Lesson Objective: Describe met hods and procedures involved in fireside and waterside cleaning.

Boiler heat transfer surfaces must be kept clean to provide for safe and economical boiler operation. In this section we will describe the methods and procedures involved in fireside and waterside cleaning.

CLEANING BOILER FIRESIDES

Excessive fireside deposits of soot, scale, and slag cause the following conditions: reduced boiler efficiency, corrosion failure of tubes and parts, reduced heat transfer rates and boiler capacity, blocking of gas passages with high draft loss and excessive fan power consumption, and fire hazards.

Methods for cleaning boiler tiresides include wire brush and scraper cleaning, hot-water washing. wet-steam lancing, and sweating.

Wire Brush and Scraper Cleaning

When too much soot is deposited and the passages become plugged, hand lancing, scraping, and brushing are generally used. Special tools required for reaching between the lanes of tubes may be made from flat bars, sheet metal strips cut with a saw-toothed edge, rods, and similar equipment. Some boilers have different sizes of tubes, so you need various sizes of brushes and scrapers to clean the boiler tubes. The brushes or scrapers are fastened to a long handle, usually a piece of pipe, inserted and pushed through the tubes.

Hot-Water Washing

This method of cleaning is often used to clean superheaters, economizers, and other sections of the steam generator that are difficult or impossible to reach by brushing or scraping. The water may be applied with hand lances and/or boiler soot blowers. Dry out the boiler setting immediately after water washing to reduce damage to the refractory and other parts of the setting.

Safety is always paramount; therefore, always be cautious when washing boiler firesides. Some precautions you should observe are as follows:

- Wet the boiler refractory and insulation as little as possible. Install canvas shields or gutters where possible to reduce wetting of refractories.
- Protect electrical equipment from water damage.
- Provide all necessary instructions and protective equipment for workers.
- Provide a compressed air lance to loosen scale after water washing.
- Provide adequate equipment to heat and pump the hot water. The water should be heated and maintained at a temperature close to about 150°F, because water exceeding this temperature cannot be handled safely and efficiently. However, because cold water does not clean satisfactorily, you have to maintain the water temperature as close as 150 degrees as possible. A water pressure of 200 to 250 psig should be provided at the cleaning lances or soot blowers. The water jets must penetrate the tube banks and strike with enough force to break up the slag accumulations.
- Start the water washing at the top of the unit and work down.
- The unit must be dried out immediately after washing.

Wet-Steam Lancing

The wet-steam lancing method is similar to the hot-water method except that wet steam is used instead of

hot water. The steam should be wet and at a pressure of 70 to 150 psig. The unit must be dried out immediately after lancing is completed.

Sweating

Fireside slag can be removed from the convection superheaters by forming a sweat on the outside of the tubes. Cold water is circulated through the tubes. and moisture from the air condenses on the tubes to produce sweat. The hard slag is changed into mud by the sweat, and the mud can be blown off by an air or a steam lance. A large tank filled with water and ice can be used as the cold-water source. Steam can be blown into the area around the tubes during the cold-water circulating period to provide adequate moisture in the air.

Cleaning Procedures

The procedures for cleaning boiler tiresides are as follows:

1. Remove the boiler from service and allow it to cool. Make sure the boiler is cool enough for a person to enter. Someone must be standing by whenever a person is in the boiler. DO NOT force-cool the boiler.

2. Disconnect the fuel line openings. Secure all valves, and chain. lock. and tag all fuel lines to the burner and install pipe caps.

3. Disconnect the electrical wiring. Secure and tag the electrical power to the boiler. Disconnect the burner conduit and wiring. Mark and tag all electrical wiring to ensure proper reinstallation.

4. Open the boiler access doors by loosening all nuts and dogs and swing the door open. Be careful not to damage the refractory door lining.

5. Remove the burner from the boiler openings. Follow the manufacturer's instructions for specified burners. Wrap this equipment with plastic, rags. or other suitable protective coverings. Remember. soot and loose carbon particles must be kept out of the moving parts of the burner because they can cause the burner to malfunction.

6. Provide all spaces with free-air circulation by opening doors and windows, or provide fresh air by mechanical means. An assistant should be stationed outside the opening and be ready at all times to lend a hand or to be of service in case of a mishap.

7. Cover the floor area around the tube ends with drop cloths to catch soot. Position a vacuum cleaner hose at the end of the tube being cleaned. Keep soot from contacting wet areas because soot and water form carbonic acid.

8. Remove tube baffles where possible and pass a hand lance or rotating power cleaner brush through each tube slowly and carefully so no damage occurs to personnel or equipment.

9. Inspect tube surfaces for satisfactory condition before continuing on to the nest tube. Use a drop cord or flashlight for viewing through the entire length of a tube. Wire brush all tube baffles either by hand or use of power tools.

10. Apply a light coat of mineral oil to all cleaned surfaces. To do this, fix an oil soaked rag to the end of a brush or rod long enough to extend through the tubes and thoroughly swab each surface, including baffles. Mineral oil is the only lubricant that prevents rusting and also burns off freely without leaving a carbon deposit.

11. Clean all flat surfaces by brushing with the hand or power tools. Make sure that powered equipment is grounded.

12. Use an industrial vacuum cleaner to remove loose soot.

CLEANING BOILER WATERSIDES

Any waterside deposit interferes with heat transfer and thus causes overheating of the boiler metal. Where waterside deposit exists, the metal tube cannot transfer the heat as rapidly as it receives it. What happens? The metal becomes overheated so that it becomes plastic and blows out, under boiler pressure, into a bubble or blister.

The term *waterside deposits* include sludge. oil, scale. corrosion deposits. and high-temperature oxide. Except for oil. these deposits are not usually soluble enough to be removed by washing or boiling out the boiler.

The term *waterside corrosion* is used to include both localized pitting and general corrosion. Most, if not all, is probably electrochemical. There are always some slight variations (both chemical and physical) in the surface of boiler metal. These variations in the metal surface cause slight differences in the electric potential between one area of a tube and another area. Some areas are ANODES (positive terminals).

Iron from the boiler tube tends to go into solution more rapidly in the anode areas than at other points on the boiler tube. This electrolytic action cannot be completely prevented in any boiler. However, it can be reduced by maintaining the boiler water at the proper alkalinity and

by keeping the dissolved oxygen content of the boiler water as low as possible.

The watersides of naval boilers may be cleaned in two ways—mechanically, by thorough wire brushing of all drums, headers, and tubes; and chemically. by circulating chemical cleaning solutions through the boiler.

Mechanical Cleaning

Before mechanical cleaning of watersides is begun, the internal fittings must be removed from the steam drum. The fittings (particularly the steam separators and apron plates) must be marked or otherwise identified as to position in the steam drum to ensure their correct reinstallation. All internal fittings must be wire brushed and cleaned before they are reinstalled.

Cleaning the watersides of the generating tubes requires a special tube cleaner. There are several types available, but perhaps one of the most common is the pneumatic turbine-driven tube cleaner shown in figure 1-31. This type of cleaner consists of a flexible hose, an air-driven motor, a flexible brush holder, and an expanding wire bristle brush. The turbine-driven motor consists of a set of turbine blades made to revolve when compressed air is admitted through the hose. The turbine-driven motor, in turn, drives the wire brush. There are several sizes of brushes available (figs. 1-32 and 1-33). Figure 1-34 shows a brush refill for the type of brush shown in figure 1-32.

Before you start cleaning tubes, be sure that adequate ventilation and lighting have been arranged. Someone should also be stationed outside the drum to act as tender

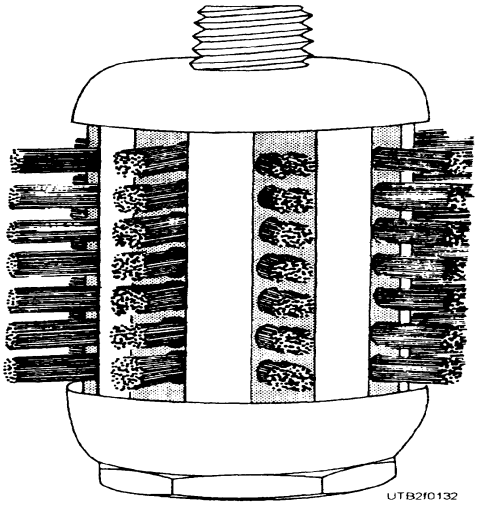


Figure 1-32.—Wire bristle brush for cleaning generating tubes.

and to assist whomever is working in the drum. Keep a written checkoff list of all tools and equipment taken into the watersides and be sure that the same tools and equipment are removed.

With the air shut off, insert the tube cleaner in the tube until the brush is about even with the far end of the tube. Wrap friction tape, a rag, or some other marking

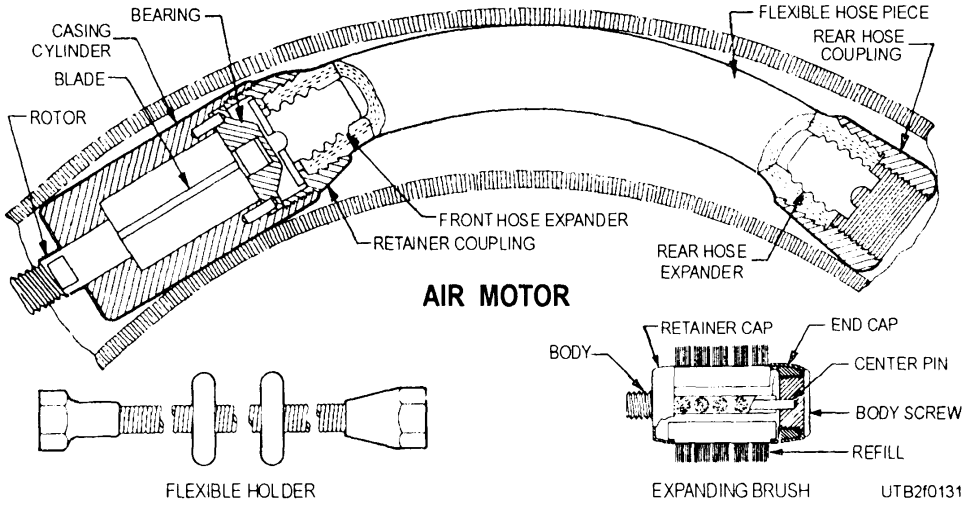


Figure 1-31.—Boiler tube cleaner (pneumatic turbine-driven type).

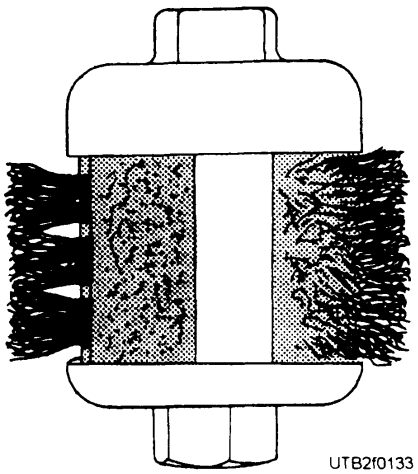


Figure 1-33.—Wire bristle brush for cleaning large tubes.

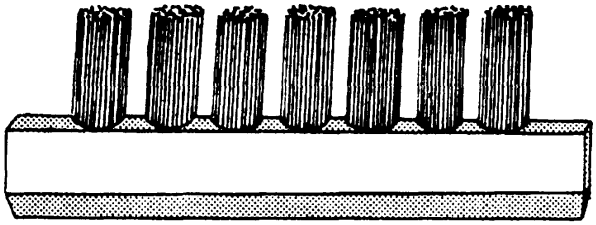


Figure 1-34.—Brush refill.

material around the hose to show how far the tube cleaner can be inserted without having the brush protrude beyond the far end of the tube. Then remove the cleaner from the tube. Remember that the tubes in each row are the same length; however, the tube lengths vary from row to row. Therefore, separate markings have to be made on the hose for each row of tubes.

After the hose has been marked, insert the brush in the tube and turn on the air to start the brush rotating. Pass the brush SLOWLY along the length of the tube until the identifying mark has been reached. Then slowly draw the brush back. withdrawing the cleaner from the tube. You do not have to shut off the air to the tube cleaner each time the cleaner is withdrawn from the tube. However, be sure to steady the brush assembly with your hand to keep the cleaner from whipping. Allowing the brush to whip at either end of the tube is the most common cause of broken tubes.

Establish a new mark for the next row and proceed with the cleaning. Make as many passes as necessary through each tube to ensure adequate cleaning. Be careful not to stop the tube cleaner in any one place in the tube, as the continued rotation of the brush in one place might damage the tube. Be careful, also, to see that the brush and the flexible shaft do not protrude from the other end of the tube, as this may result in a broken shaft.

The tube is most easily cleaned from the steam drum. However, some rows of tubes are not accessible from the steam drum and must be cleaned from the water drum or header. The lower ends of ALL tubes must be cleaned from the water drum or header. You may also find tubes bent so that brushes cannot be forced around the bend without breaking the tube cleaner. These tubes must be cleaned from both ends. Tube cleaners must be kept in good operating condition. The rotor and blades of the air motor should be kept clean and well lubricated. The hose connections should be kept tight and free from leaks. The flexible shafts should be inspected frequently and renewed when they show signs of wear or damage. When the brushes become too worn to work efficiently, a new set of brush refills should be inserted into the brush body. Store tube cleaners in a clean, dry container.

After all tubes, drums, and headers have been cleaned and after all tools and equipment have been removed from the watersides, blow through the tubes with air; then wash out the drums, tubes, and headers with fresh water. Ensure all dirt is removed from the handhold seats. Then examine the seats for scars, pits, or other defects that might cause leakage. All bottom blow, header blow, and test cock valves should be inspected and repaired under the manufacturer's instructions during each waterside cleaning.

After washing, thoroughly dry out the boiler watersides. Inspect the watersides to determine the condition of the metal to see if the cleaning was satisfactory. Also, inspect the boiler to be sure that all the parts are tight. Be sure that all openings between drums and gauge glasses, blow valves, and safety valves are clean and free of foreign matter. These openings are sometimes overlooked.

Chemical Cleaning

In most cases. mechanical cleaning is the preferred method for cleaning watersides. Chemical (acid) cleaning requires special authorization. since it requires elaborate and costly equipment and rather extensive SAFETY precautions. However, you may have to use the chemical method, so a limited discussion on it is given here.

Inhibited acid cleaning is used to remove mill scale from the watersides of new or recently serviced boilers. When compared with mechanical cleaning, acid cleaning of boilers has the following advantages:

- Less outage time is required.

- Less dismantling of the unit.
- Lower cost and labor.
- A more thorough job is accomplished because the acid reaches areas inaccessible to mechanical cleaners.
- Because the cleaning is more complete, it is possible to examine the unit thoroughly for defects, such as cracks and corrosion pitting.

ACIDS FOR CLEANING.—The following acids are used to clean boilers: hydrocholoric acid, phosphoric acid, sulfamic acid, citric acid, and sulfuric acid.

HYDROCHLORIC ACID is most frequently used for boiler cleaning because it has a relatively low cost and satisfactory inhibitors are available. Also, the chemical reactions of the hydrochloric acid with the boiler deposits usually result in soluble chlorides.

PHOSPHORIC ACID can remove mill scale from new boilers. With this acid, the boiler can be fired directly without producing noxious or corrosive fumes. Direct firing produces good circulation and distribution of the cleaning solution. Another advantage of phosphoric acid cleaning is that the metal surfaces resist corrosion after cleaning. When cleaned with phosphoric acid, you must protect metal surfaces from surface corrosion during draining and before neutralization.

SULFAMIC ACID is available in powder that must be placed in solution. The powdered acid is easier and safer to handle than liquid acids in carbons. It does not produce noxious fumes as it dissolves and it is less corrosive than hydrochloric acid, especially at higher concentrations and temperatures.

CITRIC ACID AND SULFURIC ACID are used for removing boiler waterside deposits. Sulfuric acid is economical and easily inhibited. However, a danger is that the sulfuric acid can form insoluble salts, such as calcium sulfate.

INHIBITORS.—Without inhibitors, acid solutions attack the boiler metal as readily as they attack the deposits. With the addition of suitable inhibitors, the reaction with the boiler metal is greatly reduced. Inhibitors used include arsenic compounds, barium salts, starch, quinolin, and pyridin. Commercial inhibitors are sold under trade names by various chemical concerns. Other inhibitors are manufactured by companies that furnish complete acid cleaning services.

SAFETY PRECAUTIONS—When acid cleaning a boiler installation, you must observe SAFETY precautions as follows:

- Before acid cleaning, replace all brass or bronze parts temporarily with steel or steel alloy parts.
- Provide adequate venting for safe release of acid vapors.
- Close all valves connecting the boiler with other piping or equipment.
- Provide competent chemical supervision for the cleaning process.
- Do not exceed the specified acid and inhibitor allowable temperature. The inhibiting effect decreases with the temperature rise and the probability of acid attack of the boiler metal increases.
- After acid cleaning, be sure to thoroughly flush out all of the tubes that are horizontal or slightly sloping. Obstructions in these tubes can cause poor circulation, overheating, and failure of tubes when the unit is placed in service.
- Use goggles, rubber gloves, and rubber aprons when handling acids.
- Slowly pour the acid into water when mixing the solutions.

CAUTION

NEVER POUR WATER INTO ACID.

- Do not chemically clean boilers with riveted joints.
- During acid cleaning, hydrogen gas can develop through the reaction of the acid on the boiler metal. Some of the generated gas becomes part of the atmosphere inside the boiler, and the remainder is absorbed by the boiler metal, then liberated gradually. Because hydrogen air mixtures are potentially explosive, be careful when opening a unit for inspection after acid cleaning. Until the atmosphere within the boiler pressure parts has been definitely cleared of explosive gases, do NOT use open flames. flashlights, lighting equipment. or anything that might produce a spark near the openings to the pressure parts. Do NOT enter the boiler. The unit can be cleared of explosive gases by thoroughly flushing the unit with warm water with a positive overflow from the highest vent openings. The water temperature should be as near

to 212° F as possible to accelerate the liberation of hydrogen absorbed in the metal. After opening the unit, place air blowers at the open drum manholes to circulate air through the unit. Use a reliable combustible gas indicator to test the boiler atmosphere for explosive mixtures.

ACID CLEANING PROCEDURES—Boiler units can be acid cleaned by either the "circulation" or "fill and soak" method. The circulation method (fig. 1-35) can be used to clean units with positive liquid flow paths, such as forced circulation boilers. The inhibited acid solution is circulated through the unit at the correct temperature until test analyses of samples from the return line indicate that the acid strength has reached a balance and no further reaction with the deposits is taking place. Because the strength of the acid solution can be determined frequently during the cleaning process, this method can be more accurately controlled and can use lower strength solutions than the fill-and-soak method.

The fill-and-soak method (fig. 1-36) is used for cleaning units with natural circulation. The boiler unit is filled with the inhibited acid solution at the correct temperature and allowed to soak for the estimated time. It is not possible to obtain accurate representative samples of the cleaning solution during the soaking period.

FLUSHING AND NEUTRALIZING—After acid cleaning, drain and then flush the unit with clean, warm water until the flushing water effluent is free of acid and soluble iron salts.

Next, a neutralizing solution is circulated through the unit until the effluent shows a definite alkaline reaction. The types of neutralizing solutions used are as follows: soda ash, trisodium phosphate. sodium tripolyphosphate, or other nontoxic chemicals. After circulation of the neutralizing solution, the water level can be dropped to the normal level and the boiler fired at 50 psig with open vents to permit the escape of liberated gases. Finally. the boiler is again drained and flushed with clean, warm water.

Boiling Out

New boilers. or boilers that have been fouled with grease or scale, should be boiled out with a solution of boiler compound. New boilers must be washed out thoroughly. The steps required for one method of boiling out are as follows:

1. Dissolve 5 pounds of caustic soda and 1 1/2 pounds of sodium nitrate or 10 pounds of trisodium phosphate for each 1,000 gallons of water the boiler holds at steaming level. Put the mixture into the boiler as a

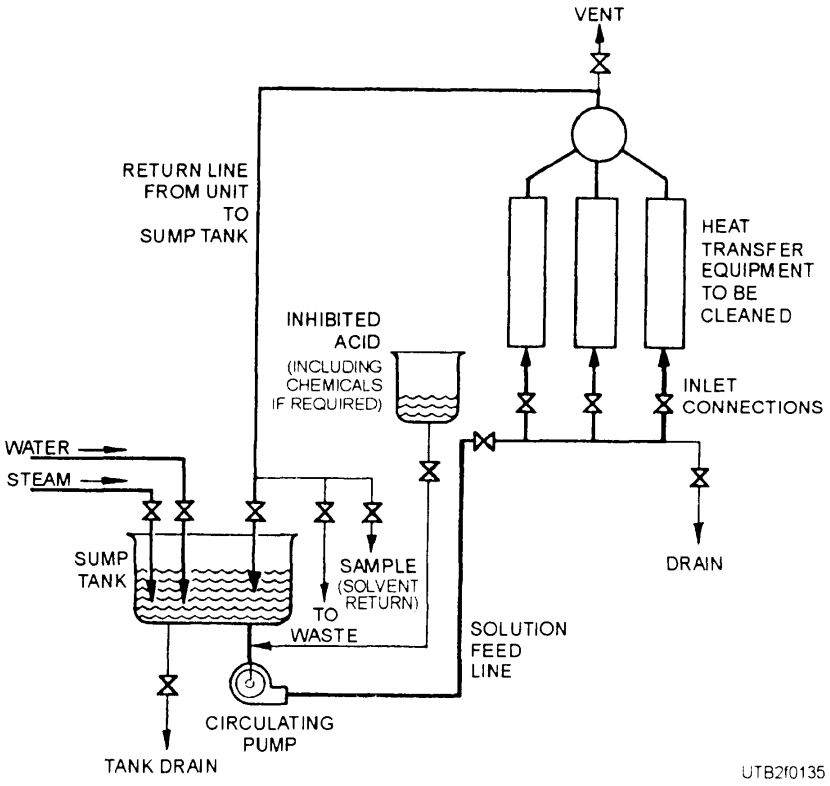


Figure 1-35.—Acid cleaning by circulation method.

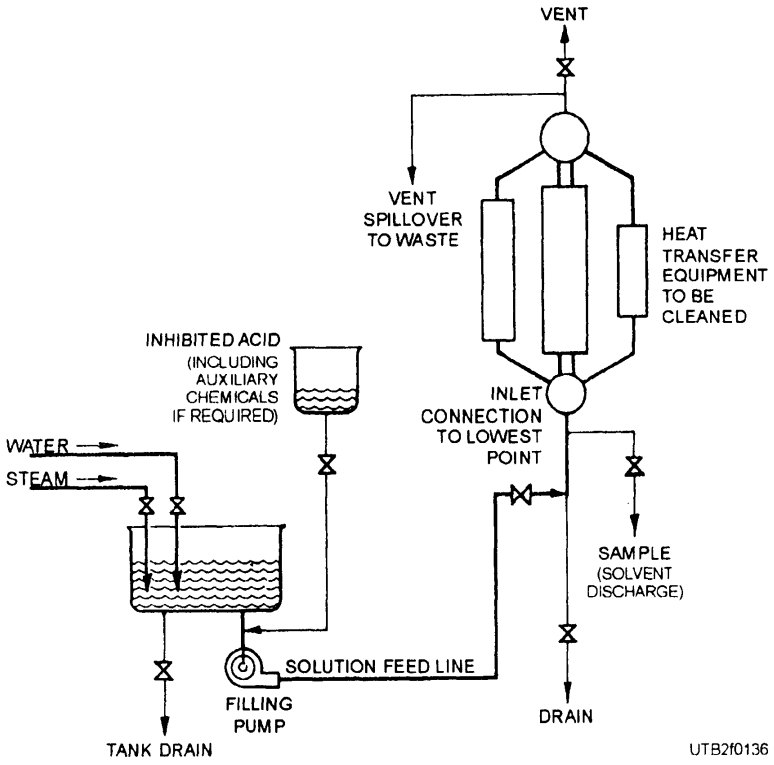


Figure 1-36.—Acid cleaning by fill-and-soak method.

solution. In multiple-drum boilers, divide the charge and put equal amounts in each of the lower drums.

2. Fill the boiler with hot feedwater to the level of the bottom of the steam drum. Turn the steam into the boiler through the usual boiling out connections, or bottom blow, and allow the boiler to fill gradually to the top of the gauge glass.

3. Steam pressure in the boiler should be kept between 5 and 10 pounds. The boiling out should continue for 48 hours. Immediately after boiling out, give a series of bottom blows to remove the bulk of the sludge. The boiler should be cooled, washed out immediately, and given the usual mechanical cleaning.

You may not always want to use the above method for boiling out. The steps for a second satisfactory method for boiling out are as follows:

1. Clean out all loose scale and any scale adhering to the boiler that can be removed manually.

2. Place about 15 pounds of caustic soda or soda ash and 10 pounds of metaphosphate for each 100-boiler horsepower (hp) of the boiler.

3. Seal the boiler openings but OPEN ALL VENTS. Fill the boiler about three-quarters full with water.

4. Start the burner and raise the temperature of the water in the boiler to about 200°F. Maintain this temperature for about 24 to 48 hours. Add makeup water as required during this period to fill the boiler to the base of the safety valve.

5. Analyze the boiler water during the boiling out period and add enough caustic soda and metaphosphate to maintain the following concentrations:

Causticity as ppm OH 300 to 500

Phosphate as ppm PO_3 100 to 150

6. Open the boiler at the end of the boiling-out period and clean out the sludge and loose scale. Pay particular attention to removing scale and sludge from water legs in fire-tube boilers.

7. Flush the boiler thoroughly.

8. If a lot of corrosion is exposed when the scale is removed, notify your superior so a boiler inspection can be made.

When the boiler is operated, any residual scale may cause faulty operation. The boiler should be taken out of service at frequent intervals to remove sludge formed from disintegrated scale. As soon as personnel can work in the boilers, wire brush the drums and ends of all tubes.

Then clean the interior of all tubes, using the approved style of boiler tube cleaning brushes.

You should operate all cleaners in the same way. After cleaning all the tubes, follow up by blowing them out thoroughly with a strong air jet. Then inspect to see if replacement of any of the tubes is necessary.

Q27. What are the four methods used to clean boiler firesides?

Q28. What pressure range should steam be for effective wet-steam lancing?

Q29. What conditions are considered waterside corrosion?

Q30. What acids are used for cleaning boiler watersides?

Q31. What are the two methods of acid cleaning?

CHAPTER 2

BOILER MAINTENANCE

Learning Objective: Recognize maintenance requirements and procedures for boilers and auxiliary equipment; recognize boiler operation steps and checks and safety requirements.

As a Utilitiesman, it is your responsibility to operate, maintain, and repair boilers. You can perform operator maintenance on shore-based boilers; perform preventive maintenance and minor repairs on boilers and associated equipment; complete chemical tests on boiler water and feedwater; replace defective boiler tubes; test, adjust, and recalibrate boiler gauges and other accessories.

This chapter provides information on some of the methods, procedures, and techniques used to operate, maintain, and repair boilers and associated equipment safely under typical conditions. Because of the broad scope of tasks involved in operating and servicing boilers, this chapter does not tell you all you need to know about the subject. Learning how to accomplish the procedures given in the following sections can help you acquire a basis on which to develop more advanced skills. While the procedures given in this chapter are typical, you should always follow the manufacturer's instructions for the equipment.

MAINTENANCE OF AUXILIARY EQUIPMENT

Learning Objective: Recognize and understand basic auxiliary equipment maintenance.

A well-planned maintenance program is the key to avoid unnecessary downtime or costly repairs, promotes safety, and aids local inspection. An inspection schedule listing the procedures should be established. It is recommended that a boiler room log or record be maintained for recording the daily, weekly, monthly, and yearly maintenance activities. This provides a valuable guide and aids in the operational efficiency, length of service, and safe operation of a boiler. It is also important to remember that improperly performed maintenance is just as damaging to a boiler as no maintenance at all.

MAINTENANCE REQUIREMENTS FOR CONTROL OF WATER LEVEL

The need to check water level controls and the water side of the pressure vessel periodically cannot be overemphasized. Most instances of major boiler damage are the result of operating with low water or using untreated (or incorrectly) treated water. Always be sure of the boiler water level and blow down the water column routinely. Check samples of boiler water and condensate according to procedures recommended by your water consultant (figs. 2-1 and 2-2).

Since the manufacturer generally sets low water cutoff devices, no attempt should be made to alter or adjust these controls. If a low water device should become erratic in operation or if the setting changes from previously established levels, check for reasons and correct it by repair or replacement.

Figure 2-3 is a replica of the low water cutoff plate attached to a steam boiler. These instructions should be followed on a definite schedule. These controls normally function for long periods of time and may lead to laxity in testing on the assumption that normal operation will continue indefinitely.

On a steam boiler, the head mechanism of the low water cutoff devices should be removed from the bowl at least once a month to check and clean the float ball, the internal moving parts, and the bowl or water column. Remove the pipe plugs from the tees or crosses and make certain the cross-connecting piping is clean and free of obstructions. Controls must be mounted in a plumb position for proper performance.

A scheduled blowdown of the water controls on a steam boiler should be maintained. It is impractical to blow down the low water cutoff devices on a hot-water boiler since the entire water content of the system would be involved. Many hot-water systems are fully closed and any loss of water would require makeup and

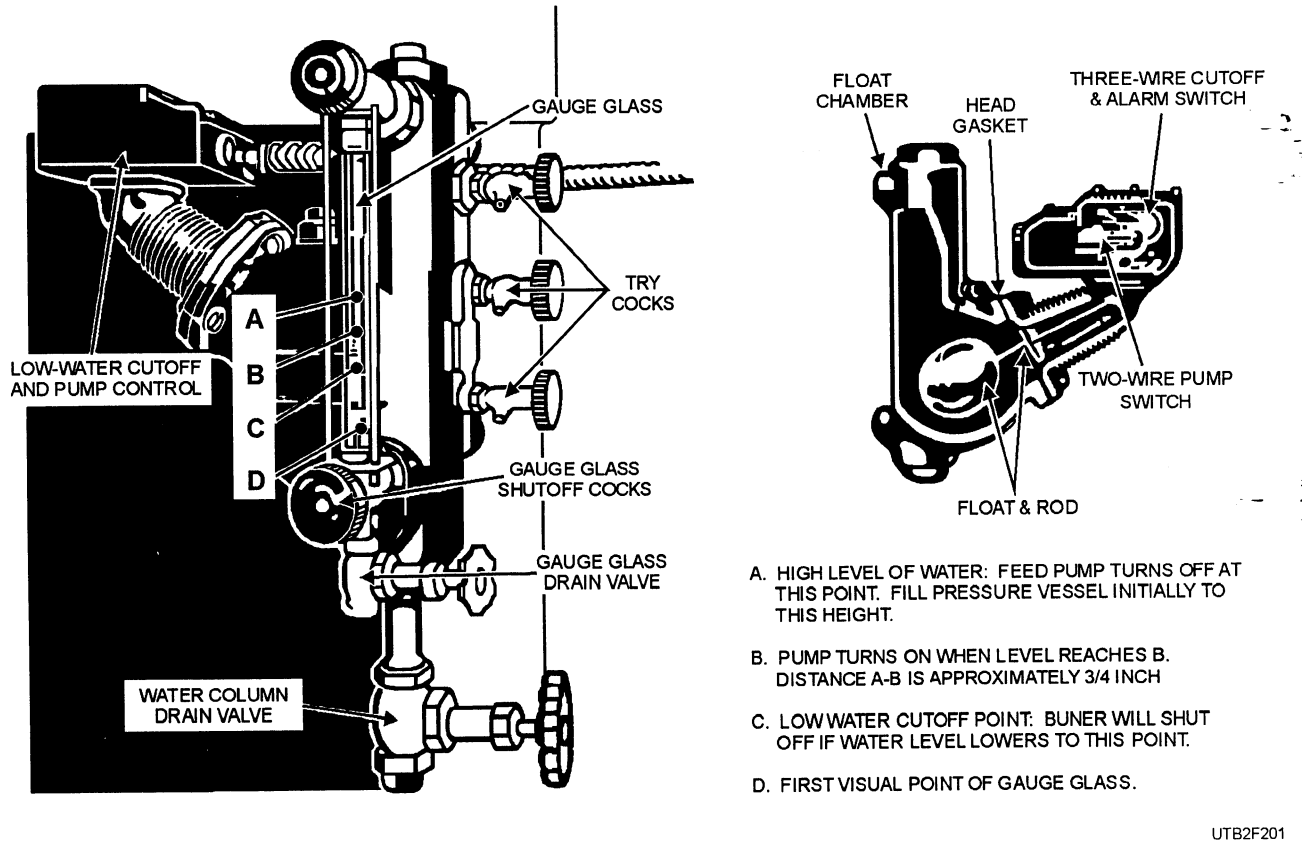


Figure 2-1.—Typical water column and low water cutoff high-pressure steam boiler.

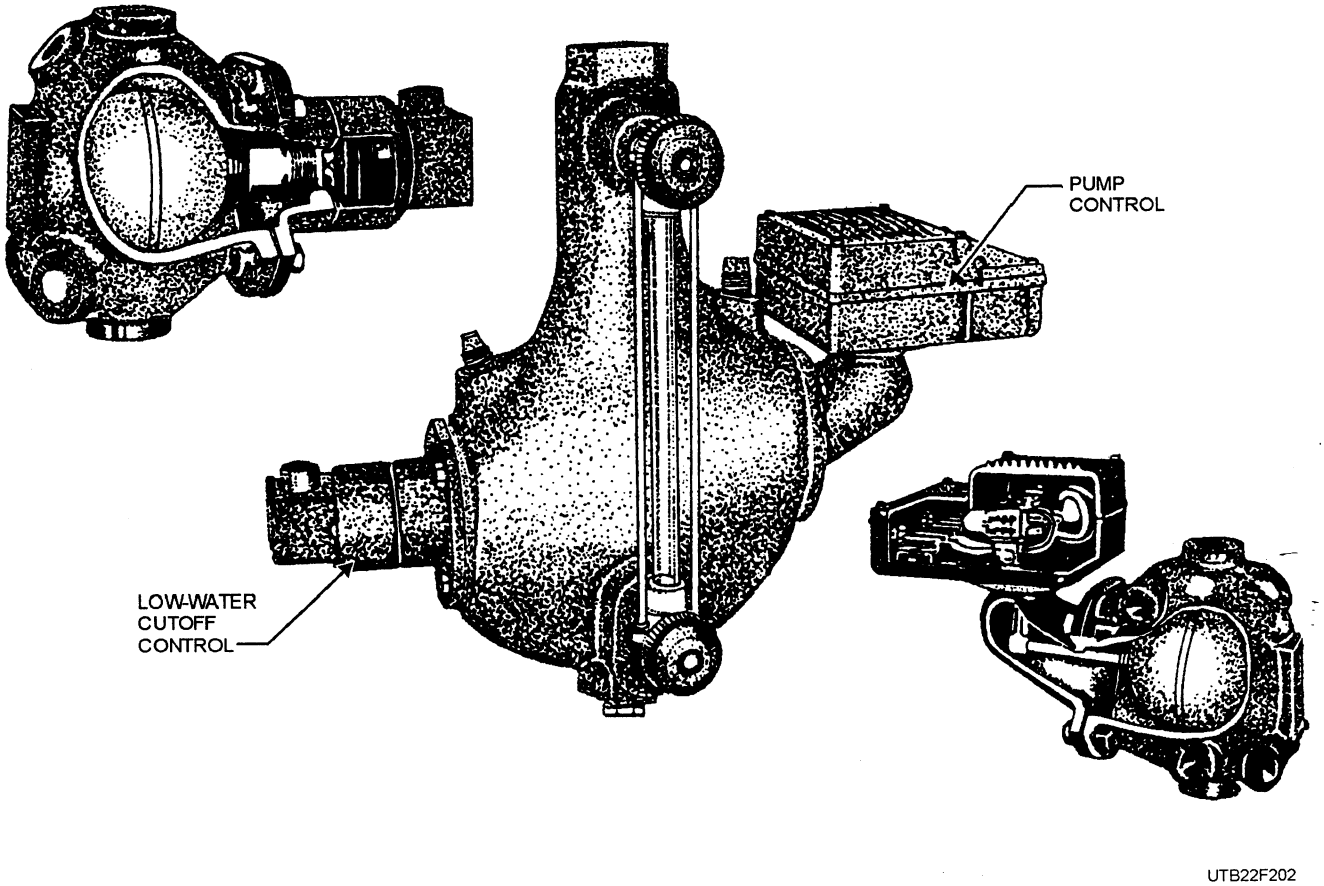


Figure 2-2.—Typical water column for low-pressure boiler.

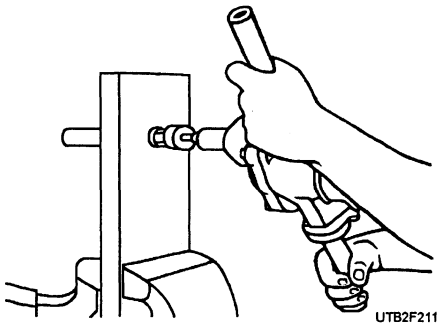


Figure 2-3.—Low water plate.

additional feedwater treatment that might not otherwise be necessary. Since the boiler and system arrangements usually make it impractical to perform daily and monthly maintenance of the low water cutoff devices, it is essential to remove the operating mechanism from the bowl annually, or more frequently if possible, to check and clean the float ball, the internal moving parts, and the bowl housing. Also, check the cross-connecting piping to make certain that it is clean and free of obstructions.

GAUGE GLASS REPLACEMENT

A broken or discolored gauge glass should be replaced at once. Always use new gaskets when replacing a gauge glass. Use the proper size rubber packing. Do not use "loose packing" that could be forced below the glass and possibly plug the valve opening.

Close the valves when replacing the glass. Slip a packing nut, a packing washer, and a packing ring onto each end of the glass. Insert one end of the glass into the upper gauge valve body far enough to allow the lower end to be dropped into the lower body. Slide the packing nuts onto each valve and tighten.

If the glass is replaced while the boiler is in service, open the blowdown valve and slowly bring the glass to operating temperature by cracking the gauge valves slightly. After the glass is warmed up, close the blowdown valve and open the gauge valves completely. Check the try cocks and gauge cocks for freedom of operation and clean them as required. It is imperative for the gauge cocks to be mounted in exact alignment. If they are not, the glass will be strained and may fail prematurely.

FEEDWATER REGULATOR MAINTENANCE

Proper control of the water level requires that the feedwater regulator be maintained. Here are a few pointers for regulators.

If the water level changes from its normal position, make sure you adjust the bypass to manual operation and check promptly for the source failure. If leaks develop around the packed stems, see that they are stopped immediately. If the boiler is off line, close the hand valve in the feed line. Bear in mind that the regulator is not designed for use as a stop valve. About once every 3 months, you will probably be called on to assist in blowing down the steam and water connections separately.

VALVE MAINTENANCE

Valves deserve special care and attention if they are to work as intended. There may be variations among activities in the type and frequency of valve inspection and servicing requirements. Therefore, follow instructions issued by your activity when they differ from those outlined here.

Types of valves that you may be responsible for helping service and maintain at regular intervals include (1) stop valves of the globe or gate type and (2) stop-and-check valves, which combine in one tray and angle or stop valve of the globe type and a check valve. At least once every 3 months, valves that have not been operated for some time should be operated to prevent sticking. Make sure that you also check for leaks, bent stems, a missing or broken handle, and lubricate the exposed threads and gearing of the valve stem.

Loosen and lift the packing follower about once every 3 months or more often if possible. Lubricate the packing with graphite bearing oil or graphite bearing grease. Replace the packing followers and tighten sufficiently to ensure against leaks.

BLOWOFF or BLOWDOWN VALVES should be opened at least once a day. There are four reasons for using these valves:

1. Controlling high water
2. Removing sludge and sediment
3. Controlling chemical concentrations in the water
4. Dumping a boiler for cleaning or inspection

The amount and frequency of blowing down depends on a chemical analysis of the water in the boiler and operating conditions.

On a quarterly basis, inspect the blowoff valves when the boiler is washed out and an internal inspection is made. Check the valves for leaks, and inspect the pipe and fittings between the blowoff

valves and the boilers. If repairs are needed, see that they are made promptly. In making a quarterly check on the blowoff valves, do not overlook the insulation, bearing in mind that it should be kept dry. Another item is the discharge piping leaking from the valves. Make sure the discharge piping is not mounted so rigidly that proper expansion and contraction are affected.

Keep SAFETY VALVES (fig. 2-4) in top working order. At regular intervals, depending upon operating conditions, the safety valves must be lifted manually. At least once each year the valves should be tested by raising steam pressure to popping pressure of the respective valve. If safety valves function improperly, promptly report the matter to your immediate supervisor. For detailed information on the maintenance of safety valves, refer to manufacturer's manual.

STEAM INJECTOR MAINTENANCE

With injectors, little maintenance is required. At times you will have to reseat the overflow and ring valve. Lime deposits also can reduce the operation by closing down the size of the combining and delivery tubes. A good way to remove lime deposits is to place the injector in a tube of muriatic acid for several hours.

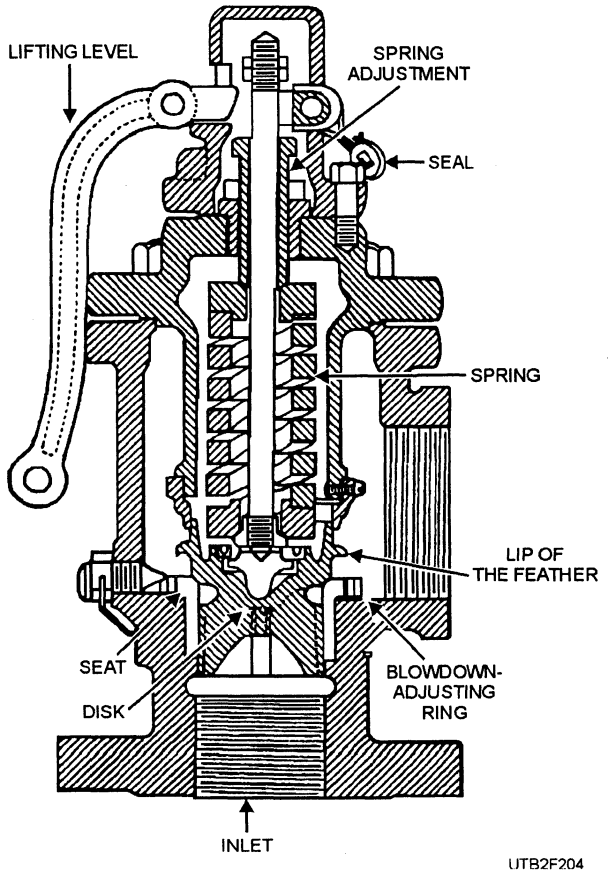


Figure 2-4.—A typical spring-loaded safety valve.

To clean the injector, remove the bottom plug (fig. 2-5). The delivery tube and ring valve drop out. Examine and clean all passages and holes. After cleaning, replace them in the plug (which acts as a guide) and screw tightly in place.

STEAM TRAP MAINTENANCE

Once each month, see that steam traps are tested for correct operation. Methods used in testing steam traps (such as the test valve method, the glove test method, etc.) are discussed in another section of this training manual.

Once a year, or more often if required, dismantle and clean all traps. Inspect for the following:

1. The accumulation of foreign matter
2. Plugging of orifices, valves, and vents
3. Cracked, corroded, broken, loose, worn, or defective parts
4. The excessive wear, grooving, and wire drawing of valves and seats
5. Defective bellows, buckets, or floats
6. Leaky vessels and pipes
7. Defective bypass valves

Repair or replace defective parts as required following yearly inspection. Replace or repair all

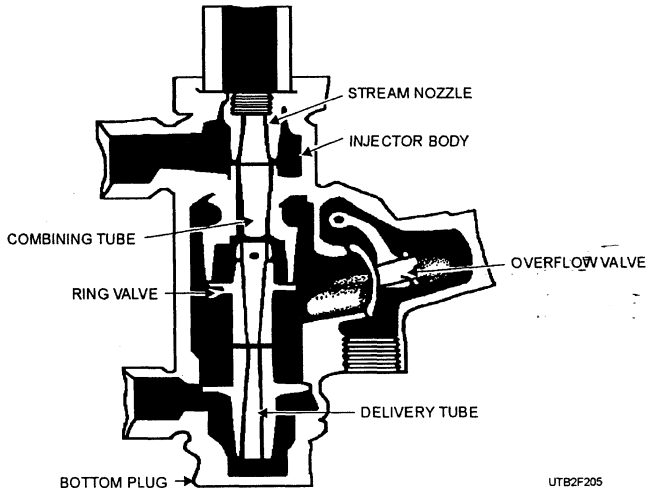


Figure 2-5.—A cross-sectional view of an injector.

defective gaskets, bellows, valves, valve seats, floats, buckets, linkages, and orifices. Use only matched sets of replacement valves and seats. Make certain all replacement parts are of the correct size. Do not change the weight of floats or buckets when repairing traps, or operation may be affected. Often, it is more economical to purchase and install new parts than to recondition defective elements. Repair or replace leaking bypass valves. Repack valve stems.

FAN MAINTENANCE

The forced-draft fan should be checked daily to prevent an accumulation of dust in or around the fan. KEEP THE FAN CLEAN! Also, check daily on the sound of the fan. If it is not normal, report the matter promptly to your supervisor.

A daily check should also be made to ensure adequate lubrication of the fan. The temperature is another item that should not be overlooked. This you can test by feel. In case of excessive temperature, notify your supervisor immediately.

Because induced-draft fans are exposed to hot, dirty gases, they must be observed closely to prevent operating difficulty. Taking proper care of the fan requires DAILY attention to ensure that the following conditions are met:

1. Bearings are kept cool and well lubricated.
2. Fan is kept clean. Also, see that any change from the normal in sound is reported promptly to your supervisor.

HANDHOLE AND MANHOLE GASKET MAINTENANCE

At each regular boiler overhaul, all handhole and manhole fittings and gasket seating surfaces on the drums and headers must be cleaned, inspected, repaired, or renewed if necessary. If the plates are warped, distorted, or otherwise damaged, they must be repaired or renewed.

Whenever handholes and manholes are opened, new gaskets must be fitted. After a gasket has once been compressed, it must be discarded, as it will not provide a seal. Be sure to use the correct size and type of gasket. Never use any makeup compound on the seating surfaces when installing the gaskets. Graphite may be used on the threads of the stud to prevent seizure of the nut.

Before installing a new gasket, thoroughly clean the two gasket seating surfaces (one on the drum or header and one on the plate). Be sure you remove all the corrosion or other surface deposits and all adhering pieces of the old gasket. It is impossible to obtain a tight joint as long as any foreign matter remains on either seating surface or in the corners of the fitting. Be sure to water-soak the new gasket for 24 hours before installation.

Power-driven wire brushes are best for cleaning the seating surfaces. Scrapers should be used only when wire brushes are not enough to clean the surface. Scrapers must be used with great care, if they are used at all, since they tend to remove too much metal from the seating surfaces.

If the gasket seating surfaces show a lot of pitting, you may have to get these surfaces machined or reground. If the seating surface on a handhole or manhole plate is badly pitted or damaged, discard the plate and replace it with a new one or one that has been machined to blueprint specifications.

The clearance between the shoulder of a manhole plate and the manhole must not exceed one-sixteenth of an inch when the plate is centered accurately. Figure 2-6 shows where the clearance is measured. If the clearance is greater than one-sixteenth of an inch, the plate should be built up by electric welding at the inner edge of the shoulder. Steelworkers should do the welding, so the manhole plate may be stress-relieved after it is welded and the welded surface may be remachined.

To position a manhole gasket properly, fit it on the long axis until the inner edge of the gasket fits the shoulder snugly at the ends of the long axis of the manhole plate. The clearance between the gasket and the shoulder should be equalized at the top and bottom of the short axis. Do NOT allow the outer edge of the gasket to protrude at any point beyond the gasket-seating surface in the drumhead. If an edge protrudes, the gasket may unravel when it is compressed by the tightening of the manhole cover. Discard any gasket that protrudes beyond the edge of the gasket-seating surface.

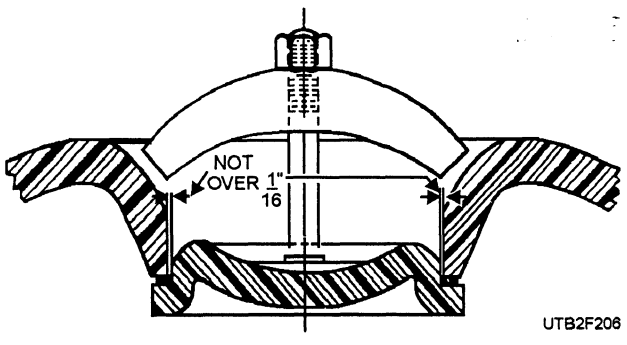


Figure 2-6.—Manhole plate clearance.

To install a manhole or handhole plate, first center the fitting in the opening. Make sure the shoulder does not bind on the edges of the opening. Then slip the yoke on and start the stud nut. Run the nut on the stud until it is hand tight; then give the nut one-quarter of a turn with a wrench. Do NOT tighten the nut enough to compress the gasket.

When the boiler is given a hydrostatic test, the pressure of the water usually forces the manhole and handhole gaskets into place and thus ensures proper seating. The plates are first set up lightly. When the boiler is ready for testing, the pressure should be pumped up to within 50 psi of the hydrostatic test pressure, regardless of any leakage from the manhole or handhole plates. Leakage is likely to be general at first, but it decreases as the pressure is increased. When the pressure is within 50 psi of the test pressure, most of the leakage stops although the nuts are still loose.

If some plates are leaking badly, the trouble is probably caused by improper seating of the gaskets. As a rule, the gasket is caught on the outer edge between the edge of the plate and the edge of the counterbore for the seat. A light blow with a hammer on the outside of the plate usually relieves the tension on the gasket and allows it to seat properly.

After leaky gaskets have been adjusted and while full test pressure is on the boiler, tighten up all plates firmly. Use only the wrenches specified for this purpose.

Some economizer headers and a few superheater headers are fitted with handhole plugs instead of handhole plates. Also, some economizers have bayonet types of cleanout plugs on the front ends of the tube loops to allow access to the tubes at the return bend end. Detailed instructions for installing and removing the plug type of manhole fittings and the return bend cleanout fittings are given in appropriate manufacturer's technical manuals.

HYDROSTATIC TESTS

The boiler should be given a hydrostatic test annually or whenever the operator doubts the boiler strength. The purpose of the test is to prove the TIGHTNESS of all the parts of the boiler or the STRENGTH of the boiler and its parts.

In preparing the boiler for a test, rinse it out with fresh water. Then check carefully to see that no loose scale or tools are left in any part of the boiler.

The procedures for making boiler hydrostatic tests are as follows:

1. Close all openings and "gag" (clamp down) all safety valves. Gags should be only hand tight and straight. Do NOT use a wrench; it will bend the valve stem and possibly damage the seat. Remember that valves are easily damaged if lifted by water pressure. Close all connections on the boiler except air cocks, test pressure gauge, and valves of the line through which pressure is to be applied.
2. Reduce the water level in the boiler by opening an air cock, and blow down the boiler until the water level is below the feedwater inlet connection. Clear the blowdown area before blowdown.
3. Connect a hydrostatic pump between the boiler and water service connection. Install all pipe and fittings between the pump and the boiler. Remember, the pipe and fittings must be able to withstand test pressures. Install a hose between the pump and the chosen water service. Ensure the chosen water service supplies ample water pressure to conduct the test.
4. Remove the plug from the feedwater inlet cross by turning it in a counterclockwise direction.
5. Open the boiler casing access doors or plates, so tube ends can be inspected during the test.
6. Install a wedge between the control switch and the pressure-actuating platform. Also, install a stop valve before the control switch to protect the control, so hydrostatic pressure will not actuate or damage the control. The range of the pressure control is usually less than the hydrostatic pressure being applied. Do NOT bend or damage the actuating parts.
7. Fill the boiler with water until water discharges out of the air cock; then close the air cock. Ensure all the air is expelled from the boiler before closing the air cock. Turn on the water service valve. The water temperature should be the same as the surrounding atmosphere. The minimum water temperature must be 70°F.
8. Check the boiler steam pressure gauge in-line cock to ensure that it is open. Ensure the butterfly handle is in-line (parallel) with the tubing.

9. Apply water pressure of 1 1/2 times the maximum allowable working pressure. To avoid rapid shock and strain, bring this pressure up in 10 equal increments, inspecting for leaks and deformities at each increase.

10. Inspect tube ends, boiler seams, pressure fittings, and connections. Make the corrections and repairs wherever possible. In case of unusual conditions, DISCONTINUE the test IMMEDIATELY and NOTIFY YOUR SENIOR PETTY OFFICER. Do NOT exceed the test pressure. NEVER apply more than 10 pounds of pressure above the maximum working pressure on a low-pressure boiler. Consult the ASME code for testing procedures for other than welded steel boilers.

11. Secure pressurizing connections at the required test pressure. Continually inspect the boiler tubes, seams, fittings, and connections. If the boiler and fittings are tight, the pressure should NOT drop more than 1.5 percent in 4 hours. If loss of pressure is over 1.5 percent, find the leak(s) and make the repairs.

Following all hydrostatic testing, steam pressure is raised to lift safety valves and to determine the fitness of the boiler for use.

Q1. Most cases of major boiler damage is caused by what operating condition?

Q2. What could happen if "loose packing" is used on a gauge glass?

Q3. What are the four reasons for using blowoff or blowdown valves?

Q4. What is the purpose of a hydrostatic test on a boiler?

BOILER TUBES

Learning Objective: Recognize and understand methods for renewing, repairing, and cleaning boiler tubes and sheets.

For any boiler retubing job, it is absolutely essential to use tubes that conform in every way to the tube requirements of the particular boiler. Boiler tubes are NOT identical. They differ in such important characteristics as composition of the metal, outside diameter, wall thickness, length, and curvature.

Much of the required information on sizes, thickness, and number of tubes per boiler is given in the manufacturer's technical manual. Some of the information is under the heading of "Tube Data." More detailed information is usually given on the drawings included in the manual.

COMPOSITION OF BOILER TUBES

Generating tubes are usually made of low carbon steel. They may be either seamless or resistance-welded. Seamless tubes were once definitely preferred for naval use. However, improved methods of manufacturing the welded tubes have led to an increased use of welded tubes in naval boilers. Repair ships, tenders, and other naval activities that use, handle, or issue plain carbon steel tubes have been instructed to make no distinction between the seamless and the welded tubes, but to stock, issue, and install them interchangeably without regard to the method of manufacture.

Superheater tubes usually are not made of plain low carbon steel. On boilers where the superheated steam temperature reaches 850°F or higher, the superheater tubes may be made of carbon-molybdenum steel, chromium-molybdenum steel, or an 18-8 chromium-nickel (stainless) steel.

To find detailed information on the composition of the metals used for generating tubes and superheater tubes in any particular boiler, check the manufacturer's technical manual. The information may be given on the drawings, or it may be included in the text.

Once you have found information on the composition of the metals used for boiler tubes, your next problem is to understand it. Do you know what it means when you see "mild steel" on a blueprint? Can you identify metals by their chemical symbols? Do you know what an "alloy steel" is, or anything about the different kinds of alloy steels? Do you know anything about the various systems of classifying steels? Do you know why different steels are used for different kinds of tubes? Answers to these questions are necessary before you can make much sense out of the information you are likely to find on blueprints on the composition of boiler tubes.

Although we all have a general idea of what we mean by the word *metal* it is not easy to give a simple, accurate definition. Chemical elements are metals if they are lustrous, hard, good conductors of heat and electrcity, malleable, ductile, and heavy. In general, these properties of hardness, conductivity,

malleability, and so forth, are known as metallic properties, and chemical elements that possess these properties are generally called metals. Chemical elements that do not possess these properties are called nonmetals. Oxygen, hydrogen, chloring, and iodine are a few examples of nonmetallic chemical elements. A few chemical elements behave sometimes like metals and sometimes like nonmetals. These elements are often called metalloids. Carbon, phosphorus, sulfur, and silicon are examples of metalloids.

Most types of steel look quite a lot alike, so you cannot go by appearances. On Navy blueprints and on drawings furnished in the manufacturer's technical manuals, materials are usually specified by federal or military specification numbers. In addition, the blueprints and drawings may refer to a commercial classification system, such as the Society of Automotive Engineers (SAE) system or the American Iron and Steel Institute (AISI) system.

Federal or military specifications usually require the tubes to be identified by some marking system. For example, one specification for boiler tubes requires that boiler tubes 1 1/4 inches or greater and 3 feet in length be legibly marked by paint stenciling, while smaller or shorter tubes may be bundled and tagged. Another boiler tube specification requires the tubes to be marked by ink stenciling approximately 3 inches from each end and again in the middle of the tube. As a general rule, boiler tube identification markings must include (1) the name or trademark of the manufacturer, (2) the heat number, (3) the class letter, (4) the specification number, and (5) the outside diameter, the wall thickness, and the length.

RENEWING TUBES

Boiler tubes should be replaced when they cannot be made tight, or when they are warped, or otherwise seriously damaged. As a general rule, boiler tubes should not be straightened in place; leaks may develop that could cause permanent damage to other parts of the boiler. Occasionally, however, you may find a screen tube or a wall tube that has bowed out of position for no apparent reason; you can straighten the tube in place and re-roll it if a replacement tube is not available. Tubes that have bowed out of position because of low water SHOULD NOT BE STRAIGHTENED.

To renew tubes in the A row, the corresponding tubes in the B row must also be renewed, regardless of their condition. Similarly, whenever superheated tubes are renewed, remove the superheater support tubes when they are not accessible without removal of the superheater tubes.

General renewal of tubes in a boiler should not be undertaken without approval of the battalion or base commander. The commander's decision as to whether to approve a general renewal of the tubes will be based on the results of inspection and examination of tube samples.

Before beginning to renew tubes, be sure all preparations have been made. Be sure the right types of replacement tubes are available and that all tools and equipment required for the job are on hand and in good working order. Check the cutters, the air hoses, and the fittings for the pneumatic tools, the tube benders, the electric equipment, and the staging.

The steam drum must be opened and some fittings removed to allow access to the ends of the tubes. Also, the water drums and headers must be opened. Any fittings removed from the drums should be carefully set aside and marked, if necessary, to ensure correct replacement.

Before allowing a person to enter the boiler, be sure all safety precautions are observed. Make it your personal responsibility to see that all cross-connecting valves between the boiler being retubed and any steaming boiler are closed and locked or wired shut and are tagged DANGER. DO NOT OPEN. Be sure, also, that the control valves of the steam-smothering system are locked in the CLOSED position. See that enough ventilation is provided; keep portable blowers running at all times while people are working in the boiler. Do not allow unauthorized types of lights in the boiler. Flashlights are preferred for boiler work. If portable lights are used, the electric leads must be thoroughly insulated and the portable fixture itself must be the grounded, watertight type. Before use, portable lights should be checked by an electrician to ensure they are safe.

REMOVING TUBES

Using an air-powered side-cutting chisel (fig. 2-7) ground, cut the old tube flush with the drum or header. Carefully work the cutter so as not to damage the surface of the drum or header. When you are removing superheater tubes, it will be impossible to cut the tube flush with the header with a side-cutting chisel. An expandable fly cutter must then be used to cut out the tubes.

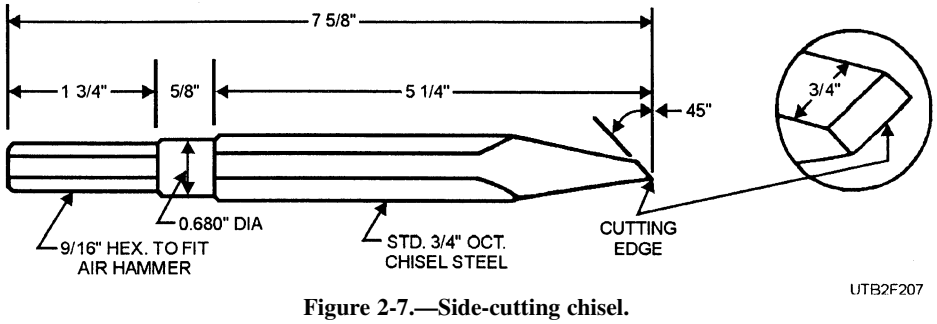


Figure 2-7.—Side-cutting chisel.

After removing the main part of the tube from the boiler, use a safety ripping chisel of the type shown in figure 2-8 to make a cut on the inside of the remaining portion of the tube. The safety ripping chisel is designed so it cannot cut entirely through the tube; therefore, it cannot score the tube sheet.

After cutting the tube approximately three fourths of the way along the tube sheet, crimp the edges of the tube and drive out the stub with a blunt chisel. If the tube is a large one, you may have to make two cuts with the safety ripping chisel instead of one; the cuts should be about an inch apart.

If a safety ripping chisel is not available, you can remove the tube by the following method:

1. Split the ends of the tube with a flat chisel, from the end of the tube to the drum or header, at two places about three fourths of an inch apart.
2. Force the 3/4-inch piece upward with a bar until it has been raised off its seat and has curled into the tube.
3. Split the tube to a point beyond the other side of the tube seat with a tool ground to conform to the tube hole. Be careful not to damage the tube hole.
4. Break in the ends of the tube with a crimping tool, and then drive out the stub.

Arc welding equipment can be used as an aid to the tube removal on some boilers. This procedure requires running two beads, three fourths of an inch apart, through the entire tube sheet, quenching with water, and then using a backing-out tool. Do NOT use this method of tube removal if the drums or headers are made of 4-6 chromium steel.

CLEANING TUBES

Replacement tubes must be thoroughly cleaned to remove all scale, dirt, and preservatives. One way of cleaning a tube is to push a kerosene-soaked rag through it and wipe the outside of the tube with a similar rag. Diesel oil may also be used. If a large enough tank is available, boiler tubes may be cleaned by immersing them in an approved cleaning solution, such as a saturated solution of boiler compound in hot water, to which a small amount of kerosene has been added. Boiler tubes may also be cleaned with steam jets.

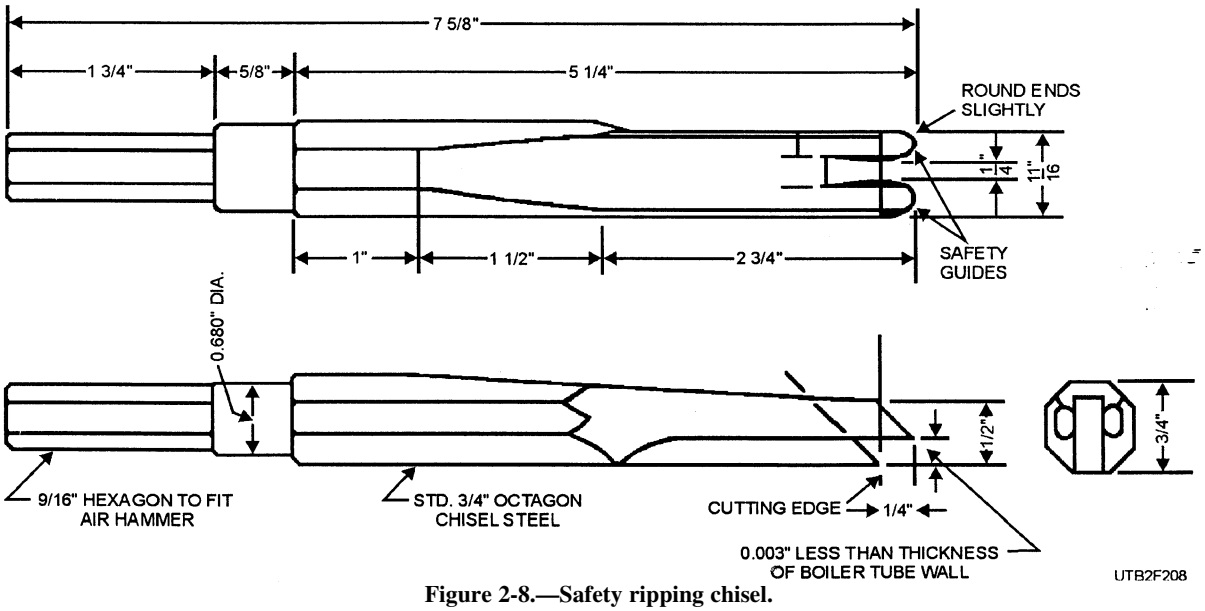


Figure 2-8.—Safety ripping chisel.

PREPARING TUBE SHEETS

The tube sheet holes must be prepared before replacement tubes are inserted. The best way is to use a piece of hardwood turned to a diameter slightly less than the diameter of the hole and covered with a medium fine-grit emery cloth. Pass the wooden piece in a circular motion, back and forth through the tube sheet or header holes to smooth the surface. Finish the job by using a fine emery cloth wrapped around your finger. Keep working until the hole is clean and smooth.

When preparing tube seats, check the size and trueness of the tube holes; use a tube nipple of corresponding size as a template. It is impossible to make tube seats tight if the tube holes are much enlarged or if they are too elliptical (out-of-round). To ensure the tightness of the tube seats, be sure that the maximum enlargement and the maximum ellipticity of the tube holes do not exceed the figure shown in table A, appendix II.

REPAIRING TUBE SHEETS

Out-of-round tube holes, small steam cuts, and other minor defects may, in some cases, be corrected by welding. NAVFAC approval is not required for this type of welding repair on drums and headers made of low carbon steel, carbon-molybdenum steel, or steel containing less than 1 percent chromium if a qualified welder uses approved welding procedures for the welding, filler metal, and position of welding under MIL-STD-248. Always check the blueprints for the material of the drums and headers before welding.

PREPARING TUBE ENDS

After the tubes have been thoroughly cleaned, prepare the tube ends inside and outside. Clean the ends with a wire brush and polish them with abrasive paper and a liquid cleaner until the tube ends are completely clean, free of burrs and mill scale, and thoroughly polished. Clean and polish the tube ends for a distance equal to the thickness of the tube seat plus 2 or 3 inches.

Round off the tube ends with a file, so no square or sharp edges remain. If the tubes are not rounded off at the ends, the tubes may split when they are belled.

FITTING TUBES

When installing tubes, always fit the tubes into the steam drum before inserting the other end in the water drum or header. Inserting the tubes into drums and headers is not particularly difficult, since all tube holes are drilled normal to the tube sheet.

If you are renewing a complete row of tubes, fit a tube at each end of the row and then work toward& middle. You may find slight differences in the lengths of tubes required, if the boiler has been in service for some years. These differences are more likely to show up at the ends of the rows than in the middle.

When fitting tubes into drums or headers, be sure each tube extends far enough into the header or drum. Tubes up to (but not including) 2 inches in outside diameter (OD) should project 3/16 to 5/16 inch into the drum or header. Tubes 2 inches OD and larger should project 5/16 to 7/16 inch into the drum or header.

After you have fitted a tube and allowed for the amount it must project into the steam drum and into the water drum or header, remove the tube and cut off the excess. You may be able to use one tube as a guide for cutting off the excess on several other tubes; if you recall, the tubes may vary slightly in length, particularly in older boilers. Do NOT use one tube to measure the rest of the tubes in a row if you believe there are big differences in tube lengths in the row. If your sample tube happened to be a little on the short side, you would end up with a whole row of tubes that were too short; therefore, they could not be used.

Each tube must be carefully aligned with the other tubes. Use a plywood batten about 1/2 inch thick, 3 feet long, and 3 inches wide to align tubes in the generating bank. After positioning the tubes, check them with the batten. Then place small, wooden wedges to hold the tubes in place until they have been expanded into the tube sheets. Be sure to remove the batten and the wedges before starting work on the next row. These wooden pieces cannot be left in the boiler. You will have a real job on your hands if, after installing five or six more rows of tubes, you suddenly discover that you have overlooked the batten or one of the wedges.

EXPANDING TUBES

The basic joint in boiler construction is an expanded joint that must not leak nor lack holding power. Leakage, if permitted to go uncorrected, leads to deficiency of holding power because of deterioration of the tube seat. Slight leakage itself should not be taken as cause for alarm, but rather as evidence to correct the fault as soon as possible. Deficiency of holding power causes the tube to pull out of its seat. In most cases, the tubes are installed within the furnace of the boiler, and any danger to personnel, if the tubes pull out of the seat, is reduced since the

steam will be discharged up the stack. For this reason, tubes 1-inch-outside diameter (OD) up to and including 2 inches OD are expanded by "boilerman's feet" as only a small amount of expansion is required to hold the tubes firmly in place. With tubes 3 inches OD and larger and all external downcomers, special precautions must be taken to ensure the tubes are properly expanded in the tube seat. Through a series of tests, the point of maximum holding power for various sizes of tubes has been found and is expressed in terms of standard diameters that should be measured after the tube has been expanded in place. In new construction or replacement of tubes where the tube and hole measurements can be obtained, the correct amount of expansion can be found by using the following formulas:

For tubes in drums: Diameter of tube hole minus OD of tube, plus 0.012 inch per inch OD of tube.

For tubes in headers for boiler design pressure under 500 psi: Diameter of tube hole minus OD of tube, plus 0.015 inch per inch OD of tube.

For tubes in headers for boiler design pressure over 500 psi: Diameter of tube hole minus OD of tube, plus 0.020 inch per inch OD of tube.

The figure arrived at by using the above formulas should be added to the OD of the tube as measured to give the required OD of the tube after rolling.

If it is impossible to reach the outside of the tubes in drums to gauge them, the inside diameter (ID) of the tube must be mea sured. Since the plastic deformation of the tube wall varies with tube wall thickness, the ID of the tube for different wall thickness will vary. Where the outside of the tube is inaccessible, the following formula is used in the expansion of a tube:

The ID of the tube, plus the tube hole diameter minus the OD of the tube plus the expansion increase factor.

Boiler tubes should be expanded with the expanding equipment furnished to the shop. Select expanders of the proper size for the tube size and the seat thickness and expanders proper for the operation to be perform ed.

There are two types of expanders: roller-type and ball-drift type. Roller-type expanders are furnished for use by the shop labor force. Roller-type expanders are shown in figure 2-9. A series of adapters are furnished for use if tube holes are not readily accessible. Some of these adapters are shown in figure 2-10.

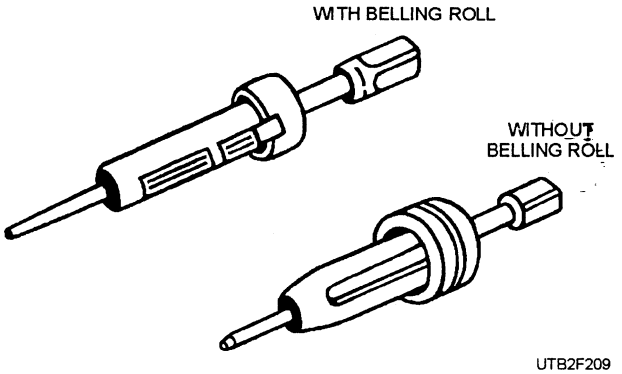


Figure 2-9.—Roller-type tube expanders.

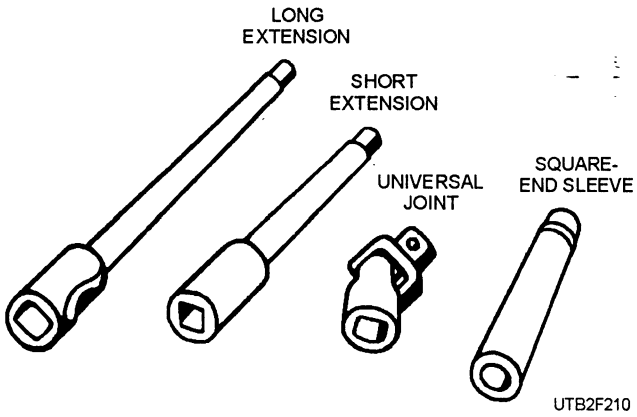


Figure 2-10.—Adapters for tube expanders.

Tube expanders are operated by air motors. The air, at about 100 psi, enters through a controlling handle and goes into the motor housing where it drives an air turbine. The turbine is attached to the shaft of the motor. The controlling handle can be turned clockwise or counterclockwise. A chuck with a tapered shank engages the shaft of the air motor, thus transmitting the power of the motor to the rollers used for expanding tubes into the tube sheet.

Both the air motors and the chucks are available in various sizes. The large sizes of motors and chucks are used for expanding the larger sizes of tubes. Figure 2-11 shows a tube expander in use.

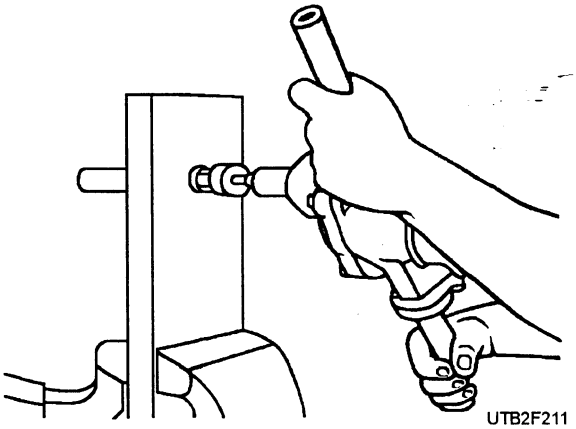


Figure 2-11.—Expanding a tube.

Tube expanders must be used carefully to avoid damage to the expanders and to prevent injury to personnel. The centrifugal force developed by the air turbine is great, so the air motor must be gripped firmly with both hands. If the roller-mandrel combination should bind, the force of the air motor could break the mandrel and quite possibly cause injury to the operator. Always have a person stationed nearby to give immediate assistance if necessary. If you run into any trouble, your safety person may be able to crimp the hose quickly and thus keep the mandrel from breaking.

BELLING TUBES

Most tubes are expanded and belled. However, check the drawing to determine if any specific instructions are shown. Some tubes in 1,200 psi boilers are lightly expanded or belled before welding; some are directly butt-welded to the studs. A roller-type or a drift-type belling tool is used. The drift-type tool is shown in figure 2-12.

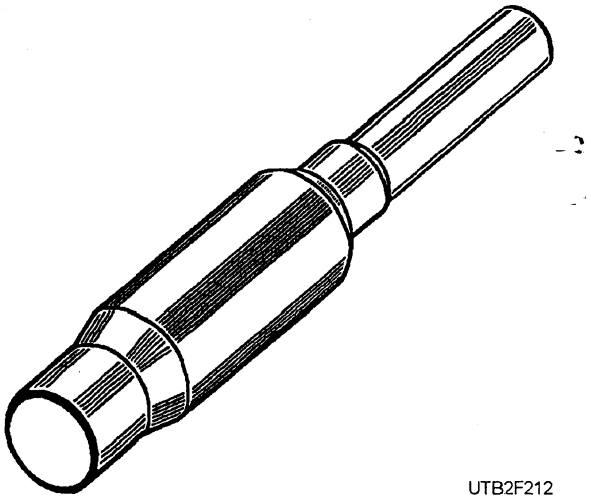


Figure 2-12.—Belling tool.

When belling a tube, be careful not to overdo the operation. Tubes up to, but not including 2 inches OD should be belled at least 1-15 inch but no more than 1/8 inch. Tubes 2 inches OD and larger should be belled at least 1/8 inch, but no more than 3/16 inch. The increase is to be measured over the outside tube diameter at the end of the tube. Figure 2-13 shows the process of belling a tube.

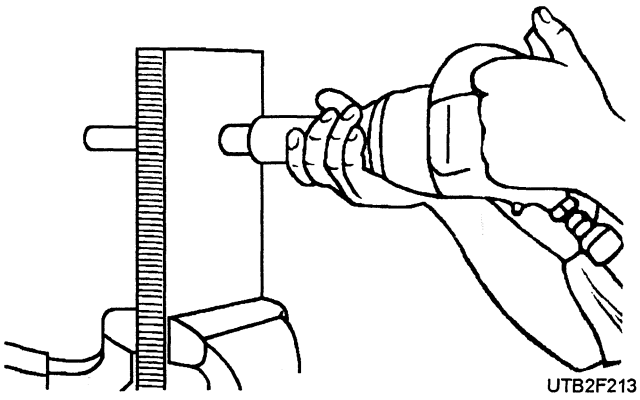


Figure 2-13.—Belling a tube.

Some expanders are fitted with belling rolls, as shown in figure 2-9. When these expanders are used, the tubes are expanded and belled at the same time; thus, there is no need for a separate belling job.

RENEWING WELDED TUBES

In some boilers of recent design, the superheater tubes and the economizer tubes are welded after they have been expanded. The renewal of these tubes is more complicated than the renewal of ordinary tubes. Procedures for renewing welding tubes are given in the appropriate manufacturer's technical manual.

PLUGGING BOILER TUBES

As an emergency measure, it is sometimes necessary to plug defective boiler tubes until they can be replaced.

CAUTION

Any tube that is plugged must have a hole drilled in it to prevent pressure buildup in the tube when the boiler is steamed.

Various sizes of tube plugs are carried in the supply system. The plugs are tapered to the required shape and are usually drilled and threaded at the larger end, so they may be removed with a tube plug extractor.

Tubes must be plugged at each end. Before driving a tube plug into position, be sure the plug and the inside of the tube are absolutely clean, so the plug makes good metal-to-metal contact with the tube. Drive the plug far enough in to ensure it will hold, but do not drive it so far in that it damages the tube sheet.

In plugging superheater tubes, use an offset driver to drive in the plugs when the tube holes do not fall in line with the handhole opening. When a superheater tube is plugged, it will eventually burn away after a period of service. When tubes have burned away (or when they have been removed) so much that they leave a gas lane more than three tube rows wide through the entire superheater tube bank, plug the gas lane with a

plastic or castable refractory. If the lane cannot be plugged, the firing rate of the boiler must be restricted to avoid overheating the superheater tubes next to the gas lane.

When a sidewall tube needs to be plugged, cut the tube 3 to 4 inches above the sidewall heater and 3 to 4 inches below the steam drum. The space left exposed after removal of the tube should be packed with plastic refractory to protect the pressure parts previously cooled by the plugged tube. Do not plug more than two tubes next to each other, since an exposed area wider than this cannot be effectively protected for an extended operation. Sidewall tubes that have been plugged should be replaced at the earliest opportunity.

When a rear wall tube needs to be plugged, cut the tube 3 to 4 inches from the headers or at other cutoff points specified in the manufacturer's technical manual. Use a plastic refractory to plug casing openings, to cover exposed areas not protected by firebrick or high-temperature castable refractory, and to cover the exposed pressure parts previously cooled by the plugged tube. Rear wall tubes that have been plugged should be replaced at the earliest opportunity.

Superheater screen 1 1/2 and 2 inches in outside diameter should, in general, be replaced, rather than plugged, when tube failure occurs.

In plugging generating tubes 1 inch and 1 1/4 inches in outside diameter behind the superheater tube bank (in single-furnace boilers) and behind the 2-inch tubes (in double-furnace boilers), consider gas laning and drum protection. Any complete lane through the tube bank more than three tube rows wide should be retubed, especially if such a lane is bounded by the boiler casing. Any drum area greater than 4 inches square should have refractory protection over the drum or, if this is not practicable, have blind nipples replace the failed tubes instead of just plugging the failed tubes. The blind nipples give greater protection to the drum than plugged tubes.

If an economizer element develops a leak, the ends of the element should be plugged at the inlet header and at the outlet header. To install a tapered plug in an economizer element, screw the plug extractor into the plug and insert the plug into the tube. Unscrew and remove the extractor from the plug. Drive the plug securely into position by holding one end of a piece of pipe against the plug and striking the pipe on the other end.

Figure 2-14 shows how to remove a plug from an economizer element. Screw the plug extractor into the plug. Place the handhole plate binder in position over the extractor, and then thread on the handhole fitting nut. As you tighten the handhole fitting nut, the plug pulls out.

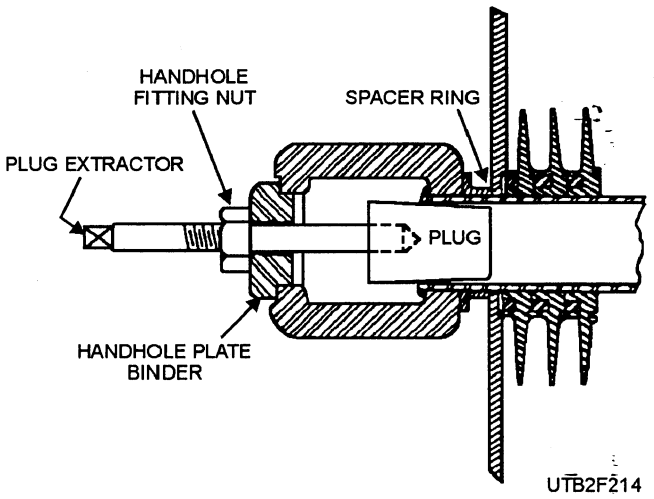


Figure 2-14.—Removing plug from economizer element.

Some activities, using boilers of recent design, are furnished with expandable gasketed plugs for plugging economizer elements. One of these plugs is shown in figure 2-15. The installation of the expandable plug is shown in figure 2-16. After inserting the plug assembly into the tube, hold a screwdriver in the slot of the retainer stem to keep the

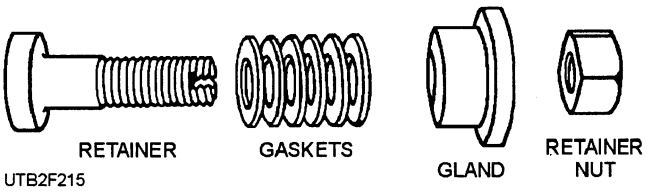


Figure 2-15.—Expandable gasketed plug for economizer element.

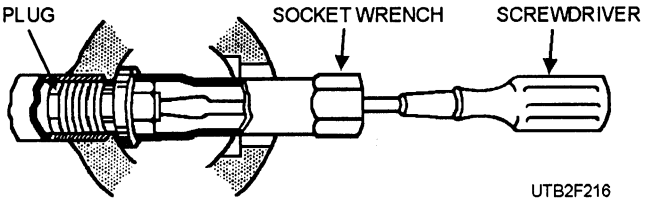


Figure 2-16.—Installing expandable plug in economizer element.

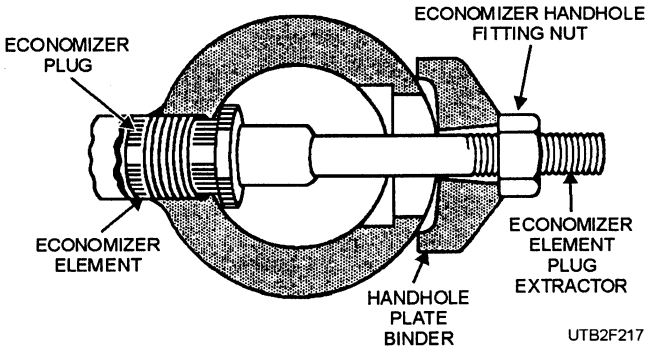


Figure 2-17.—Removing expand able plug from economizer element.

plug from turning, as you tighten the nut. As you tighten the nut using an open-end wrench or a socket wrench, the gaskets expand radially, as they are compressed axially.

The removal of an expandable plug is shown in figure 2-17. Insert a socket wrench or an open-end wrench through the handhole and remove the retainer nut. Insert the economizer plug extractor and then thread it onto the retainer. Place the handhole plate binder in position over the extractor and the thread on the handhole fitting nut. As you tighten the nut, the plug pulls out.

Q5. What five items of information are generally required on boiler tubes?

Q6. When tubes on a boiler drum or header made of 4-6 choromium steel are removed what method of removal cannot be used?

Q7. When tubes are fitted, tubes up to 2-inch-outside diameter should project how far into the drum or header?

Q8. Tubes 2 inches or larger should be belled between what size range?

Q9. What should you do to a plugged boiler tube to avoid pressure buildup in the tube when the boiler is operating?

REPAIRING BOILER REFRACTORIES

Learning Objective: Recognize maintenance and repair procedures for boiler refractories.

Furnaces are built with high-grade, fire-resistant materials that take a lot of punishment. Sooner or later, however, repairs become necessary. Furnace walls or floor may need repairing. The procedure for this repair is as follows:

First, mix the mortar, using a Navy-recommended fire clay or fire cement and fresh water. Do not add anything else. Make the mortar rather thin and without lumps.

Inspect the bricks for flaws and evenness. Choose the best edge for the furnace side. Dip the brick in fresh water and allow the excess water to drip off.

Now, dip one end and side of the brick into the mortar, using an edgewise motion to prevent air bubbles from forming. Lift the brick from the mortar and allow the excess mortar to drip off. Do not place any mortar on the wall or brick with a trowel.-The mortar sticking to the brick is all that is used.

If the mortar is too thick, you will not get the thin joints that you want. The mortar should be a little thinner than the usual wall plaster. You can feel the proper thickness with your hand. Some mortar will stick to your hand, as you lift it away from the mortar. Add more clay or water as necessary, and stir the batch often to keep the mortar at the desired consistency.

Place the brick quickly in position in the wall and pound it in place with a wooden mallet until no mortar can be forced out of the joints. With high-grade brick, joints can be made less than one thirty-second of an inch thick. Joints should never exceed one-sixteenth of an inch.

With a small trowel, fill in any unevenness in the furnace side of the seam and bead over the joints, as shown in figure 2-18. Be sure that no edges of the brick are exposed. The wall should be laid up evenly and smoothly. Any excess mortar that protrudes from the joints should be smoothed off with a small trowel, so the corners of the brick are protected.

Allow the wall to dry for about 12 hours with the burner shutters open to allow circulation of air, which permits the escape of some of the water added to the mortar. As soon thereafter as practicable, light the burner under the boiler and slowly bring the furnace up to operating temperature to bond the mortar to the adjacent brickwork.

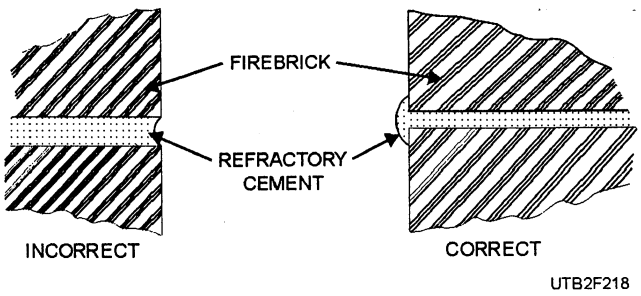


Figure 2-18.—Cementing brick.

When inspecting the boiler, you may find cracks or holes in the furnace lining. To make necessary repairs, mix some of the fire clay you used for brick mortar into a thick mixture. Use more mortar than you used for the brick mortar mix. Use a trowel to apply this wash.

While standard firebrick generally is used for normal refractory work, plastic firebrick is recommended for emergency patches and for building up furnace openings. Plastic firebrick is unfired firebrick in a stiff plastic condition. It offers a particular advantage in that, because of its plastic nature, it can be pounded into places where otherwise a firebrick of special shape would be required. The fusion point of plastic firebrick is practically equal to that of standard firebrick. Because of the moisture in the plastic material, however, a greater degree of shrinkage takes place. This factor prevents its general use for sidewalls. It provides an excellent material, though, for repairing brickwork, topping off side and back walls, repairing and constructing the burner openings and, general, for any part of the furnace not exposed to temperatures in excess of 2000°F. It is particularly adapted for use in place of specially formed brick of complicated shapes.

Plastic firebrick material, as received from the factory, ordinarily contains enough moisture for working. Avoid the addition of water or any foreign material. In laying up, chunks of plastic just as taken from the can should be rammed tightly into place (preferably in horizontal layers). In general, the more solidly the section of plastic is rammed up, the better it will be.

As the next step, the plastic section should be vented with 3/16-inch holes. Ensure that the holes extend clear through the plastic and are not more than 2 inches apart. This positioning allows deeper heat penetration during the baking-out process. It also permits ready escape of the steam formed from the moisture in the plastic. Do NOT trowel the surface of a new plastic section. This tends to prevent the escape of steam during baking out.

The plastic section should be held in place with as many anchor bolts as would have been provided had standard firebrick been used instead of plastic. The plastic section should be air-dried. This takes from 48 to 72 hours, depending upon the atmosphere. As soon as practicable after air drying, the furnace should be fired with a small fire and gradually brought up to operating temperature to complete baking out. Plastic requires a temperature of about 2900°F to 3000°F for baking out. If small shrinkage cracks open up, they should be filled with fire clay. If large cracks occur, they should be filled with plastic.

When used for patches, as in the case of brick falling out, the hole should be cleaned out to give at least 4 inches of body thickness to the plastic brick. In building up furnace openings, the use of a metal form is desirable. However, it is not absolutely necessary if care is exercised in making openings of the proper shape and concentric with the atomizer at every point. If furnace openings, as built, have a smooth surface, they should be roughened with a stiff wire brush before baking out.

The following ways to maintain newer boilers are recommended. The boiler is normally shipped with a completely installed refractory. This consists of the rear head (fig. 2-19), the inner door, and the furnace liner (fig. 2-20). Follow the instructions in the manufacturer's manual for the boiler you are maintaining. Where specific directions or requirements are furnished, follow them.

Normal maintenance requires little time and expense and prolongs the operating life of the refractory. Preventive maintenance through periodic inspection keeps the operator informed of the condition of the refractory and helps guard against unexpected downtime and major repairs.

Frequent wash coating of refractory surfaces is recommended. A high-temperature bonding air-dry type of mortar diluted with water to the consistency of light cream is used for this purpose. Recoating intervals vary with operating loads and are best determined by the operator when the heads are opened for inspection.

Maintenance consists of occasional wash coating of the entire liner. Face all joints or cracks by applying high-temperature bonding mortar with a trowel or use your fingertips. This should be done as soon as the cracks are detected. Should segments of the liner become burned out or broken, replace the entire refractory. Any refractory that may break out should be removed as soon as detected, so it will not fuse to the bottom of the furnace and obstruct the burner flame.

Remove the existing refractory and thoroughly clean that portion of the furnace covered by the liner to remove all old refractory cement or other foreign material to ensure the new liner seats firmly to the steel. Inspect all furnace metal for soundness. There may be metal clips welded in the furnace at the extreme end of the liner. These clips were installed to prevent shifting during original shipment and serve no other

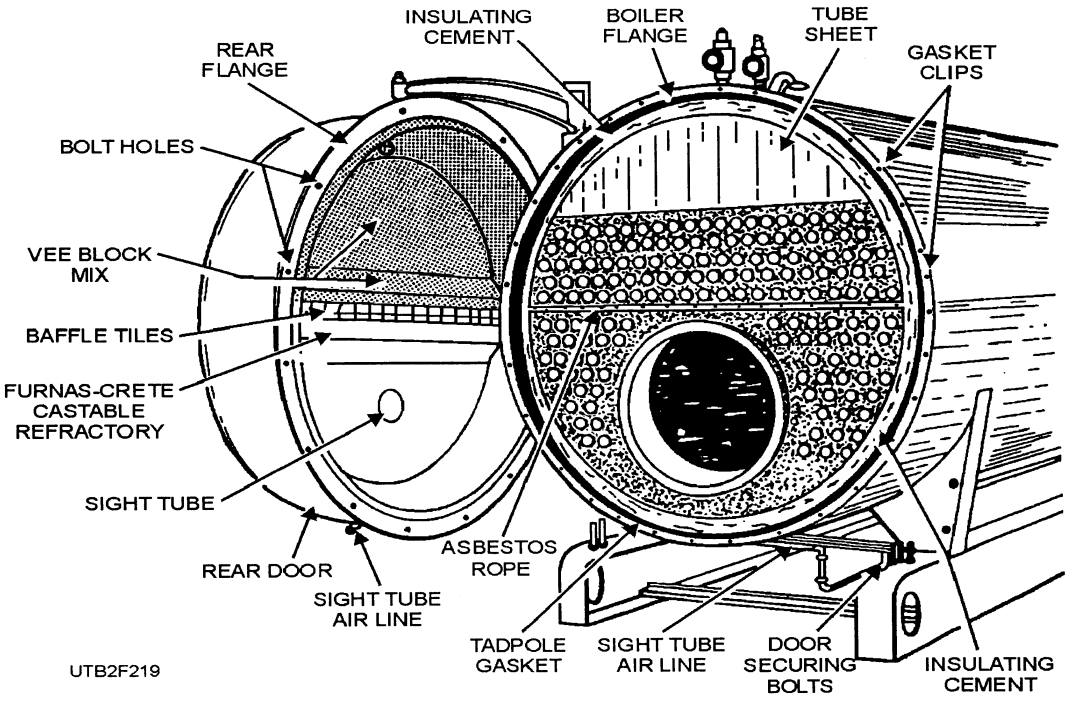


Figure 2-19.—Rear door open.

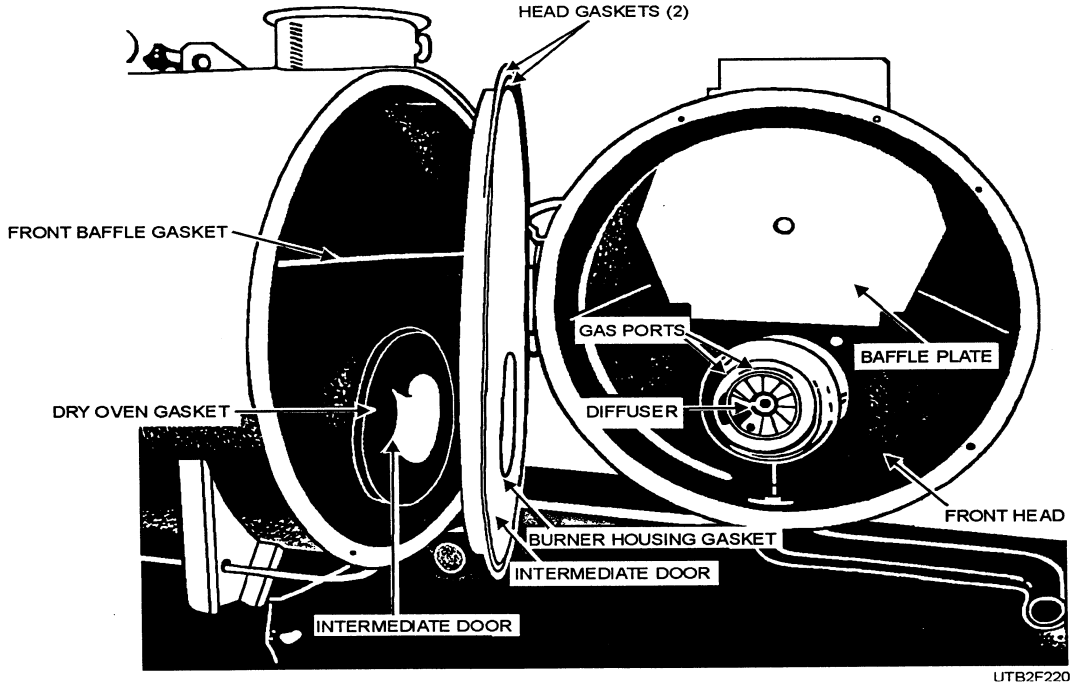


Figure 2-20.—Front head open-gas-fired CB 125-150-200.

purpose. They are tack-welded in place and can be removed when you are installing the new liner. If they are not removed, make sure the liner has clearance between this clip and the end of the refractory to allow for expansion in this direction.

Depending upon the design pressure of the boiler, the furnace may be of the corrugated type. Although it is not necessary to fill in the depressions for convenience of installation, some or all of the corrugation valleys may be filled with insulating cement. The liner tile should be fitted tightly against the crown of the corrugations.

The furnace extension of the boiler or a dry oven is shown in figure 2-21. The throat tile should be installed flush with the front of the oven and should fit tightly against its sides. The two rows of furnace tile should be fitted tightly against the furnace wall. It is not necessary to allow for expansion.

It is recommended that the tile be dry fitted, match marked, removed, and then reinstalled with the proper amount of refractory cement. Thin joints are desirable. Generally, it is necessary to shave a portion from one or more tiles to obtain a fit. If a fill piece is required, cut it to fit and install this piece at the bottom of the furnace. It is important to have a good seal between-the burner housing and the throat tile. Liberally coat-the sealing area with an insulating pulp cement or equivalent mixed with water before swinging the burner housing into place.

The rear door is a steel shell containing horizontal baffle tiles and lined with insulation material and a castable refractory (fig. 2-19).

Burned or discolored paint on the outer surface of the door does not necessarily indicate refractory trouble but may be an indication of other conditions such as the following:

- Leaking gaskets.
- Improper seal.
- Door retaining bolts insufficiently or unevenly tightened.
- Air line to the rear sight tube is blocked or loose.

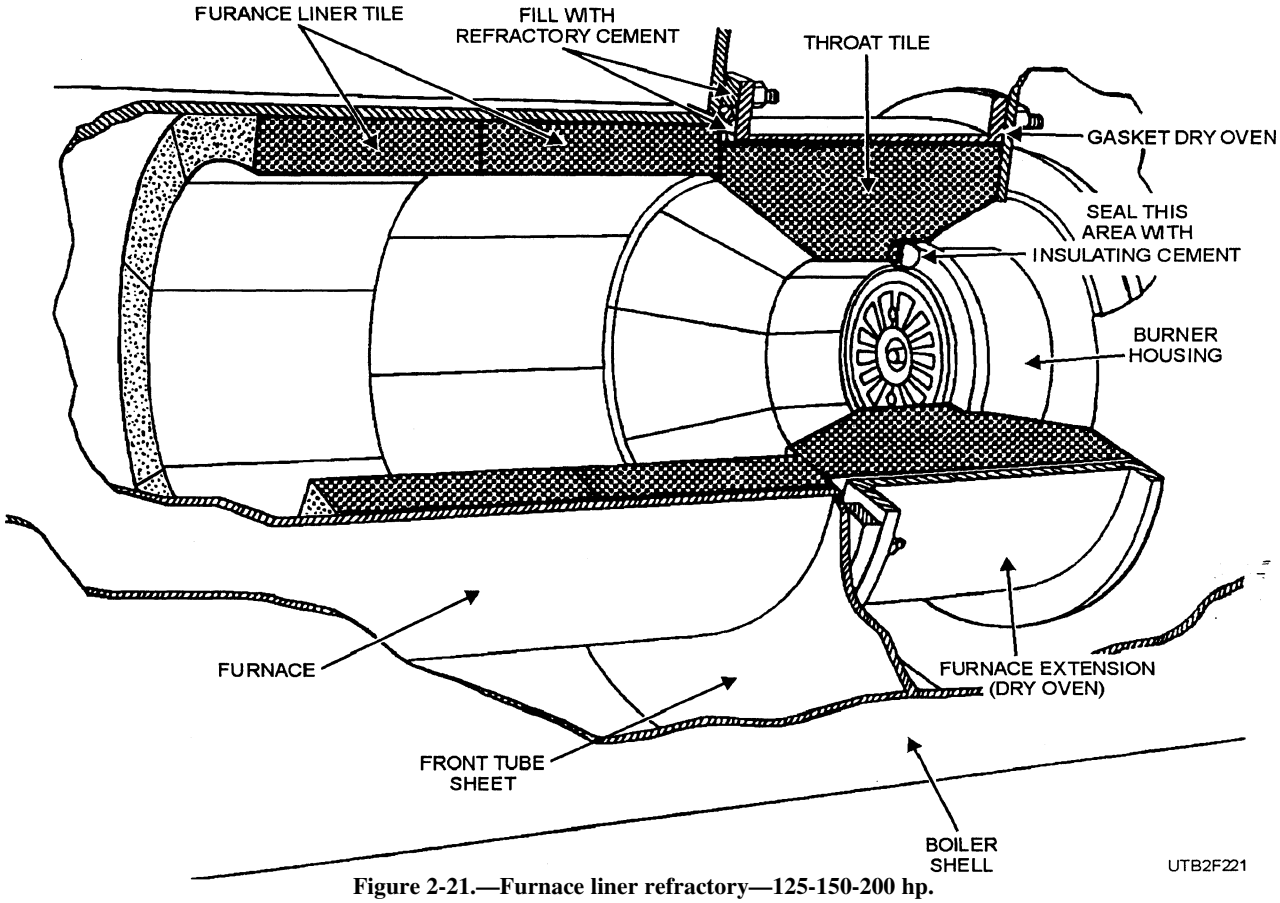


Figure 2-21.—Furnace liner refractory—125-150-200 hp.

- Repainted with other than heat-resistant paint.

Therefore, before you assume the refractory requires re-working. check the following:

- Condition of the tadpole gasket.
- The condition of the insulating cement protecting the tadpole gasket.
- Horizontal baffle tile for large cracks, breaks, chipped corners, and so forth.
- Cracks in the castable refractory at the ends of the baffle tile.
- Tightness of door bolts.
- Air line to the sight tube to ensure it is clear and all connections are tight. If necessary, blow it clear with an air hose.

It is normal for refractories exposed to hot gases to develop thin "hairline" cracks. This by no means indicates improper design or workmanship. Since refractory materials expand and contract to some degree with changes in temperature, they should be expected to show minor cracks because of contraction when examined at low temperature. Cracks up to approximately one-eighth of an inch across may be expected to close at high temperature. If there are any cracks that are relatively large (1/8-inch to 1/4-inch width), clean and fill them with high-temperature bonding mortar. Any gap that shows between the castable refractory and the baffle tile should be filled-in in a similar fashion.

After opening the rear door, clean off the flange surface of the door with a scraper or wire brush. Clean the surface of the refractory carefully with a fiber brush to avoid damaging the surface. Clean the mating surfaces of the baffle tile and the boiler shell. Remove all dried-out sealing material. Wash-coat the lower half of the rear door refractory before closing it. The upper half of the door contains a lightweight insulating material similar to that used in the inner door. A thin washcoat mixture applied gently with a brush is helpful in maintaining a hard surface.

The front inner door is lined with a lightweight castable insulation material. Thin "hairline" cracks may develop after a period of time; however, these cracks generally tend to close because of expansion when the boiler is fired. Here, again, a thin washcoat mixture is helpful in maintaining a hard surface. Minor repairs can be accomplished by enlarging or cutting out affected areas, making certain they are clean, and then patching as required.

Should the entire installation require replacement, remove existing material and clean to the bare metal. Inspect the retaining pins and replace if necessary. Reinforcing wire suitably attached may also be used. The recommended insulation is known as Vee Block Mix and is available in 50-pound bags. Mix the material with water to a troweling consistency. Mixing should be completely uniform with no portion either wetter or drier than another. Trowel this mixture into any areas that are being patched. If replacing complete insulation, begin at the bottom of the door and apply the mixture to a thickness equal to the protecting shroud. With a trowel, apply the mixture horizontally back and forth across the door in layers until the required thickness is reached. Allow the mixture to air-dry as long as possible. If immediate use of the boiler is required, fire as slowly as possible to avoid rapid drying of the material.

Whenever the front or rear door is opened for inspection, the head gasket should be checked for hardening and brittleness. Doubtful gaskets should be replaced. Coat the gasket with an oil and graphite mixture before closing the door. Make certain all gaskets retaining rivets are in place. The flange of the door should be clean and free of any hardened cement, scale, and so forth. Check the condition of the rope gasket used as a baffle seal. Replace if necessary. If the rope is in good condition, liberally coat it with an insulating pulp before closing. Make sure the rope is properly positioned.

If it is necessary to replace the rope, wire brush the tube sheet area to remove all of the old sealing material. Place a new piece of 1 1/2-inch-diameter rope gasket on the lip of the baffle tile. Hold it in place with furnace cement or an adhesive.

NOTE

Earlier models have several steel bar segments tack-welded across the tube sheet to serve as a gasket retainer for 5/8-inch-diameter rope. It is suggested that these bars are removed and 1 1/2-inch-diameter rope be used.

Generously apply a seal, consisting of a pulp mixture of insulating cement and water, around the entire rear door circumference. Place the pulp around the inside diameter of the head gasket, as shown in figure 2-16. Also coat the tube sheet area adjacent to the baffle tile. When the door is closed, the pulp compresses to protect the tadpole gasket and to form a

seal between the refractory surface and the tube sheet. The insulating pulp seal is not needed or used on the front head. Make sure the gaskets are in position when closing.

When you are closing the door, bolts should be snug and tightened evenly to avoid cocking the door and damaging the gasket. Start tightening at the top center bolt and alternate between the top center bolt and the bottom center bolt until both are drawn-up tight. Do not overtighten. Continue the tightening sequence along top and bottom, tightening the bolts alternately until the door is secured and gas-tight. After the boiler is back in operation, retighten the bolts to compensate for any expansion.

NOTE

Proper sealing of the doors is essential to avoid leakage of combustion gases and loss of heat and operating efficiency.

Q10. When plastic firebrick is used, troweling the new section of refactory will cause what condition to occur during the baking-out process?

Q11. What temperatures are required to bake out plastic firebrick?

Q12. Leakage of combustion gases, loss of heat, and loss of operating efficiency can be caused by what condition?

BOILER OPERATIONS

Learning Objective: Recognize different boiler checks, start-up, securing procedures, and boiler emergencies. Understand the purpose and types of data in boiler operating logs.

The operation of a boiler consists of seven major phases: (1) prewatch assumption checks, (2) preoperating checks, (3) lining up systems, (4) operating procedures, (5) operating checks, (6) securing procedures, and (7) boiler emergencies.

PREWATCH ASSUMPTION CHECKS

The prewatch assumption checks are often neglected by boiler watch standers. Before you assume the responsibility of a boiler watch stander, you must complete specified checking procedures to ensure that the equipment in service is in sound operating condition and is functioning satisfactorily. When the watch is relieved, the watch stander coming on duty inspects the instrument readings and charts, visually inspects all equipment, and exchanges information with offgoing watch standers. Oncoming watch standers should complete the following inspections and tests before assuming duty:

- Visually inspect the setting and casting.
- Observe the furnace and firing conditions.
- Inspect the charts, logs, controls, and so forth, on equipment performance during previous watch.
- Inspect the fans, dampers, damper drives, and other driven auxiliaries.
- Test the water columns and gauge glasses.
- Obtain information from the watch standers on duty on the boiler operating condition and any unusual event or trouble that occurred during the previous watch.

Immediately after accepting the operational responsibility, you should make a complete inspection of all auxiliary equipment as follows:

- Inspect all electric motor drives for abnormal temperature, condition of bearings, and so forth.
- Inspect the fan and pump bearings for overheating and adequacy of lubrication.
- Visually inspect the boiler and all associated equipment, listen for unusual sounds, friction, vibration, and other abnormal conditions.
- Inspect the burners, fuel supply, pilot systems, and other fuel supply components.
- Review the log sheets to obtain information on past operating conditions and unusual events.

REOPERATING CHECKS

The preoperating checks should be completed before lining up and lighting off a boiler. These checks are performed to ensure that the plant and associated equipment are in a safe and efficient operable condition. The major preoperating procedures applicable to boilers in general, as well as additional procedures for gas-fired and oil-fired boilers are shown in tables B, C, and D, appendix II.

LINING UP SYSTEMS

After you have completed the preoperating checks, your next job is to line up the boiler systems. The procedure used in lining up boiler systems (fuel,

water, steam, and electrical) vary with different types and kinds of boil ers. Always follow the manufacturer's instructions for the boiler being used. Before lining up a boiler, complete the following basic tasks:

1. Fuel oil
   a. Measure with a stick or gauge.
   b. See that the proper valves are open.
   c. Remove any excess accumulation of water in the tank.
2. Gas
   a. Check the pressure.
   b. Check for leaks.
3. Gas-fired unit
   a. Check and regulate the water level and line up the feed system.
   b. Examine the burner, control valves, and safety shutouts for proper working condition before lighting off.
   c. Purge air out of the gas lines by external vents before lighting off.
   d. Check the draft devices and purge the combustion chamber.
   e. Light the pilot and set the flame.
   f. Open the main gas cock.
   g. Close the burner controls switches to light the burner.
   h. Maintain the fuel-air ratio for complete combustion.
4. Oil-fired unit
   a. Check and regulate the water level. Line up the feedwater system. Check the operation of the feed pump.
   b. Line up the fuel oil system.
   c. Purge the combustion chamber.
   d. Close the burner control switch; if automatic, the burner should light off.
   e. Should ignition fail, the furnace must be purged before a second attempt is made.
   f. Do not allow oil to impinge on brickwork or part of the boiler.
   g. Maintain the proper air-fuel ratio.

In general, the basic lighting off procedures for most boilers are as follows:

1. Close the following valves:
   a. All blowdown valves and boiler drains.
   b. Chemical feed valves.
   c. Boiler nonreturn.
   d. Main steam stops.
   e. Soot blower header (steam system) and all soot blowers.
   f. All burner fuel valves.
   g. Water column and feedwater regulator drains.
   h. Auxiliary valves, as necessary.
2. Open the following valves:
   a. Vent valves on boiler drums and superheaters.
   b. Superheater drain valves.
   C. Recirculating line valves in economizer, if so fitted.
   d. Feedwater stop and check.
   e. Drum steam gauge connection.
   f. Water column gauge connections.
   g. Water column gauge glass valves.
   h. Auxiliary valves, as necessary.
3. Start filling the boiler with properly treated water at a temperature close to the temperature of the pressure parts. The temperature difference should not be greater than 50°F to avoid severe temperature stresses. Fill the boiler to level just below the middle of the glass on the water column.
4. Close the induced draft fan dampers (or other flue gas control dampers).
5. Start the induced draft fan.
6. Close the forced draft fan dampers (or other air control dampers).
7. Start the forced draft fan.
8. Start the air heater rotor, if a regenerative type of air heater is installed.
9. Light off the boiler under the manufacturer’s instructions and maintain a firing rate so the water temperature in the boiler is raised 100°F per hour until operating pressure is reached. On

new boilers, expansion movement should be checked to see that no binding or interference occurs.

10. When burning oil, prevent incomplete combustion in the furnace: Unburned oil is deposited on the cooler surfaces in the back of the unit, such as the economizer and air heater, and this creates a potentially dangerous condition.
11. When the steam drum reaches about 25 psig, close the vent valves on the boiler drum. Check the steam pressure gauge now to be sure that it is registering.
12. Ease up on the stem of the main steam stop valve to prevent any serious expansion stresses. If there is no steam on either side of the main steam stop valve, gently lift and reseat it to make sure that it is not stuck. Open the drain valve on the boiler side of the main stop valve.
13. Observe the water level carefully to ensure that no water is carried over into the superheater. Maintain a normal water level in the drum by blowing down or feeding water as may be required.
14. Operate the vent and drain valves in the superheater headers and economizer by following the manufacturer's instructions. In general, drain valves in the superheater inlet header are closed first, followed by the drains in the superheater outlet header. In any case, the superheater outlet header drain and vent valves must not be completely closed until enough steam flow through the boiler outlet valve is assured.
15. Check for leaking gasket joints. If a leaking gasket is discovered, shut down the boiler and tighten the joints.
16. If the gasket still leaks, drop the pressure again, replace the gasket, and repeat the lighting off sequence.

Before cutting in the boiler, proceed as follows:

1. Open all drain valves between the boiler and the header, especially the drains between the boiler and the two stop valves.
2. Warm up the steam line between the boiler and the header by backfeed through the drip line or by means of the bypass valve.
3. When the steam line is thoroughly heated and at header pressure, open the bypass valve.
4. When the boiler pressure almost reaches line pressure, open the bypass line around the main steam stop valve to equalize pressures and temperatures in the piping; then slowly open the main steam stop valve. As the boiler reaches line pressure and is actually steaming, slowly raise the nonreturn valve stem to the full open position.
5. After the boiler is on line, close all superheater drains.
6. Inspect the entire boiler, and close any drain valves that are not discharging condensate.
7. Close the economizer-recirculating valve when an adequate continuous feedwater flow is established.
8. Close the drain valve at the nonreturn valve.
9. Close the bypass valve around the nonreturn valve.
10. A boiler with a pendant (nondrainable) superheater has a slightly different operation. Superheaters of this type trap condensate in the loops that must be boiled off before the firing rate can be increased and the steam flow started.
11. Maintain a constant firing rate. The strength of thick steam drums may be impaired by excessive temperature differentials between the top and the bottom of the drum, if the proper firing rate is not maintained. Tubes may start leaking at rolled seats and the superheater tubes may overheat.
12. On boilers generating saturated steam, follow the above instructions for removing air and condensate.

OPERATING PROCEDURES

Success in operating boilers depends largely upon the operator's performance. No fixed set of rules can be established to fit all conditions. Consequently, the operator must see and interpret all prevailing operating conditions and, if necessary, take action to control, modify, or correct them. To be able to do this, the operator must be thoroughly familiar with the characteristics and standard operating procedures for the boiler for which the operator is responsible. This section acquaints you with some of the basic operating procedures that generally apply to most, if not all,

boilers you will be assigned to operate. For specific operating instructions, consult the manufacturer's manual for the boiler concerned.

Normal Operation

During normal operation of boilers, the operators have two major responsibilities. First is to maintain proper water level at all times. If the water level is too low, tubes may overheat, blister, and rupture. If water level is too high, carry-over of water to the superheater tubes may damage the superheater elements and the turbine. The second is to prevent loss of ignition when burning fuel is in suspension. Maintain safe and efficient combustion conditions in the furnace and correct fuel-air ratios.

Blowdown

Establish definite intervals for blowing down the boiler, depending on the type of operation and chemical analysis of the boiler water. During regular operation, never blow down economizers or water-cooled furnace walls. Blowdown valves on this type of equipment serve only as drain valves.

Blowdown should be at reduced or moderate rates of steam for low point drains or blowdown valves. When the water glass is not in full view of the operator blowing down a boiler, another operator should be temporarily assigned to observe the water glass and signal the operator handing the valves. For control of water conditions when working, use continuous blowdown to maintain the proper concentration at all times and to prevent blowing down large quantities of water while the boiler is operating at a high capacity.

Boiler Makeup Water

Use only properly treated water for makeup, and maintain the boiler water conditions as specified in water treatment instructions. Make an accurate water analysis at specified intervals. Carefully control the blowdown and the addition of treatment chemicals to meet the manufacturer's specifications.

Soot Removal

Remove soot from hoppers and pits at definitely established intervals, as necessary.

Instrument Readings

Establish definite intervals for observing and recording the readings on all important instruments and controls. Be sure you obtain accurate readings-and see that the readings are recorded properly on the log sheet or other required record.

OPERATING CHECKS

To help ensure efficient operation of the boiler, operators should ensure that proper operating checks are done during boiler operations. Operating checks, as shown in table E, appendix II, apply to most, if not all boilers.

Keys to efficient boiler operation and performance are as follows:

1. Flue-gas temperature
   a. Keep the temperature low.
   b. Temperature should be about 150 degrees higher than temperature of steam produced.
2. Flue-gas analysis
   a. Take periodically.
   b. Maintain proper CO;! level for fuel used.
3. Flame
   a. Should be long and lazy.
   b. Must not enter the tubes.
   c. Not dark and smoky.
   d. Have a light brown haze from stack, except gas.
   e. When the fuel is oil, have a yellow flame with dark or almost smoky tips.
4. Draft
   a. Usually 0.03-0.06 inch of water.
   b. Check the manufacturer‘s recommendations.
5. Makeup feed
   a. Maintain low rate.
   b. Avoid excessive boiler blowdown.
6. Insulation
   a. Ensure boiler and lines are well insulated.
7. Water treatment
   a. Carry out prescribed treatment of boiler water.

SECURING PROCEDURES

The recommended procedures for securing boilers are as follows:

1. Reduce the load on the boiler slowly, cutting out the fuel supply by proper operation of the fuel-burning equipment.
2. Maintain normal water level.
3. When the boiler load is reduced to about 20% of rating, change the combustion control and the feedwater control to manual operation.
4. Before securing the final fuel burner, open the drain valves at the steam and nonreturn valve and the drain valve on the superheater outlet header. Be sure the bypass valve around the nonreturn valve is closed.
5. Secure the final fuel burner when the load has been reduced sufficiently.
6. Continue operating the draft fans until the boiler and the furnace have been completely purged.
7. Shut down the draft fans.
8. Close the dampers, including the air heater and superheater bypass dampers, when provided.
9. Follow the manufacturer's instructions for the rate of cooling the boiler. A thermal strain may occur if the change is too fast.
10. When the boiler pressure has started to drop, close the steam stop and nonreturn valve.
11. When the boiler no longer requires any feed and the nonreturn valve is closed, open the valve in the recirculating connection of the economizer, if provided.
12. Let the boiler pressure drop by relieving steam through the superheater drain valve and the drain valve at the nonreturn valve. If the boiler is losing pressure at a rate faster than specified by the manufacturer, throttle the drain valves as necessary to get the proper rate. Do not close the valves completely.
13. When the drum pressure drops to 25 psig, open the drum vent valves.
14. If a regenerative type of air heater is used, the rotor may be stopped when the boiler exit gas temperature is reduced to 200°F.
15. The boiler can be emptied when the temperature of the boiler is below 200°F. Before sending someone into any part of the boiler, close and properly tag all controls, valves, and drains or blowdown valves connected with similar parts of other units under pressure at the time. This move prevents any steam or hot water from entering the unit. The tags are to be removed only by the authorized person who tagged out the boiler and must remain in place until the work is completed. Ventilate the boiler thoroughly and station a person outside. Inside, use only low voltage portable lamps provided with suitable insulation and guards. Even 110 volts can kill under the conduction conditions inside a boiler. All portable electrical equipment should be grounded; and electric extension cords should be well insulated, designed to withstand rough usage, and maintained in good condition.

BOILER EMERGENCIES

Typical emergency situations encountered with the operation of boilers are (1) low water, (2) high water, (3) serious tube failure making it impossible to maintain water level, (4) flarebacks caused by an explosion in the combustion chamber, (5) minor tube failure indicated by trouble in maintaining water level under normal steam demand, and (6) broken gauge glass on the water column. Table F, appendix II, lists the safe procedures to follow when these boiler emergencies occur.

BOILER OPERATING LOGS

The main purpose of boiler operating logs is to record continuous data on boiler plant performance. Logs become a source of information for analyzing the operation of the boiler for maintenance and repair. The daily operating log sheets provide the basic information around which maintenance programs are developed. The log is arranged for use over a 24-hour period divided into three 8-hour shifts. Log sheets vary among different activities, but you should have no difficulty in making log entries once you understand what information is required. The types of information to be entered in the appropriate column of the log are as follows:

- Steam pressure. Based on steam gauge readings and indicates the performance of the boiler.
- Steam flow. Actual output of the plant, in pounds per hour, to obtain steam flow. The data from these entries are used to determine the number of boilers to operate for greatest efficiency.

- Feedwater heater pressure. Indicates whether the proper deaerating temperature can be maintained in the heater.

- Feedwater heater temperature. Shows the effectiveness of the feedwater heater. A drop in steam-supply pressure or insufficient venting may cause low heater temperature.

- Feed pump pressure. Indicates the effectiveness of the boiler feed pumps. If the feedwater supply fails, the pressure reading enables the operator to determine whether the trouble is in the feed pumps. Pumps are defective when the feed pump pressure reading is below normal.

- Last-pass draft. Indicates the actual draft produced by the stack or the induced-draft fan. A decrease in the last-pass draft with other conditions constant indicates leaking baffles. An increase shows gas passages are becoming clogged.

- Percent CO_2 flue gas. This value is a measure of relative quantities of air supplied with fuel. It is kept at a value that has been established as most satisfactory for the plant, fuel, firing rate, and other related factors. In plants not equipped with CO_2 recording meters, this value is determined with a hand gas analyzer.

- Flue gas temperature. Shows the quantity of heat leaving the boiler with flue gases. This heat represents a direct energy loss in fuel. Dirty heating surfaces or leakage of baffles causes high flue gas temperatures. Excessive fouling of firesides of boilers increases draft loss, while leaking baffles decrease draft loss. Either condition raises the temperature of flue gas above normal.

- Fuel. Fuel oil quantities are determined by the use of a measuring stick and tables supplied with a given tank. Some tanks are equipped with gauges to show the fuel volume. Always determine the quantity of fuel used, as this represents a major operating cost.

- Outside temperature. The load on a heating plant is greatly influenced by outside temperature. Record this temperature for comparison with steam generated and fuel used. These comparative values are useful in finding abnormal fuel consumption and in estimating future requirements.

- Makeup water. Record the quantity of makeup water used to enable the operator to note an abnormal increase before a dangerous condition develops. Return all possible condensate to the boiler plant to save water and chemicals used to treat water.

- Water pressure. Indicates whether water is sufficient.

- Hot-water supply temperature. Insufficiently heated water can cause scaling or deposits in a boiler.

- Water softeners. Where softeners are used, a decrease in the quantity of time used for runs between regeneration indicates either an increase in hardness of incoming water or a deterioration of softening material.

- Total and average. Space is provided for recording the total and average quantities per shift.

- Steam flowmeter. The steam flowmeter integrator reading at the end of a shift and multiplied by the meter constant gives the quantity of steam generated. Dividing steam generated by fuel burned (gallons of oil) yields a quantity that shows the economy obtained. If a plant does not have a steam flowmeter, pumps can be calibrated for flow and a record kept of their operating time or condensate and makeup water can be metered.

- Boiler feed pumps in service. Makes it possible to determine operating hours and to ensure that various pumps are used for equal lengths of service.

- Phosphate, caustic soda, and tannin added. Is valuable in keeping the correct boiler water analysis and in determining total chemicals used.

- Remarks. The Remarks column is used to record various types of information for which space is not provided elsewhere on the log sheet. Note irregularities that are found during inspections, dates boilers are drained and washed out, equipment to be checked daily, and so forth.

- Other personnel. Names of personnel responsible for specific tasks and data must be entered on the log sheet, if required.

Q13. Why are prewatch assumption checks performed?

Q14. What is the next step after completing preoperating checks?

Q15. What is the first step to be taken when cutting in the boiler?

Q16. What are the two major responsibilities of boiler operators during normal boiler operations?

Q17. Flu-gas temperatures should be at how many degrees above steam production temperature during boiler operations?

Q18. When securing a boiler, at what pressure should you open the drum vent valves?

Q19. What is the purpose of a boiler operating log?

SAFETY

Learning Objective: Understand the relationship of safety in operating and maintaining boilers. Recognize the different types and use of lockout devices in boiler maintenance.

In servicing boilers, the need for SAFETY cannot be overemphasized. Much progress has been made over the years in the development of safety devices for boilers. There are still many ways, however, in which serious accidents can happen around boilers. A boiler operator or serviceman who is careless on the job threatens the safety of everyone. Accidents somehow have a way of happening at a moment we least expect. All the more reason, therefore, for constant alertness and close attention to detail. Do not take chances! BE SAFETY CONSCIOUS!

Some of the major safety precautions to be observed by Utilitiesmen engaged in boiler operation and servicing are presented below.

As protection against toxic or explosive gases, boiler settings must be ventilated completely and tested for toxic or explosive gases before crews are permitted to enter.

The covers of manholes must be removed for ventilation before people enter the drum.

Before anyone enters a steam drum, mud drum, or other waterside enclosure, steam and feed lines connected to the headers under pressure should be isolated by a stop valve and a blank with an open telltale valve in between, or by two stop valves with a telltale valve opened in between.

A ventilating fan should be operating in the drum when someone is working in the boiler.

Workers should not be inside the waterside of the boiler when pressure is being applied to test a valve that has not been under pressure.

Workers should wear protective clothing when making boiler water tests.

Boiler settings must be examined daily for external air leaks. Cracks, blisters, or other dangerous conditions in joints, tubes, seams, or blowoff connections are to be reported to your senior chief petty officer immediately.

Boilers should also be examined regularly for deposits on their heating surfaces and for grease or other foreign matter in the water. Boilers showing any such faults should be cleared at the first opportunity and should not be used until cleared.

Performing certain adjustments and repairs while pressure is up is prohibited. A complete absence of pressure is to be ensured by opening the air cock or test and water gauge cocks connecting with the steam space before fittings or parts subject to pressure are removed or tightened, and before manhole or handhole plate fittings are loosened on a boiler that has been under pressure.

Combustion control, feed control, and burner, stoker, or similar adjustments are permitted with the boiler steaming, since many adjustments can be made only when pressure is up.

When cleaning operations are performed, workers should wear the proper personal protective equipment. The following requirements apply:

- Hard hats and goggles must be worn.
- When a worker is chopping slag inside a furnace, a respirator must be worn.
- Safety-toed shoes or toe guards must be worn to prevent injuries from falling slag.
- When someone is working inside the furnace, a large warning sign, such as Caution-Man Working Inside, should be placed near the furnace entrance.
- The use of open-flame lights is prohibited in boilers. When cleaning where flammable vapors and gases may be present, workers are to use only explosionproof portable lamps equipped with heavily insulated three-wire conductors, with one conductor connecting the guard to ground.
- Oil accumulated on furnace bottoms should be cleaned out immediately.
- The fuel-oil suction and discharge strainers should be cleaned at least every 8 hours and more frequently if necessary.
- Condensate pits in boiler rooms should have metal covers. If the pits must be opened for maintenance, adequate guards should be placed around them and warning signs posted.

- Wear goggles with dark lenses, Number 1.5 to 3 shade, and suitable fireproof face shields when working near or looking through furnace doors of boilers in operation.

- When firing a cold boiler, be sure that the air vents are open on the boiler proper and that the drains are open on the superheater; keep these open until steam is liberated from the openings. Superheater vents must remain open until the boiler is on the line.

- Be sure gas-fired and oil-fired boilers, whether manual or automatic, are cleared of combustible gases after each false start.

All semiautomatic (multiburner) boilers and all fully automatic boilers should be equipped with a manually activated switch for pilot ignition and a control device to prove the pilot flame is on before the main fuel valve is opened. DO NOT USE A HAND TORCH TO LIGHT OFF A BOILER. If a hand torch is applied to a firebox filled with vaporized oil, a severe boiler explosion is likely to occur.

Prevent overheating of boilers equipped with superheaters by. firing at a slow rate during the warm-up period and by allowing a small amount of steam to flow through the superheater.

When taking over a watch, blow the water gauges and note the return of the water in the glass. Be certain of the water level at all times. Do NOT be misled by a dirt marking on the gauge that may look like the surface of the water. Do NOT depend entirely upon automatic alarm devices and automatic feedwater regulators.

If the water goes out of sight in the bottom of the gauge glass, kill the fire with the quickest means available; immediately close the steam stop valve, and allow the boiler to cool slowly; then, drain the boiler completely and open it for inspection. DO NOT FEED COLD WATER TO A BOILER THAT HAS HAD LOW WATER UNTIL THE BOILER HAS COOLED.

Check the water on steaming boilers by try cocks at least once each watch and before connecting a boiler to the line.

Check safety valves often to be sure they will pop at the correct pressure, as marked on the nameplate. Do NOT break the seal of a safety valve or change its adjustment, unless such action has been authorized. NEVER weight pop valves, relief valves, and so on, to increase the recommended steam pressure for which the boiler is approved.

Do not use oil from a tank in which a lot of water is mixed with oil unless a high suction connection is provided. When an atomizer sputters, shift the suction to the standby tank or another storage tank. A sputtering atomizer indicates water in the oil.

Reduce the fouling of oil heaters by using as few heaters as possible. Recirculate the oil through the used heaters for a short time after securing the burners. Maintain the prescribed fuel-oil temperature; do NOT exceed it.

If a large steam leak occurs in a boiler, shut off the burners, continue to feed water until the fire is out, close the steam stop valve, ease the safety valves, clear the furnace of gases, close the registers, and cool the boiler slowly.

Do NOT tighten a nut, bolt, or pipe thread, nor strike any part, nor attempt other adjustments to parts while the boiler is under steam or air pressure.

Take care to prevent lubricating oil, soap, or other foreign substances from getting into the boiler. Condensate from cleaning vats should be drained to waste and not returned to the boiler.

Close the furnace openings as soon as all fires have been put out and the furnace has been cleared of gases.

At shore installations, the handles on pull chains to boiler water-gauge cocks and water-gauge glass stop valves should be painted the following colors:

Opening water-gauge glass stop valves	WHITE
Closing water-gauge glass stop valves	RED
Top gauge cock	YELLOW
Center gauge cock	GREEN
Bottom gauge cock	BLUE

Do NOT use water to put out an oil fire in the furnace.

When fires are banked, make certain the draft is enough to carry off flammable gas accumulations.

The following lists contain a number of actions to which you should ALWAYS be alert and a number of actions you should NEVER perform.

SAFETY PRECAUTIONS

Always study every conceivable emergency and know exactly what action to take.

Always proceed to proper valves or switches rapidly but without confusion in time of emergency. You can think better walking than running.

Always check the water level in the gauge glass with the gauge cocks at least daily—also at any other time you doubt the accuracy of the glass indication.

Always accompany orders for important operations with a written memorandum. Use a logbook to record every important fact or unusual event.

Always have at least one gauge of water before lighting off. The gauge cocks should check the level.

Always be sure the blowdown valves are closed, and proper vents, water-column valves, and pressure-gauge cocks are open.

Always use the bypass if one is provided. Crack the valve from its seat slightly and await pressure equalization. Then open it slowly.

Always watch the steam gauge closely and be prepared to cut the boiler in, opening the stop valve only when the pressures are nearly equal.

Always lift the valve from its seat by the hand lever when the pressure reaches about three quarters of popping pressure.

Always consult the CEC officer in charge of the plant, your CPO, or other proper superior and accept his/her recommendations before increasing the safety-valve setting.

Never fail to anticipate emergencies. Do not wait until something happens before you start thinking.

Never start work on a new job without tracing every pipeline in the plant and learning the location and purpose of each and every valve regardless of size. Know your job!

Never leave an open blowdown valve unattended when a boiler is under pressure or has a fire in it. Play safe, your memory can fail.

Never give verbal orders for important operations or report such operations verbally with no record. Have something to back you up when needed.

Never light a fire under a boiler without checking all valves. Why take a chance?

Never open a valve under pressure quickly. The sudden change in pressure, or resulting water hammer, may cause piping failure.

Never cut a boiler in on the line unless its pressure is within a few pounds of header pressure. Sudden stressing of a boiler under pressure is dangerous.

Never bring a boiler up to pressure without trying the safety valve. A boiler with its safety valve stuck is the same as playing with dynamite.

Never increase the setting of a safety valve without authority. Serious accidents have occurred from failure to observe this rule.

In case of an oil fire in the boiler room, close the master fuel-oil valve and stop the oil pump.

Other than the above precautions, the following list contains a number of SAFE practices that you should try to follow in your work. It also contains a number of UNSAFE practices that you must avoid.

SAFE PRACTICES

Always have the valve fitted with a new spring and restamped by the manufacturer for changes over 10 percent.

Always keep out loiterers, and place plant operation in the hands of proper persons. A boiler room is not a safe place for a club meeting.

Always consult the CEC officer in charge of the plant, your CPO, or other proper superior before making any major repair to a boiler.

Always allow the draft to clear the furnace of gas and dust for several minutes. Change draft conditions slowly.

Always consult someone in authority. Two heads are better than one.

UNSAFE PRACTICES

Never change adjustment of a safety valve more than 10 percent. Proper operation depends on the proper spring.

Never allow unauthorized persons to tamper with steam plant equipment. If they don't injure themselves, they may injure you.

Never allow major repairs to a boiler without authorization.

Never attempt to light a burner without venting the furnace until clear. Burns are painful.

Never fail to report unusual behavior of a boiler or other equipment. It may be a warning of danger.

LOCKOUT DEVICES

A lockout device is a mechanism or arrangement that allows the use of key or combination locks (most commonly padlocks) to hold a switch lever or valve handle in the OFF position. Some switches and valves have lockout devices built in; others must be changed before locks can be used. As a Utilitiesman, you may use lockout devices when working on potentially hazardous equipment, such as high-pressure steam lines, electrically operated equipment, and boilers. The use of a lockout device is a great advantage since the machine or equipment cannot be started up, energized, or activated while you are working on it. The photographs in figure 2-22 will give you an idea of how devices may be used in locking out valves.

Multiple Lock Adapter

It is often an advantage for a lockout device to accommodate more than one padlock. In this way, when you are working on a machine or an item-of equipment with the valve locked off, another person can come along and use the padlock to do other hazardous work on the machine or equipment at the same time, rather than wait until you are finished.

Since most controls are not designed to accommodate more than one padlock at a time, multiple lock adapters, called lockout clamps or tongs, may be used (fig. 2-23). These adapters should be permanently chained to the control, or, alternately, issued to all people with padlocks.

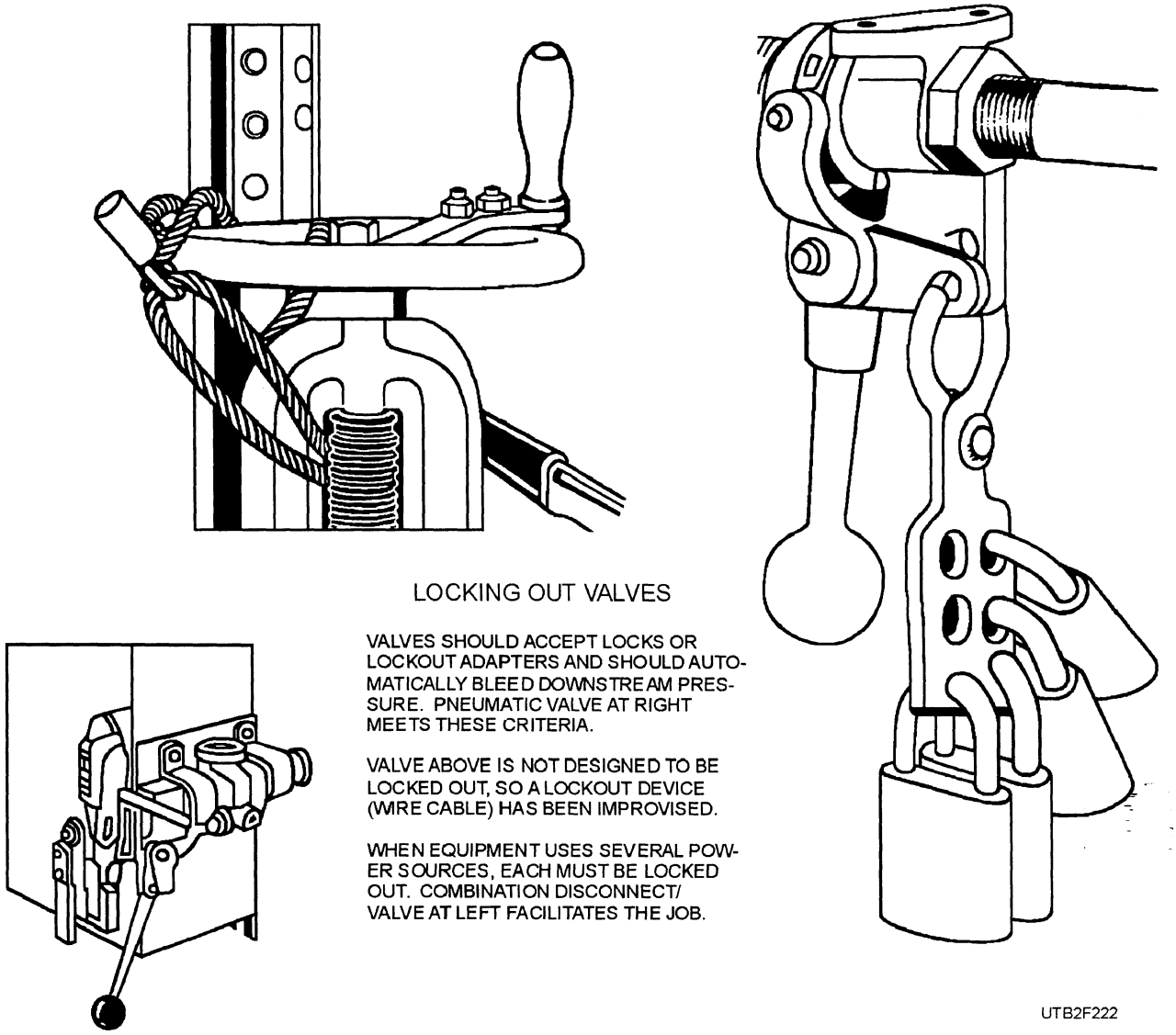


Figure 2-22.—Locking out valves.

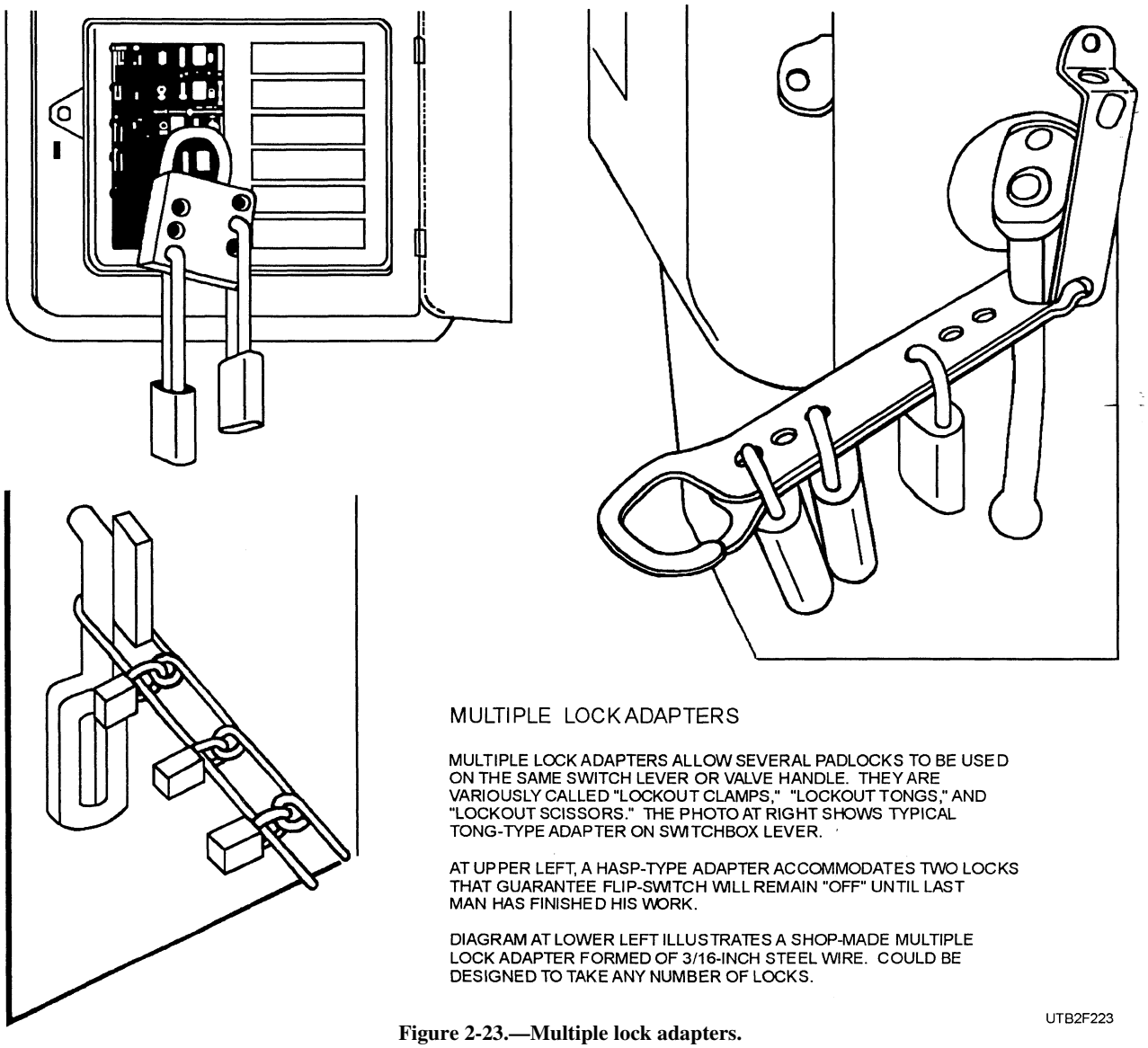


Figure 2-23.—Multiple lock adapters.

Locks

Perhaps you are wondering what kind of lock should be used—key or combination? What person should have a lock? Who should be in possession of the keys or combinations? How should the lock be identified? The answers to these questions may vary from one activity to another, but some guidelines are as follows:

1. Key-operated padlocks are more commonly used than combination locks. Supervisors can control keys easier than combinations.

2. Locks should be issued to every person who works on closed-down equipment. No key (or combination) should fit more than one lock.

3. Only one key should be issued to a person authorized to use the lock. At some activities, the supervisor may be permitted to maintain a duplicate set of keys for locks under his/her control, or a master key. Some activities, however, may have only one lock-one key. In an emergency, bolt cutters may be used to remove a lock. As a word of caution: KEYS AND LOCKS SHOULD NEVER BE LOANED.

4. Locks should identify the user by name, rate, and shop. This information can be stamped into the lock case, stenciled on, or carried on a metal tag fixed to the shackle of the lock. In addition, locks may be color coded to identify the skill or rating of the lock folder, such as UT, CE, or CM. The colors could also follow the hard hat color code.

Lockout Procedures

If locks, lockout devices, and multiple lock adapters are to be effective, they must be used properly on every occasion where they are needed. Make sure that you follow the steps of the lockout procedure below.

1. Before any equipment is locked out, there should be agreement as to the specific machine or unit to be taken out of operation. The supervisor should oversee lockout procedures.

2. Turn off the point-of-operation controls. (Remember that disconnect switches should never be pulled while under load because of the possibility of arcing or even explosion.)

3. See that the main power controls (switch, breaker, or valve) are turned OFF. Where electrical voltages are involved, do NOT attempt this yourself but have it done by a Construction Electrician.

4. After the switch has been opened or the valve closed, the person who will be doing the work should snap the locks on the control lever or multiple lock adapter. At this point, tag the switch, valve, or device being locked. Tags should indicate the type of work being done, approximately how long the job will take, and the name of the supervisor.

5. Try the disconnect or valve to make sure it cannot be moved to ON.

6. Try the machine controls as a test to ensure the main controls are really off.

7. As each person completes work, only that person should remove the lock and supplemental tag. The person removing the last lock should notify the supervisor that the work is finished and the equipment is ready to be placed back in operation.

Q20. When cleaning operations are performed, what basic personal protective equipment should be worn?

Q21. What color should the pull chain handle be painted for the center gauge cock?

Q22. You should never bring a boiler up to pressure unless what valve has been tested?

Q23. Why are key-operatedpadlocks more commonly used than a combination lock for a lockout device?

CHAPTER 3

STEAM DISTRIBUTION SYSTEMS

Learning Objective: Recognize the purpose, operating principles, and maintenance procedures of steam distribution systems.

"What good is steam without some means of transporting it from the steam plant to the user"? In answer to this question, you will find information in this chapter about steam distribution systems. A steam boiler is virtually useless for heating without a good distribution system for taking the steam to the areas to be heated. In this chapter, both exterior and interior steam distribution systems are discussed. Also discussed in this chapter are maintenance requirements along with the various components and their purpose in the distribution system. The term *distribution system,* as used in this chapter, refers to the network of piping required to distribute steam from a boiler room or a boiler plant through the steam pipes to the equipment using it. Steam distribution systems are grouped under two classifications: exterior and interior. The first discussion pertains to the types of exterior distribution systems.

EXTERIOR STEAM DISTRIBUTION SYSTEMS

Learning Objective: Recognize types and configurations of exterior distribution systems and their application and maintenance.

The exterior distribution system is further divided into underground and aboveground systems.

UNDERGROUND SYSTEMS

The major underground systems are the conduit and the utilidor types of systems. These systems are normally installed only in permanent heating installations because of their high cost of installation.

Conduit Type

In the conduit type of steam distribution system, the pipe is installed inside a conduit that is usually buried in the ground below the frost line. The frost line is the lowest depth that the ground freezes during the coldest part of the winter. The pipe used for steam is black steel pipe, which is not as strong as that required for condensate return lines. The conduit and insulation serve to protect and insulate the steam pipe. One type of conduit is shown in figure 3-1. The conduit must be strong enough to withstand the pressure of the earth and the usual additional loads imposed upon it.

Several types of materials and various designs are used in the manufacture of conduit. Common types of conduit are constructed of masonry cement, galvanized iron, and steel. The conduit is usually sealed with asphaltic tar or some other type of sealer to prevent water from getting into the insulation and deteriorating it. Insulation may be attached directly to the pipe, attached to the inner surface of the conduit, or in loose form and packed between the pipe and the conduit.

The bottom of the trench for the conduit should be filled with coarse gravel or broken rock to provide support and adequate water drainage. When water is allowed to collect, it seeps into the conduit through porous openings in the sealer. This wets the insulation and causes it to lose much of its insulating value. Manholes are required at intervals along the line to

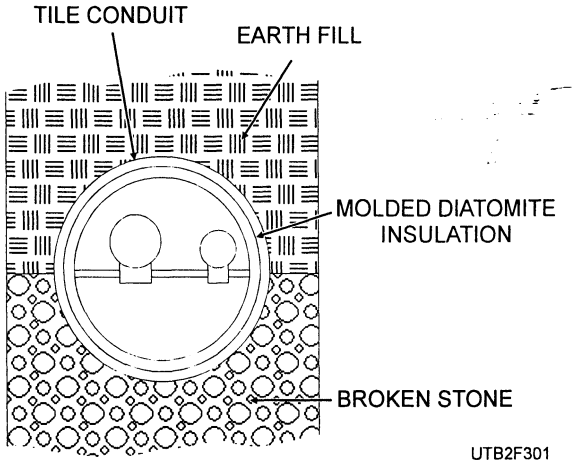


Figure 3-1.—One type of steam distribution conduit.

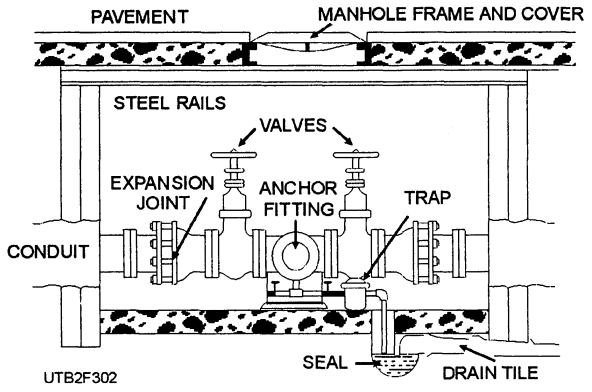


Figure 3-2.—A typical manhole for distribution system.

house the necessary valves, traps, and expansion joints. A typical manhole is shown in figure 3-2.

Utilidor Type

The utilidors, or tunnels, of the utilidor type of system are constructed of brick or concrete. The size and shape of the utilidor usually depend upon the number of distribution pipes to be accommodated and the depth the utilidor must go into the ground. Manholes, sometimes doors, are installed to provide access to the utilidor (tunnel). A typical utilidor is shown in figure 3-3. The utilidor is usually constructed so the steam and condensate return lines can be laid along one side of the tunnel on pipe hangers or anchors. This is usually done with the type of hanger with rollers that provides for free movement required by the expansion of the pipe. The other side of the utilidor should be a walkway that provides easy access to lines when you are inspecting and doing maintenance.

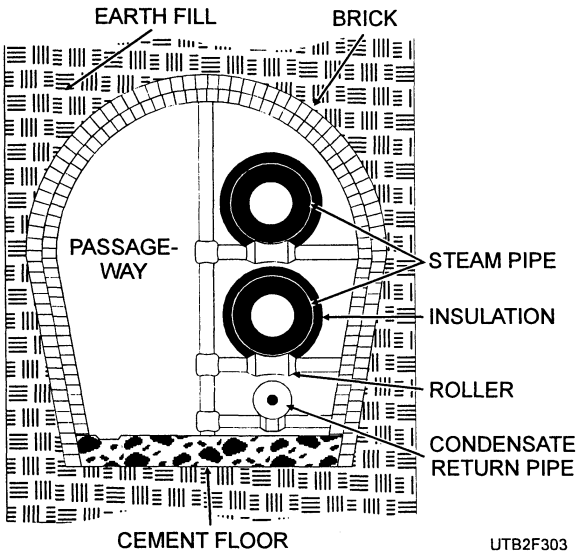


Figure 3-3.—A typical utilidor.

ABOVEGROUND SYSTEMS

Aboveground steam distribution systems are further divided into overhead and surface systems:

Overhead Distribution Systems

Overhead distribution systems are often used in temporary installations; however, they are sometimes used in permanent installations. The main drawback to this type of distribution system is the high cost of maintaining it. These overhead systems are similar in many respects to underground distribution systems. They require valves, traps, provision for pipe expansion, and insulated pipes. The main difference is that the steam distribution and condensate return piping are supported on pipe hangers from poles, as shown in figure 3-4, instead of being buried underground.

Surface Distribution Systems

In some cases, you will find that steam and condensate lines are laid in a conduit along the surface of the ground. These systems, however, are not as common as overhead and underground systems. Surface systems require about the same components as the overhead and the underground systems—traps, valves, pipe hangers to hold the pipes in place, and provision for pipe expansion. Sometimes an expansion loop, formed by a loop of pipe, is used instead of an expansion joint to provide for pipe expansion.

MAINTENANCE

The maintenance required for exterior distribution systems normally consists of inspecting, repairing, and replacing insulation, traps, valves, pipe hangers, expansion joints, conduit, utilidors, and aluminum or

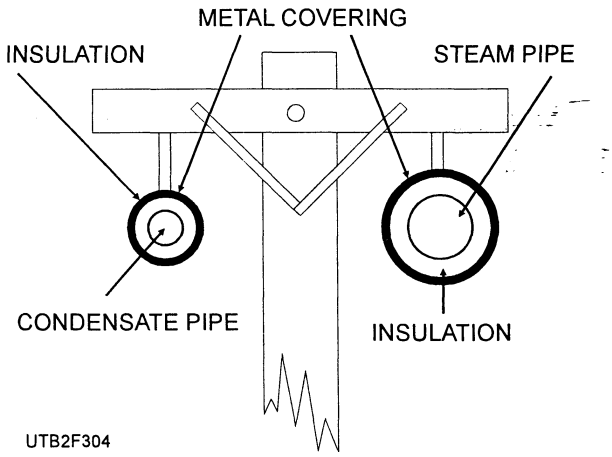


Figure 3-4.—Steam and condensate lines supported by poles.

distribution systems. The maintenance required on conduit and utilidors consists of keeping the materials of which they are constructed from being damaged and of ensuring that water is kept out of the tunnels and pipes. The maintenance required on outside metal coverings is about the same as that for the conduit and utilidors.

Q1. What are the two classifications of exterior steam distribution systems?

Q2. Conduit and utilidor steam distribution systems are normally installed as a permanent installation because of what reason?

Q3. What is the main disadvantage of an overhead steam distribution system?

INTERIOR STEAM DISTRIBUTION SYSTEMS

Learning Objective: Recognize types and configuration of interior distribution systems. Understand their basic installation, operation, and maintenance.

Interior steam distribution systems may be classified according to pipe arrangement, accessories used, method of returning condensate to the boiler, method of expelling air from the system, or the type of control used. The interior steam systems discussed in this chapter are classified according to pipe arrangment.

Steam may be fed to interior steam distribution systems from a boiler in the same building or from the exterior distribution system of a central plant.

GRAVITY, ONE-PIPE, AIR-VENT SYSTEM

The gravity, one-pipe, air-vent system, as shown in figure 3-5, is one of the oldest types of internal distribution systems. Its capacity is usually ample, and its installation cost is low. Because the condensate is returned to the boiler by gravity, this system is usually confined to one building and is seldom used as a central plant distribution system. The steam is supplied by the boiler and is carried by a single system of piping to the radiators. The return of condensate depends upon the hydrostatic head. Therefore, the end of the steam main, where the main is drained to the wet return, should be high enough above the waterline to provide the required hydrostatic head above the entrance to the boiler. The radiators in the system are equipped with an inlet valve and an air valve. The inlet valve is the radiator shutoff valve, while the air valve permits the venting of air from the radiators. Condensate is drained from the radiators through the same pipe that supplies the steam; they flow in opposite directions, however, which is a disadvantage. Under certain conditions, the condensate is held in the radiators. This causes noisy operation and a fluctuating water level in the boiler. Water hammer and slow heating are characteristic of this system when the pipe sizing, pitch, and general design are inadequate.

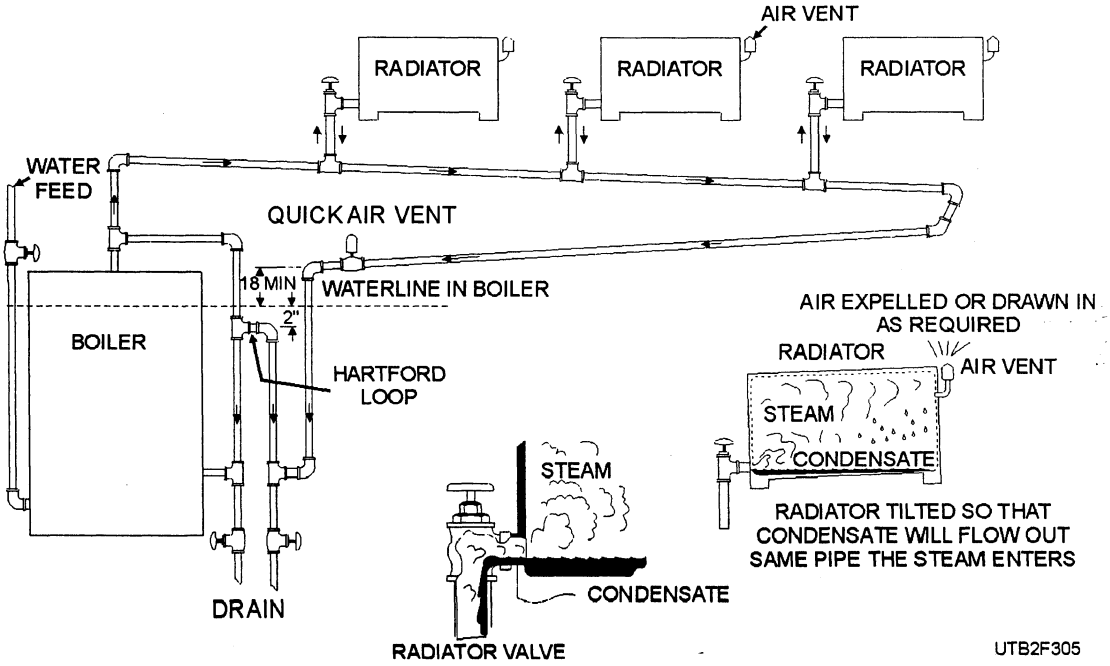


Figure 3-5.—A gravity, one-pipe, air-vent system.

Installation

Although all gravity, one-pipe, air-vent systems are alike in design, it is seldom that two installations are alike in detail. Since the details differ with the make and model of equipment, it is recommended that the manufacturer's installation procedures be followed. Also, you should follow the mechanical blueprints for a particular installation. There is some general information in this section that applies to most heating systems of this type.

To prevent water hammer and re-evaporation of the water, drain all condensate from the lines. The necessary internal drainage can be obtained by sloping the lines down, in the direction of condensate flow, at least one-fourth of an inch for every 10 feet of pipe. The radiators must also be tilted, so the condensate flows out of them into the same pipe through which the steam is entering.

Air vents are installed in the steam lines and radiators to eliminate air in the system. Air in the system tends to block the flow of steam, and it consequently acts as an insulator by preventing the emission of heat from the heating surface. Therefore, the air must be 'quickly and effectively vented from the heating equipment and steam lines to get quick and even heating from the steam-heating system. Most steam distribution systems are now fitted with automatic vents that permit the air to pass but which block the passage of steam. Figure 3-5 shows air vents in the radiator and the distribution system.

Operation

The operating instructions for gravity, one-pipe, air-vent systems vary from one installation to another. The manufacturer of the equipment usually furnishes the specific operating instructions for the equipment.

Generally speaking, most steam systems have a main steam stop valve located on the top of the boiler. The purpose of this valve is to hold the steam in the boiler until you are ready to let it out. When you are ready to turn the steam into the distribution system, you should only crack (open very little) the valve. The reason for doing this is to allow the system to warm up slowly and avoid any thermal shock to the lines and fittings. After the system has warmed up, the main steam stop valve should be opened slowly. While opening the valve, you should check often to ensure that the proper water level is maintained in the boiler.

You will also note that the radiator valves in one-pipe steam distribution systems should be either completely open or completely closed. Partial opening of the valve interferes with the proper drainage of water from the radiator.

Maintenance

In this portion of the text, the common problems you are most likely to encounter in the field when maintaining a gravity, one-pipe distribution system are discussed. The most probable causes of these problems and the remedies for them are considered.

When a radiator fails to heat or water hammer occurs, there are several probable causes. One is the failure of the air vents to function, thereby causing the radiator to become air bound. A second cause is that the radiator valves are not completely open. Another cause is that the radiators and lines are not correctly pitched. To remedy these causes of heat failure, you should inspect the operation of the air vents and the positions of the radiator valves to make sure they are open. You should then check and correct, if necessary, the pitch of the radiators and lines when the other checks do not correct the trouble.

A fluctuating waterline in the boiler can be caused by an excessive pressure drop in the supply lines, which, in turn, is usually caused by partial stoppage in the pipes. This, of course, can only be remedied by removing the cause of the stoppage. Uneven heat distribution is another trouble that you may encounter. This can be caused either by inoperative radiator vents, improperly vented steam mains, or incorrectly pitched mains. To eliminate this uneven heat distribution, you should check and clean the air vents at the radiator and those in the steam mains. Then check and correct, as required, the pitch of the steam lines if the other remedies have not corrected the trouble.

TWO-PIPE VAPOR SYSTEM WITH A RETURN TRAP

The two-pipe vapor system with an alternating return trap, as shown in figure 3-6, is an improvement over the one-pipe system. The return from the radiator has a thermostatic trap that permits the flow of condensate and air from the radiator. It also prevents steam from leaving the radiator. Because the return mains are at atmospheric pressure, or less, a mechanical return trap is installed in the system to equalize the condensate return pressure with the boiler pressure. The mechanical return trap is primarily a double-valve float

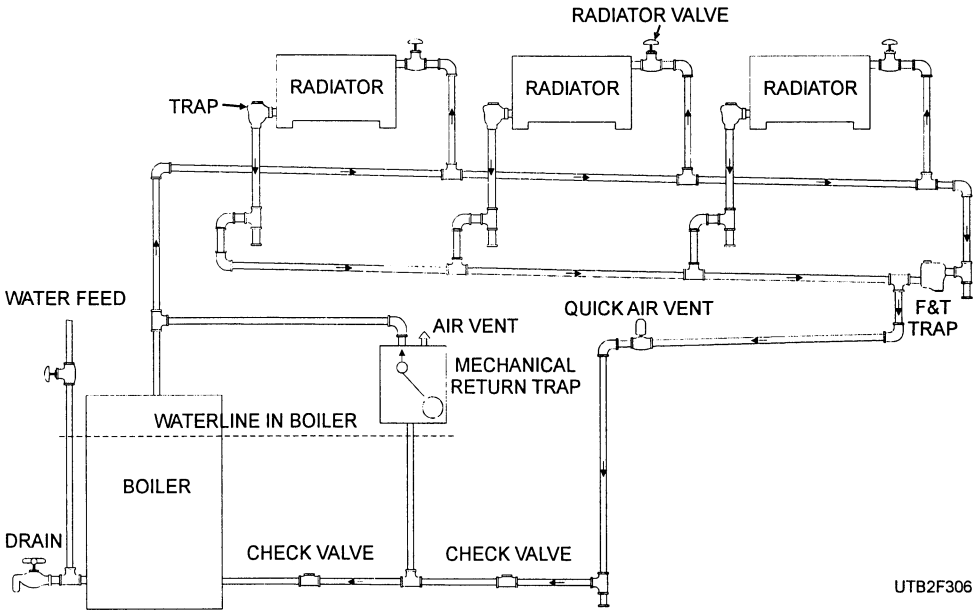


Figure 3-6.—A two-pipe vapor system with a return trap.

mechanism, which permits equalization of the boiler pressure and the pressure within the return trap.

Installation

Vapor-steam systems with return traps are similar in design. However, it is seldom that two installations are alike. Since the details differ with the type of heating equipment, it is recommended that the manufacturer's installation instructions be followed.

However, the mechanical return trap should be installed on a vertical pipe in the return system that is adjacent to the boiler. The top of the trap should be level with, or below, the bottom of the dry return main. The bottom of the trap should be approximately 18 inches above the boiler waterline to provide a sufficient hydrostatic head to overcome friction in the return piping to the boiler.

Operation

The two-pipe vapor system with a return trap alternately fills and dumps. It returns condensate to the boiler by a mechanical alternating-return trap instead of by gravity. The alternating-return trap consists of a vessel with a float that, by linkage, controls two valves simultaneously so that one is closed when the other is open. One valve opens to the atmosphere; the other is connected to the steam header. The bottom of the vessel is connected to the wet return.

In operation, when the float is down, the valve connected to the steam header is closed and the other is open. As the condensate returns, it goes through the first check valve and rises into the return trap, which is normally located 18 inches above the boiler waterline. The float starts to rise when the water reaches a certain level in the trap, the air vent closes, and the steam valve opens. This action equalizes the trap and boiler pressures and permits the water to flow by gravity from the trap, move through the boiler check valve, and go into the boiler. The float then returns the trap to its normal vented condition, ready for the next flow of returning water.

Maintenance

The problems you are likely to encounter in maintaining the two-pipe vapor system with a return trap will differ with each system. Some of the more common troubles are discussed here. For specific instructions, you should refer to the manufacturer's manual or pamphlet pertinent to each piece of equipment.

When a radiator fails to heat, the air vent being plugged or the radiator being waterlogged because of a plugged or defective trap can cause the condition. In case there is a plugged air vent, all you need to do is clean it. When there is a waterlogged radiator, the trap should be checked to determine if it is plugged; also you should check to see if the bellows is serviceable. If the trap is plugged, then cleaning it should solve your problem. However, if the trap is damaged, the damaged part, or the whole trap, must be replaced.

When the entire steam distribution system fails, the trouble can be caused by inoperative return traps or

inoperative check valves. The return traps and the check valves should be cleaned and inspected; and, if necessary, the defective parts or the whole unit should be replaced.

TWO-PIPE VAPOR SYSTEM WITH A CONDENSATE PUMP

The two-pipe vapor system with a condensate pump, as shown in figure 3-7, is similar to the two-pipe vapor system with the return trap, except that the condensate is returned to the boiler by a power-driven centrifugal pump, instead of by a return trap. This system includes a separate main, a radiator feed at the top, and a return system with thermostatically trapped outlets located at the bottom of the radiators opposite to the feed end. The return main terminates at the receiver of the condensate pump, where all of the air in the system is discharged to a vent on the receiver. With the use of a condensate pump, all of the returns to the pump are kept dry and the radiators can be located below the boiler waterline. This is not possible with the steam distribution systems previously described. The radiators should be installed above the return main to permit gravity flow of the condensate from the radiator, and the return main should pitch downward to the pump receiver.

Installation

Two-pipe vapor systems with condensate pumps are basically alike in design. However, since two installations are seldom alike, it is necessary to install each system according to the mechanical blueprints furnished by the civil engineer and the instructions of the manufacturer of the equipment.

Operation

The two-pipe vapor steam distribution system can be operated at the pressure limit of the steam plant boiler, provided the condensate pump is designed for sufficient discharge head necessary to overcome discharge pipe friction loss, boiler pressure, and the hydrostatic head between the pump outlet and the waterline of the boiler. The ends of the steam mains are drained and vented into the dry return main through a combination float and thermostatic trap.

The two-pipe system with a condensate pump is adapted to relatively large installations and is probably the most practical and trouble-free system. Most vapor systems differ somewhat with each installation. For specific instructions for the correct operating procedures, you should refer to the manufacturer's instructions for the specific type of equipment installed.

Maintenance

Most of the two-pipe vapor steam distribution systems differ from one system to another. Therefore, you will encounter different maintenance problems with each system. It is not feasible to try and cover all of the problems you might encounter with different systems of this type. However, the more common ones are discussed.

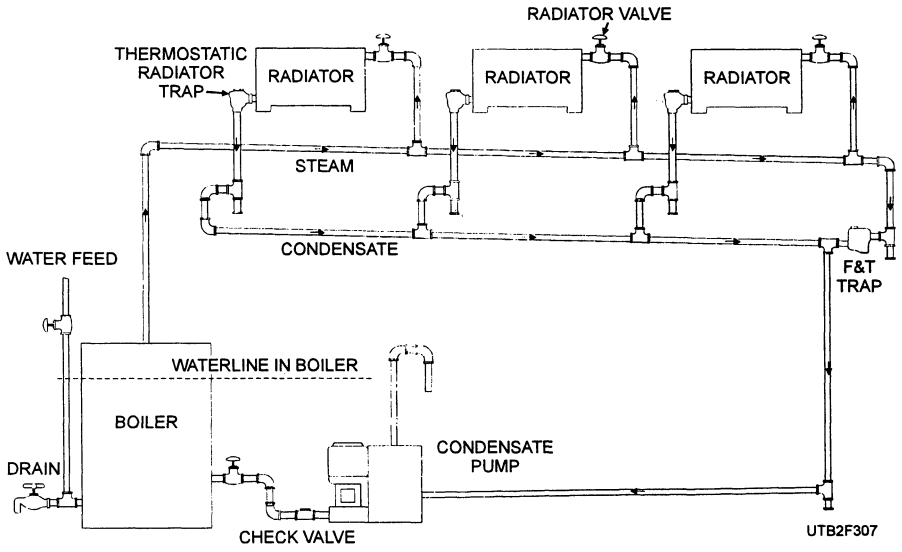


Figure 3-7.—A two-pipe vapor system with a condensate pump.

When you find that the individual radiator fails to heat, either an inoperative steam trap or a radiator that is not installed correctly can cause the trouble. Repairing or replacing the steam trap or correcting the improper installation of the radiator can eliminate these troubles.

When it is the whole distribution system that fails to heat, clogged or closed receiver vents can cause the trouble, a flooded return line, the lack of pump capacity, or air binding the system. These troubles can be remedied by opening the vents, checking and adjusting the pump cut-in, replacing the pump, or repairing inoperative rerun traps.

One common trouble that occurs in this type of distribution system is the overflow of water from the receiver vent. An inoperative pump usually causes this condition. The pump may be causing the flooding because of its inadequate capacity or because it is unable to handle the volume of condensate required. This condition can be corrected by either repairing or replacing the pump.

Another cause of overflow of water from the receiver vents is an obstruction in the line between the condensate receiver and the boiler. The trouble can be remedied by eliminating the obstruction, regardless of whether it is a closed valve or a clogged line.

TWO-PIPE VAPOR SYSTEM WITH A VACUUM PUMP AND A CONDENSATE RETURN

The two-pipe vapor distribution system with a vacuum pump and a condensate return, as shown in figure 3-8, is similar to the two-pipe vapor system with a condensate pump. The piping in this system includes separate steam and return mains.

Installation

Most vapor distribution systems with vacuum pumps and condensate returns are similar. However, it is seldom that two steam distribution installations are alike in detail. When installing vapor-heating distribution systems, it is advisable to refer to the manufacturer's recommendations, civil engineer mechanical drawings, and specifications for the proper installation procedures.

Operation

When this type of distribution system is operated, the steam is supplied at the top of the radiator and the air and condensate discharged through a thermostatic trap from the bottom of the opposite end of the boiler. All returns are dry and terminate at the vacuum pump. The vacuum pump is usually a motor-driven unit, although low-pressure steam turbines have been successfully used to a limited extent. The vacuum pump returns the condensate to the boiler and maintains the vacuum or subatmospheric pressure in the return system. The maintenance of a vacuum in the return system (3 to 10 inches of water) enables almost instantaneous filling of the heating units at low steam pressure (0 to 2 psi) since air removal is not dependent upon steam pressure.

The vacuum pump withdraws the air and water from the system, separates the air from the water, expels the air to the atmosphere, and pumps the water to the

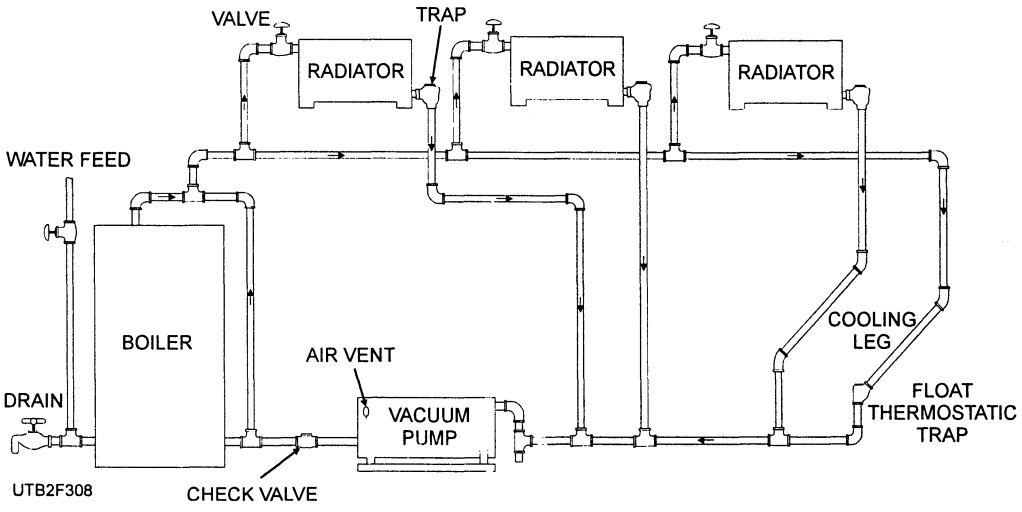


Figure 3-8.—A two-pipe vapor system with a vacuum pump.

boiler, feedwater heater, or surge tank. Usually, the vacuum pump is supplied with a float switch as well as a vacuum switch, and it can be operated as a condensate pump unit. The float switch should be used only when the vacuum switch is defective, and then only until the defects can be repaired or corrected.

This system can be used in all types of buildings, and it is of particular advantage for the satisfactory operation of indirect radiation units, heating coils, and ventilating units, and for other units that requires close automatic control. *Indirect radiation* is a term applied to warm-air heating systems that receive their heat from steam supplied to their heat exchanger coils.

Maintenance

When considering the subject of maintenance on a two-pipe vapor distribution system having a vacuum pump, you will find that most of the troubles that have previously been discussed also apply to this system. In this distribution system, however, keeping air from leaking into the system is more of a problem than in the other distribution systems. Excessive air leakage often causes the pump to run all the time, or the leakage can cause the system to fail to heat altogether. To eliminate -air leakage, you must find the point where air is leaking and repair it, so air cannot get into the system. Rusty spots and water seepage usually indicate the points at which air is leaking into the system.

Q4. On a gravity, one-pipe, air vent system, the return of condensate to the boiler depends on what factor?

Q5. Air in a one-pipe system has what adverse effects?

Q6. What is the major difference between a two-pipe system with a return trap and a two-pipe system with a condensate pump?

Q7. What is the function of the vacuum pump on a two-pipe vapor system?

STEAM DISTRIBUTION SYSTEM COMPONENTS

Learning Objective: Recognize different system components and understand their basic operation, application, and maintenance.

In previous sections of this chapter, you read about various components as you studied the various distribution systems. The components were only mentioned, however, and not explained in detail. Therefore, in this section, we are going to discuss these components, their purpose, operation, and maintenance.

RADIATORS

Steam radiators. are normally classified into two categories. One is the fin-tube radiator, which consists of a metal tube that has metal fins attached on the outside to increase its total heating surface. It generally has a valve at one end and a trap at the other end. This radiator has been used more extensively in the past 15 years. It is readily adaptable to areas where floor space is limited, since the radiator is normally mounted on the walls. The second category is the cast-iron radiator, which is made in sections. A typical cast-iron radiator is shown in figure 3-9. These radiators are similar to those used in hot-water heating systems. The cast-iron radiator is generally used in the one-pipe distribution system. In this system, there is only one distribution pipe connected to the radiator. This pipe delivers steam to the radiators, and it also returns water from the condensed steam to the boiler. For this reason, the radiators must be tilted slightly toward the distribution pipe.

The radiators in a two-pipe steam distribution system are connected to the boiler by means of a distribution pipe as well as by a condensate return pipe. Since the steam and condensate in this system flow in separate pipes, the pipes are smaller than those required for the same size radiator in a one-pipe system. The radiator outlet is usually equipped with a steam trap that prevents steam from leaving the radiator until it condenses into water.

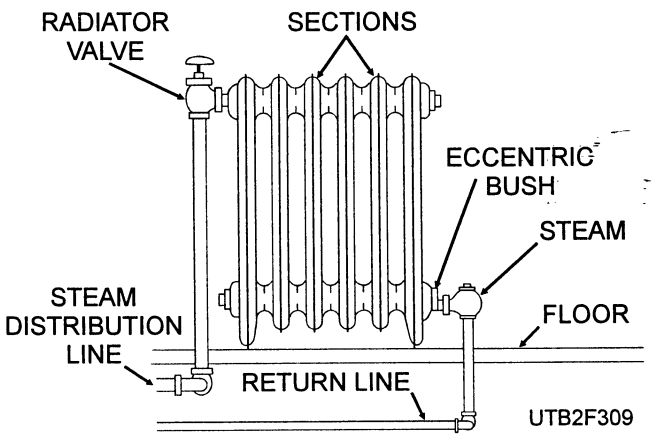


Figure 3-9.—A typical cast-iron radiator.

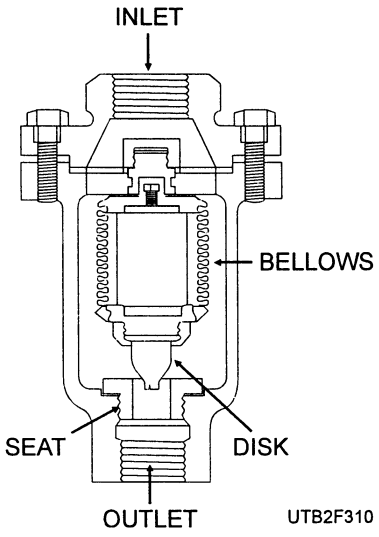


Figure 3-10.—A typical automatic air vent.

RADIATOR AIR VENTS

There are two types of radiator air vents: automatic and manually operated. A typical automatic air vent is shown in figure 3-10. Air vents are installed to remove air from the radiators, because air keeps the radiator from heating properly.

The type of air vent shown consists of a hermetically sealed bellows, a valve disk and seal, and a vent body. The bellows contains a volatile liquid with a boiling point 10°F or lower than that of water. So, when this liquid is heated to a temperature 10°F below the steam and water temperature, the liquid volatilizes, expands, and closes the valve. When air surrounds the bellows, the air is cooler than the steam. This causes the bellows to contract, to open the valve, and to allow the air to escape. This cycle then starts over again.

The type that is operated manually is usually a small valve that has a slotted screw incorporated in the stem and a little spout on one side for the discharged air. These manual vents are normally installed in the same place in the distribution system as automatic vents.

STEAM TRAPS

Steam traps are designed to retain the steam in a radiator or other using device until it changes into condensate. After the steam has turned into condensate, the trap releases the water so it can enter the return lines. However, it keeps the steam coming into the radiator from escaping. The trap performs an important function, since the excessive accumulation of water prevents the proper heating of the radiator or other steam equipment. Also, steam that is permitted to blow through a defective trap results in heat loss.

Types of Traps

Traps are generally classified according to their operation. The most common types of traps are float, bucket thermostatic, float thermostatic, impulse, thermodynamic, throttling, and bimetallic element.

FLOAT TRAP.—The float trap normally consists of a body, float, linkage, seat, and valve. A typical float trap is shown in figure 3-11. As water enters the trap, the float rises, opens the valve, and allows the accumulation of water to flow into the return lines that take it to the boiler. When the water has run out, the float falls, closes the valve, and traps the steam.

The maintenance to be done on a float trap is of a simple nature. One of the most common difficulties is that of the float getting water in it and not rising. In this case, the float must be replaced. The valve sometimes gets plugged or worn and has to be cleaned or replaced.

BALL-FLOAT TRAP.—In a ball-float trap, the valve of the trap is connected to the float so the valve opens when the float rises. When the trap is in operation, the steam and water that may be mixed with it flow into the float chamber. As the water level rises, the float is lifted, thereby lifting the valve plug and opening the valve.

The condensate drains out and the float moves down to a lower position, closes the valve. The condensate that passes out of the trap is returned to the feed system.

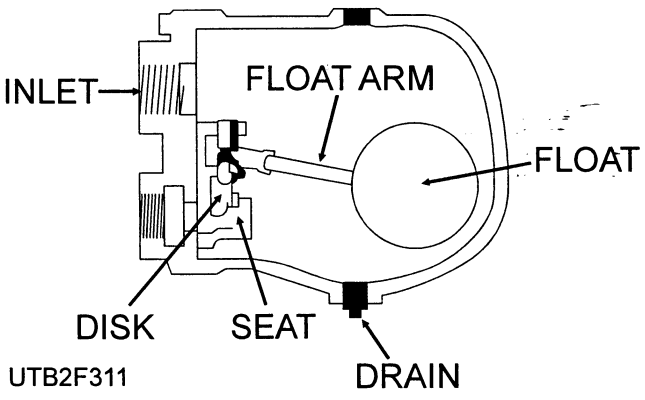


Figure 3-11.—A typical float trap.

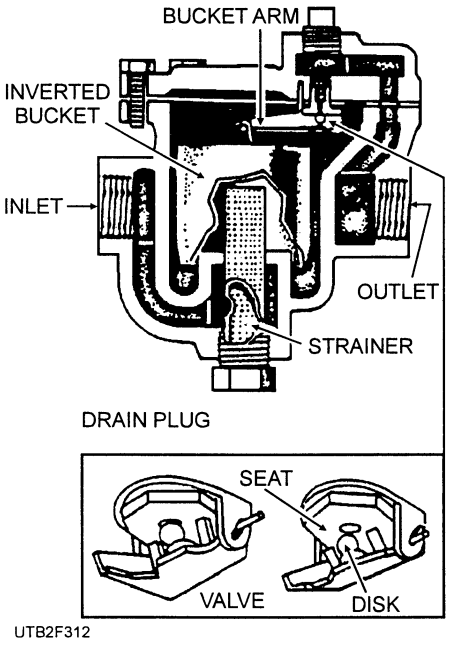


Figure 3-12.—An inverted bucket trap.

BUCKET TRAP.—There are two types of bucket traps: the upright and the inverted. An example of the inverted bucket trap is shown in figure 3-12.

During operation of the upright bucket trap, the steam and water both enter the trap body. As the water enters, it causes the bucket to float and the valve to close. The water continues to rise; it overflows into the bucket that sinks. When the bucket sinks, the trap valve is opened and the steam pressure forces the water out. When all of the water is expelled from the bucket, the bucket again floats, the valve closes, and the cycle starts again.

During the operation of the inverted bucket trap, the steam and water both enter under the bucket. The steam makes the bucket buoyant, causes it to rise, and closes the valve. When the steam condenses, the bucket drops, opens the valve, and the steam blows the water out of the trap.

Maintenance on bucket traps consists mainly of cleaning and inspecting them periodically. If the trap begins to leak steam, replace the valve disk and seat. However, if the bucket fails to open the valve, the trap usually becomes waterlogged. When a valve disk or seat becomes damaged, the trap allows steam to leak through. The condensate return line becomes excessively hot when the trap is leaking steam. Bucket traps contain some water at all times. Therefore, they must be drained when the system is to be off during freezing weather.

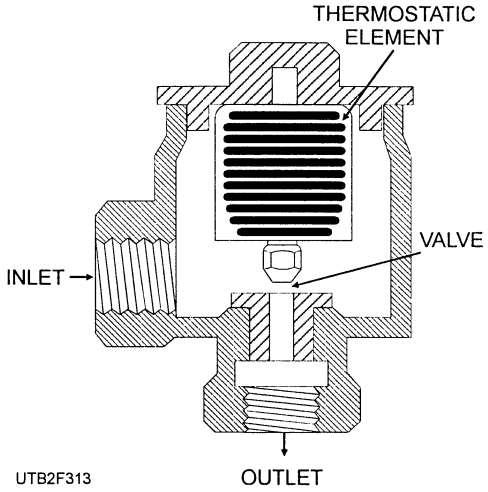


Figure 3-13.—A typical thermostatic trap.

THERMOSTATIC TRAP.—The thermostatic trap is often used on radiators and is commonly known as a radiator trap. It has a bellows that contains volatile fluid that expands and vaporizes when heated. Pressure builds up inside the bellows and causes it to lengthen and close the valve. A typical thermostatic trap is shown in figure 3-13.

When water collects around and cools the bellows, the bellows contracts. This action opens the valve and permits water to escape. As the water goes out, the steam that enters contacts the bellows and causes it to expand, closing the valve and preventing the steam from escaping.

The most common trouble with the thermostatic trap is that the bellows develops holes. So, the bellows does not work and has to be replaced. The bellows and lower valve seat can be removed for repair without disconnecting any of the piping.

FLOAT THERMOSTATIC TRAP.—The float thermostatic trap operates on the principle of the float trap and the thermostatic trap. Practically the same maintenance is required. A typical example of the float thermostatic trap is shown in figure 3-14. The thermostatic bellows acts as an air eliminator.

IMPULSE TRAP.—The operation of the- impulse trap (fig. 3-15) is based on the principle that a portion of hot water, under pressure, flashes into steam when its pressure is reduced. The trap is operated by a moving valve impelled by changes of pressure in a control chamber. The valve has tiny orifices drilled through its center that allow the continuous bypassing of condensate from the inlet of the trap to the control chamber. This bypassing reduces the chamber pressure below the inlet pressure, so the valve opens and allows

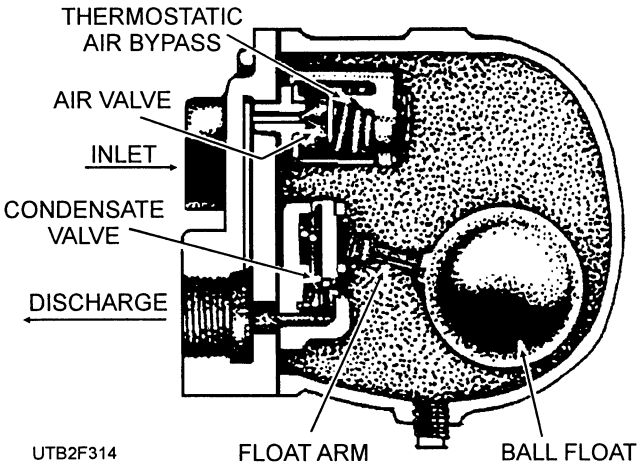


Figure 3-14.—A float thermostatic trap.

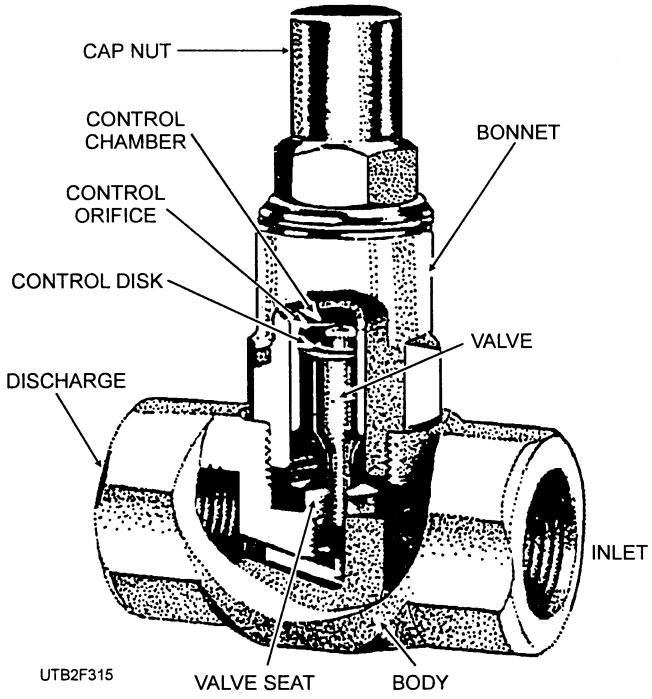


Figure 3-15.—An impulse trap.

free discharge of the condensate. The temperature of the remaining condensate rises and flashes back to steam. The flow through the valve orifice is choked and pressure builds up in the control chamber, closing the valve.

About 5 percent of the rated capacity of the trap flows through the valve orifice. The pressure on the discharge side of the trap should not be over 25 percent of the inlet pressure if the trap is to function properly. Very little maintenance, except some periodic cleaning, is required for the impulse trap. The trap may be disassembled for cleaning or repairing without disturbing any of the piping.

THERMODYNAMIC TRAP.—A typical thermodynamic trap is shown in figure 3-16. It contains only one moving part—a disk. This disk is operated by changes in steam pressure. Pressure under the disk raises it to allow the condensate to be discharged. Droplets of condensate form on top of the disk. Then steam enters at high velocity and creates a low pressure under the disk; the droplets of water above the disk then flash into steam and create a high pressure above the disk. (You recall that water expands to as much as 1,728 times its volume when it changes to steam.) The high pressure against the top of the disk overcomes the lower pressure of the incoming steam, so the trap closes. As more condensate collects in the trap, the steam above the disk condenses and relieves the high pressure and the cycle is repeated.

The most common trouble is that the trap becomes plugged and has to be disassembled and cleaned. The thermodynamic trap can be cleaned or repaired without disturbing any of the piping. Very little other

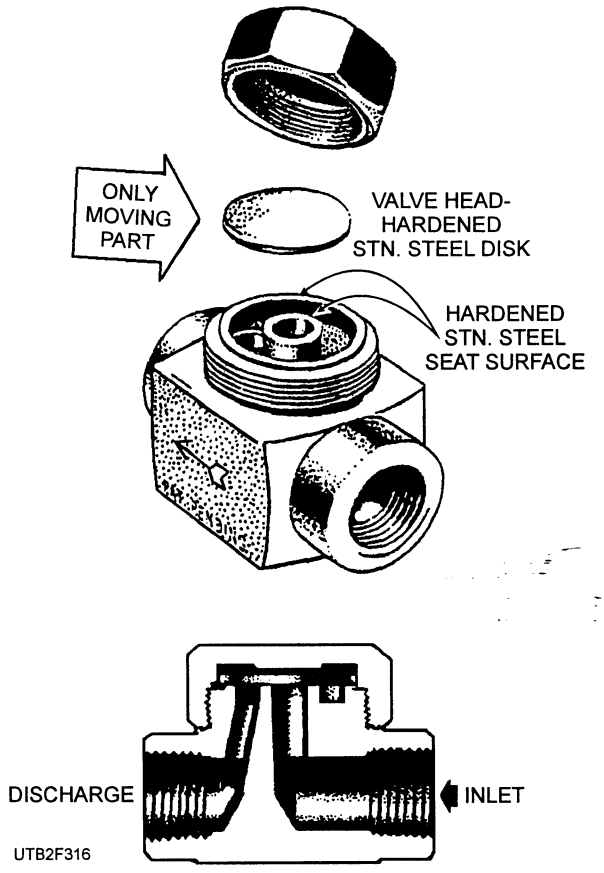


Figure 3-16.—A thermodynamic steam trap.

maintenance is required for this trap because of its simple construction. Too, the trap is usually constructed of stainless steel.

THROTTLING TRAP.—The operation of the throttling trap (fig. 3-17) is based on the principle that the flow of water through an orifice decreases as its temperature approaches that of the steam used. The rate of flow of the condensate may be adjusted by raising or lowering a stem (needle valve) that fits into a tapered seat. This throttling trap has no moving parts.

Condensate that is slightly cooler than steam enters the trap, travels up through a baffle arrangement, and is discharged through an orifice. If the condensate discharge rate is higher than the inlet rate, the water (condensate) level in the chamber drops. This allows steam to enter the baffle passage and heat the condensate. The amount of water flashing into steam increases; so the volume of steam-water mixture handled by the orifice increases and thereby reduces the capacity of the orifice. The reduced flow through the orifice permits the level of condensate in the chamber to rise until the heater water in the baffle passage has been completely discharged and replaced with water that is slightly cooler. Then the cycle is repeated. Air is vented from this trap through the same passage as the condensate.

The throttling trap can be replaced without disturbing any of the piping.

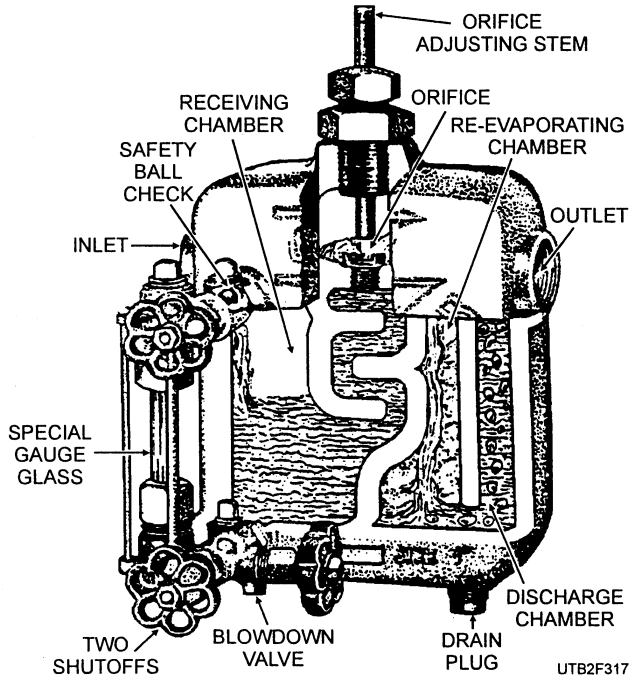


Figure 3-17.—A throttling trap.

BIMETALLIC-ELEMENT TRAP.—The bimetallic-element trap, as shown in figure 3-18, contains bimetallic elements that bend when heated. The metals in the bimetallic strip generally are Emvar and copper. The copper expands rapidly when heated, but Emvar expands very little. Therefore, the bimetallic strip bends when it is heated. This trap may be used for higher or lower steam pressure by increasing or decreasing the number of bimetallic leaves in the trap.

This trap works basically the same as the thermostatic trap. When steam enters the trap, the element is heated and bends, thus closing the valve. As steam condenses, the elements cool and straighten out to allow the valve to open and let the condensate escape. The bimetallic trap can be repaired without disturbing any of the piping.

Pointers on Operating Procedures

To help ensure trouble-free service of steam traps, follow the proper operating procedures carefully. Some important factors involving operating procedures are furnished below.

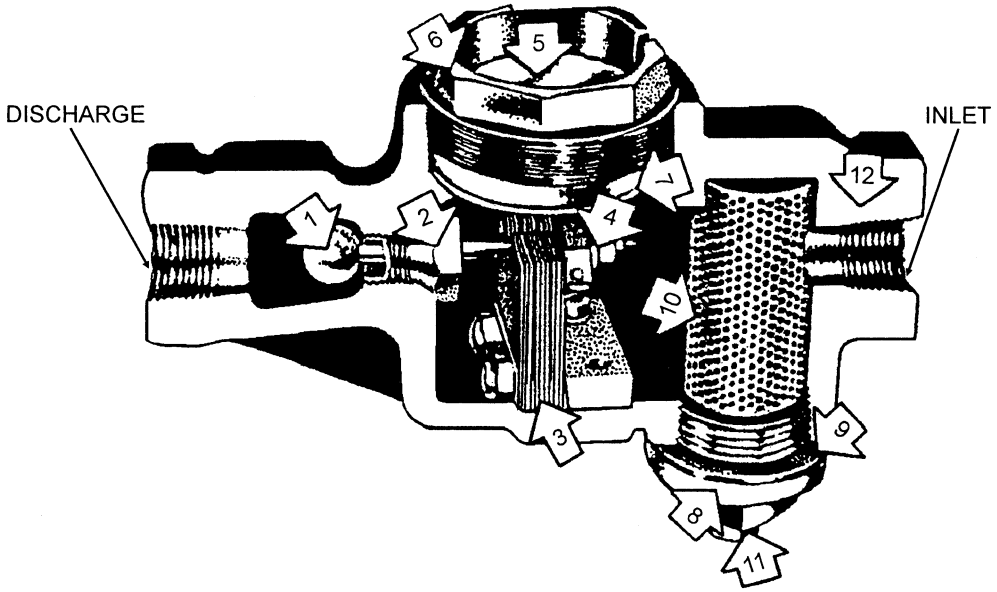
- Steam traps should be operated within the capacity rating and pressure differentials recommended by the manufacturer. Use traps for the correct pressure and temperature. If operating pressures change, it may be necessary to change trap sizes, or internal parts, to fit the new pressure conditions.

- Traps should be insulated where heat must be conserved. Some types of traps, which depend on the cooling effect of the condensate for operation, should be left bare. Check the manufacturer's instructions regarding insulation.

- Where continuity of service is a requirement, a three-valve bypass is usually provided to permit drainage while the trap is being overhauled. Bypasses are also used to speed up the discharge of condensate and air when you are starting a system. In normal operation, however, the bypass valve should be kept closed to prevent steam from being wasted.

- Check valves, located in the discharge line, are important in parallel installations to prevent the discharge of one trap from backing up into that of another. Also, when condensate from the trap must discharge to a higher elevation, a check valve prevents backflow of condensate.

- Inverted bucket traps must be primed for operation by providing a condensate seal in the bottom



1. BALL VALVE, CHROME STEEL, MIRROR FINISH
2. VALVE SEAT, CORROSION-RESISTANT STEEL
3. BIMETALLIC THERMAL UNIT
4. DISCHARGE TEMPERATURE SETTER
5. OPTIONAL OBSERVATION GLASS, HEAT RESISTANT
6. COVER PLATE
7. GASKETS, ASBESTOS-METAL
8. REMOVABLE STRAINER PLUG
9. GASKET, ASBESTOS-COPPER RING TYPE
10. STRAINER BASKET, PHOSPHOR BRONZE MESH OR CORROSION-RESISTANT STEEL
11. DRAIN PLUG FOR CLEANING WHILE IN OPERATION
12. BODY, SEMI-STEEL, CAST STEEL, OR ALLOY STEEL

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Figure 3-18.—A bimetallic-element steam trap.

of the trap. Prime the trap before starting operation by removing the test plug on top of the trap and filling the trap with water. If no test plug is available, the trap can be primed by closing the discharge valve and opening the steam supply valve slowly until the steam is condensed and the trap is filled with condensate.

- Blow down steam traps periodically to rid them of dirt and sediment. Blow down and clean strainers as required.

- When overhauling traps, do not remove thermostatic elements while hot. This practice may result in expansion beyond the stroke range of the bellows or diaphragm.

- Periodically, open the air vents of float traps not provided with thermostatic air vents to vent out accumulated air.

Steam Trap Tests

Methods for testing traps without breaking the installation are stated below:

TEST VALVE METHOD.—Close the discharge valve and open the test valve. Observe discharge characteristics. Intermittent discharge, dribble, or semicontinuous discharge indicates correct operation. A continuous steam blow indicates loss of prime, defective valve operation, or foreign matter embedded in the valve seat. A continuous condensate flow may indicate that the trap is too small, the amount of condensate abnormally high, or a pressure differential that is too low.

GLOVE TEST METHOD.—Grab inlet and outlet pipes simultaneously, using a canvas glove on each hand for protection. A slight temperature difference indicates that no condensate is passing.

PYROMETER TEST METHOD.—This method is more accurate than the previous one, as it uses a surface contact pyrometer to check inlet- and outlet temperatures. File a clean spot on both pipes before taking readings.

PYROMETRIC CRAYON TEST METHOD.—Temperature-indicating crayons can be used when no pyrometer is available. Select crayons of proper temperature ratings and mark the required pipe spots. When the crayon marks melt, the temperature of the test spots corresponds to those of the crayon ratings.

EAR TEST METHOD.—Hold one end of a metal rod to the trap body and place the other end in the ear, or use an engineer's stethoscope. If the trap is operating properly, you will hear the regular opening and closing of the valve. If operation is defective, you will hear considerable rattling or the continuous flow of steam.

PROTECTION AGAINST FREEZING.—Protect traps from freezing in cold weather. If the steam is shut off during freezing weather, drain the traps and piping of all condensate. Make certain insulation is in good condition. The inverted bucket is especially prone to freezing because, in normal operation, it is half filled with water.

WATER TANKS

A boiler plant and heating system cannot be operated so the flow of water and the flow of steam are always in balance. The demand for water by the boiler may exceed the rate at which water is being returned from the heating system, or the water may be returning at a rate that is greater than the requirements of the boiler. One or more tanks can be installed to compensate for uneven flows and for differences between the demand and supply of water. These vessels are called surge tanks.

Sudden reductions in pressure may lead to violent steam formation. Flash tanks help eliminate disturbances in the piping system caused by this process. These tanks are usually small and are located near the traps where the pressure release occurs.

Unit steam heaters are convection heaters in which the air is circulated by means of a fan. The unit heater is similar to an automobile radiator. It is enclosed in a sheet metal case with the fan mounted at the rear. A typical unit heater is shown in figure 3-19. The steam enters the unit at the top and the heat is transferred to the fins of the heater. The fan blows the air over the fins and out into the space to be heated. When the steam condenses, the steam trap, usually a float thermostatic type, allows the condensate to drain into the condensate return line. A strainer is installed just ahead of the trap to help keep foreign matter out of the trap.

Unit heaters are usually suspended from the ceilings of shops, offices, dining halls, and warehouses. This type of installation saves on floor space, provides for rapid heating, and gives wide distribution of heat.

Unit heaters should be taken down periodically and cleaned, because dust and lint collect between the fins and reduce the flow of air.

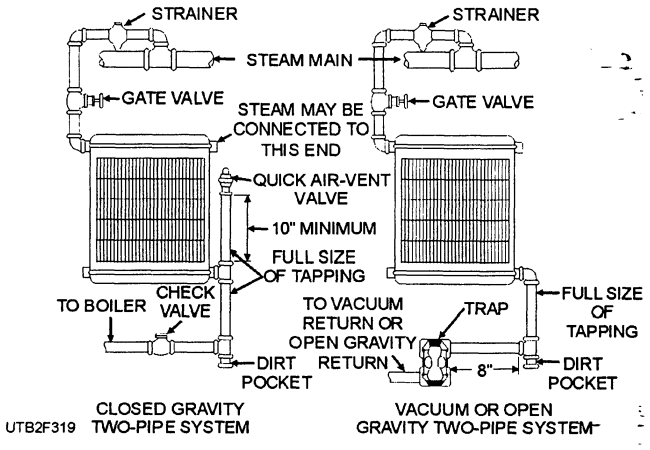


Figure 3-19.—A typical unit heater installation.

WATER HEATERS

Steam-operated water heaters are used to supply hot water for laundries, dining halls, latrines, and other facilities. There are two general types of these heaters: storage and instantaneous.

Storage Type

The storage type of water heater is used to provide potable (drinking) water. The steam-operated storage type of water heater consists of a steel tank that contains a steam-heating coil like that shown in figure 3-20. The hot-water tank is connected to the base water supply system and remains full of water at all times.

The steam is circulated through the heating coil or "bundle," as it is sometimes called. The heat from the steam is transferred through the walls of the coil to the water in the tank. Because of the difference in weight between hot and cold water, the hot water rises and the cold water goes to the bottom of the tank where the

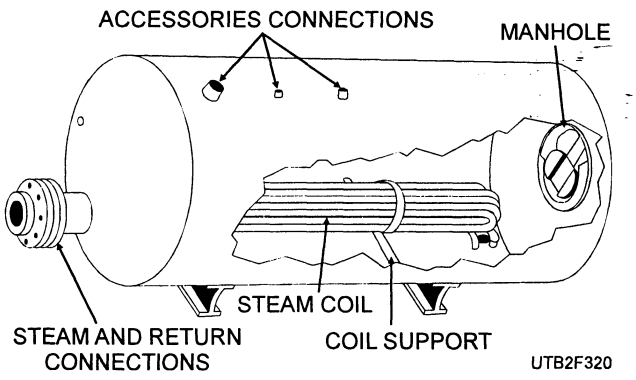


Figure 3-20.—The storage-type water heater.

steam-heating coil is located. Here the water is heated and begins to circulate. Eventually, all of the water in the tank becomes heated. When hot water is drawn, more cold water enters the tank and this heating process repeats itself. This action maintains a full tank of hot water for use whenever hot water is needed. According to safety regulations, the hot water should not exceed 180°F. The storage type of water heater may be constructed to be installed in either the horizontal or the vertical position.

Tappings are usually provided in the tank for a thermometer—a thermostatic element for a temperature-regulating valve (which will be discussed later in this chapter) and a safety valve. The tube coil should be inspected annually to make sure steam is not leaking into the water. The chemicals that are sometimes used in the steam may make the people who use the water sick if they drink it.

Instantaneous Type

Instantaneous heaters are used primarily as boiler feedwater heaters; however, they are sometimes used to provide potable (drinking) water at some installations. The operation of the instantaneous-type heater is basically the same as the storage-type heater; their construction, however, is quite different. The diameter of the instantaneous heater is small in comparison to the storage-type heater. The outer shell of the instantaneous heater is small in comparison to the storage-type heater. The outer shell of the instantaneous heater barely covers the tube coil, as you can see in figure 3-21. In some makes, the water is circulated through the coil, and the steam is released in the shell and surrounds the coil. A temperature-regulating valve controls the water temperature for both types of heaters.

TEMPERATURE REGULATORS

The temperature regulator is used to regulate the quantity of steam necessary to maintain the hot water at the desired temperature. The unit consists of a temperature bulb, copper line, diaphragm, spring and temperature adjustment, and steam valve. A typical temperature-regulating valve is shown in figure 3-22.

The bulb and copper tube are called the capsule and capillary tube. They contain a gas that expands or contracts with a change in temperature. The capillary tube is connected to the top of the temperature regulator which contains a diaphragm (bellows). The diaphragm (bellows) is connected to the valve stem. A spring holds the valve open at low temperatures. When the temperature rises in the water tank, the gas in the temperature bulb expands and forces the diaphragm down, closing the steam valve. Adjusting the tension of the spring can control the water temperature. A steam trap in the steam-heating system returns the condensed steam to the condensate tank.

The hot-water tank accessories consist of a temperature gauge that has a range of 40°F to 210°F and a safety valve or pressure relief valve. The relief valve is set at a pressure that is 10 pounds higher than the operating pressure, and both the setting and the valve must comply with current ASME code specifications.

CONDENSATE RETURN PUMP

Condensate return pumps cause the water that has condensed from the steam in radiators, heating coils, convectors, and unit heaters to circulate back to the boiler. One type of condensation return pump is shown

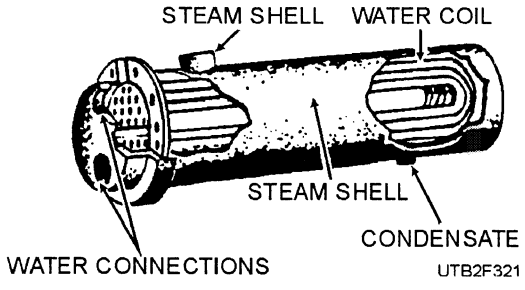


Figure 3-21.—The instantaneous-type water heater.

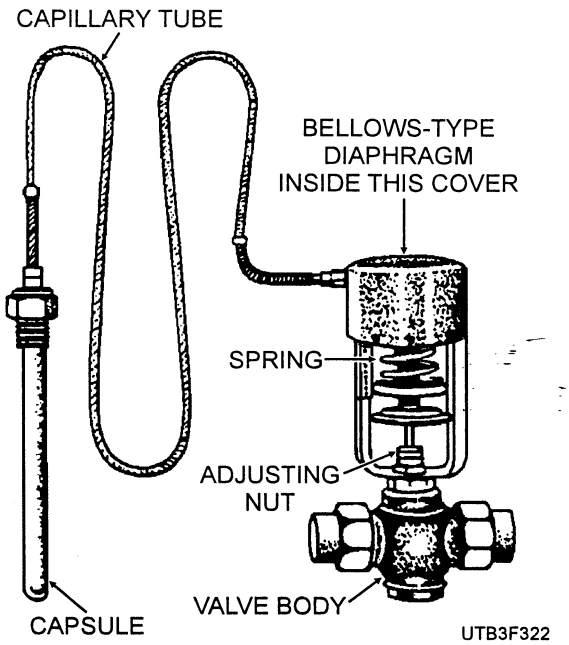


Figure 3-22.—A typical temperature-regulating valve.

in figure 3-23. Units of this type normally consist of a receiver or condensate tank and pump independently controlled by float switches. A check valve and a vent on the receiver allow the receiver to fill and empty as the need arises.

Condensate return pumps are maintained as prescribed by the manufacturer of the unit. Usually, the motor should be oiled, the check valves and vents cleaned, the float switches adjusted, the pump repacked, and the tank cleaned at least once each year.

EXPANSION JOINTS

Expansion joints and expansion loops in long heating lines are convenient devices for handling the pipe elongation caused by expansion. The five major types of expansion joints are as follows: slip joint, bellows joint, swing joint, expansion loop, and ball joint.

The slip joint is shown in figure 3-24. The female part of the joint is placed over the male part and the joint is held tight by the packing that permits expansion. The kind of packing used determines the temperature to which the joint can be subjected.

The bellows joint, as shown in figure 3-25, has a metal bellows that flexes as expansion occurs. The joint

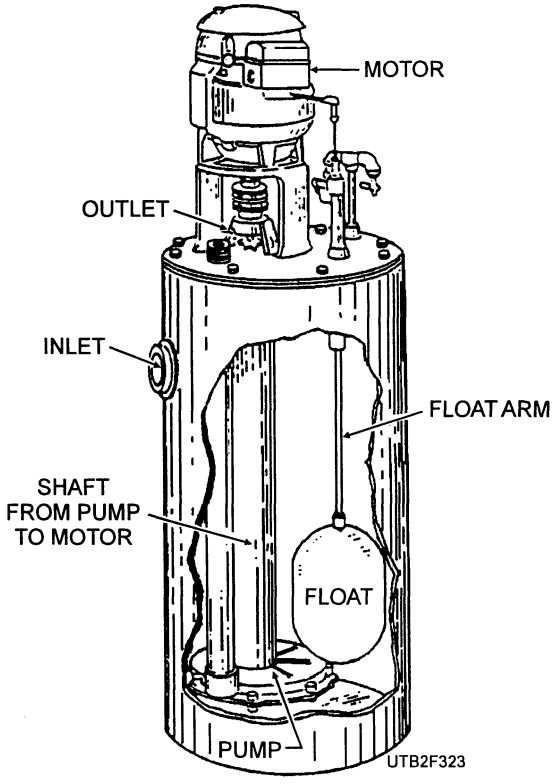


Figure 3-23.—A typical condensate return pump.

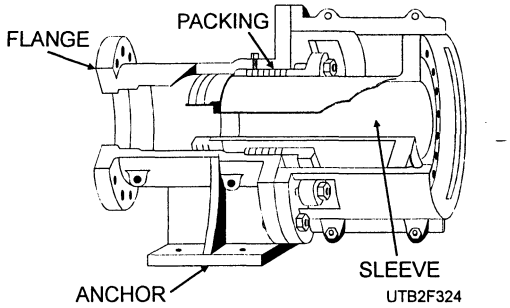


Figure 3-24.—-A typical slip-type expansion joint.

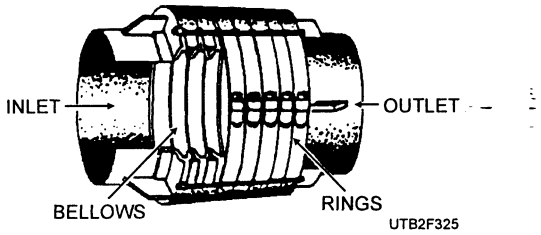


Figure 3-25.—A typical bellows-type expansion joint.

consists of a thin-walled corrugated copper stainless steel tube clamped between flanges. Rings help to keep the corrugations under relatively high pressure. The steam pipe and joint should be supported and guided to keep misalignment to a minimum.

The swing, or swivel, joint is most often used to allow expansion to occur naturally in a system that has screwed joints. When it is used with welded elbows, the swing joint introduces torsional strains in the elbows and in the swing piece.

The expansion loop absorbs expansion through the formation of U- or Z-loops in the pipeline.

The ball joint is often used instead of the expansion loop, because it requires less space and material. A ball joint consists of four basic parts. The joint has a casing or body to hold the gaskets and a ball. The ball is a hollow fitting shaped externally like a ball at one end (inside the casing) and is threaded, flanged, or adapted for welding to the pipe at the other end. There are two gaskets that hold the ball and provide the seat. There is also a retaining nut or flange that holds the ball and gaskets in the casing. The end of the two pipes being coupled is connected to the joint casing; the end of the other pipe is connected to the ball. In operation, the ball joint allows the movement of the pipe with 30° to 40° of flexibility, plus a rotating or swivel motion of 360°.

The slip-type joint must be kept properly aligned, adequately packed, within the proper limit of travel, and thoroughly cleaned and lubricated. You should adjust or replace the packing, as required, to prevent leaks and

assure a free-working joint. It is necessary to lubricate every 6 months with the proper grease for this type of joint and the service conditions. Once a year, you should check the flange-to-flange distance of the slip joints. You should check the flanges first when they are cold and next when they are hot. Measuring makes sure that the travel is within the limits shown in the manufacturer's data. A change in slip travel usually indicates a shift in anchorage of a pipe guide, so you must locate and correct the difficulty. You should also inspect annually for signs of erosion, corrosion, wear, deposits, and binding. Then you should repair or replace the defective parts, as required.

The bellows-type joint is checked annually for misalignment, metal fatigue, corrosion, and erosion. You should note the amount of travel between cold and hot conditions. If the joint fails, you should replace the bellows section of the joint.

Expansion loops require little specific maintenance except inspection for alignment and leaks.

The ball joint must be kept adequately packed. You should adjust or replace the gaskets, as required, to correct leaks and obtain a free-working joint. You should always refer to the manufacturer's instructions for doing maintenance work.

The swing joint requires only the normal maintenance required for pipe fittings.

Q8. What are the two categories of radiators?

Q9. The bellows of an automatic air vent contains a liquid with a boilingpoint of what temperature?

Q10. What are the two types of bucket steam traps?

Q11. What is the most common trouble with a thermostatic steam trap?

Q12. The bimetallic strip in a bimetallic-element trap is made of what materials?

Q13. Which steam trap test method uses a crayon?

Q14. What are the two general types of steam-operated water heaters?

Q15. What device controls the quantity of steam required for both types of water heaters?

Q16. What are the five major types of expansion joints?

Q17. A bellows type expansion joint is inspected for misalignment, metal fatigue, corrosion, and erosion how often?

CHAPTER 4

HEATING SYSTEMS

Learning Objective: Identify the principles and theory of heating and the procedures required for installing, operating, maintaining, troubleshooting, and repairing warm-air heating and hot-water heating systems and associated peripheral equipment.

Heat is one of the prime necessities of life. It is as essential as food, clothing, and shelter. You can have a very good shelter, but you still need heat to be comfortable in it. By studying this chapter, you will start to gain knowledge of what you will be required to know to become efficient in the Utilitiesman (UT) field.

PRINCIPLES OF HEATING

Learning Objective: Understand the basic principles and theory of heat, heat measurement, and heat transfer.

Long after people had advanced to the stage of house building, heating methods had not improved much. For centuries fires for heating and lighting were contained in braziers or confined to an unused corner of a room. The smoke was supposed to escape through a hole left in the roof of the building during construction. Of course, a considerable amount of rain and snow entered the room during bad weather. During the twelfth century, however, the people in the northern part of Europe started using crude fireplaces and flues to replace the brazier and hole-in-the-roof method of heating. Some of these rudimentary heating systems still exist in France.

In the thirteenth and fourteenth centuries, the round, hollow stone chimneys began to be used. At the end of the fourteenth century, people were using a number of fireplaces in their homes and grouping the chimneys together in a vertical, rectangular mass of masonry with decorative effect. By the end of the Italian renaissance period, chimneys were in common use.

During colonial days in America, the fireplace chimneys were a large masonry mass projected through the center of the roof or were an important feature of the gable end walls. This general trend is often followed in architecture today because central heating, required in places where fires are required 5 or 6 months of the year, makes the chimney an important feature of a heating plant. There are heating installations, however, that do not make use of the masonry chimney and have substituted an inconspicuous metal smoke pipe. Other types of heating, such as electrical heating, require no chimney. Methods and equipment used for heating the places we live and work have progressed quickly in the last 100 years. This quick advance is due to our understanding of the principles and theory of heat, which in earlier times was not yet understood.

THEORY OF HEAT

Heat is a form of energy that is known for its effect. Heat can be produced or generated by the combustion of fuels, by friction, by chemical action, and by the resistance offered to the flow of electricity in a circuit. However, the particular form of generated heat with which the heating specialist will be dealing is produced by combustion. Generated heat is obtained by burning common types of fuels, such as coal, oil, and gas.

MEASUREMENT

To operate a heating plant efficiently, you must be familiar with the measurement of heat and how this heat is transferred from the plant to the space being heated. The first part of this section is devoted to measuring temperature; the second part is concerned with the transfer of heat from the plant to the space being heated.

Measurements of temperature and pressure, which are obtained continuously, are very important factors in the operation of a heating plant. The degree of correctness of these measurements directly affects the safety, the efficiency, and the reliability of the operation of the heating plant. Although heat and temperature have a direct relationship, there is also a distinction between them. For example, a burning match develops a much higher temperature than a steam radiator, but the match does not give off enough

heat to warm a room. Another example tells us that IO pounds of water at 80°F will melt more ice in a given length of time than 1 pound of water at 100°F. The former has more heat, but the latter has a higher temperature. Temperature is the measurement of heat intensity in degrees Fahrenheit or Celsius. Therefore, temperature measurements can be made by using a glass thermometer calibrated either in degrees Fahrenheit or Celsius. The generally accepted way of stating measurements of temperature in English-speaking countries is in degrees Fahrenheit.

The thermometer measures the degree of sensible heat of different bodies. The thermometer can make a comparison only between the temperature of a body and some definitely known temperature such as the melting point of ice or the boiling point of water. Figure 4-1 shows a comparison of the scales of Fahrenheit and Celsius thermometers. It also shows the marking of the freezing and boiling points of pure water at sea level. The range of the Fahrenheit thermometer between the freezing point and the boiling point is 180° (32° to 212° = 180°). On the Celsius thermometer, the range is 100° (0° to 100° = 100°) from the freezing point to the boiling point.

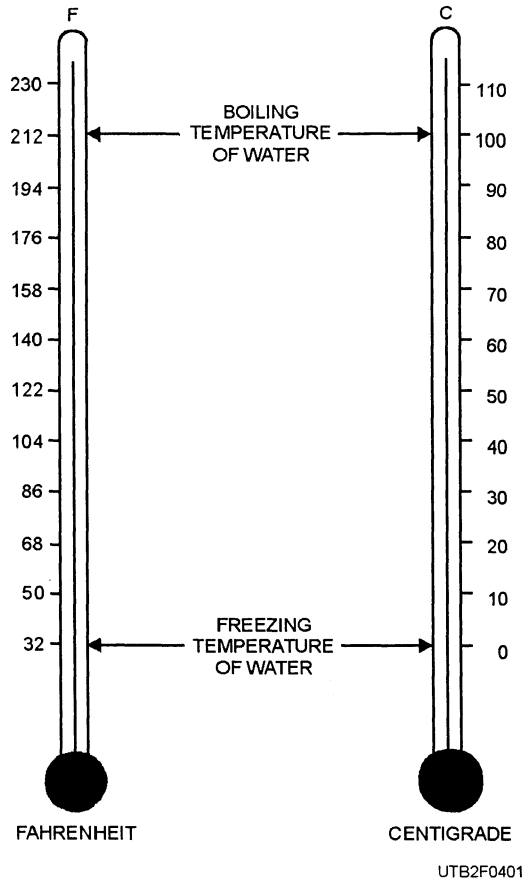


Figure 4-1.—Comparison of Fahrenheit and Celsius thermometers.

To convert Fahrenheit readings to Celsius:

(°F - 32°) ÷ 1.8 = °C

To convert Celsius readings to Fahrenheit:

(°C x 1.8) + 32° = °F

The heat that can be measured by a thermometer and sensed or felt is referred to as "sensible heat." An example of sensible heat is presented by placing a small vessel of cold water over a gas flame and putting a thermometer in the water. Upon observation, you note that the thermometer indicates a rise in temperature. Also, if you place your finger in the water several times, you will feel (or sense) the change in temperature that has taken place.

The unit of measurement for a given quantity of heat is the British thermal unit, abbreviated and commonly known as Btu. One Btu is the amount of heat needed to change the temperature of 1 pound of water 1° Fahrenheit at sea level. If one Btu is added to 1 pound at 50°F, the temperature of that pound of water will be raised to 51°F.

All substances above absolute zero contain heat. There is heat even in ice, and its melting point is fixed at 32°F. Because of a fundamental law of nature, when ice at 32°F melts into water at 32°F, a change of state takes place. The ice (solid) has turned into water (liquid). A certain amount of heat is required during this change of state. This heat is known as latent heat. Latent heat is the amount of heat required to change the state of a substance without a measurable change in temperature.

There are other types of heat that you will encounter in heating. These are as follows:

- Specific heat–The ratio between the quantity of heat required to raise 1 pound of any substance 1°F and the amount of heat required to raise the temperature of 1 pound of water 1°F.
- Superheat–The amount of heat added to a substance above its boiling point.
- Total heat–Is the sum of sensible heat plus latent heat.

We previously mentioned absolute zero. But, what is absolute zero? Scientists have determined that when the temperature of a substance has been reduced to -460°F that all the heat has been removed from a substance. At this point all the molecules cease to have motion. Absolute zero is the lowest temperature obtainable. Heat is present in all substances when the temperature is above absolute zero.

HEAT TRANSFER

The transfer of heat is the next problem to consider after the heat has been produced. It must be moved to the space where it is to be used. Heat always flows from a warmer to a cooler substance; consequently, there must be a temperature difference before heat can flow. Naturally, the greater the temperature difference, the faster the heat flow. Two objects that have different temperatures, when placed together, tend to equalize their temperature. Heat travels in heating systems from one place to another by three different methods. All three of these methods are used in most heating systems. They are discussed in the paragraphs that follow

Conduction

Conduction is the flow of heat from one part of a substance to another part of the same substance or from one substance to another when they are in direct contact.

When one end of a stove poker is held in a flame, the other end will soon be too hot to hold. This indicates that the heat is being conducted, or transferred, from one end of the poker to the other end. Such a transfer of heat is called conduction. Conduction is used to transfer heat through the walls of a stove, furnace, or radiator so that the warmth can be used for heating. Some materials do not conduct heat as well as others. For example, if a piece of wood had been used instead of the poker, the end of the wood away from the fire would have remained cool. Those materials that offer considerable resistance to heat flow are referred to as insulators or poor conductors.

Convection

Convection is the transfer of heat by means of mediums, such as water, air, and steam. When air is heated, it expands, becomes lighter in weight, and rises. The cooler air, which is heavier, then flows in to replace the warm air. Thus a convection current is set up. Water, when heated, acts in the same way as air. The water next to the heating surface becomes warmer, lighter, and rises. This action allows the cooler water to flow in next to the heating surface and become heated. Convection is a very important factor in a heating system. It is this force, developed by heating the medium, which circulates that medium to the space to be heated.

Radiation

Radiation is the transfer of heat through space. When a hand is held in front of a stove, it is quickly warmed by means of radiation. In this same manner, the earth receives its heat from the sun.

Radiated heat is transferred by heat waves, similar to radio waves. Heat waves do not warm the air through which they pass, but they must be absorbed by some substance to produce heat. For example, when you stand in the shade of a tree, you feel cool because the leaves and limbs are absorbing the heat waves before they reach you.

When heat waves strike an object, some are reflected, some may pass through, and the object absorbs the rest. Polished metals are the best reflectors known; therefore, they are a poor absorber of heat. A poor absorber is also a good radiator. Rough metal absorbs heat more readily than a highly polished metal, and it also loses heat faster by radiation.

The color of a substance also affects its absorbing power. A black surface absorbs heat faster than a white one. That is why light-colored clothes are cooler in summer than are dark-colored clothes.

Q1. Heat can be produced or generated by what methods?

Q2. What two types of measurements directly affect the safety, efficiency, and reliability of heat plant operations?

Q3. Temperature is the measurement of what?

Q4. Convert 82 degrees Fahrenheit to degrees Celsius.

Q5. Heat travels in heating systems by what three methods?

COMBUSTIBLE FUELS

Learning Objective: Understand the types and characteristics of combustible gases and fuel oils used in heating systems.

If electricity and coal are disregarded, the fuels most commonly used with heating equipment are either gas or petroleum. Next, we will take a brief look at the types and characteristics of combustible gases and fuel oils used for heating.

TYPES OF GASES

Gaseous fuels are usually classified according to their source that, in turn, determines their chemical composition. The heat valve (Btu per cubic foot) varies with the types of gas and determines the quantity

required for a specific heating requirement. The types principally in use are natural gas, manufactured gas, and liquid petroleum gas (table G, appendix II).

Natural Gas

Natural gas is a mixture of combustible gases and usually small amounts of inert gases obtained from geologic formations. While the composition of natural gas varies with the source, methane (CH_4) is always the major constituent. Most natural gases also contain some ethane (C_2H_6) along with small amounts of nitrogen and carbon dioxide (CO_2). Natural gas is colorless and odorless in its natural form; however; a distinctive odor is usually added as a safety factor for detecting leaks. Natural gas mixes readily and completely with combustion air and thus is substantially free from ash and practically smokeless. These characteristics contribute to good environmental pollution control. From a standpoint of trouble-free performance, ease of handling, and control, natural gas offers many advantages that make it the most desirable of all heating fuels.

Manufactured Gas

The common manufactured gases are carbureted water gas, oil gas, and producer gas. These gases are roughly one-half hydrogen and one-third methane, plus small amounts of carbon dioxide, nitrogen, and oxygen. They are made by converting low-grade liquid or solid fuels to the gaseous form by destructive distillation (cracking) of oil or coal, by the steam-carbon reaction, or by a combination of both processes. These gases are ordinarily used at or near the production point because of high manufacturing costs rule out the added expense of distribution.

Liquefied Petroleum Gas

Liquefied petroleum gases are hydrocarbon gases normally obtained as a by-product of oil refineries or by stripping natural gas. These compounds are normally gaseous under atmospheric conditions; however, they can be liquefied by moderate pressure at normal temperatures.

The principal LPG products are propane (C_3H_8) and butane (C_4H_{10}). Propane, the most common, is available by the bottle or cylinder and in bulk form. Its boiling point is -44°F (note that this is very close to that of refrigerant R-22).

Butane is generally available in bulk form. It boils or vaporizes at 32°F. In other words, if the temperature of butane is 32°F or lower, at atmospheric pressure, it remains a liquid, and heat must be applied to bring it to the gaseous state. Note in table G, appendix II, the high heating. values of propane and butane.

Fuel Oils

Fuel oils are derived from crude oil, which consists primarily of compounds of hydrogen and carbon (hydrocarbons), and smaller amounts of oxygen, nitrogen, and depending on the source, sulfur. Practically all fuel oil is either a product or a by-product of refining crude oil by the fractional distillation process or by cracking.

The Bureau of Standards, United States Department of Commerce, standardizes commercially used fuel oils. The oils are numbered in grades 1, 2, 4, 5, and 6 and are titled commercial standard grades (CSG). These grades are identified in the Navy by military specifications and are intended for use in oil-burning equipment for the generation of heat in furnaces for heating buildings, for the generation of steam, and for other purposes. A more in-depth discussion of fuels and their characteristics is contained in *Fundamentals of Petroleum,* NAVEDTRA 10883. A comparison of fuel oils by grade is given in table H, appendix II.

Q6. What are the principal types of gases used in heating?

Q7. Fuel oils consist primarily of what compounds?

WARM-AIR HEATING EQUIPMENT

Learning Objective: Identify the different types of warm-air heating units and equipment and basic installation and maintenance guidelines.

Advances in the field of warm-air heating have made it one of the most popular and widespread forms of heating in use today. It has the advantage of adaptability with various fuels and can be used in a variety of buildings, including barracks, hangars, personnel housing, schools, and theaters. It is likely, therefore, that at one time or another you will be responsible for performing technical maintenance and repair and installation of warm-air heating equipment and systems.

The different types of heating equipment that will be discussed include unit heaters, electric and gas- and

oil-fired space heaters, and gas-fired and oil-fired furnaces.

UNIT HEATERS

In this manual the term *unit heater is* defined as an installed equipment item and a component of a system consisting of an extended finned heat transfer surface (coil) and a propeller or blower fan to create airflow through it. Unit heaters are indirect units that differ from space heaters because they generate heat indirectly from a medium of steam or hot water piped through a central distribution system. Space heaters are direct-fired units that generate heat directly by the use of an electrical coil or by a combustible fuel.

Unit heaters can be used for many heating requirements, the major limiting factor being the availability of a steam or hot-water system. They are commonly used with heating systems in shops, offices, dining halls, and warehouses. There are three basic types: (1) the suspended horizontal discharge, (2) the suspended vertical discharge, and (3) the floor-mounted or horizontal type of blower unit (fig. 4-2).

The units are rated in Btu or equivalent direct radiation heat output and cubic feet per minute air discharge capacity at a given fan or motor speed. These ratings are important in the application of unit heaters.

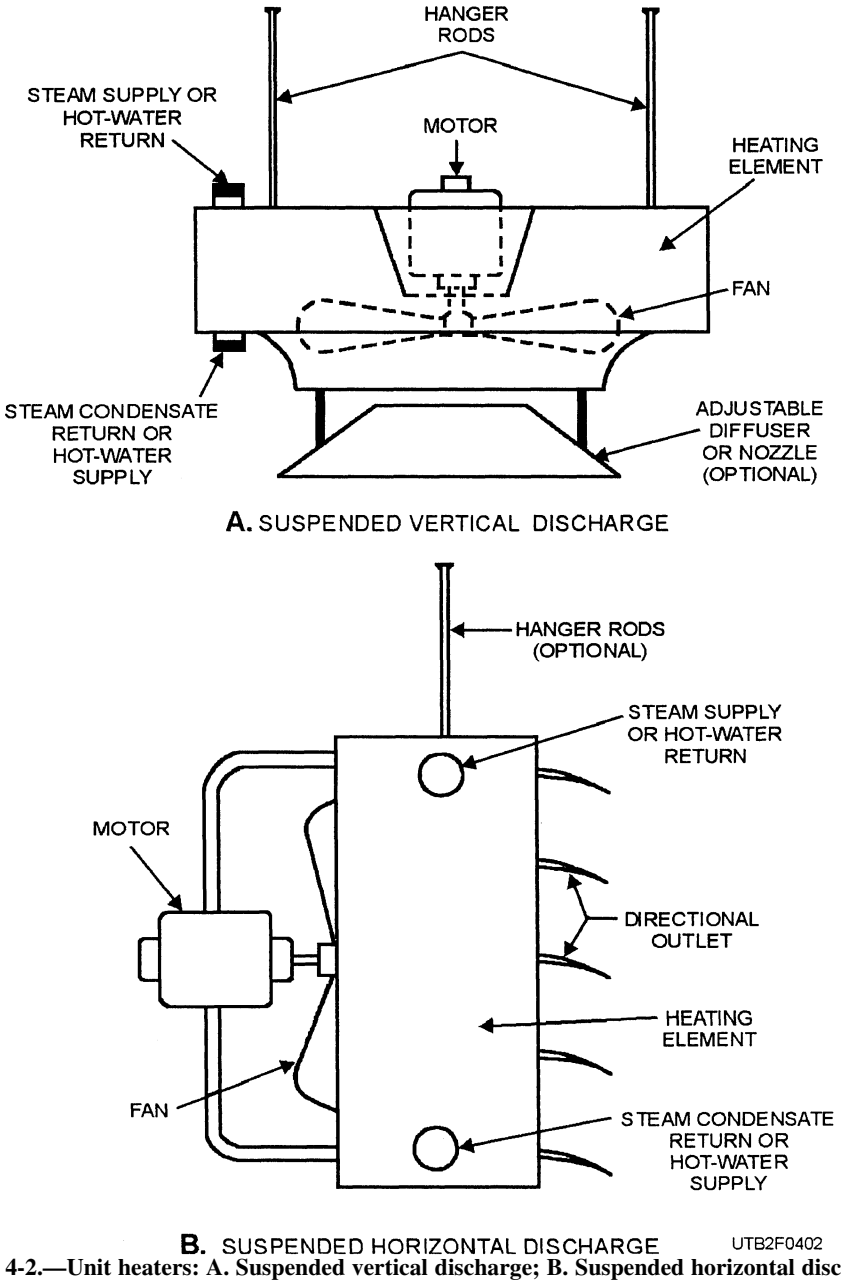


Figure 4-2.—Unit heaters: A. Suspended vertical discharge; B. Suspended horizontal disc harge.

Manufacturers furnish information regarding the area effectively heated by units to enable proper planning and location of the units. Generally, units under 50,000 Btu per hour are designated to operate on low-pressure steam or high-temperature hot water.

Space Heaters

Space heaters are used for heating rooms and similarly enclosed spaces, either in addition to, or in place of, a central heating system. They are desirable as a means of providing heat to a small space because of their simplicity of construction, low initial cost, and reasonable fuel consumption. They may be placed directly in the space or at such a location where heat can be delivered through a single register into the space.

Space heaters are sometimes classified by the manner in which they transfer heat to the space to be heated; for example, by radiation and/or convection. The terms *direct-fired* and *indirect-fired* are also used to identify such heaters. In this manual, space heaters are identified as direct-fired units and by their heat source or fuel. This discussion will include electric, gas-fired, coal-fired, and oil-fired units.

Electric Heaters and Installation

Space heaters with electrically powered heating elements are used in spaces where it is desired to eliminate cold spots and maintain uniform temperatures, where other fuels are useful as portable units on the floor to overcome floor drafts, and as fixed units mounted in, or to walls or ceilings. They are generally rated in kilowatts (kW). One kW (1,000 watts) is equal to 3,415 Btu per hour.

Electric space heaters are available in two general types—the radiant and natural convection type and the forced warm-air (fan) type. In the radiant and natural convection type, heat from electric elements rises and strikes parabolic (bowl-shaped) reflectors. The reflectors are highly polished curved metal surfaces, which deflect the heat outward into the place where heat is desired (fig. 4-3). Some radiant heat units have no deflectors but provide a combination of radiant and natural convection heat, which rises from the coils into a chamber open on the side where heat is required. The electric baseboard convection heater is an example of this type. The forced warm-air type uses a motorized fan to circulate heat from the heating element outward into the space (fig. 4-4). The electric units are operated manually with an ON-OFF switch or automatically with a thermostat.

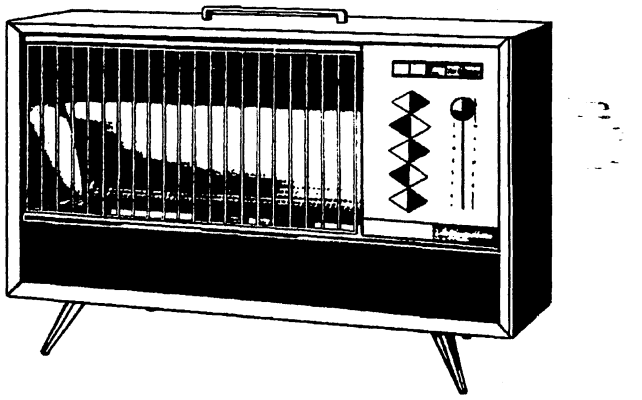


Figure 4-3.—Radiant electric space heater.

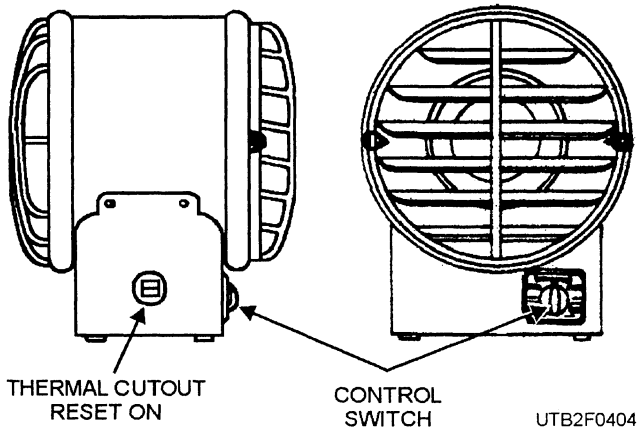


Figure 4-4.—Forced warm-air electric space heater.

In the selection and installation of electrical space heaters, safety must be assured. Units that are to be installed should bear the label of the Underwriter's Laboratories (UL). They should also conform to the safety standards outlined in space heating equipment UL-573. All electrical work required for an installation should be done according to the manufacturer's instructions and by a qualified electrician.

Gas Heaters and Installation

Gas-fired space heaters are clean in operation; they are easily operated and require no fuel handling. They are adaptable for use with natural gas, manufactured gas, or liquefied petroleum gas. Their construction features are similar regardless of the type of gas used. Basically, there are two types—the vented and the unvented.

VENTED UNITS are enclosed metal cabinets with either top and bottom or front and rear grilles for

warm-air circulation. The flame burns in a closed combustion chamber, and the heater vent carries away the gases (fig. 4-5). The flow of heat is maintained by a motor-driven fan and is controlled by vanes, fins, louvers, or diffusers. This type of unit is more satisfactory than the unvented type because there is less danger of carbon monoxide poisoning. A panel unit is one type of vented unit (fig. 4-6). It may be recessed or surface-mounted in either an interior or exterior wall with a vent properly insulated and run up

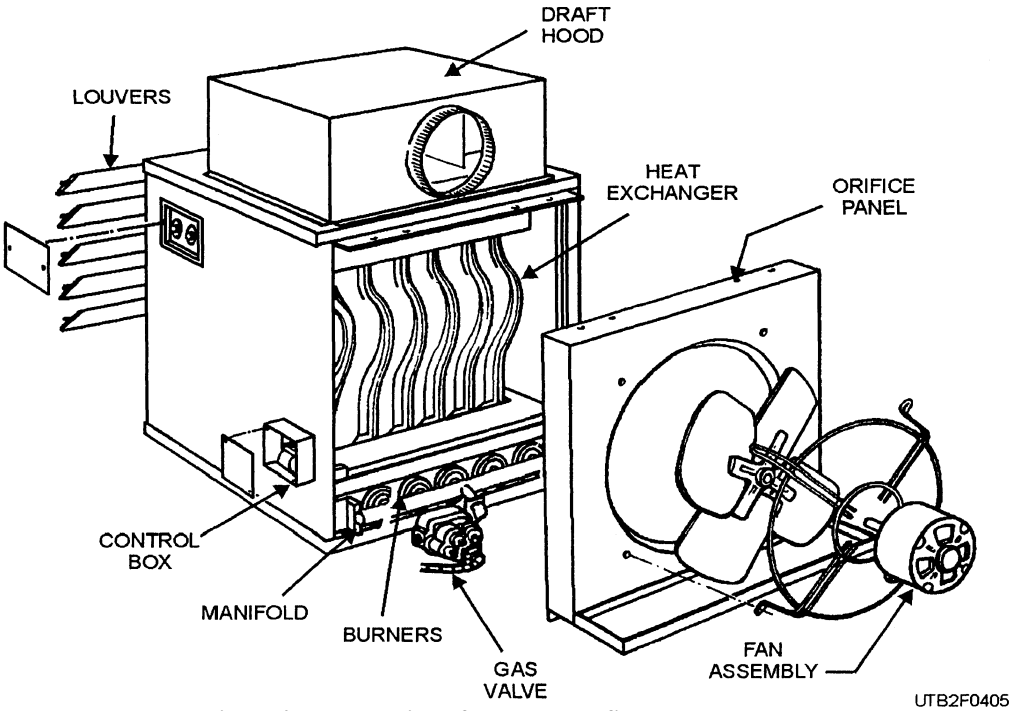


Figure 4-5.—Rear view of a vented gas-fired space heater.

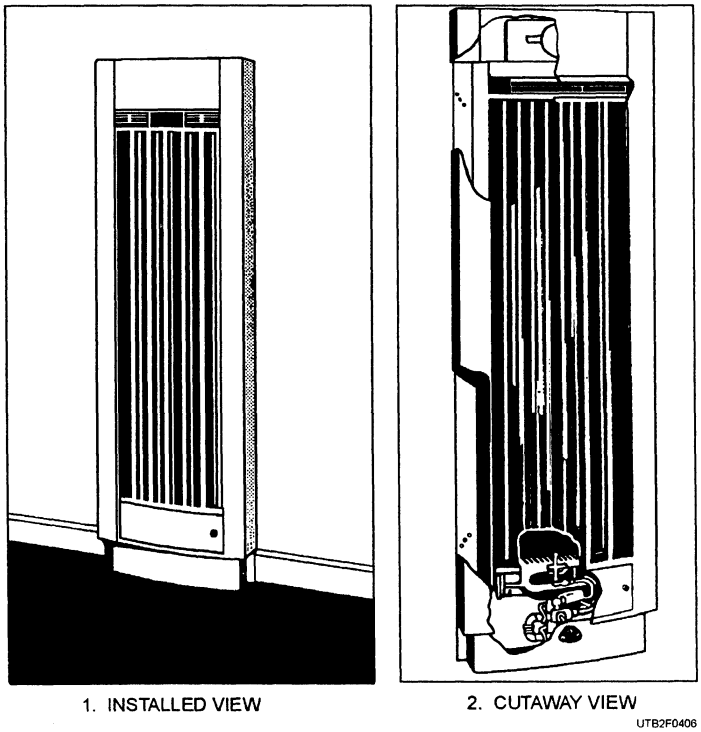


Figure 4-6.—Gas-fired panel space heaters.

through the wall. This type of unit has the advantage of requiring less floor or ceiling space.

UNVENTED UNITS are usually the open-flame type where the gas burns in an open combustion chamber. These heaters should be used in a well-ventilated area. Ventilation ensures that the carbon monoxide produced by the gas flame is removed.

Gas-fired space heaters and their connections must be of the type approved by the American Gas Association (AGA). They must also be installed according to AGA specifications. Installation factors, such as the type of gas, the capacity of the heater, and the line pressure drops, must be known to ensure proper plumbing procedures with respect to the gas service line. All newly installed piping should be tested for gas leaks. These tests should comply with NAVFAC DM3.

On vented gas units, be careful to install the venting system properly to minimize the harmful effects of condensation and to ensure that the combustion products are carried away. During operat ion, the inner surface of the vent must be heated above the dew point of the combustion products. This prevents water from forming in the flue pipe. Vent sections must be installed with the male ends of the inner liner down to allow any condensation that forms to return. This is important since the burning of 1,000 cubic feet of natural gas produces approximately 12 gallons of water. For the same reason, horizontal flue pipes should have an upward pitch of at least 1-inch per running foot.

Vent pipes should be equipped with draft diverters. A diverter is a type of inverted cone through which the flue gases must pass on their way to discharge. It allows air from the heated room to be drawn into the flue pipe joining the combustion-gases. This action prevents excessive downdrafts or updrafts that are apt to extinguish the pilot light or possibly the main burner.

Oil-Fired Space Heaters

In areas where oil is the principal fuel, oil-fired space heaters are used for many space heating requirements. Oil-fired space heaters are very simple in construction. They consist of a burner, a combustion chamber and outer casing, a fuel tank, and fuel control valve. An air space is provided between the combustion chamber and the outer casing. Air enters through grilles in the bottom of the heater, is heated, and passes out through grilles in the top of the unit. Some oil-burning heaters are equipped with a blower and electric motor to force the heated air out into the room. They turn at slow speed and may be either direct drive or belt driven.

Oil-fired space heaters have atmospheric vaporizing-type burners. The burners require a light grade of fuel oil that vaporizes readily at low temperatures and leaves only small amounts of carbon and ash. Number 1 fuel oil is generally used. The two types of burners that will be discussed are the natural draft pot and the perforated sleeve.

NATURAL DRAFT POT DISTILLATE BURNERS are widely used for space heaters, room heaters, and water heaters. A cutaway view of a natural draft pot type of burner is shown in figure 4-7. In operation, the distillate (oil) is fed at the bottom of the burner, either at the center or on the sides, and is

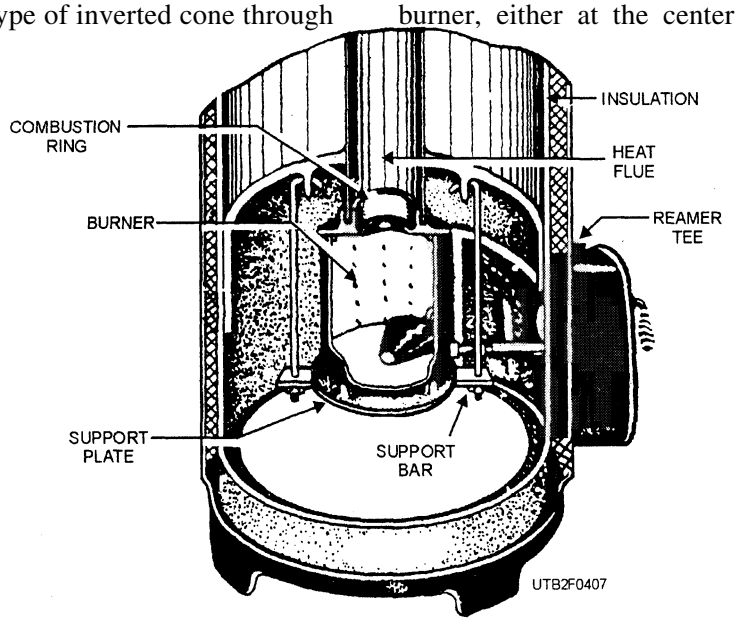


Figure 4-7.—Cutaway view of a natural draft pot type of burner.

vaporized at this point by radiant heat from above. The vapors rise and mix with the air drawn through the perforated holes in the burner. During high fire conditions, the flame burns above the top combustion ring, as shown in figure 4-8; and under low fire conditions, the flame burns in the lower portion or pilot ring of the burner, as shown in figure 4-9.

The PERFORATED SLEEVE BURNER consists of a metal base formed of two or more circular fuel vaporizing grooves and alternate air channels (fig. 4-10). Several pairs of perforated sleeves or cylinders force the air through the perforations into the oil vapor chamber. In this way a large number of jets of air are introduced into the oil vapor, bringing about a good mixture. This mixture burns with a blue flame and is clean and odorless.

These burners usually have a short kindling wick. Some burners have a cup below the base in which alcohol is burned to provide heat for starting. The wick and alcohol are used only for lighting.

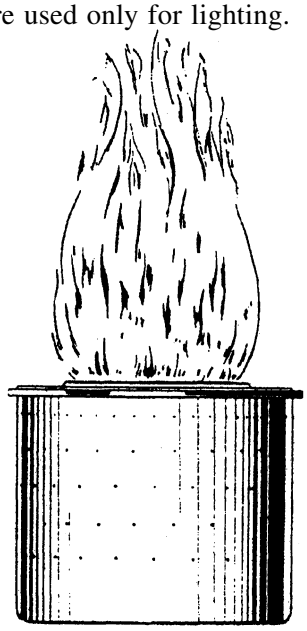


Figure 4-8.—High fire flame.

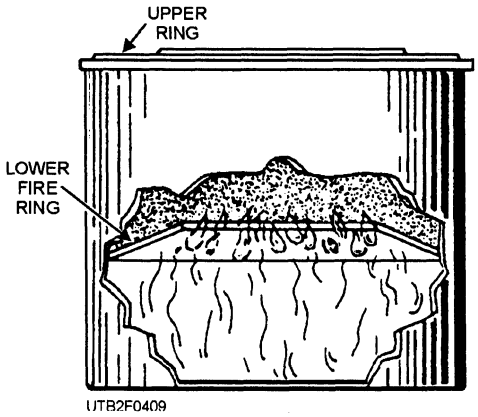


Figure 4-9.—Low fire flame.

Installation

Oil-burning heaters are portable and are easily moved from one location to another. For satisfactory operation, follow the installation procedures supplied by the manufacturer. In both pot type and perforated sleeve burners, oil is fed to the burner under control of a float-operated metering valve (fig. 4-11). Set the unit level so the oil can be properly distributed in the burner.

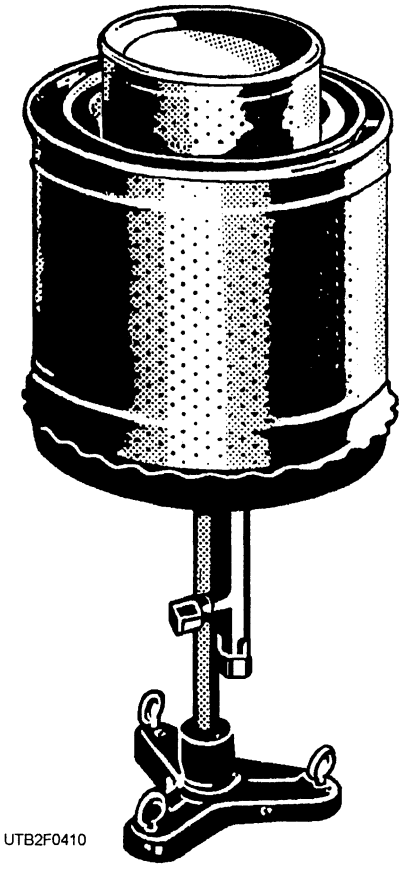


Figure 4-10.—Perforated sleeve burner.

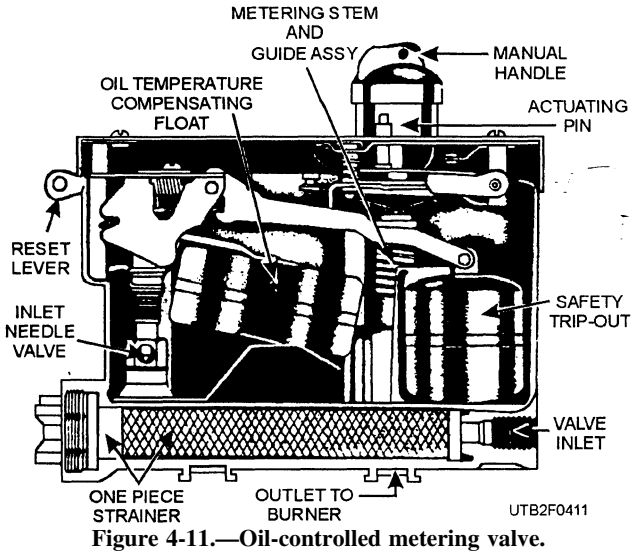


Figure 4-11.—Oil-controlled metering valve.

NOTE

The fuel level control valve is the only safety device on the oil-fired space heater.

When several space heaters are installed in a building, an oil supply from an OUTSIDE TANK to all of the heaters is often desirable. This eliminates frequent filling of individual tanks and reduces waste from spilling. Figure 4-12 shows the principal elements of such a system and important points to consider during installation.

Be sure that the space heater is placed a safe distance from the wall. You also need a metal pan for it to sit in. This pan catches the oil if a leak occurs. Do not use a sandbox or cement as both absorb oil and create a fire hazard. In case of wood floors, place a piece of fire-retardant material, such as Gypsum board (Sheetrock) on the floor underneath the metal pan. It may also be needed on the wall behind the heater if the wall is made of wood.

Since the flow of air to a vaporizing type of burner is induced by a chimney DRAFT, pay careful attention to this feature. The draft produced by any chimney depends upon the height of the chimney and the difference in temperature between the flue gas and outside air. The cross-sectional area required depends upon the volume of flue gas to be carried. Since outside air temperature varies during the heating season, arrange the chimney or flue to produce the necessary draft under the most unfavorable conditions likely to be encountered, usually an outside temperature of 60°F. Above this temperature, heat is not usually required, and below this temperature, draft would be increased.

Install the draft REGULATOR to maintain a constant draft adjustment for the rate at which the heaters are fired. The regulator is a swinging damper or gate with provision for adjustment. Since balance and free action are the fundamentals on which its operation depends, be sure the installation provides for these features. Install the damper section with the word *top* at the true top position. Make sure the face is plumb. When the damper regulator is installed in a horizontal run of pipe, do not use a counterweight on the damper.

A DOWNDRAFT may seriously interfere with proper functioning of these burners. Downdraft may result when the chimney is not high enough above the roof line or is too close to other high buildings, trees, or terrain features. The chimney top must be at least 3 feet above the highest point of the building roof. If the difficulty is caused by other factors, a downdraft hood may prove effective. There are several successful designs; a simple constructed type is shown in figure 4-13.

Copper tubing is often used in an oil supply system to burners because of its high resistance to corrosion and ease of installation. The use of compression fittings or flair fittings is best for fuel supply applications. A major advantage in using copper tubing is that it can be bent easily without collapsing the tube, especially if a tubing bender is used; this cuts down on the number of fittings required for installation.

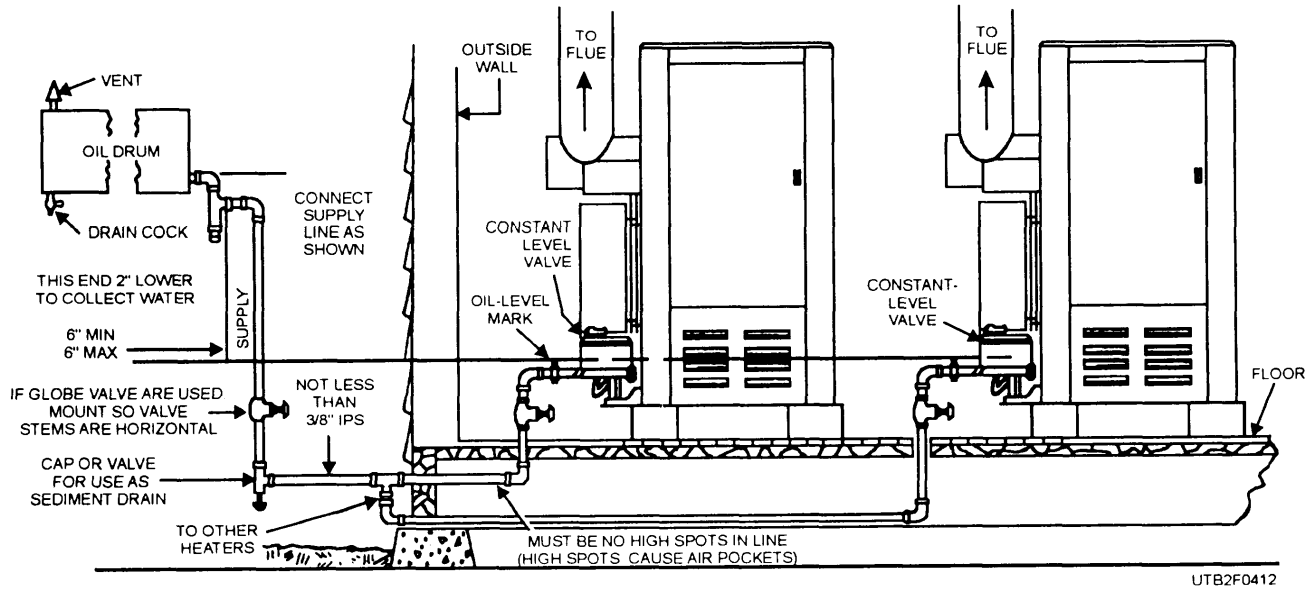


Figure 4-12.—Space heaters installed in series.

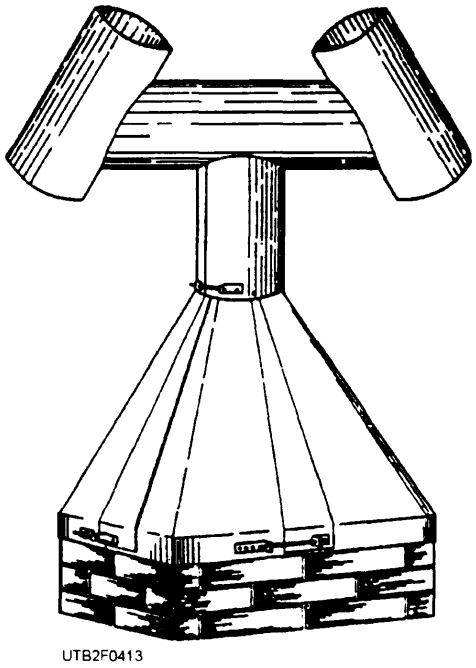


Figure 4-13.—H-type downdraft hood.

UNIT HEATER MAINTENANCE

Oil-fired space heaters require periodic cleaning. Frequent checks must be made to ensure that equipment is kept clean, because accumulations of carbon and soot can cause disastrous fires. Units should be moved when they are cleaned, so they can be cleaned inside and out. Accumulations of soot must be removed from inside the fuel pipe. All piping and tubing should be kept clean and free of oil drippings.

The pot or burner assembly may be cleaned without removing the heater. When cleaning this component, remove it through the front door opening and clean all the air holes using a soft copper wire. Do not remove all the carbon from the bottom, because a small accumulation of carbon at the bottom acts as a wick and helps maintain the pilot light. In replacing the burner assembly, make sure both sides of the burner are tightened equally, so the top of the burner and the fire-retardant gasket are set firmly against the flue projection.

In checking the constant-level control valve, check the operation of the heater through a complete cycle of operation from the pilot fire position to the main fire position, and then back to the pilot fire position. Set the control valve, if it is the manual type, to high fire; and if equipped with a thermostatic device, set the thermostat above room temperature. If the heater fails to operate properly through the cycle, check the constant-level control valve and follow the manufacturer's instructions for disassembly and cleaning. A parts breakdown of the valve is shown in figure 4-14.

Some of the common problems with pot and sleeve oil burners, gas-fired space heaters, their causes, and possible remedies are listed in appendix II, tables I and gentlemen.

Q8. What are the basic types of unit heaters?

Q9. How are electrically powered space heaters generally rated?

Q10. When you select and install an electric space heater, what factor should be paramount?

Q11. On vented gas-fired space heaters, it is important to install the venting system properly to minimize the effects of what problem?

Q12. What type of burner is used in an oil-fired space heater?

Q13. What is the only safety device on an oil-fired space heater?

Q14. To maintain a constant draft for the burner of an oil-fired space heater, what device should you install in the chimney?

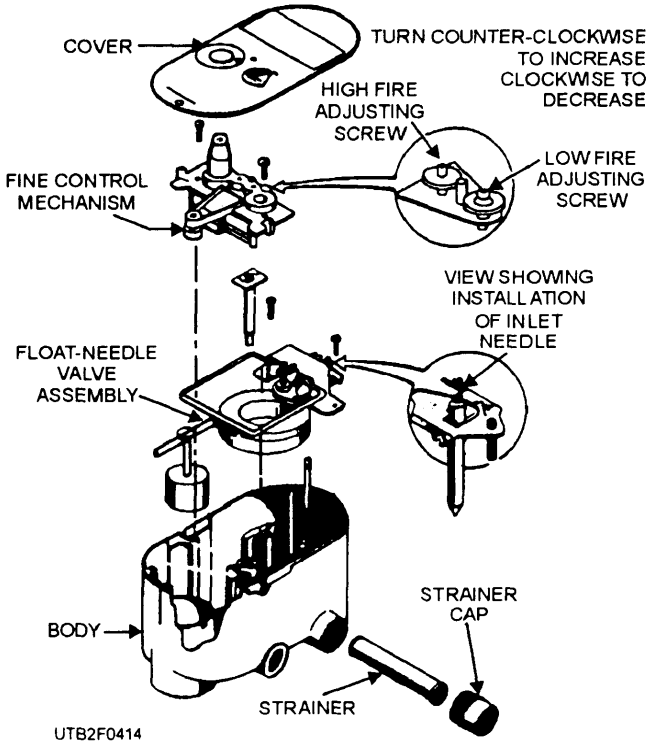


Figure 4-14.—Constant-level control valve.

WARM-AIR HEATING SYSTEMS

Learning Objective: Identify the different types of warm-air systems, gas-fired and oil-fired furnaces, components, controls, and the procedures for installation, operation, and maintenance.

Heating equipment for complete air-conditioning systems is classified according to the type of fuel burned, the Btu capacity of the furnace, and the method of circulating the warm air. Warm-air systems are generally identified as either a gravity-type or a forced-air type system.

GRAVITY SYSTEM

Gravity furnaces are often installed at floor level. These are really oversized, jacketed space heaters. The most common difficulty experienced with this type of furnace is a return-air opening of insufficient size at the floor. Make the return-air opening on two or three sides of the furnace wherever possible. Provide heat insulation above the furnace top to avoid a possible fire hazard.

Gravity warm-air heating systems operate because of the difference in specific gravity (weight) of warm air and cold air. Warm air is lighter than cold air and rises when cold air is available to replace it.

FORCED-AIR SYSTEM

The majority of the furnaces produced today are of the forced warm-air type. This type of furnace includes the elements of a gravity warm-air system plus a fan to ensure adequate air distribution. It may include filters and a humidifier to add moisture to the air. The inclusion of a positive pressure fan makes possible the use of smaller ducts and the extension of the system to heat larger areas without the need for sloping ducts. It is possible to heat rooms located on floors below the furnace if necessary. Forced-air furnaces are manufactured in a variety of designs. A typical oil-fired furnace is shown in figures 4-15 and 4-16. A typical gas-fired furnace is shown in figure 4-17.

In a forced-air system, the fan or blower is turned on and off by a blower control which is actuated by the air temperature in the bonnet or plenum. The plenum is

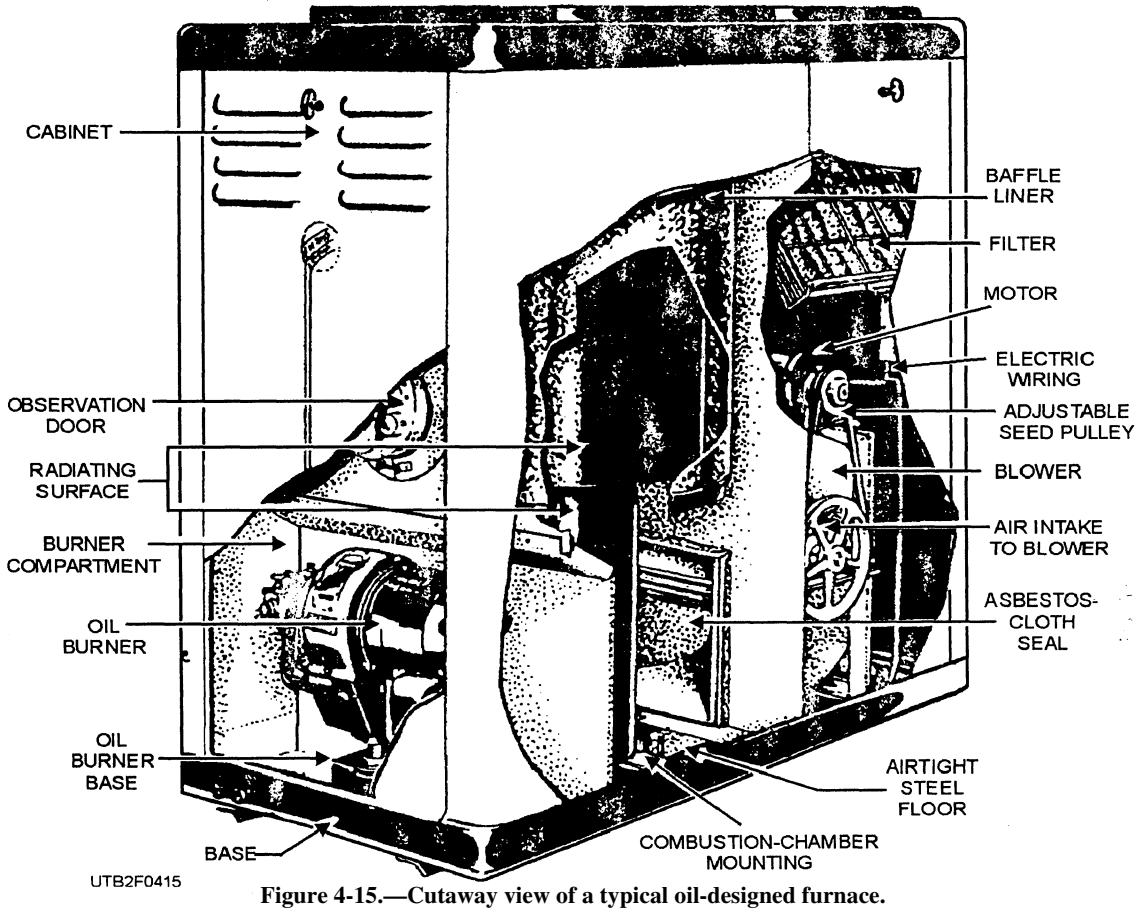


Figure 4-15.—Cutaway view of a typical oil-designed furnace.

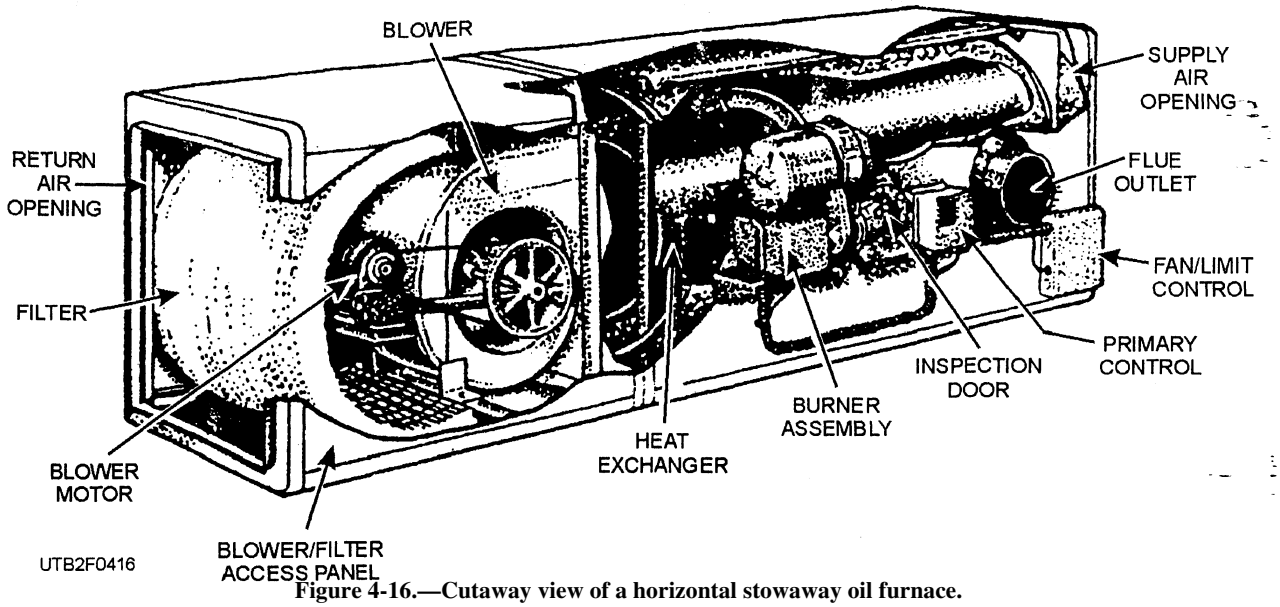


Figure 4-16.—Cutaway view of a horizontal stowaway oil furnace.

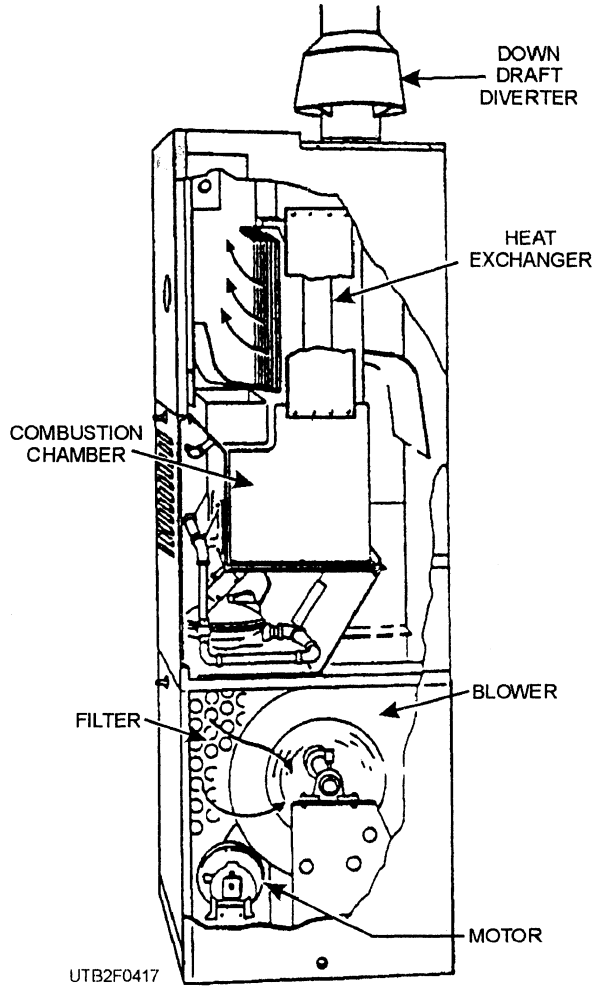


Figure 4-17.—Gas-fired vertical warm-air furnace.

that part of the furnace where it joins the main trunk duct (fig. 4-18). The blower control starts the fan or blower when the temperature of the heated air rises to a set value and turns the fan or blower off when the temperature drops to a predetermined point. Thus the blower only circulates air of the proper temperature.

AIR DISTRIBUTION

A knowledge of air distribution principles is important when dealing with central warm-air heating systems. Satisfactory heating from warm-air systems is absolutely dependent upon proper distribution of warm air from the heat source to all portions of the space served. Warm air must be distributed in quantities that are required to offset the rate of heat released to each room. With radiator systems, distribution is primarily a problem of getting enough hot water or steam to each radiator to be sure the radiator heats to its rated capacity. It is not possible to deliver more heat through steam or hot water than the radiator is designed to transmit. With warm-air systems, however, the rate of air delivery and the temperature of the air delivered to the room determine the amount of heat reaching each room. Temperature balance, therefore, is primarily a problem of controlling air distribution.

Factors, such as velocity, volume, temperature, and airflow direction, play an important part in temperature balance. In addition and for human comfort, space-temperature variations and noise levels must also be considered. Convection currents result from the natural tendency of warm air to rise and cold air to fall. Examples are the temperature variations near doors and windows, and when dense, cool air is drawn away quicker than warm air. Objectionable noise will result at supply diffusers if room velocities exceed 25 to 35 feet per minute (fpm). Air stratification and cold floors may also result when supply diffusers are not properly located within the space.

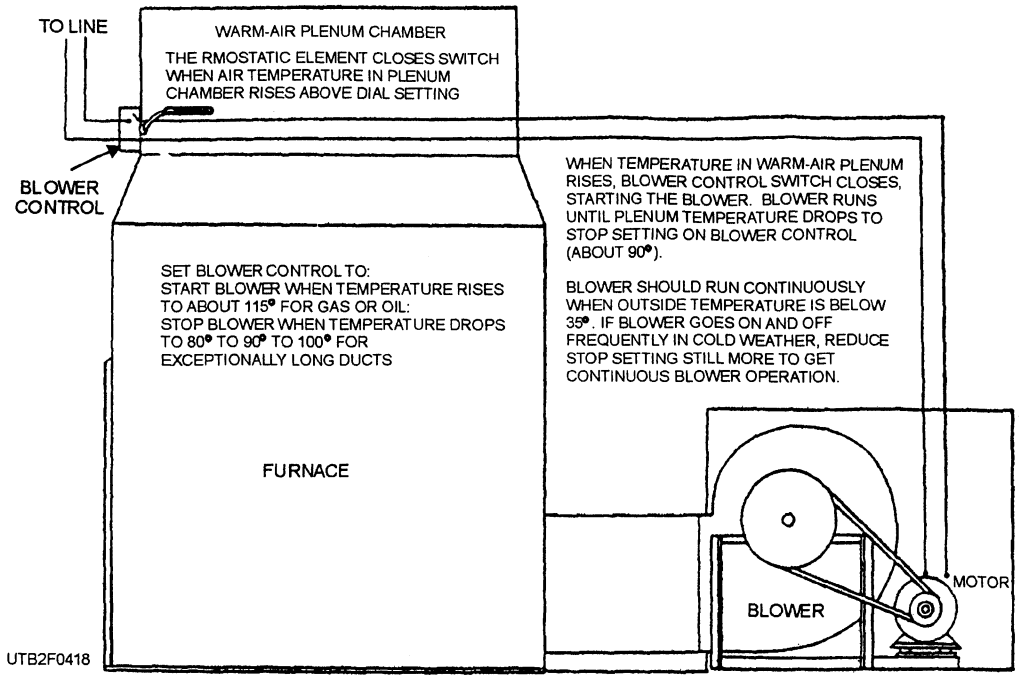


Figure 4-18.—Electrical circuit showing how blower control operates blower motor when temperature in plenum rises.

Patterns of air distribution vary with the positions of supply diffusers. A diffuser that discharges through the floor in an upward direction or downward through the ceiling provides a vertical distribution of air. On the other hand, a diffuser that discharges through a wall provides a horizontal distribution of air. The spread for either the horizontal or the vertical pattern depends on the setting of the diffuser vanes. A low horizontal discharge provides the most effective distribution Airdistribution that results from different diffuser locations is shown in figure 4-19.

As previously mentioned, warm-air heating systems are generally identified as either the GRAVITY TYPE or the FORCED-AIR TYPE. The type of duct distribution used further identifies these installations. There are two

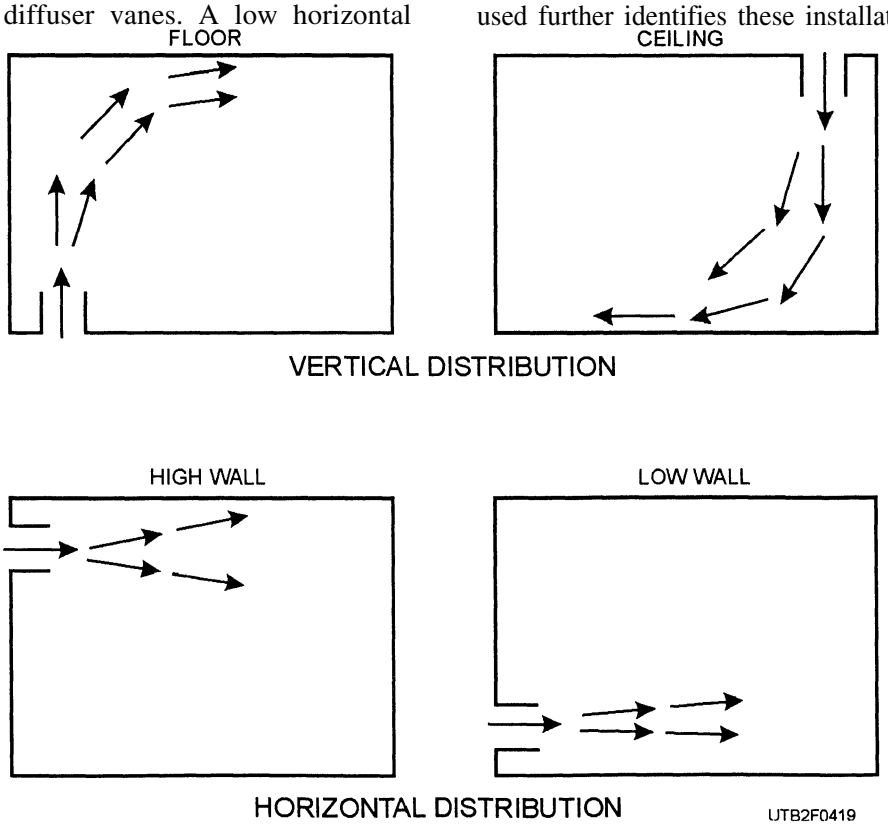


Figure 4-19.—Air diffuser distribution.

types of duct layouts: (1) the INDIVIDUAL DUCT, where each duct is connected directly to the furnace plenum, and (2) the TRUNK AND BRANCH DUCT, where the trunk duct connects to the furnace plenum and then branches off to the outlets. These two types are shown in figures 4-20 and 4-21.

Gravity-type furnaces are rated in leader area capacity, the LEADERS being the warm-air pipes. With respect to return ducts, the register-free area and the return-air duct should not be less than 1 1/4 times the area of the leader serving a given area. Gravity-type installations, as shown in figure 4-21, use the individual duct layout.

Forced warm-air systems usually have a register temperature range of 150°F to 180°F. Ducts can be in the form of a trunk with branches or with individual leaders from a plenum chamber. Furnaces used with forced-air installations must be equipped with automatic firing devices. Velocities usually are in the range of 750 to 900 fpm in trunks and approximately 600 fpm in branches. Outlet velocities at registers may be as high as 350 fpm.

GAS-FIRED FURNACES

In this section, construction features, basic components, gas burners, and controls of gas-fired furnaces are discussed.

Construction Features

The various gas-fired furnaces available today have similar basic components; however, there, are variations in design with respect only to dimensions and airflow. Unit features pertinent to dimensions and airflow are important when selecting a furnace for a particular space or application. A vertical counter-flow unit, for example, is normally used where supply ducts are located beneath the floor, because it has the return in the top and the outlet in the bottom. The most commonly used unit is the UPFLOW HIGHBOY which, as a rule, draws air from the side or bottom and discharges it from the top. It can be installed in small spaces. In the HORIZONTAL UNIT, the air flows in one side and out the other. This unit is suitable for installation in crawl spaces, attics, and basements. In another type, sometimes called a LOWBOY, both the return and the outlet are at the top. It is a shorter and wider version of the up-flow unit. The different airflows are shown in figure 4-22.

Another type of furnace is the DUCT FURNACE. It is designed for mounting in a duct system where air circulation is provided by an external fan. It is generally used with an air- conditioning system to supply heat during the heating season by using the same ductwork. This type can be installed as a single unit or in batteries for larger requirements. A

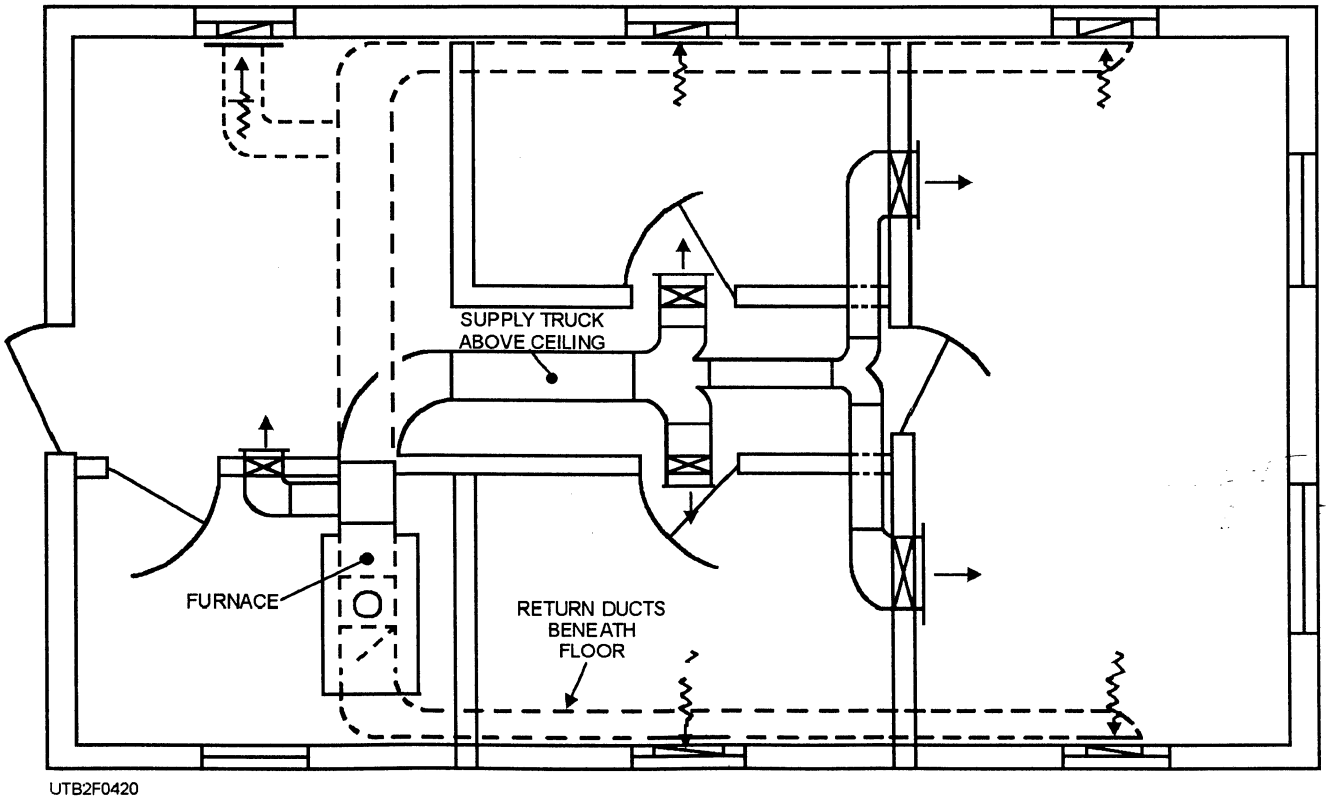


Figure 4-20.—Trunk and branch duct distribution systems.

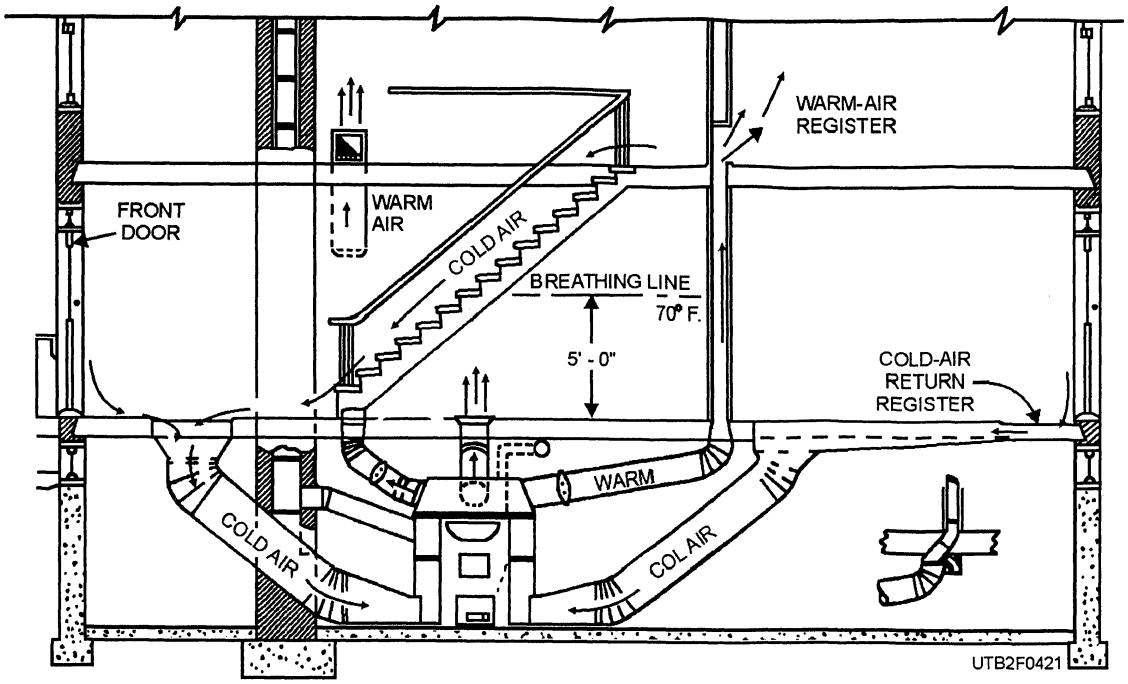


Figure 4-21.—A typical gravity warm-air heating system (individual duct).

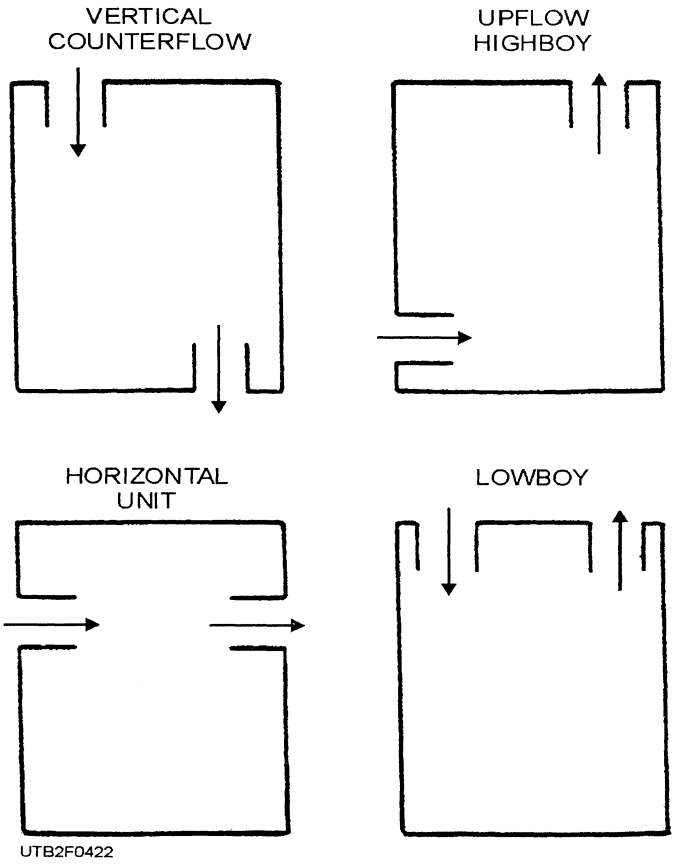


Figure 4-22.—Furnace airflow designs.

typical gas-fired duct furnace is shown in figure 4-23.

Gas-fired furnaces have three main parts—the return-air compartment that houses the blower and filter components, the warm-air compartment that includes the heat exchanger radiators and combustion enclosure, and the combustion air and fuel compartment. This arrangement is shown in figure 4-24.

Basic Components

The components and assemblies of a gas-fired furnace can be broken down into six units. Each unit is discussed briefly below. Refer to figures 4-23 and 4-24 as we go along to identify the location of individual parts.

The furnace casing, sometimes called the cabinet, along with the framework, contains and supports the components of the unit. It also provides an insulating chamber for directing return air through the heat exchanger into the warm-air outlet.

The blower is a centrifugal fan that provides the circulation required to move warm air across the heated space. It also pulls the return air from the space back to the furnace.

The burners are usually the Bunsen type regardless of their size or shape. Figures 4-25 and 4-26 show Bunsen burners. The burner nourishes the flame, as it provides the correct mixture of primary air and fuel gas to the combustion area.

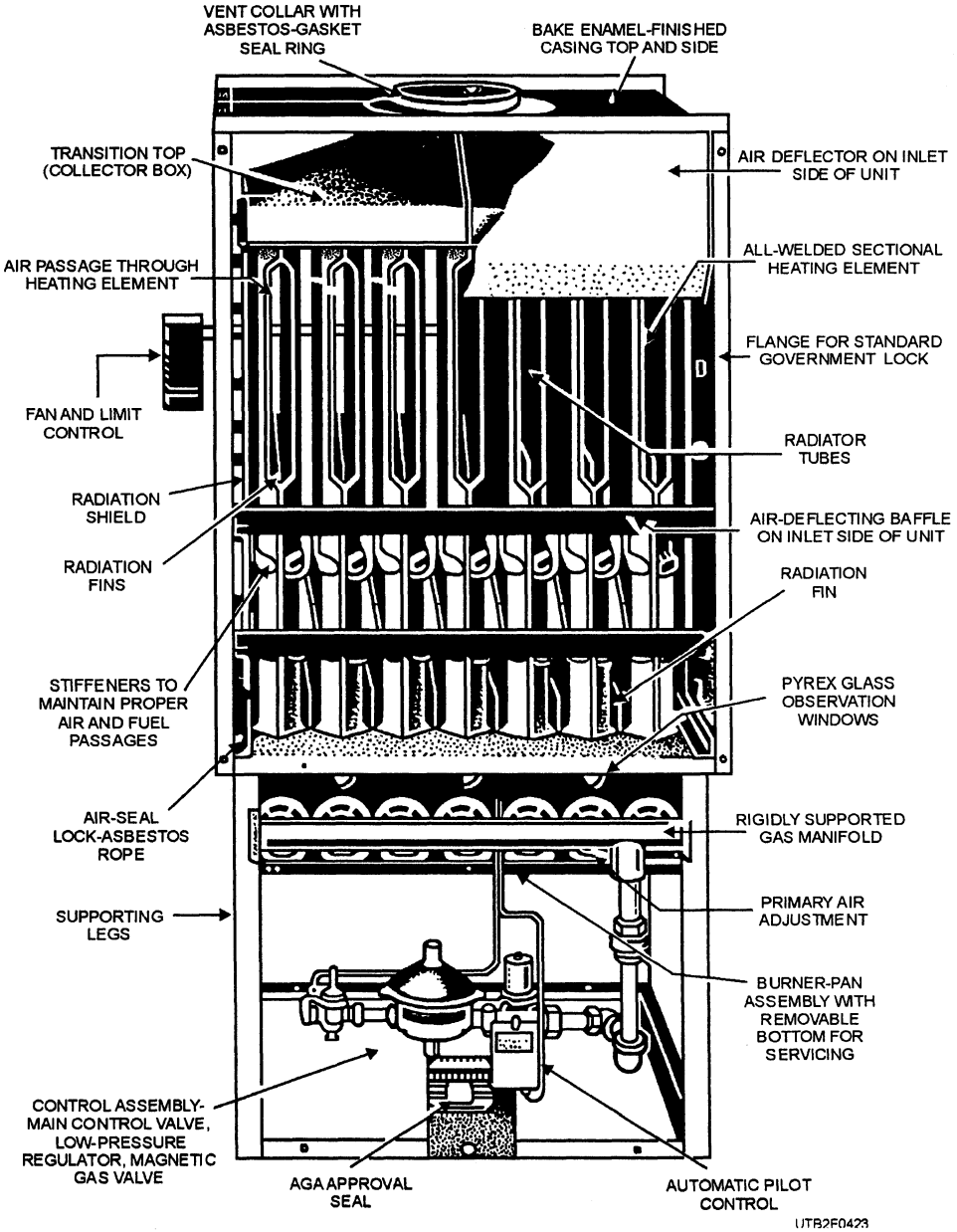


Figure 4-23.—Typical gas-fired duct furnace.

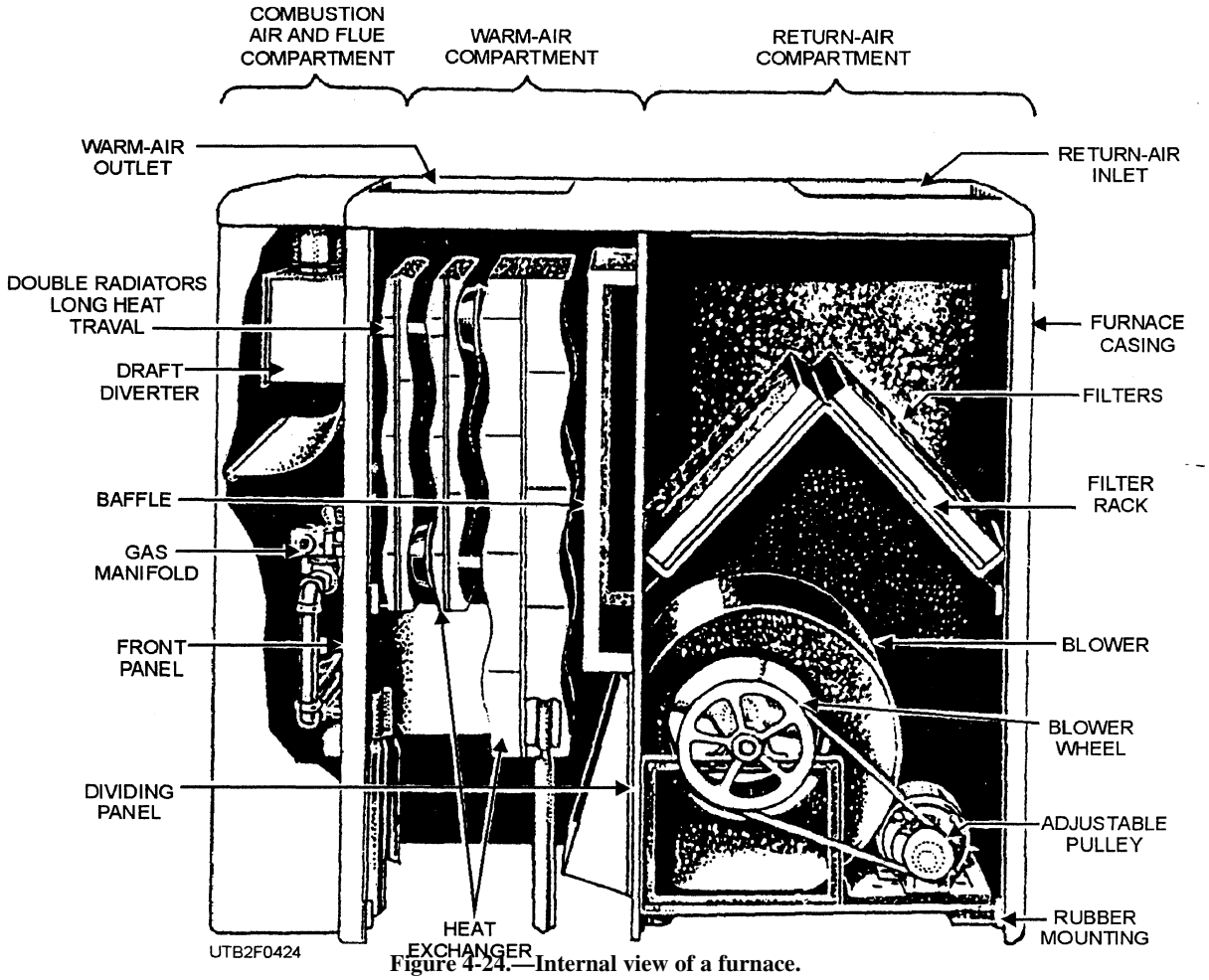


Figure 4-24.—Internal view of a furnace.

The gas manifold assembly includes the gas valves, pressure regulator, and those components that automatically control the flow of gas to the pilot and main burner. It is directly connected to the burner.

Gas Burners and Controls

To use natural gas, a nearly ideal fuel, requires comparatively simple equipment and unskilled labor. This clean gas is almost free of noncombustible and is therefore clean. However, it is relatively dangerous compared to coal or oil because it mixes easily with air and burns readily. Extreme care must be exercised to prevent or stop any leakage of gas into an unlighted furnace or into the boiler room. All gas burners should be approved by the American Gas Association and installed according to the standards of the National Board of Fire Underwriters.

The gas burners used in gas-fired furnaces usually have a nonluminous flame and are the Bunsen type, as shown in figures 4-25 and 4-26. Part of the air needed for combustion is primary air that is drawn into the burner mixing tube or "venturi," where it mixes with the gas that burns at the burner ports. The secondary air is supplied around the base of each separate burner flame by natural draft or is induced by a draft fan.

The gas burner controls include the following units—manual gas valve, gas pressure regulator, solenoid gas valve, diaphragm valve, pilot light, thermocouple, thermocouple control relay limit control, heat exchanger, draft diverter, and humidifier (fig. 4-27). A manual gas cock or valve must be installed ahead of all the controls.

MANUAL GAS VALVE.—The manual gas valve is installed on the heating unit next to the gas pressure regulator. It is used to shut off the gas to the heating unit in case some of the controls must be repaired or replaced.

GAS PRESSURE REGULATOR.—The gas pressure regulators used in domestic gas-heating systems are usually of the diaphragm type, as shown in figure 4-28. A gas pressure regulator maintains the desired pressure in the burner as long as the gas main

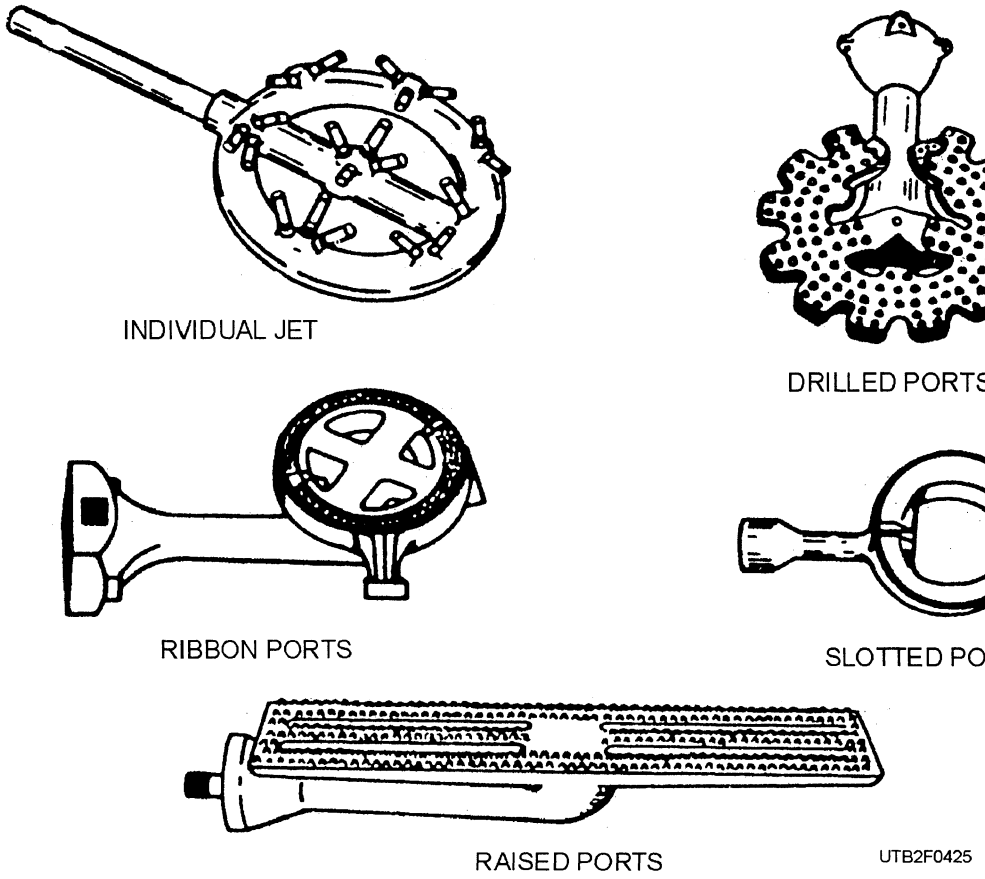


Figure 4-25.—Typical Bunsen burners.

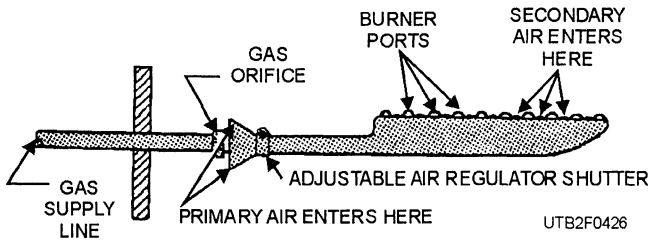


Figure 4-26.—Bunsen type of burner.

pressure is above the desired pressure. When the gas pressure to the burner is low, the pressure-regulating spring pushes the diaphragm down, in turn, pushing the pilot valve down. When the pilot valve opens, supply pressure is applied to the top of the operating piston. As the operating piston moves down, the main valve opens, admitting supply pressure to the burner. As burner pressure rises, the diaphragm is pushed up against the pressure-regulating spring, closing the pilot valve. This removes the supply pressure from the top of the operating piston and the piston return spring pushes the piston up, closing the main valve. The regulator is thus closed every time the burner pressure gets above the desired amount. Turning the adjusting screw at the top can vary the setting of the regulator.

SOLENOID GAS VALVE.—The basic principles of construction and operation applied in all solenoid gas valves are similar. However, the design of each individual unit differs somewhat from the others. The two most common types of solenoid gas valves are the standard solenoid valve and the recycling solenoid valve discussed in the following paragraphs.

The standard solenoid gas valve shown in figure 4-29 is of the electric type. It is suitable for use with gas furnaces, steam and hot-water boilers, conversion burners, and industrial furnaces. This valve operates when a thermostat, limit control, or other device closes a circuit to energize the coil. The energized coil operates a plunger, causing the valve to open. When there is a current failure, the valve automatically closes because of the force of gravity on the plunger and valve stem. The gas pressure in the line holds the valve disk upon its seat. To open this valve during current failure, use the manual-opening device at the bottom of the valve. When the electric power is resumed, you should place the manual-opening device in its former position.

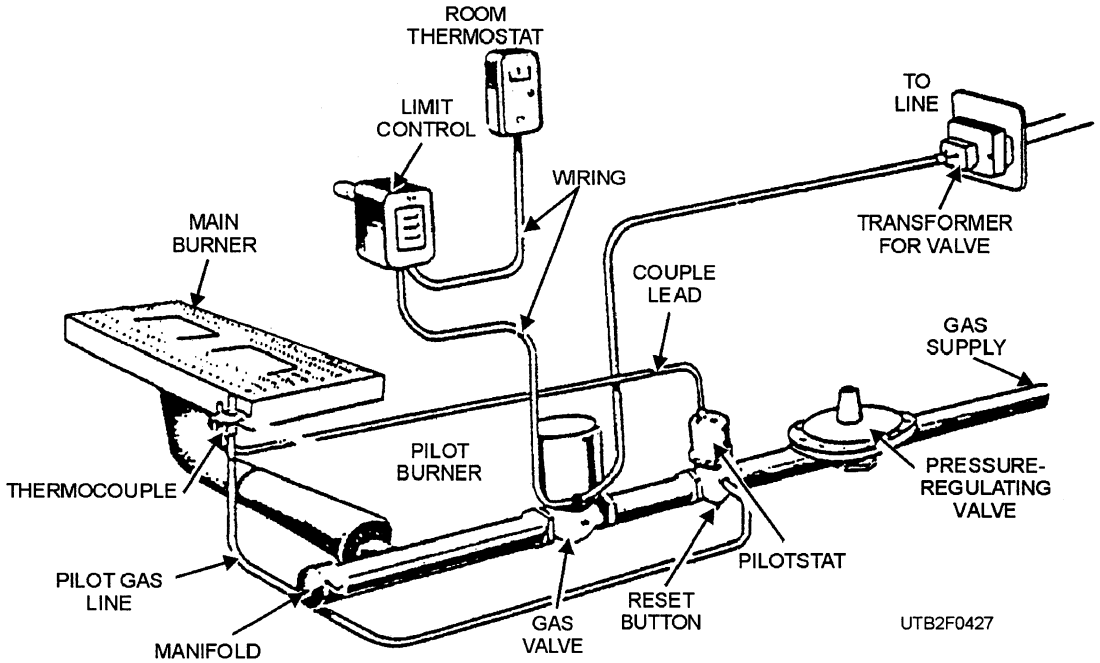


Figure 4-27.—An automatic gas burner control system.

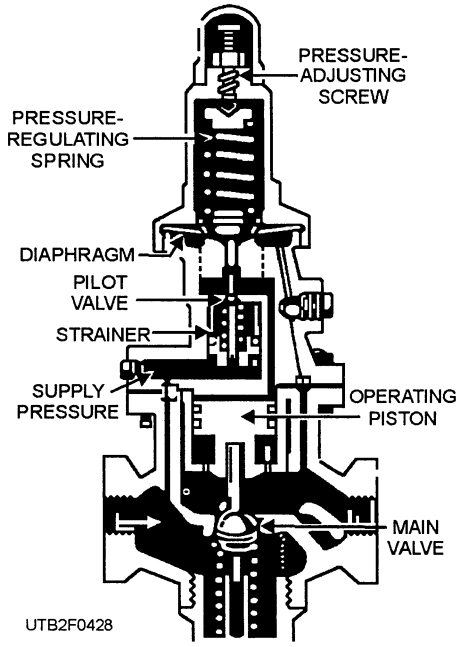


Figure 4-28.—A gas pressure regulator.

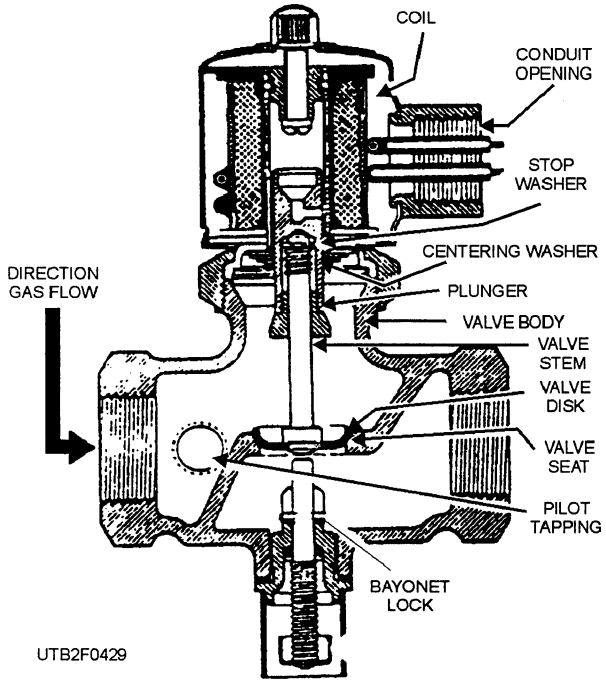


Figure 4-29.—A standard gas solenoid valve.

The recycling solenoid gas valve shown in figure 4-30 can be used with the same heating equipment as the standard solenoid gas valve. The design of this valve differs from that of the standard solenoid gas valve, because it is equipped with an automatic recycling device that allows the valve to switch to manual operation during power failure. However, upon the resumption of power, the thermostat automatically resumes control of this valve.

DIAPHRAGM VALVE.—The diaphragm gas valve shown in figure 4-31 can be used interchangeably with a solenoid gas valve. Its main feature is the absence of valve noise when it is opening or closing. In this type of diaphragm valve, the relay energizes and opens the three-way valve, so the gas pressure on the top of the diaphragm is released to the atmosphere. Reducing the pressure on the top of the diaphragm in this manner causes the gas supply pressure to flex the diaphragm upward, opening the main gas valve. When the relay is de-energized, the vent to the atmosphere is sealed and pressure from the

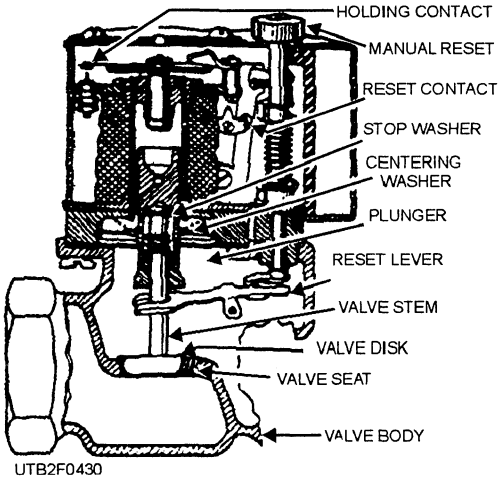


Figure 4-30.—A recycling solenoid valve.

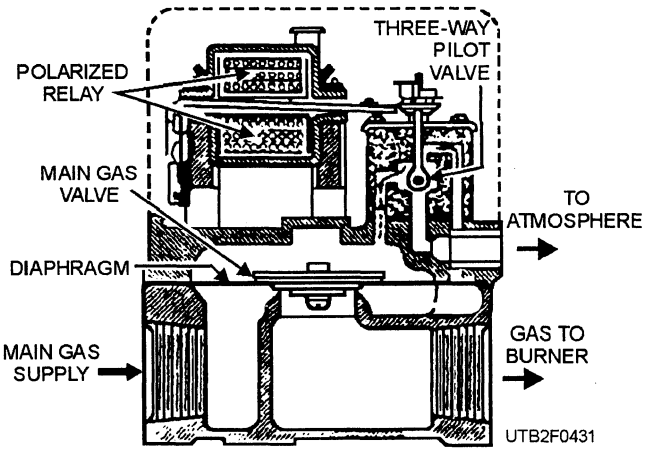


Figure 4-31.—A diaphragm gas valve.

gas supply is allowed to be applied to the top of the diaphragm, forcing it down and sealing the main valve.

PILOT LIGHT.—The gas pilot light in a gas-heating unit is a small flame that burns continuously and lights the main burner during normal operation of the heating unit. It is located near the main burner, as shown in figure 4-27.

The gas flow to the pilot light is, in some cases, supplied by a small, manually operated gas shutoff valve on the main gas line above the main gas valve. In other cases, the gas can be supplied from the pilot tapping on a solenoid gas valve, as shown in figure 4-29. In more expensive heating units, the gas for the pilot light is often supplied by a thermocouple-controlled relay.

THERMOCOUPLE.—A thermocouple is probably the simplest unit in the electrical field that is used to produce an electric current by means of heat. It is constructed of two U-shaped conductors of unlike metals in the form of a circuit, as shown in figure 4-32. If these conductors were composed of copper and nickel, respectively, and are joined as shown in the figure, two junctions between the metals exist. If a flame heated one of these junctions, a weak electric current would be produced in the circuit of these conductors. A series of junctions can be arranged to form a thermopile to increase the amount of current produced, as shown in figure 4-33.

In the heating field, thermocouples and thermopiles are used to produce the electrical current used to operate such units as gas valves, relays, and other safety devices.

The thermocouple is located next to the pilot light of the main gas burner, as shown in figure 4-27. It generates the electric current (usually 50,000 microvolts) which holds open a main gas valve, a relay, or any other safety devices, permitting gas to flow to the main burner. Soon after the pilot light is extinguished, current ceases to flow to these safety devices, thus causing them to shut off the gas to the heating unit. These safety devices will not operate again until the pilot light is lighted and current is again generated by the thermocouple.

THERMOCOUPLE CONTROL RELAY.—The thermocouple-operated relay shown in figure 4-34 is a safety device used on gas-fired heating equipment. The thermocouple, when placed in the gas pilot flame, generates electricity. The electric current energizes an electromagnet that holds a switch or valve in the OPEN position as long as the pilot flame is burning. When the pilot flame goes out because of high drafts or fuel failure, the electromagnet is de-energized, thus closing and preventing the opening of the switch or valve. The

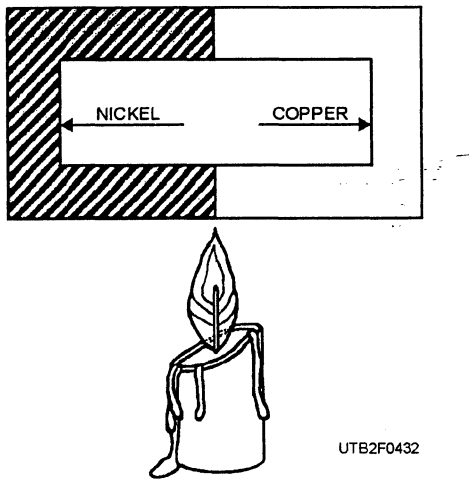


Figure 4-32.—The principle of a thermocouple.

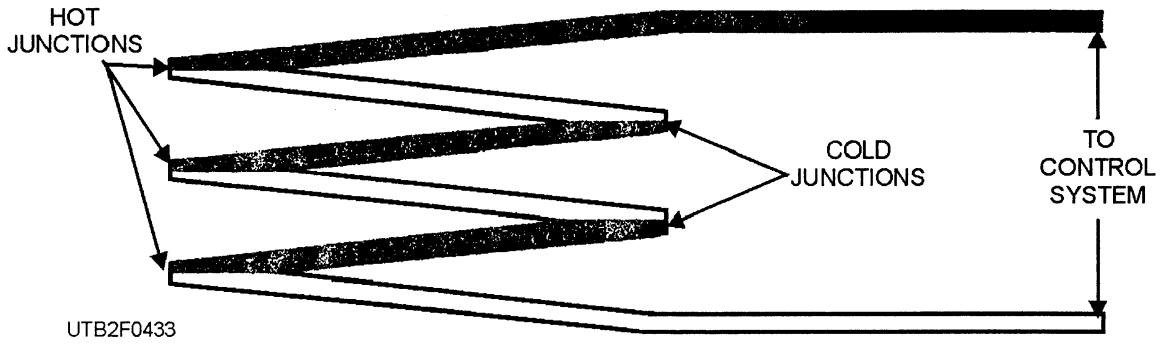


Figure 4-33.—A thermopile.

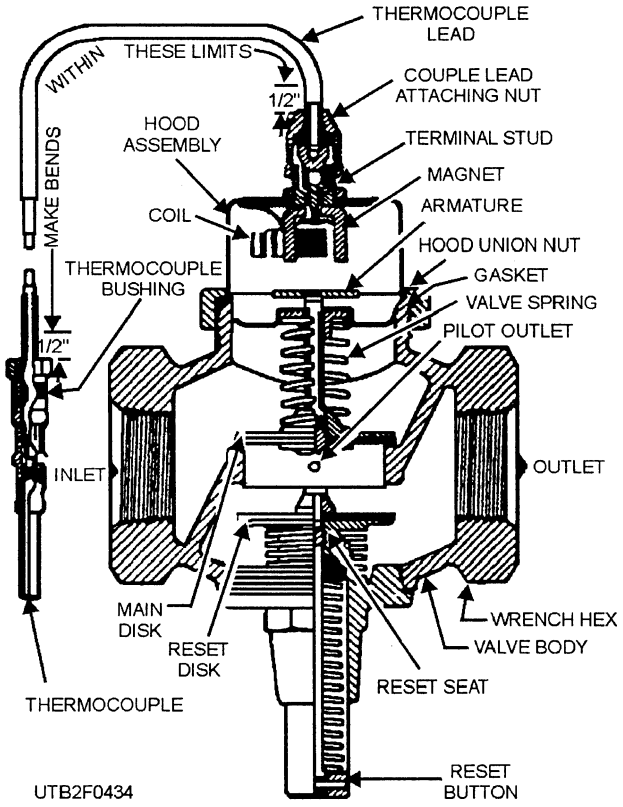


Figure 4-34.—A typical thermocouple and valve relay assembly.

closing of the valve or switch prevents the burner from filling the combustion chamber with unburned gases.

To re-light the pilot light, push up the reset button at the bottom of the relay and allow the gas to flow to the pilot light. Since some heating units are not equipped with relays, the pilot light is not automatically shut off in case of gas supply failure.

The relay shown in figure 4-35 is an electrical switch type of relay. It is entirely electrical and can be used as a controlling unit for either the magnetic or diaphragm gas valves. This unit is actuated by the electric current generated by the thermocouple. It controls the operation of the gas valve in the magnetic and diaphragm valves. A relay of this type must also be reset manually for normal operation.

LIMIT CONTROL.—The limit control in a gas burner system is a safety device. It shuts off the gas supply when the temperature inside the heating unit becomes excessive. The limit control device can be adjusted to the desired setting. It exercises direct control on the gas or diaphragm valve.

HEAT EXCHANGER.—This unit or assembly may be either a single or sectional contoured steel shell. It extends vertically from the burner enclosure to the flue exit. Functionally, it transmits heat from the hot gases of combustion to the circulating warm air that passes the outer surfaces.

Draft Diverter.—The diverter is simply a sheet metal chamber that encircles the flue. It has an opening at the bottom to allow air to be drawn in by the flue draft. Its purpose is to reduce the downdrafts and updrafts that are objectionable to pilot and burner operation.

Humidifiers. —Humidifiers used with forced warm-air heating systems are usually of the pan type shown in figure 4-36. Unless the water is relatively free of solids, these humidifiers require frequent attention, since the float may stick in the OPEN position or the valve may clog. Overflowing of the pan may result in a cracked heating section, and a stopped-up inlet valve will make the humidifier inoperative.

The drum type of evaporative humidifier uses an evaporation pad in the shape of a wheel. The slow-turning wheel is submerged in the water in the lower pan where the spongelike plastic foam material becomes saturated with water. The wheel lifts this portion of the pad and exposes it to the warm, dry air flowing through it. The air then absorbs more moisture because of lower relative humidity at a higher temperature.

OIL-FIRED FURNACES

Oil-fired furnaces are similar to gas-fired units in physical arrangement. Internally, oil-fired units have three areas—the burner compartment, the combustion

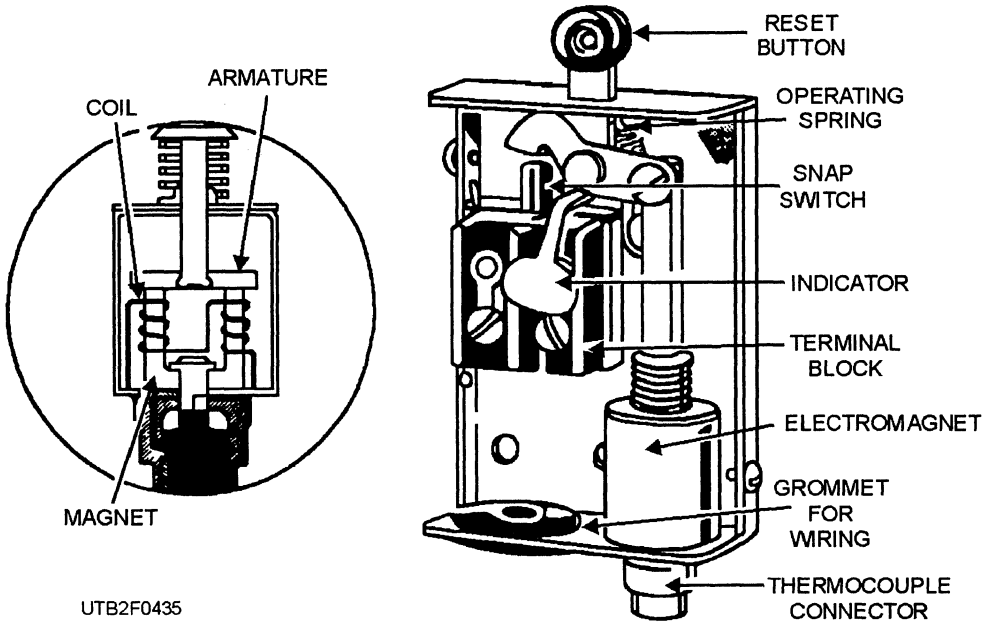


Figure 4-35.—An electric switch type of relay.

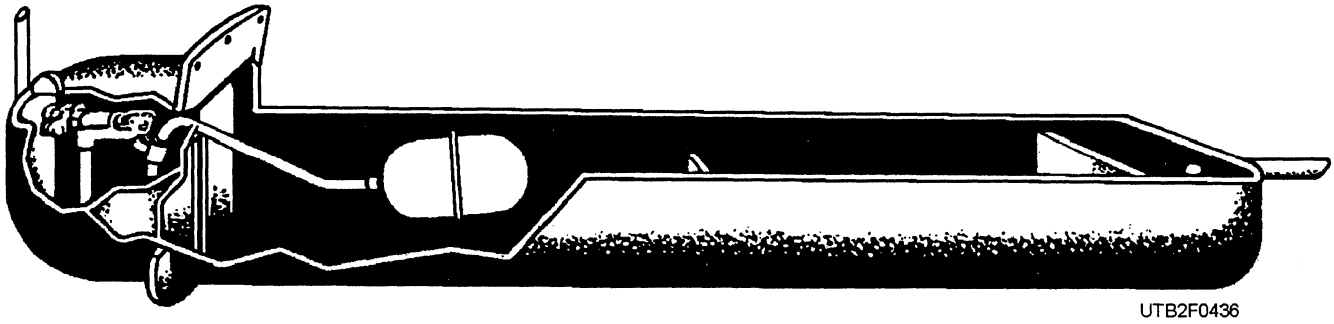


Figure 4-36.—Cutaway view of a typical humidifier.

and radiating chamber, and the blower compartment. Figure 4-37 shows a cutaway view of a typical oil-fired furnace.

Like gas-fired units, oil-fired units are also available with various airflow designs. The model shown in figure 4-15 is designed with both the return-air inlet and the warm-air outlet in the top. More compact models (fig. 4-37) are available with the return-air inlet at the side or bottom below the radiating and combustion area. The warm-air outlet is at the top.

A floor furnace is shown in figure 4-38. This type of oil-fired unit is smaller, lighter in construction, and is designed to be hung from the floor of the space served. Only a minimum of clearance is required below the floor.

Oil burners may be separated into various classes, such as domestic and industrial. Since domestic oil burners are used almost universally in warm-air furnaces, they are the only ones covered in detail in this chapter.

Domestic Oil Burners

Domestic oil burners atomize the oil and are usually electrically power driven and are used in small central heating plants. They deliver a predetermined quantity of oil and air to the combustion chamber, ignite it, and automatically maintain the desired temperature.

Domestic oil burners are classified according to various methods, none of which is entirely satisfactory because of the overlapping among a great number of models. Classification may be by type of ignition, draft, operation, method of oil preparation, or features of design and construction.

DESIGN AND CONSTRUCTION.—One of the most common types of domestic oil burners is the pressure-atomizing gun type of burner. Gun type

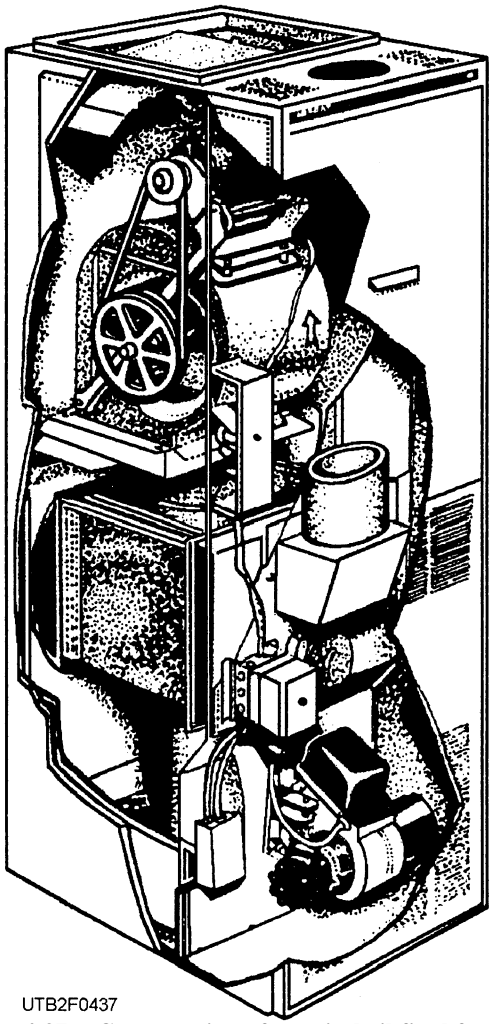


Figure 4-37.—Cutaway view of a typical oil-fired furnace.

burners atomize the oil by fuel-oil pressure. The fuel-oil system of a pressure-atomizing burner consists of a strainer, pump, pressure-regulating valve, shutoff valve, and atomizing nozzle (fig. 4-39). The nozzle and electrode assembly includes the oil pipe, nozzle holder, nozzle, strainer, electrode insulators, electrodes, supporting clamp for all parts, and static disk. The oil pipe is a steel rod with a fine hole drilled through it. This hole reduces oil storage in the nozzle to a minimum that prevents squirting at the nozzle when the burner shuts off.

The air system consists of a power-driven blower with means to throttle the air inlet, an air tube that surrounds the nozzle and electrode assembly, and vanes or other means to provide turbulence for proper mixing of the air and oil. The blower and oil pump are generally connected by a flexible coupling to the burner motor. Atomizing nozzles can be furnished to suit both the angle of spray and the oil rate of a particular installation. Flame shape can also be varied by changing the design of the air exit at the end of the air tubes. Oil pressures are usually about 100 psi, but pressures considerably greater are sometimes used.

Electric ignition is almost exclusively used. Electrodes are located near the nozzle but must not be in the path of the fuel oil spray. The step-up tran sform er provides the high voltage (usually 10,000 volts) necessary to make an intense spark jump across the electrode tips.

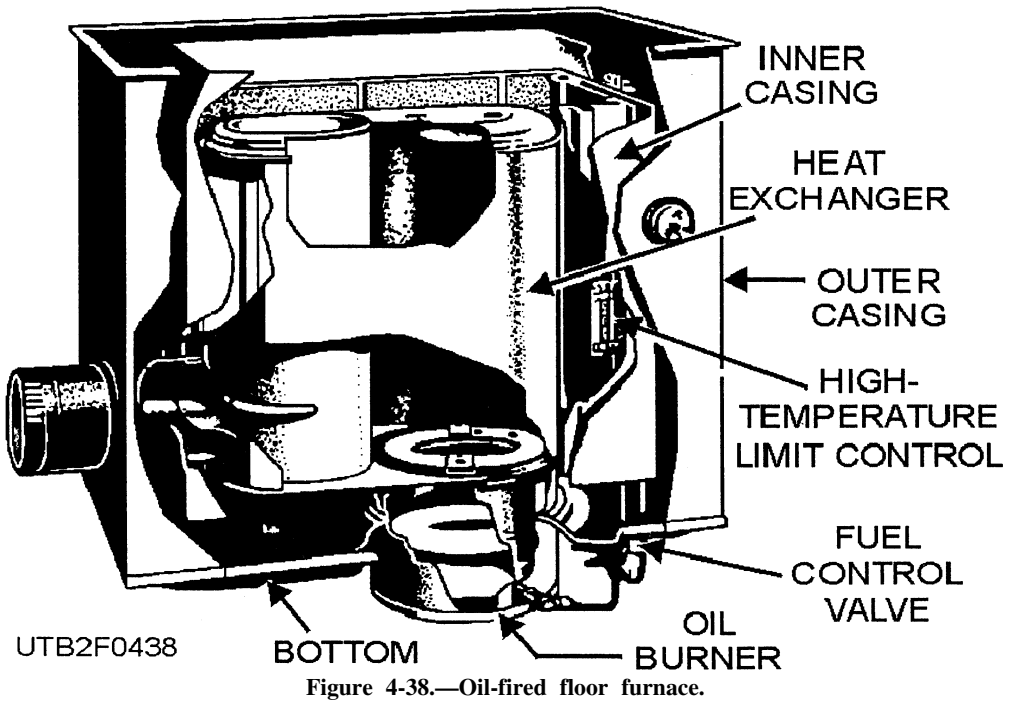


Figure 4-38.—Oil-fired floor furnace.

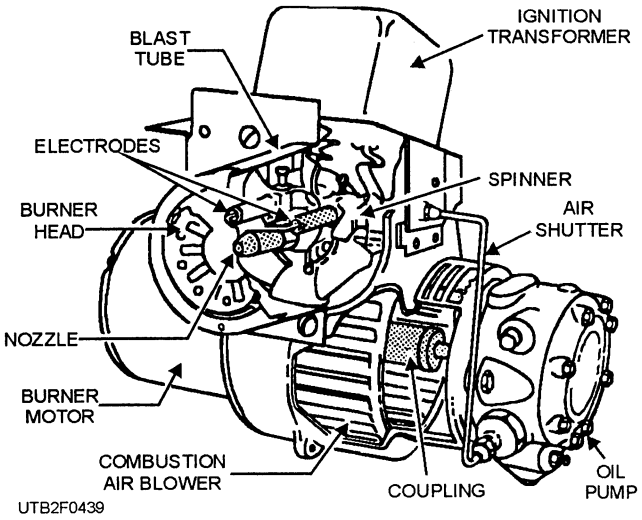


Figure 4-39.—High-pressure gun type of oil burner.

FUEL UNIT.—There are many types of fuel units available for oil burners; however, the T-type, two-stage fuel unit is the most commonly used. Figure 4-40 shows this type of unit. It is an oil pump with two strainers mounted on the body of the oil burner and operated by the blower motor shaft.

The T-type, two-stage fuel unit can be used on a single-line or on a two-line system. When Number 1 on the strainer cover is next to the letter marked on the body of the pump, it is correctly arranged for a single-line system. It is set up for a two-line system when the cover is turned so Number 2 is adjacent to the same letter.

A two-line system is necessary when the bottom of the fuel tank is below the level of the pump. The suction line from the tank is connected to the pump port marked "Inlet." The return line is connected to the pump bypass port and is directed back into the tank. With the one-line system, the return line is not used.

Ignition Electrodes.—The heat of a spark jumping between two ignition electrodes ignites the fuel (fig. 4-39). The voltage necessary to cause the spark to jump is much more than the line voltage available. Therefore, an electric transformer is used to step up the line voltage to approximately 10,000 volts.

The wall flame burner has an oil distributor and fan blades mounted on a vertical shaft directly connected to the motor. The oil distributor projects the oil to a flame ring made of either refractory material or metal. Figure 4-41 shows this type of burner. The hot flame ring vaporizes the oil, and the oil vapors mix with air and burn with a quiet blue flame that sweeps the walls of the furnace. Ignition may be electric, gas-electric, or gas. High-grade fuel oil is necessary for satisfactory performance.

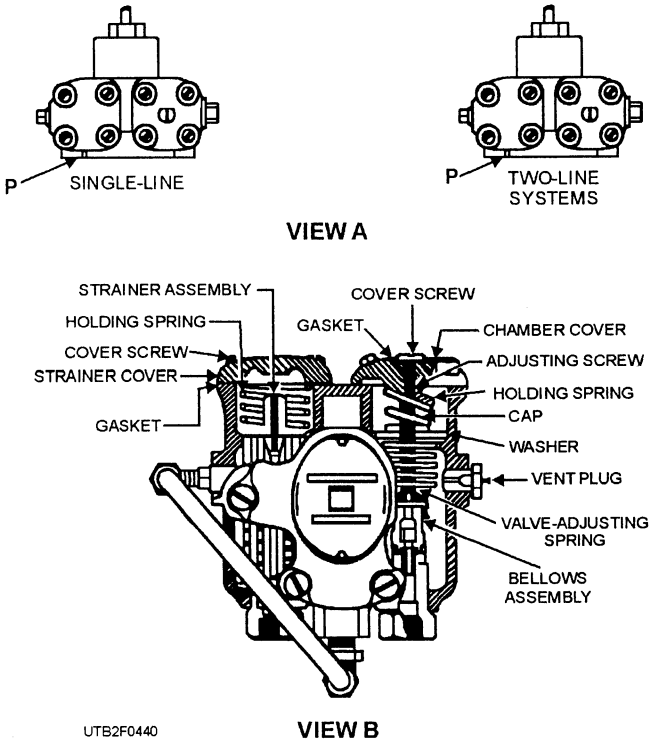


Figure 4-40.—A typical T-type, two-stage fuel pump.

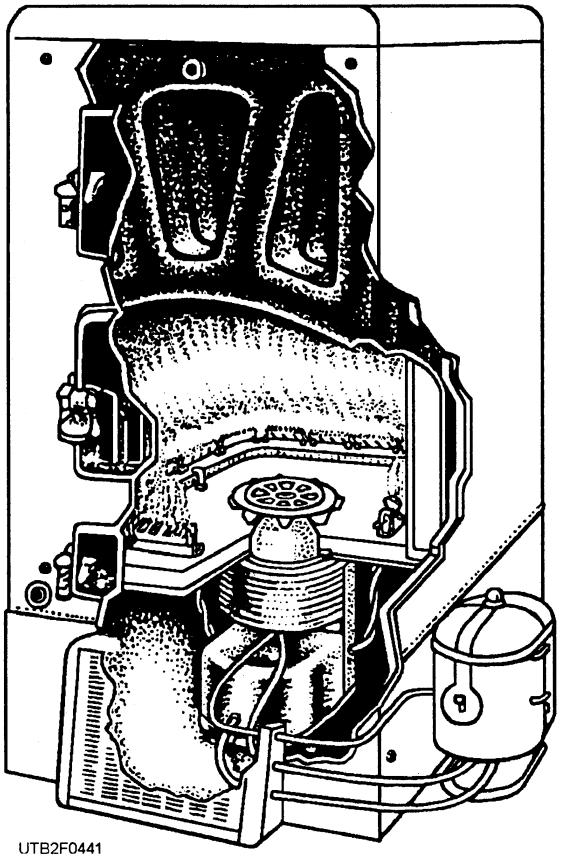


Figure 4-41.—Vertical-rotary burner of the vaporizing or wall flame type.

Horizontal Rotary Type.—The horizontal rotary type was originally designed for industrial use; however, sizes are available for domestic use. It has a wider range of fuel-burning capacity than the high-pressure gun type and can accommodate heavier grades of fuel. Figure 4-42 shows this type of burner.

The major parts of the burner are the housing, fan, motor, fuel tube, and rotating atomizing cup. The atomizing cup and fan are driven at the same speed by a directly connected electric motor. Oil is fed through the fuel tube to the inner surface of the atomizing cup. The oil spreads over the surface of the cup, which turns at 3,450 revolutions per minute (rpm). It then flows to the edge of the cup where it is thrown off. The whirling motion and the resulting centrifugal force separates the oil into fine particles, as it leaves the cup. Primary air supplied by the fan is thrown in around the outer edge of the rotating cup and given a whirling motion in the direction opposite that of the oil. The streams of air and oil collide and thoroughly mix, as they enter the combustion chamber.

OIL BURNER CONTROLS.—The purpose of oil-burner controls is to provide automatic, safe, and convenient operation of the oil burner. The system is designed to maintain the desired room temperature, to

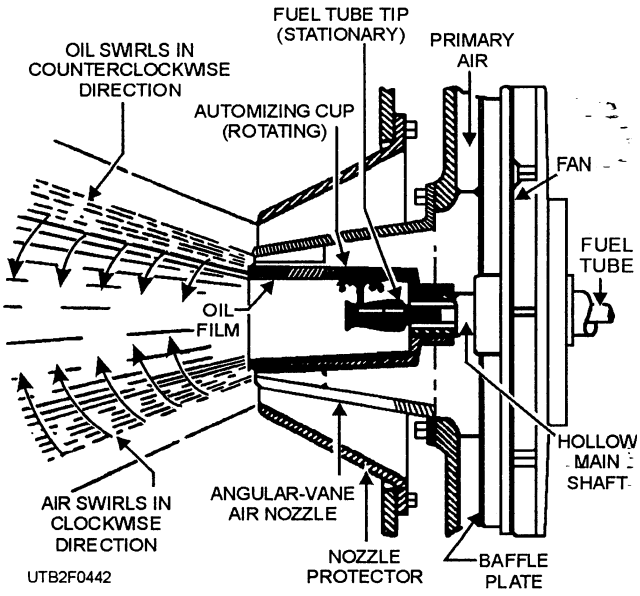


Figure 4-42.—A horizontal-rotary oil burner.

start the burner as required, and to ignite the fuel to initiate combustion. However, in case trouble arises during operation, the burner must be stopped and further operation prevented until the trouble has been corrected.

Oil-burner controls are essentially the same as stoker or gas controls. The only difference is that the oil burner has, in addition, two ignition electrodes and a primary or safety control. A diagram of a typical forced warm-air control system is shown in figure 4-43.

Primary Control.—The burner primary control is electrically connected between the thermostat and the burner, as shown in figure 4-43, and it performs several functions. The primary control closes the motor and ignition circuits when the thermostat calls for more heat. It breaks the motor circuit and stops the burner when the motor first starts if the fuel fails to ignite or if the flame goes out. The control prevents starting of the burner in case of electrical failure until all safety devices are in the normal starting position.

An interior view of a primary control is shown in figure 4-44. This control device is also equipped with a high-temperature limit control. This control shuts down the heating plant whenever the temperature of the furnace becomes excessive. For example, if the thermostat is exposed to a blast of cold air for a long period of time, the heating plant could run long enough to become overheated to the point of severe damage or external fire if it was not for this high-temperature limit control.

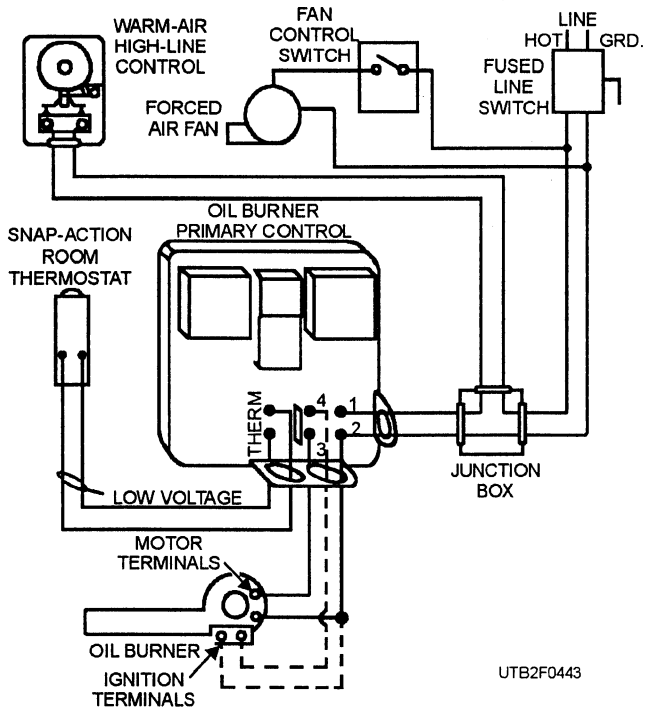


Figure 4-43.—Typical forced warm-air control system.

Limit Control.—The limit control is a device that responds to changes in air temperature (in a warm-air heating system), to changes in water temperature (in a hot-water heating system), and to changes in steam pressure (in a steam-heating system). The limit control has two distinct functions. The first function is to control the operation of the fire so the temperature and pressure of the heating plant never exceeds safe operating limits. This function is distinctly for safety control.

The second function of the limit control is to limit the temperature and pressure of the heating system for better temperature regulation in the building. This function is particularly useful in controlling coal-fired heating systems where the coal bed continues to give off heat when the stoker motor stops. By lowering the setting of the limit control, however, it is possible to prevent an excessively hot fire that would continue to throw off excessive amounts of heat after the thermostat has been satisfied.

Temperature-Responsive Devices.—Many automatic control units, such as the thermostat, limit control, fan control, and many others, must respond to temperature changes. Actually, these are the instruments that use a temperature change to cause the electrical contacts inside each unit to open and close. The opening and closing is an indicating signal that is transmitted to the primary control for specific action, such as starting or stopping the operation of the heating plant.

Bimetallic Strip.—Some automatic control units are equipped with a switch that contains a straight

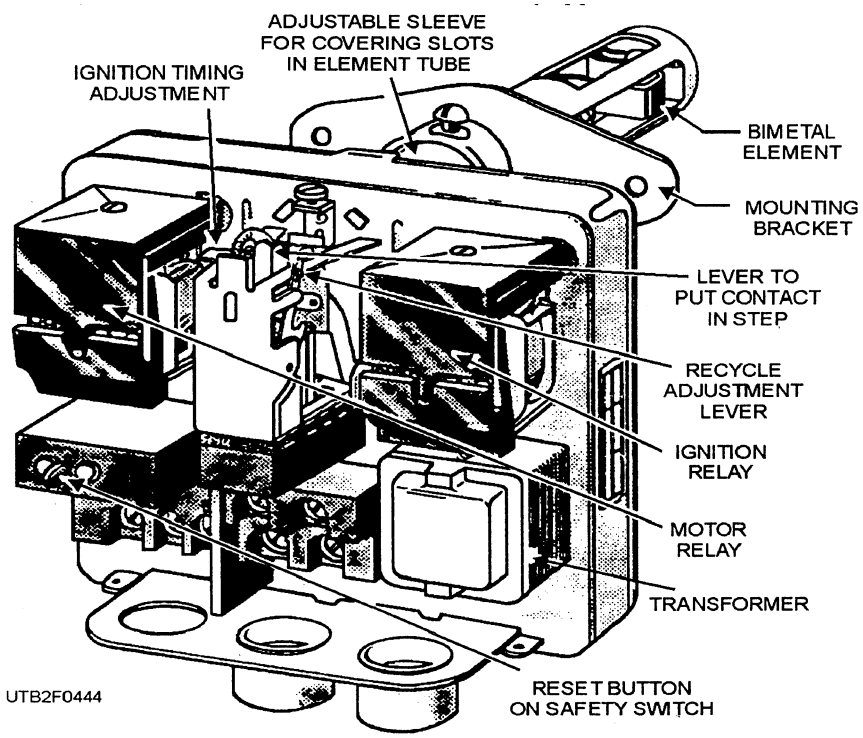


Figure 4-44.—Interior view of a primary control.

bimetallic strip to open and close electrical contacts. This actuating device is made by welding together two pieces of dissimilar metals, such as brass and Invar, as shown in figure 4-45, view A. Below a certain predetermined temperature, this strip does not deflect or bend. However, when the strip is heated, it bends in the direction of the metal that expands the least, as shown in figure 4-45, view B.

Actually, this electrical switch is constructed, as shown in figure 4-45, view C, by welding two electrical connections and contacts to the strip. A switch of this type can then be used to control electrical circuits, because the bimetallic strip responds to temperature changes. This is a basic example of how this principle of bimetallic strip operation is used in many temperature-responsive automatic units. Other control switches contain bimetallic strips that are spiral, U-shaped, Q-shaped, or even in the shape of a helix, as shown in figure 4-46.

Vapor-Tension Device.—The vapor-tension principle is also used to actuate some types of automatic control units. This is a common type of temperature-measuring device in which the effects of temperature changes are transmitted into motion by a highly volatile liquid. The most used vapor-tension device is the simple compressible bellows, as shown in figure 4-47, view A.

The bellows is made of brass. It is partially-filled with alcohol, ether, or other volatile liquid not

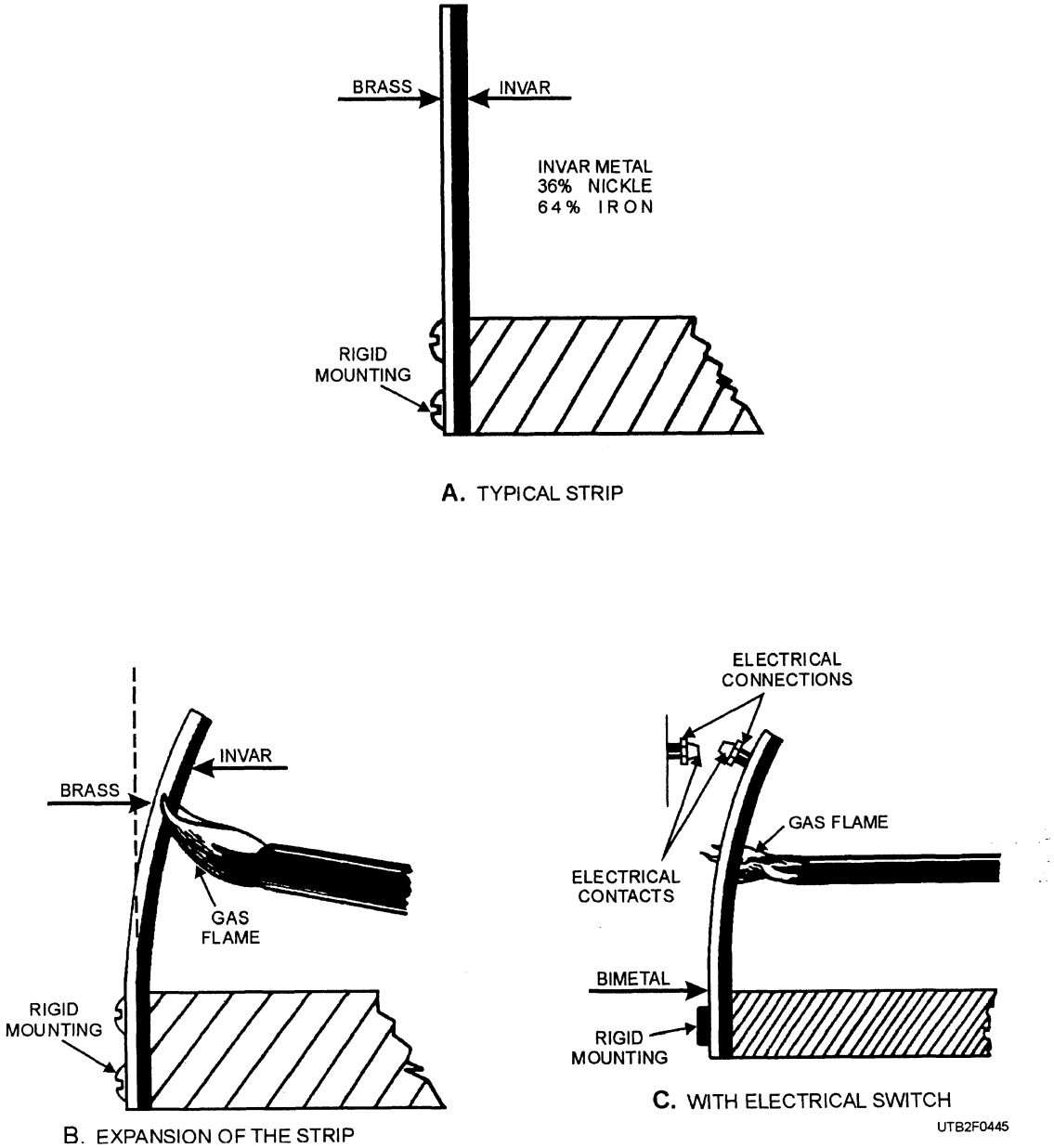


Figure 4-45.—Bimetallic strips: A. Typical strip; B. Expansion of the strip; C. With electrical switch.

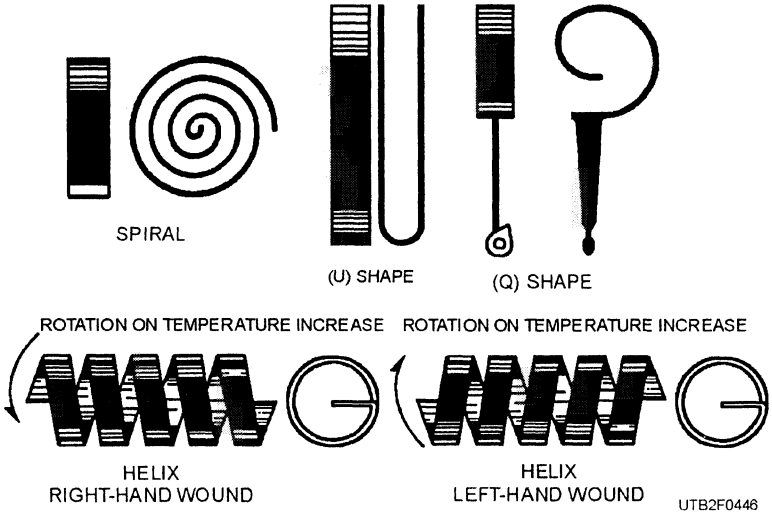


Figure 4-46.—Various types of bimetallic strips.

corrosive to brass. When the temperature around the bellows increases, the heat gasifies the liquid inside and causes the bellows to extend. The extension closes a set of electrical contacts, as shown in figure 4-47, view B. When the bellows cools again, it contracts. The contraction opens the electrical contacts.

Remote-Bulb Device.—Liquid-filled devices are not always limited to the simple bellows. There are some remote-bulb devices that not only have a bellows but also have a capillary tube and a liquid-filled bulb, as shown in figure 4-48.

When the liquid in the bulb is heated, part of it gasifies and forces its way through the capillary tube into the bellows. This increased pressure inside the bellows causes it to extend and open a set of electrical contacts (or open or close a valve). When the bulb cools, the gas liquefies and decreases pressure inside the bell ows. This decreased pressure allows the bellows to contract and close the electrical contacts.

Pressure-responsive devices are actuating mechanisms installed in units, such as steam-pressure controls, steam-pressure gauges, and pressure regulators.

Bellows.—One type of pressure-responsive actuating device uses bellows in a way similar to that of the remote-bulb type. In this application, the bellows extends and contracts in response to changes in steam pressure. The action caused by movement of the bellows opens or closes a set of electrical contacts.

Bourdon Tube.—Another type of pres sure-responsive actuating device is found inside of the pressure gauge shown in figure 4-49. In this actuating device, the pressure is applied inside a

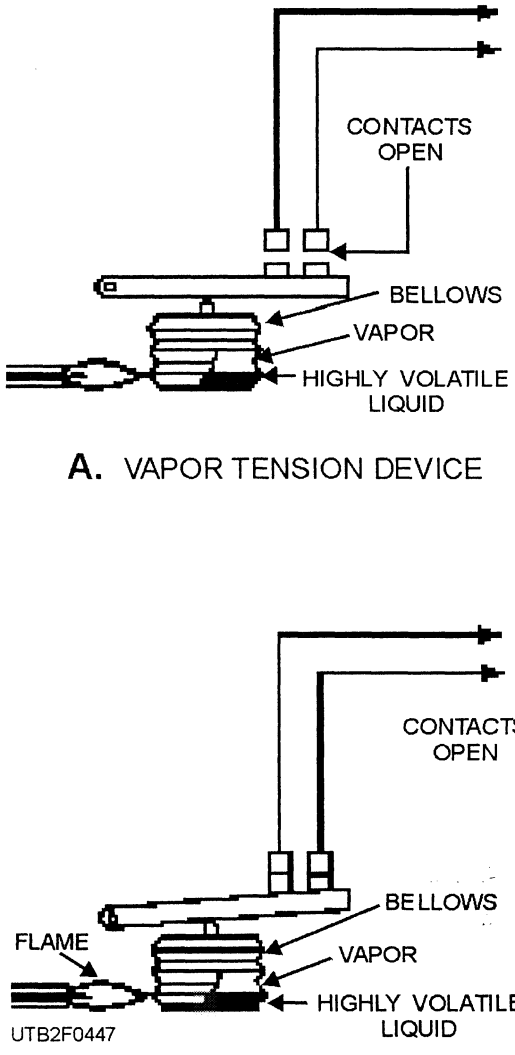


Figure 4-47.—Tension devices: A. Vapor-tension device; B. Pressure-tension device closing electrical contacts.

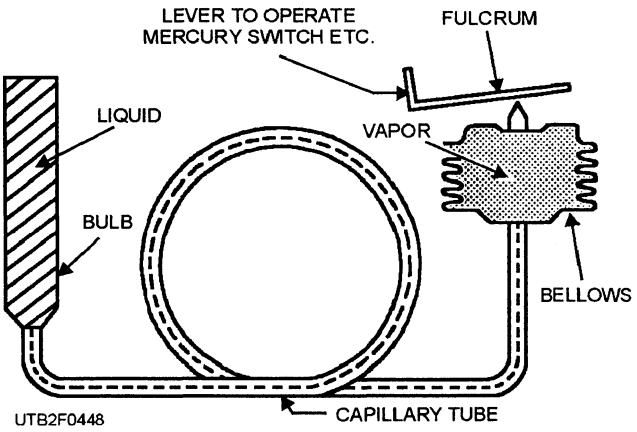


Figure 4-48.—Schematic of a remote-bulb device.

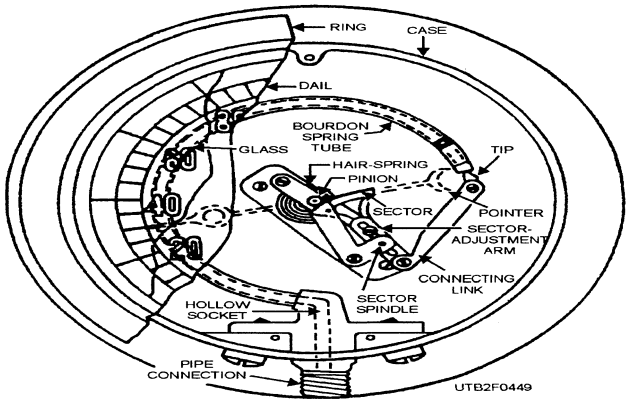


Figure 4-49.—A typical Bourdon spring tube.

hollow, partially flattened, bent tube, called a Bourdon spring tube. The pressure inside this tube tends to straighten it, and in so doing, it moves the lever mechanism that turns the pointer. The pressure gauge measures the pressure in pounds per square inch (psi).

Humidity-responsive devices open or close solenoid or motorized valves, which control the flow of water or steam to humidifying equipment. The sensitive element, which actuates the motion in this device, consists of a group of human hairs. These hairs lengthen when the humidity is high and shorten when the humidity is low.

Accumulation of dust and grease on these hairs, while not damaging, may decrease the sensitivity of the controller. Consequently, the element should be cleaned periodically with a camel's-hair brush and clean ether. A complete wetting with distilled water should follow this cleaning.

Electrical Switches.—Electrical switches in heating control equipment operate electrical circuits in response to signals from automatic control units. In other words, the actions initiated by devices responsive to temperature, pressure, and humidity changes open or close switch contacts. These, in turn, control the operation of the heating plant through electrical circuits. Switches may be either the snap-action type or the mercury type.

Snap-action switches vary in their designs.-Some are constructed so they have an over-center spring arrangement that is designed so the movement of the actuating lever engages the spring and causes the switch to move with snap-action. The snap-action type of switch is shown in figure 4-50, view A.

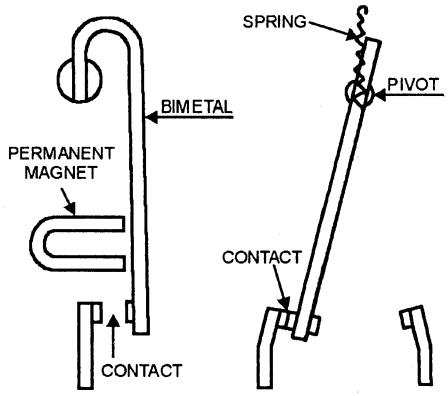
Another snap-action switch shown in figure 4-50, view A, has a small magnet that causes the electrical contacts to remain firmly closed. It also provides the switch with the snap-action effect. The contacts of this switch must open or close quickly to avoid excessive arcing across the points. Arcing burns the contacting surfaces, which eventually causes switch failure.

A mercury switch has the electrical contacts and a small amount of mercury in a hermetically sealed short glass tube, as shown in figure 4-50, view B. Tilting the switch causes the mercury inside the tube to cover or uncover the contacts. When the contacts are covered, the electrical circuit is completed.

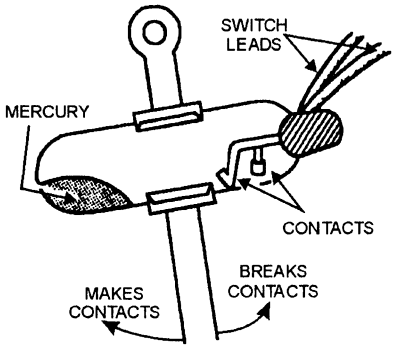
Every electrical switch is designed so it has a specific rated capacity in amperes and volts; for example, a capacity of 8 amperes at 110 volts. An electrical switch should never be overloaded because overloading causes overheating, which eventually results in switch failure that can create a fire hazard.

The standard controls furnished for automatic fuel-burning equipment come in sets designed for warm-air, hot-water, and steam-heating systems. A standard set usually consists of a thermostat, limit control, primary control, and electric motor. Auxiliary controls are those designed for a specific function in a warm-air, hot-water, or steam-heating system. They are in addition to the standard controls.

Thermostat.—The thermostat is the nerve center of the heating-control system. It is the sensitive unit that responds to changes in room temperature. It indicates whether more or less heat is required from the



A. SNAP-ACTION SWITCH



B. MERCURY SWITCH

UTB2F450

Figure 4-50.—Electrical switches: A. Snap-action switch; B. Mercury switch.

heating plant. It transmits the indicating signal to a primary control for action. This indicating signal is initiated by closing or opening electrical contacts in the thermostat.

Thermostats often differ in construction according to the type of primary control with which they are to be used. Probably the most used thermostats are the spiral-bimetallic type and the mercury-bulb type.

An electric clock thermostat has the additional features of an electric clock and an automatic mechanism that can be adjusted to change the thermostat setting at a desired time. For instance, it can be adjusted to reset the thermostat automatically from 80°F to 60°F at 11:00 p.m. (when 80°F heat is not needed). Then it will reset the thermostat to 80°F at 6:00 a.m. (when more then 60°F heat is needed).

The location for the thermostat should be representative of that part of the building in which heat is needed to maintain a comfortable temperature. The best location is on an inside wall, just a few feet from an outside wall and about 4 1/2 feet above the floor. The thermostat wiring must conform to local electrical ordinances.

To check the calibration of a thermostat, hang-an accurate test thermometer within 2 inches of the device. Allow 15 to 30 minutes for the thermostat and thermometer to adjust themselves to room temperature. The thermostat contacts should close when the control knob or dial is set at the temperature indicated by the test thermometer. You should not try to recalibrate the thermostat if the closing point varies 1°F or less. When calibration is necessary, follow the manufacturer's instructions.

FURNACE INSTALLATION

Since there are many types and makes of oil- and gas-fired warm-air furnaces on the market, detailed assembly instructions to suit all makes and types cannot be given in this manual. However, some general instructions, which apply to both oil-fired and gas-fired furnaces, except as noted, are given below.

Carefully follow assembling instructions included with each furnace or blower shipment. Each piece or casting is manufactured to fit in its proper place. Parts are seldom interchangeable.

Install furnaces in a level position. If the floor is uneven, use a steel wedge, a cast-iron wedge, or the leveling bolts provided on some equipment. Use a spirit level to make sure the unit is level.

Gas-fired and oil-fired forced-air units, which have the blower below the heating element or combustion chamber, should be set on masonry at least 3 inches thick and extending at least 12 inches beyond the casing wall. Install all other units on a cold masonry floor. Provide enough clearance to permit easy access for repairs. Make the clearance at least 18 inches from wood or other combustible material unless you install an asbestos board at least 1 inch from the combustible material. Units may be installed near masonry walls; however, leave ample room to permit proper servicing.

Furnace cement is furnished with each cast-iron furnace. Seal all furnace joints with a liberal amount of furnace cement between sections to ensure the furnace is gastight. Asbestos rope is furnished with a number of furnaces; follow the manufacturer's instructions covering its use. See that projections from the furnace, such as the smoke pipe or clean-out doors, extend through the outside of the casing.

In assembling a furnace, be sure to tighten all bolts. Draw each bolt until it is almost tight. Then, after all

bolts have been installed, draw each one gradually until all are uniformly and properly tight. Avoid drawing bolts too tight, as this can crack or break a casting or buckle a steel plate.

After assembling the furnace, check all doors for free operation and tight fit.

Install the downdraft diverters furnished with the equipment on all gas-burning furnaces. Diverters are developed for individual furnaces.

Use a vent or smoke pipe that is at least as large as the smoke-pipe outlet of the furnace.

Securely fasten the vent or smoke pipe at each joint with a minimum of three sheet metal screws. Install horizontal pipe with a pitch upward of at least l-inch per linear foot (fig. 4-51).

Ventilate the furnace room adequately to supply air for combustion. Provide an opening having 1 square inch of free-air area for each 1,000 Btu per hour of furnace input rating with a minimum of 200 square inches. Locate the opening at or near the floor line whenever possible. In addition, provide two louvered openings, each having a free-air area of at least 200 square inches in it, at or near the ceiling as near opposite ends of the furnace room as possible.

Tank installation is largely governed by local conditions. Listed here are the principles of tank installation that give greatest freedom from service problems. Adhere as closely to these recommendations as local conditions permit.

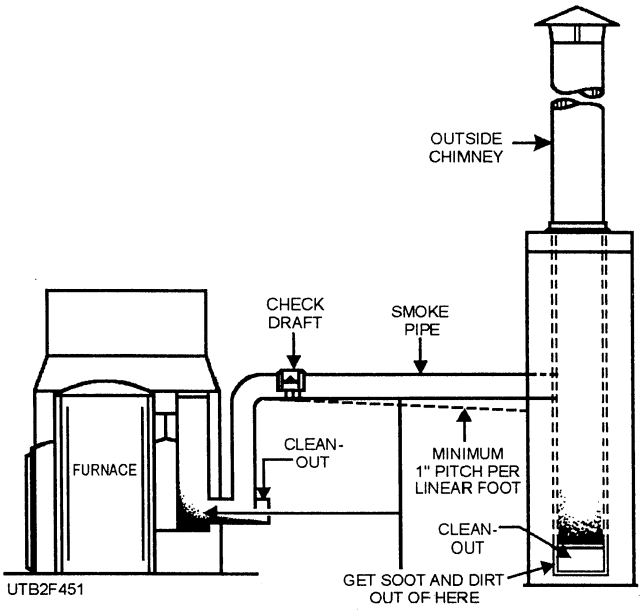


Figure 4-51.—Typical smoke pipe (flue) installation.

When possible, install single-pipe gravity oil feed on inside tanks or elevated outside tanks (fig. 4-52). This type of installation is used for single-stage pumps. Use a 1/4-inch globe valve at the tank instead of a larger size. Larger valves sometimes cause tank hum.

For all installations, use a continuous piece of 1/2-inch copper tubing from the oil tank or valve to the burner and a similar piece for the return when required. The principle is to minimize the number of joints and thus minimize the possibility of air or oil leaks.

For inside installations where it is necessary to run the piping overhead between the tank and burner, when the burner is either above or below the tank level, the two-pipe system is recommended. This requires the use of a two-stage pump.

A dual-stage pump may be changed from a single-stage to a two-stage pump to accommodate a single-pipe or two-pipe system. The stages on a Webster fuel pump can be changed by removing the four screws on the pressure side of the pump and lining the Number 1 up with the letter on the pump body for a one-pipe system. The Number 2 lined up with the letter is for a two-pipe system. Most Sunstrand fuel pumps are shipped from the factory set up for a one-pipe system. To change to a two-pipe system, remove the 3/8-inch pipe plug from the bottom of the pump housing. There you will find an Allen head plug. Remove this plug for a two-pipe system.

Install the outside tanks (fig. 4-53) according to the instruction below.

Normally, when you are installing an underground fuel tank, the suction and return lines are made of black iron from the tank to the inside of the building, and there the burner is connected by copper tubing with a coil in it (not shown in the illustration) to eliminate vibration.

The return line is usually installed in the opposite end of the tank. Carry it to within 5 inches of the bottom. This creates an oil seal in the two lines, and any agitation caused by return oil is safely away from the suction line.

A 1 1/2-inch fill line and a 1 1/2-inch vent line are recommended. Carry the vent well aboveground and put a weatherproof cap on it. Pitch the vent line down toward the tank.

Use special pipe dope on all iron pipe fittings that carry oil. Treat the underground outside tank and piping with a standard preparation or commercial corrosion-resistant paint.

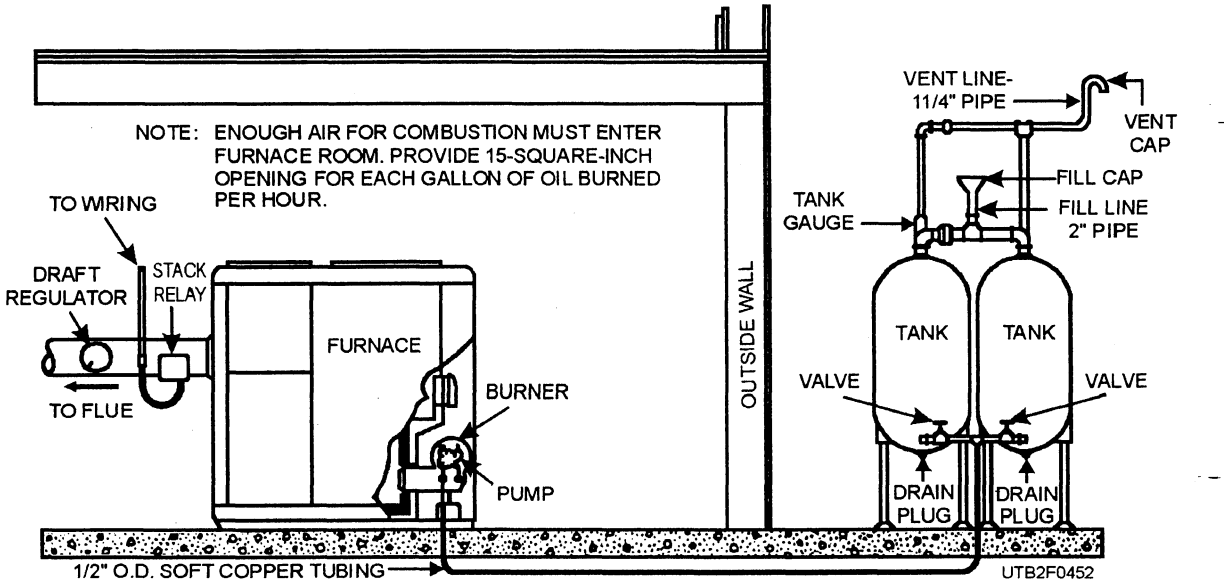


Figure 4-52.—Diagram of piping for inside or outside elevated tank installations.

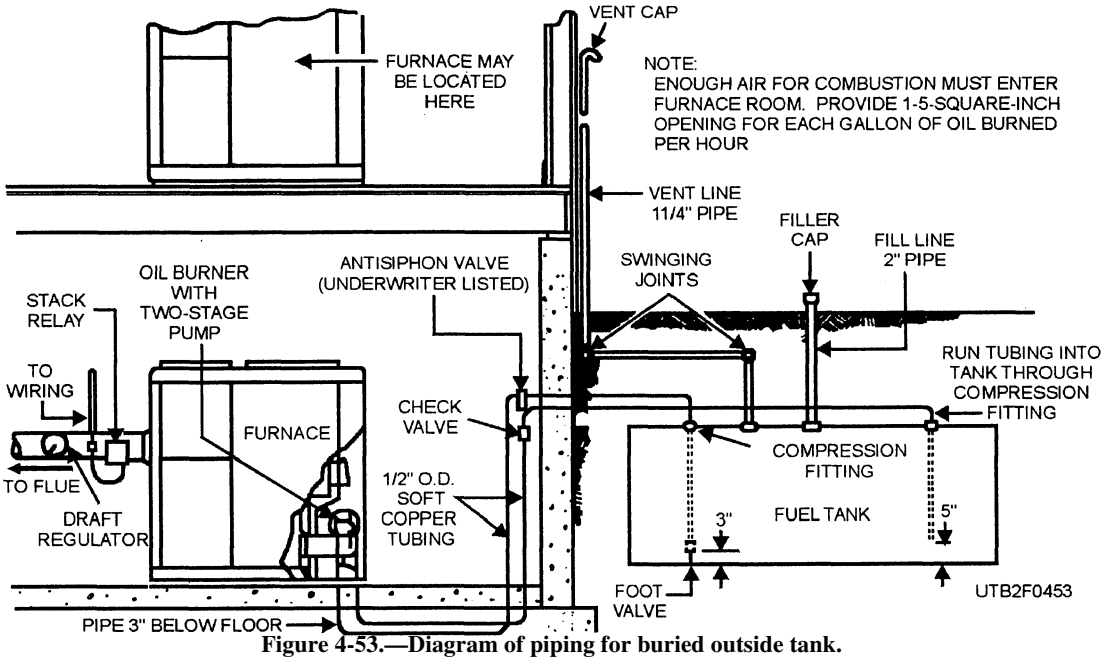


Figure 4-53.—Diagram of piping for buried outside tank.

MAINTENANCE OF FUEL OIL SYSTEMS

Among the major duties of the Utilitiesman are troubleshooting and servicing oil burners. To keep the burner in good operating condition, you must be able to recognize the symptoms of various types of trouble and must know how to make various service and maintenance adjustments to the burner.

Before getting into a discussion on trouble-shooting and servicing of oil burners, let's point out some information on fuel oil firing.

Fuel Oil Firing

Because fuel oils do not burn in the liquid state, several physical conditions must be attained to affect complete and efficient combustion.

1. Either the liquid must be thoroughly vaporized or gasified by heating within the burner, or the burner must atomize it so vaporization can occur in the combustion space.
2. The mist must be thoroughly mixed with sufficient combustion air.

3. Required excess air must be maintained at a minimum to reduce stack thermal loss.

4. Flame propagation temperature must be maintained.

Vaporization within the burner is generally confined to small domestic services, such as water heating, space heating, and cooking, and to some industrial processes. Burners for this purpose are usually of the pot type with natural or forced draft, gravity float-type feed control, and hand or electric ignition. Kerosene, diesel oils, and commercial oils of grades Nos. 1 and 2 are suitable fuels because they vaporize at relatively low temperatures.

If oil is to be vaporized in the combustion space in the instant of time available, it must be broken up into many small particles to expose as much surface as possible to the heat. This atomization is done in three basic ways:

1. By using steam or air under pressure to break the oil into droplets
2. By forcing oil under pressure through a suitable nozzle
3. By tearing an oil film into tiny drops by centrifugal force

Primary combustion air is usually admitted to the furnace through a casing surrounding the oil burner. The casing is spiral-vaned to impart a swirling motion to the air, opposite to the motion of the oil. Three types of burners used for atomization are the steam- or air-atomizing burner, the mechanical-atomizing burner, and the rotary-cup burner.

Burners should be piped with a circulating fuel line, including cutout, bypass, pressure-relief valves, and strainer ahead of the burner. Burners should be accessible and removable for cleaning, and the orifice nozzle plates should be exchan geable to compensate for a wide range in load demand.

Steam-Atomizing and Air-Atomizing Burners

The burners consist of a properly formed jet-mixing nozzle to which oil and steam or air is piped. The conveying medium mixes with fine particles of fuel passing through the nozzle, and the mixture is projected into the furnace. Nozzles may be of the external or internal mixing type, designed to project a flame that is flat or circular and long or short. A burner should be selected to give the form of flame that is most suitable for furnace conformation. Nozzles should be positioned so there is no flame impingement on the furnace walls and so combustion is completed before the i-lame contacts the boiler surfaces.

Steam-atomizing burners are simpler and less expensive than the air-atomizing type and are usually used for locomotive and small power plants. They handle commercial grade fuel oils Nos. 4, 5, and 6 and require a steam pressure varying from 75 to 150 psi. The oil pressure needs to be enough to carry oil to the burner tip, usually from 10 to 15 psi. Burners using air as the atomizing medium are designed for three air pressure ranges: low pressure to 2 psi, medium pressure to 25 psi, and high pressure to 100 psi.

Figure 4-54 shows a steam-atomizing burner of the external mixing type. In view (A), the oil reaches the tip through a central passage and whirls against a sprayer plate to break up at right angles, view (B), to the stream of steam. The atomizing stream surrounds the oil chamber and receives a whirling motion from vanes in its path. When air is used as the atomizing medium in this burner, it should be at 10 psi for light oils and 20 psi for heavy oils. In view (C), combustion air enters through a register; vanes or shutters are adjustable to give control of excess air.

Mechanical-Atomizing Burner

The burner is universally used except in domestic or low-pressure service. Good atomization results when oil under high pressure (to 300 psi) passes through a small orifice and emerges as a conical mist. The orifice atomizing the fuel is often aided by a slotted disk that whirls the oil before it enters the nozzle.

Figure 4-55 shows a mechanical-atomizing burner. View (A) is a cross section of the burner; view (B) shows the central movable control rod that varies, through a regulating pin, the area of tangential slots in the sprayer plate and the volume of oil passing through the orifice; view (C) shows a design with a wide-capacity range, obtained by supplying oil to the burner tip at a constant rate in excess of demand. The amount of oil burned varies with the load; the excess is returned.

Horizontal Rotary-Cup Burner

The burner (fig. 4-56) atomizes fuel oil by tearing it into tiny drops. A conical or cylindrical cup rotates at high speed (about 3,450 rpm), if motor driven. Oil moving along this cup reaches the periphery where centrifugal force flings it into an airstream. It is suitable for small low-pressure boilers.

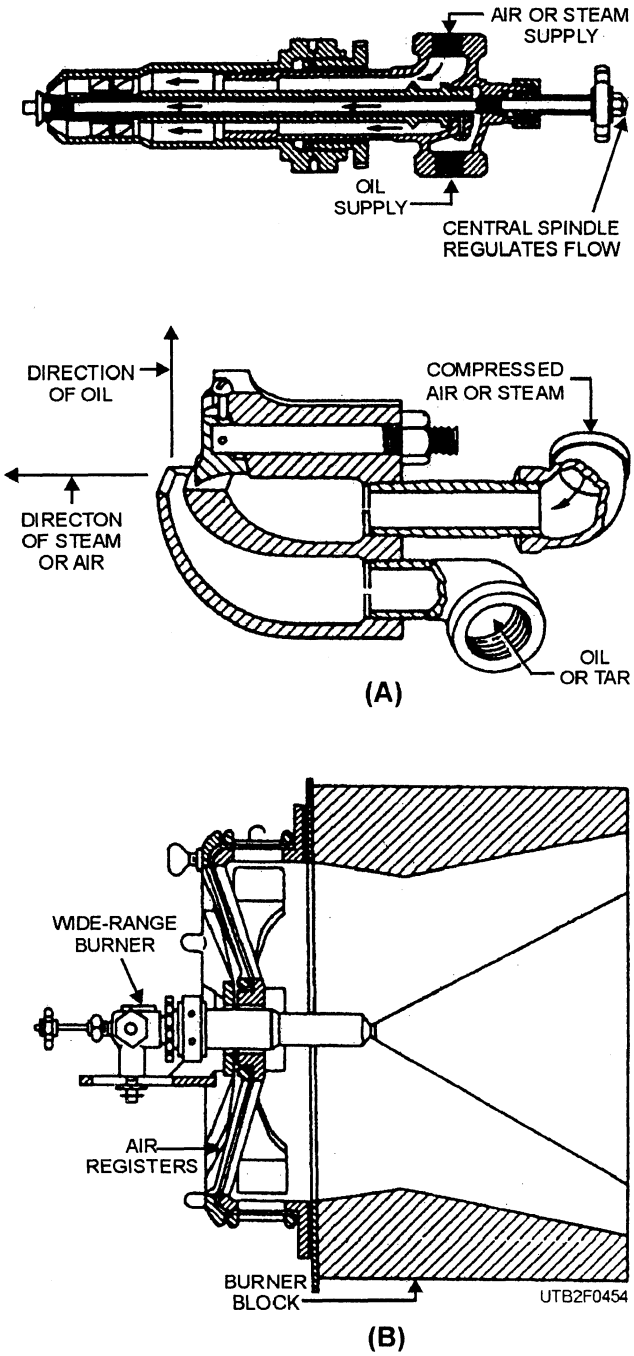


Figure 4-54.—Steam-atomizing burner.

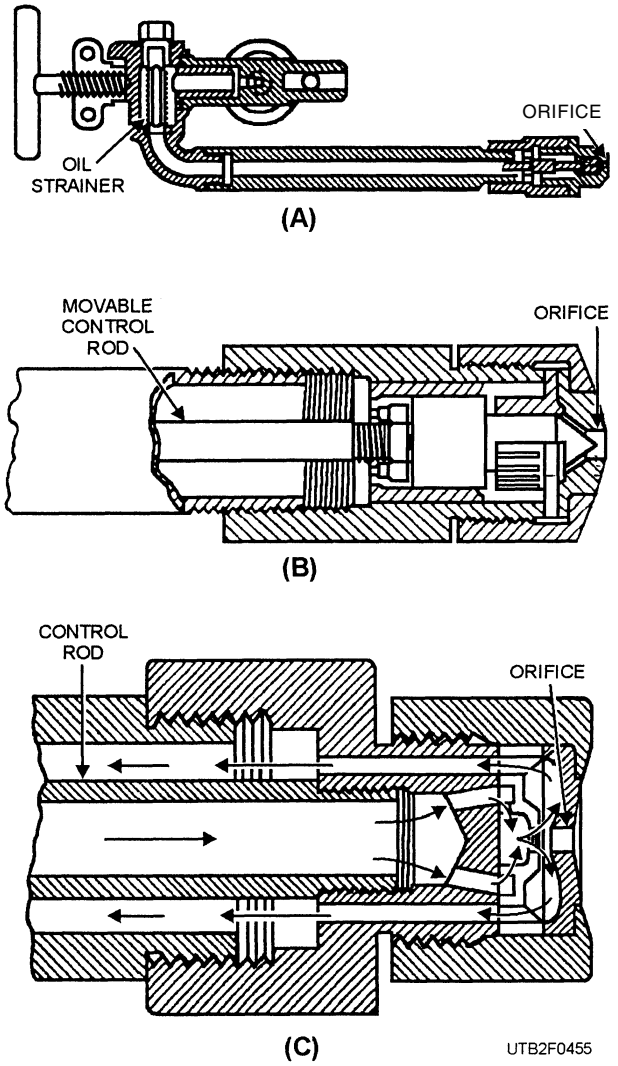


Figure 4-55.—Mechanical-atomizing burner.

OIL-BURNER MAINTENANCE

Before attempting to start or to service oi I burners, see that you have the proper maintenance equipment available. One item of equipment needed is a pressure gauge set. This should consist of a 150 psi pressure gauge, fittings to connect it, and a petcock for removing the air from the oil line when starting the burner. You will need a full set of Allen setscrew wrenches for bypass plugs and for adjusting the nozzle holder and electrodes. Make sure you have a socket wrench of proper size for removing or replacing the nozzle, an open-end wrench as required for the nozzle holders, and a small thermostat wrench. This wrench comes packed with the thermostat and is used for adjusting the differential. A small screwdriver is required for adjusting pressure at the regulator and installing and servicing the thermostat. Another important item is pipe dope, and if available, use the oil-line type only. If in doubt, order a can of special oil-pipe dope for use on all pipe threads requiring dope. A nozzle assortment should also be kept on hand. It is cheaper to make a change, time considered, than to clean the nozzle on the job. When a few nozzles have accumulated, clean them in the shop.

When installing a nozzle, use a socket wrench for turning the nozzle. Be sure the nozzle seat is clean. Screw it on until it reaches the bottom, then back it off and retighten it several times to make sure of a tight oil seal. Do not overtighten the nozzle or the brass threads will become deformed, making it difficult to remove the nozzle.

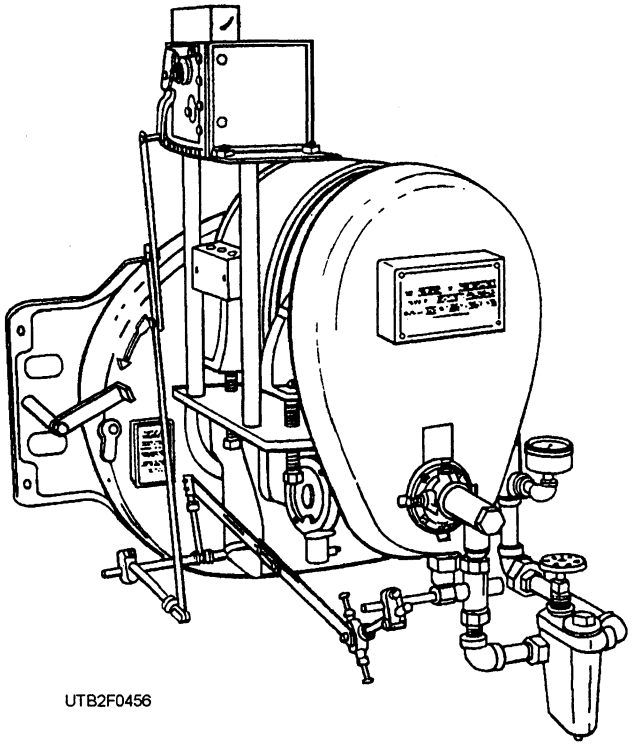


Figure 4-56.—Rotary-cup oil burner.

Clean the nozzles in the shop on a clean bench. A nozzle is a delicate device. Handle it with care. Use kerosene or safety solvent to cut the grease and gum; use compressed air, if available, to blow the dirt out. Use goggles for eye protection when blowing dirt out with compressed air. Never use a Jnetal needle to clean the opening; it will ruin the nozzle. Sharpen the end of a match or use a nonmetallic bristle brush to clean the opening.

When you are checking the nozzle, adjustments may have to be made in the distance of the nozzle from the tube end, the distance of the ignition points ahead of and above the nozzle, and the distance or gap between the ignition points. Figure 4-57 shows these nozzles adjustments. The nozzle tip is set 5/8 inch apart, 1/8 inch ahead of the nozzle, and 1/2 inch above the nozzle center line. These settings are given only for this particular illustration. Actual adjustments should always be made according to the specific settings in the manufacturer's instruction manual. Always tighten electrodes securely to ensure permanent adjustment.

When reinstalling either the pump or the motor, check the coupling to ensure there is no end pressure on the pump shaft as evidenced by lack of end play. If there is end pressure, the coupling should be loosened, moved closer to the pump, and re-tightened.

Troubleshooting

When oil burners are operated, operating problems will occur. These problems can cause interruption of service, inefficiency, and damage to the equipment in the system. To ensure proper operation and efficiency, you will need to be able to identify and correct these difficulties. A list of common difficulties and their remedy are contained in appendix II, table L.

Flame Adjustment

After the burner has been visually adjusted and allowed to run about 30 minutes, reduce the stack draft until there is just enough over-fire draft in firebox to keep the pressure from increasing under unfavorable draft conditions. The draft regulator helps Jnaintain a constant draft in the furnace regardless of outside weather conditions. Adjust the draft by properly setting the ad-juster. Too little draft is likely to cause firebox pressure, odors in the building, and possible smoke or smothering of the flame. Too much draft accentuates the effect of a possible leak in the furnace, lowers the percentage of CO_2 in the flue gas, and, in turn, reduces the overall efficiency of the unit. After the burner flame and draft are properly adjusted, a flue-gas analysis should show a CO_2 content of approximately 10 percent. If it does not, recheck the burner air adjustment and inspect for air leaks. For best results, the flame should be just large enough to heat the building properly in cold weather.

Air supplied to the burner will then be the minimum for clean combustion. If the furnace is large enough and the burner has been set for correct oil flow and minimum amount of air, stack temperature should not exceed 600°F. Higher stack temperatures indicate that the fire is too large or the furnace too small, or that there is too much excess air.

Test Equipment

It is almost impossible to set and adjust a burner without instruments or test equipment. Proper instruments, in good working order, must be available in the heating shop for use by personnel who service this equipment.

The draft gauge, usually of the pointer-indicating type, is used to determine suction in the smoke pipe or combustion chamber. Suction is measured in inches of water. Carefully follow the instructions for operating the instrument.

The stack thermometer is used to indicate the temperature of gases in the smoke pipe. Insert the

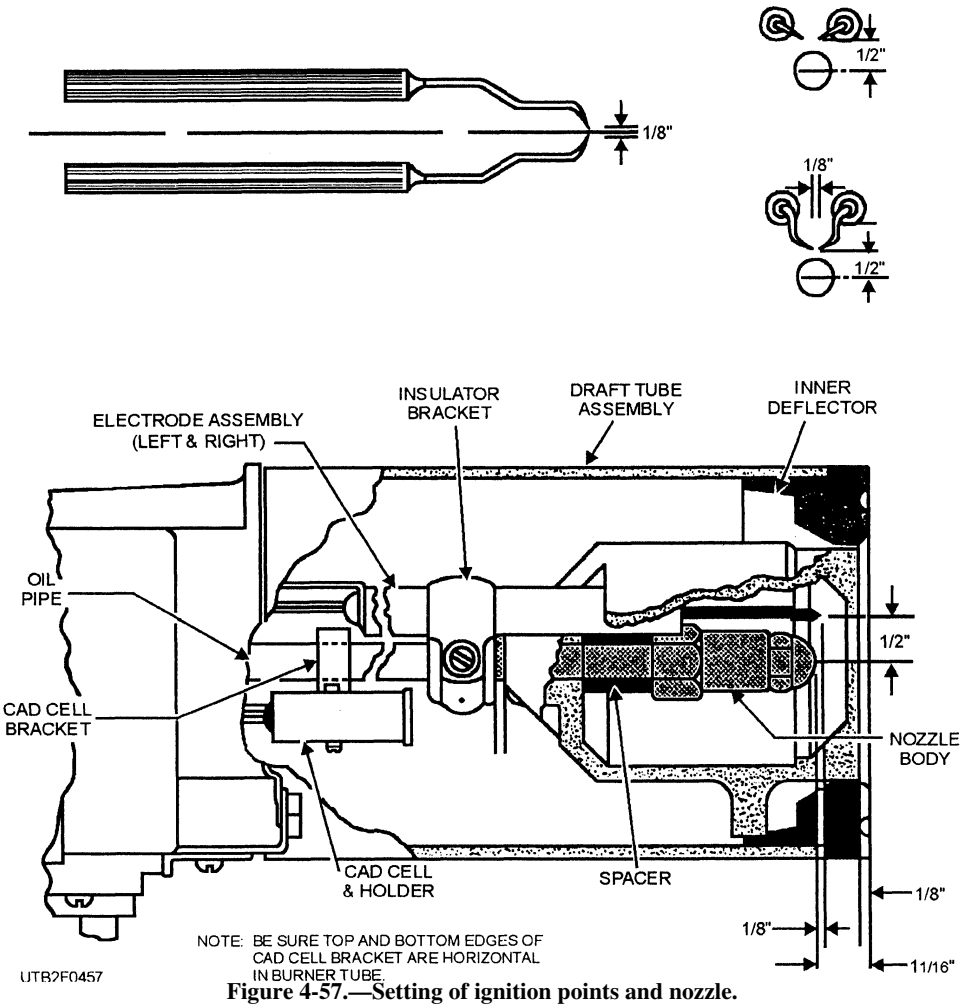


Figure 4-57.—Setting of ignition points and nozzle.

thermometer halfway between the center and outside of the smoke pipe and not more than 12 inches from the furnace between the smoke pipe connection and the draft regulator or barometric damper. Be careful to prevent the thermometer from being influenced by cold air taken in by the draft regulator.

The flue-gas analyzer is used to determine the percentage of CO_2 produced by combustion. The CO_2 reading shows how much excess air is being used. Along with the stack temperature, it denotes the efficiency of the furnace. If, despite a good flame setting, CO_2 readings are low, examine the furnace for air leaks.

FUEL PUMP

Maintenance requirements include cleaning the strainer, servicing the valve seat and needle valve, and adjusting the pressure regulator. Strainers must be cleaned frequently to prevent the screen from clogging and causing a shutdown. A good test for valve operation consists of removing the nozzle line at the pump connection, starting and stopping the pump, and observing whether the valve cuts off sharp and lean. When necessary, the valve is easily serviced by removing the valve chamber cover, holding spring, washer, adjusting spring, cap, and bellows assembly. Then, by taking off the nut that is marked "Nozzle," the valve, valve guide, and plug assembly can be removed.

Adjustment of the pressure regulator can be done by replacing the vent plug with a pressure gauge, removing the cover screw, and using an Allen wrench to turn the adjusting screw clockwise to increase the pressure or counterclockwise to decrease the pressure.

Burner failure or improper unit operation can be caused by various problems. Often the problem can be pinpointed by observing the type of failure and giving it some thought before attacking the problem. At other times, the cause can only be determined by a process of elimination. Table M in appendix II lists specific oil pump troubleshooting procedures, while table K, also in appendix II, lists general oil burner troubleshooting

procedures. Check the simplest and more obvious items before progressing to the other checks.

Q15. With warm-air systems, the amount of heat reaching each room is determined by what two factors?

Q16. What are the four airflow designs of gas-fired furnaces?

Q17. What safety device on gas-fired heating equipment reacts to the operation of the pilot flame?

Q18. What device shuts off the gas supply when the temperature inside the heating unit becomes excessive?

Q19. What are the three internal areas of an oil-fired furnace?

Q20. What device is the nerve center of the heating control system?

Q21. What are the two most commonly used types of thermostats?

Q22. A steam-atomizing burner requires a steam pressure of what range for atomizing?

Q23. Electrode adjustments should always be set on burners according to what publication?

Q24. What instrument is used to determine the percent of CO_2 produced by combustion?

DOMESTIC HOT-WATER HEATING AND HOT-WATER BOILERS

Learning Objective: Identify types of hot-water boilers, their fittings and accessories, and their operation.

The Navy uses both cast-iron and steel hot-water boilers as sources of heat for domestic hot-water systems in residences and other buildings. Small hot-water heaters heat the hot water for domestic and for limited industrial uses.

Hot-water boilers come in many shapes and sizes. They are constructed with a firebox for burning fuel and have provisions for passing the hot gases over the heat-absorbing surfaces of the boiler. In most cases, baffles guide the gases over the most effective route. These baffles also retard the flow of the gases from the furnace, so water can absorb as much of the heat as possible. Both ends of the boiler have openings for cleaning the boiler tubes and for washing the interior of the boiler. Since most boilers are stationary units permanently installed at the site, they have specified fittings and accessories for a specific heating job. Some boilers, however, called package boilers, are complete units, including fittings and accessories. These boilers are normally mounted on skids so they can be moved to different sites.

This accounts for the term *package boiler.* Package boilers usually have the same accessories and controls as the comparable stationary type of hot-water or steam boiler. Cast-iron boilers are seldom used as package boilers because of the danger of cracking the boiler sections during transportation.

Cast-iron hot-water boilers vary in size from small domestic units to moderately sized units capable of developing 31 through 98 horsepower. These boilers are usually constructed of several sections joined together by push nipples (round pieces of metal pipe tapered at both ends). Pipes, known as header connections (fig. 4-58) ordinarily connect the boiler sections.

Cast-iron boilers normally do not have brick settings. Usually, the only bricks used with these boilers are those that are sometimes used as a base for the boilers. In most cases, the bases are made of cast iron. Square sectional cast-iron boilers are similar to the typical unit shown in figure 4-59. This boiler consists of a front and rear section and a number of intermediate sections, depending on the size of the boiler. The sections are connected on each side at the top and bottom either by push nipples or by an outside header. When nipples are used, these sections are held firmly together by rods and nuts.

The boiler has a separate base that does not contain water and, therefore, requires a floor of fireproof construction. Boilers that have water in their bases are referred to as wet-bottom boilers. These boilers are relatively small water units that may be installed on floors constructed of combustible materials. This method of installation, however, is not desirable.

The construction of square sectional boilers is ordinarily such that the sections can be taken through regular-sized doors for assembly inside the boiler room. This is a distinct advantage from the standpoint of both installing new equipment and replacing broken sections. Cast-iron boilers resist the chemical action of corrosive agents much better than steel boilers.

The disadvantage of cast-iron hot-water heating boilers is the danger of the sections cracking or breaking when improperly handled or fired.

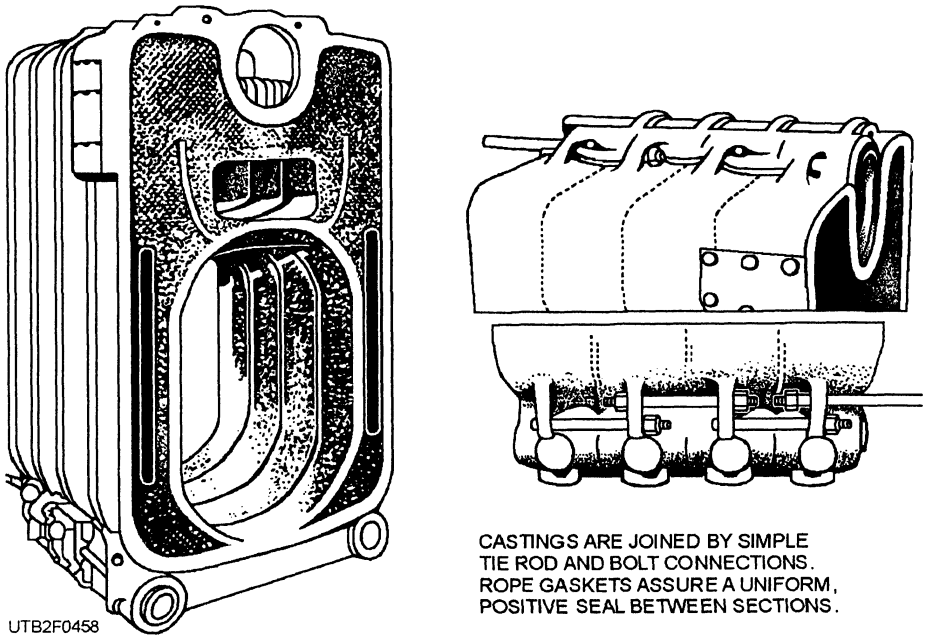


Figure 4-58.—Cast-iron boiler castings.

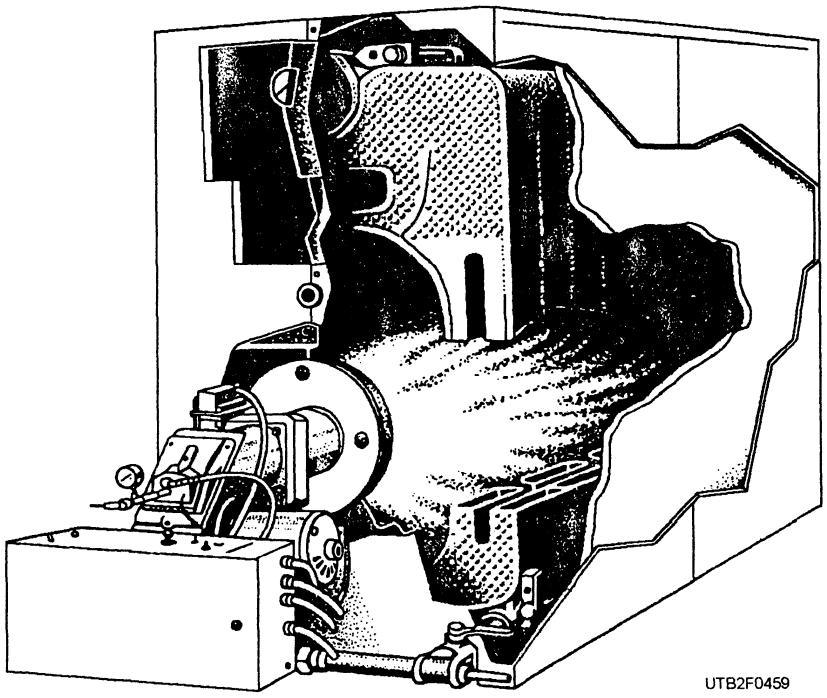


Figure 4-59.—Cutaway view of a cast-iron boiler.

STEEL HOT-WATER BOILERS

Most steel hot-water boilers are constructed in two sections. One section consists of the water jackets, combustion chamber, and smoke passages. These components are either welded or riveted together as a unit. The other section consists of the base and either the grates or burner and is constructed according to the type of fuel used (fig. 4-60).

Another steel boiler is a horizontal unit of the portable type, having an internal firebox surrounded by water lanes. It rests either on a cast-iron or a brick base. The front part of the boiler rests on a pedestal. A disadvantage of this one-piece steel boiler is that it is heavy and requires special equipment to lift it.

INSTALLING BOILERS FOR HOT-WATERHEATING

A boiler must have a good foundation. The top surface of the foundation should be level to ensure

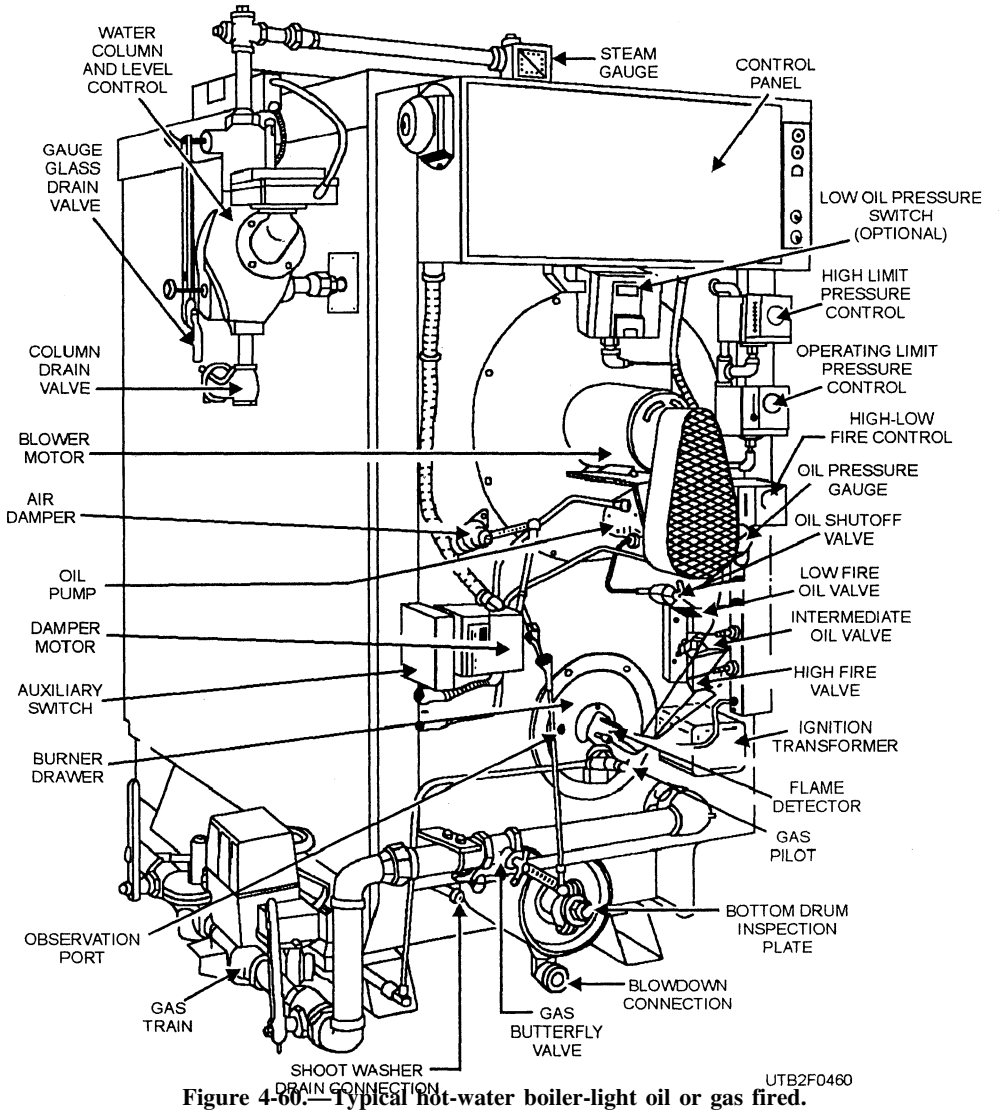


Figure 4-60.—Typical hot-water boiler-light oil or gas fired.

proper alignment of the boiler sections, and thus eliminate strain on the boiler castings. The furnace foundation should be poured separately from the finished floor. It should be of sufficient width and depth to support the boiler without any settling, and it should extend 2 inches above the finished floor. Assembly procedures vary in detail for various boilers. However, manufacturers furnish detailed procedures for the assembly of their boilers. Usually, the plans for the foundations can be procured from them.

OPERATION OF HOT-WATER BOILERS

Hot-water boilers, regardless of their design and type, operate on the same basic principle. The fuel burns in the combustion chamber and produces heat. The resultant heat is radiated and conducted to the water in the water jackets surrounding the combustion chambers and passes through the boiler tubes; heat is liberated by the flue gases and absorbed by the water surrounding the tubes. The amount of heat transferred into the water depends on the rate of heat conduction through the metal in the boiler tubes and the rate of water circulation in the boiler. For this reason, boilers are designed with baffles to hold the hot gases as long as possible. They give up maximum heat before passing into the chimney.

BOILER FITTINGS AND ACCESSORIES

All boilers have certain accessories for safety and ease of operation. These accessories are pressure-relief valves, pressure gauges, water-level control valves, and automatic controls.

Pressure-Relief Valve

In a closed hot-water heating system, there is always the possibility of building up a dangerous pressure. Consequently, a pressure-relief valve is installed to allow this pressure to escape. A typical

pressure-relief valve is shown in figure 4-61. This valve is usually on the top of the boiler. It contains a spring-loaded valve that unseats when the pressure in the system increases to a predetermined value, thereby allowing water to escape until the pressure drops to a safe point. A valve of this type can be adjusted for different pressure.

Pressure-relief valves may eventually corrode and stick if they are not forced to operate occasionally. It is a good practice, once each month, to increase the pressure to a point that operates the valve. When the relief pressure on the gauge exceeds the setting of the valve, check the valve pressure with an accurate gauge and adjust it to the required amount. However, do not exceed the maximum safe pressure of the boiler.

Pressure Gauge

The operator must know the water pressure in the boiler at all times. A gauge is connected to the top of the boiler. It shows the water pressure in the boiler and in the system in pounds per square inch. This gauge is usually a combination gauge that also indicates boiler water temperature and altitude. The type shown in figure 4-62, however, indicates pressure only.

Little maintenance is required for this unit other than to clean the glass so the gauge can be read. Some types of pressure gauges are constructed so they can be re-calibrated. However, the proper equipment to do this is not always available in the heating shop. To calibrate a pressure gauge properly, you must have either a master gauge set or a deadweight tester.

Water-Level Control Valve

Water is added to a hot-water heating system by either a manually operated water valve or an automatic valve, which is controlled by a float mechanism. Both valves are nearly identical to those used in the free-water system of a steam boiler.

Airflow Switch

The airflow switch, or "sail switch" as it is sometimes called, is in the stack, breeching, or the air inlet to the boiler. This switch shuts down the firing equipment in the event of an induced or forced draft failure. To check the operation of this switch, you restrict or shut off the draft. When you have done this, the switch should shut off the burning equipment.

Q25. It is a good practice to test the pressure relief valve by what method and what frequency?

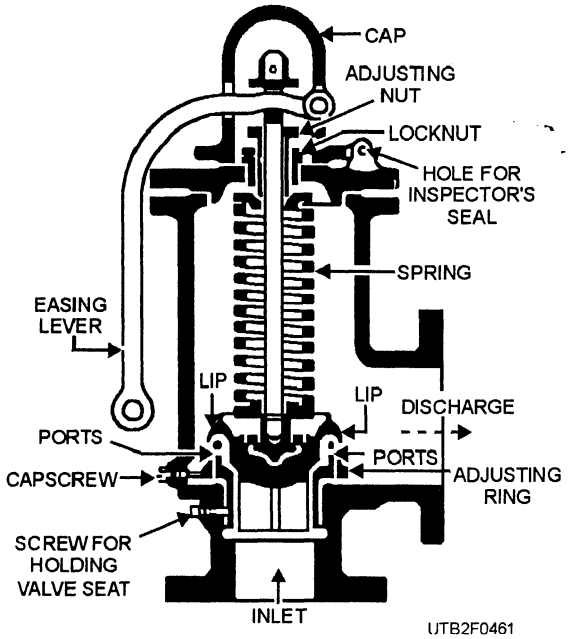


Figure 4-61.—A typical pressure-relief valve.

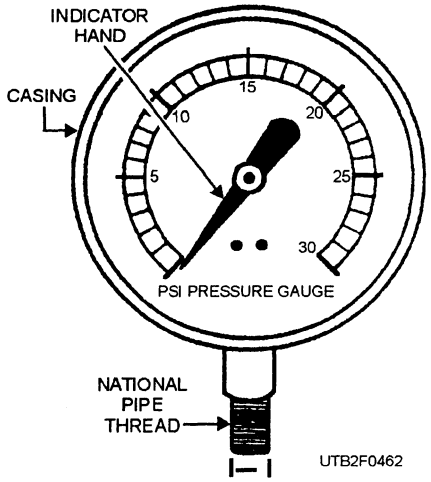


Figure 4-62.—A typical water pressure gauge.

Q26. What is the name sometime used to refer to an airflow switch?

HOT-WATER HEATING DISTRIBUTION SYSTEMS

Learning Objective: Identify types of hot-water distribution systems and components. Understand the operation and maintenance of these systems.

In hot-water heating systems, the water is heated at a central source and circulated through pipes to radiators, convectors, or unit heaters. There are two general types of low-temperature, hot-water heating systems. The first type is a gravity system in which water circulation depends upon the weight difference between the hot column of water leading to the

radiators and the relatively cooler, heavier column of water returning from the radiators. The second type is the forced-circulation system in which water is circulated by a power-driven pump.

GRAVITY SYSTEMS

The distribution systems and piping for hot-water heating systems and for domestic hot-water supply systems are simpler in design than those for steam because there are no traps, drips, or reducing valves. Several items, such as supports, insulation, and some valves and fittings, are the same for steam and hot-water distribution.

Gravity hot-water distribution systems operate because of the gravitational pull on the heavier cool water, which sinks as the heated water becomes lighter and rises. At this point, some of the types of gravity systems that are currently used are discussed.

One-Pipe, Open-Tank System

The one-pipe, open-tank gravity distribution system shown in figure 4-63 consists of a single distribution pipe that carries the hot water to all of the convectors or radiators and returns it to the boiler. This system is easy to install and moderate in cost.

The water that flows into the radiators at the end of the system has a lower temperature than the water entering the first radiators. A system of this type should be designed so the water reaching the last convector is not too much cooler than the water reaching the first convector. Because of this progressive temperature drop in the distribution system, convector radiators should be installed at the end of the system to equalize the amount of heat radiation per radiator. It is difficult to get enough circulation by gravity to give the system small convector temperature drops; consequently, we do not recommend the one-pipe, open-tank gravity system.

Two-Pipe, Open-Tank System

Many hot-water gravity distribution systems are two-pipe, open-tank systems, as shown in figure 4-64. This heating system is constructed with separate water mains for supplying hot water and returning cold water. The radiators are connected in parallel between the two mains. In the two-pipe, open-tank gravity system, the distributing supply mains are either in the basement with upfeed to the radiators or in the attic. When the system is in the attic, it has overhead downfeed supply risers. The return mains are in the basement. Return connections for the two-pipe system

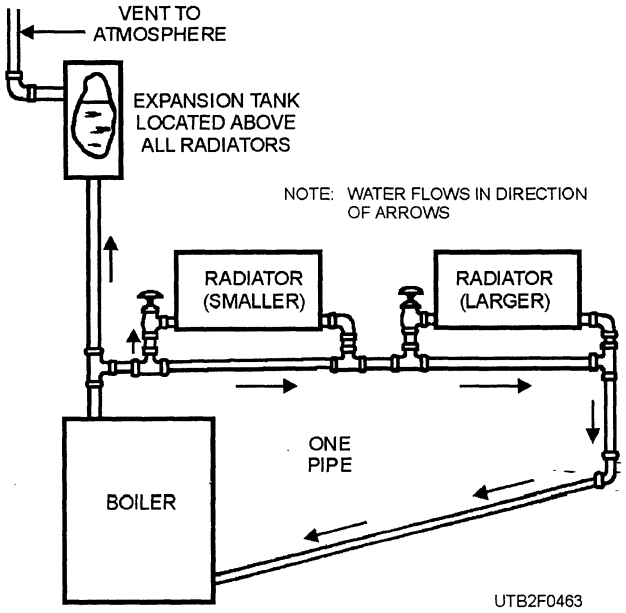


Figure 4-63.—A one-pipe, open-tank gravity hot-water distribution system.

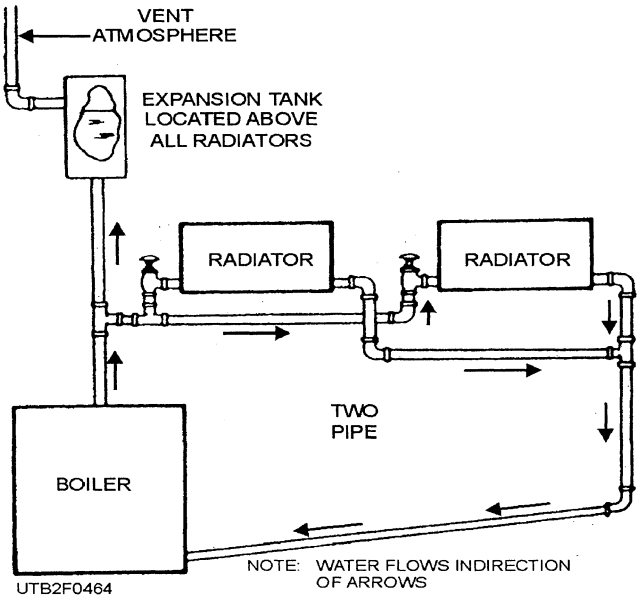


Figure 4-64.—A two-pipe, open-tank gravity hot-water distribution system.

are usually made into a gravity return, which pitches downward to the return opening in the heating boiler. The water temperature is practically the same in all radiators, except for the allowance to be made for the temperature drop in the distribution supply mains occurring between the boiler and the end of the circuit. Water temperatures are the lowest at the end of the circuit. The amount of temperature drop between the beginning and the end of the line depends upon the length of the main and upon the heating load.

A tank with its vent open to the atmosphere is installed in the system above the highest radiator for water expansion. The water level in the expansion tank rises and falls, as the system is heated and cooled, and the system is full of water and free from air at all times. In the open-tank gravity hot-water heating system, the expansion tank is installed on a riser directly above the boiler, so the air liberated from the boiler water enters the tank and is not retained in the system.

One-Pipe, Closed-Tank System

A one-pipe, closed-tank gravity hot-water distribution system, as shown in tigure 4-65, is similar to the one-pipe, open-tank gravity hot-water heating system, except the expansion tank is a pneumatic compression tank not open to the atmosphere. When the water in a closed-tank system is heated, it. expands into the pneumatic compression tank. This action permits system operation at a much higher water temperature, without boiling, than the temperature in the one-pipe, open-tank gravity system. This also results in higher heat emission from the radiators.

A gravity open-tank system with an average boiler water temperature of 170°F has a radiator emission rate of 150 Btu psi, whereas a gravity closed-tank system with an average boiler water temperature of 190°F has a radiator emission of 180 Btu per square foot (psf). Higher boiler water temperatures permit higher temperature drops through the radiators; consequently, smaller pipe sizes can be used. The closed pneumatic compression system requires a relief valve, usually set for the relief of water pressure over 30 psi, depending upon the height of the building. A pressure-regulating valve automatically maintains the system full of water. Installation of the radiators and piping for an equivalent two-pipe, closed-tank gravity upfeed or overhead downfeed system is the same as that for the open system, except the sizes of both the pipe and the radiators are uniform and can be smaller. The open-tank system may have a reversed return main that does not go directly back to the boiler.

It doubles back from the last radiator and parallels the supply main back to the boiler entrance. The reversed return system allows equal length of heating circuits for al I radiators. Friction and temperature losses for all radiators are nearly equal. In most cases, the reversed return system involves no more piping than other piping arrangements. With the correct size of piping and radiator supply tappings, the reversed return system provides even heat and circulation to all radiators, even those near the end of the circuit.

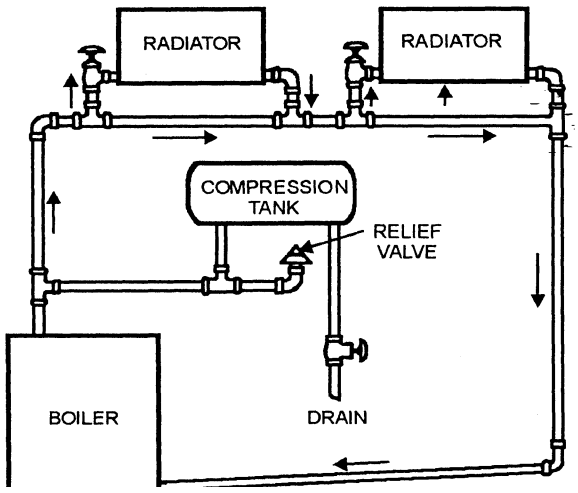


Figure 4-65.—.A typical one-pipe, closed-tank distribution system.

Expansion in a Gravity Hot-Water Distribution System

In the gravity and forced-circulation systems, open and closed expansion tanks allow the water in the distribution system to expand as the temperature rises. An open tank must be mounted at the highest point in the system; a closed tank can be located at any point. If the air cushion leaks out of the closed expansion tank, it fills with water. At times, you must recharge the tank by draining part of the water out of the tank and allowing air to -fill the space.

In the open system, an expansion tank open to the atmosphere allows the system to expand. The open system is normally designed to operate at the maximum boiler temperature of 180°F. This gives an average radiator temperature of 170°F or a radiator output of 150 Btu psf. The closed system, in which the expansion takes place against a cushion of air in the tank closed against the atmosphere, can be operated at temperatures above 212°F because the pressure built up in the system prevents the water from boiling. Radiator temperatures then become equal to those of low-pressure steam systems.

When a hot-water system is first filled with water, it is normally necessary to bleed the air out of the system at the same time. You can remove the air by opening an air vent on a radiator or by breaking a union near the end of the line. The temperature of the water distributed is from 150°F to 250°F. The higher temperatures are used with the forced-circulation systems.

FORCED-CIRCULATION SYSTEMS

Forced-circulation hot-water distribution systems have several advantages. They permit the use of smaller pipe sizes and allow the installation of radiators at the same level as the boiler, or below, without impairing water circulation. By using a circulation pump, a positive flow of water is assured throughout the system. In larger installations, especially where more than one building is served, forced circulation is almost invariably used. With the development of a circulation pump of moderate cost, the forced-circulation system is being used more in small heating installations.

Even as in gravity systems, forced-circulation systems can consist of a one-pipe or a two-pipe, upfeed or downfeed, and can be equipped with a direct or a reversed return. Although these systems usually have closed expansion tanks, they may have open tanks.

One-Pipe, Closed-Tank System

The general arrangement of a one-pipe, closed-tank, forced-circulation system shown in figure 4-66 is similar to the one-pipe gravity system, but with the addition of a circulating pump.

The circulation to individual radiators is improved by special supply and return connecting tees. These tees, by an ejecting action on the distribution supply main and an ejecting action on the return, combine to use a portion of the velocity head in the main to increase circulation through the radiators. Tees of this type also aid stratification of hot and cold water within the distributing main. They are designed to take off the hot-test water from the top of the main and to deposit the colder water on the bottom of the main.

Two-Pipe, Closed-Tank System

The general arrangement of the piping and radiators for the two-pipe, forced-circulation distribution system is the same as that for the two-pipe gravity system. The relative locations of the compression tank relief valve and the circulating pump are shown in figure 4-67.

DISTRIBUTION SYSTEM COMPONENTS

The component parts of a hot-water distribution system are similar to that of steam heating systems as described in chapter 3. They include the following: pipelines, radiators, convectors, unit heaters,

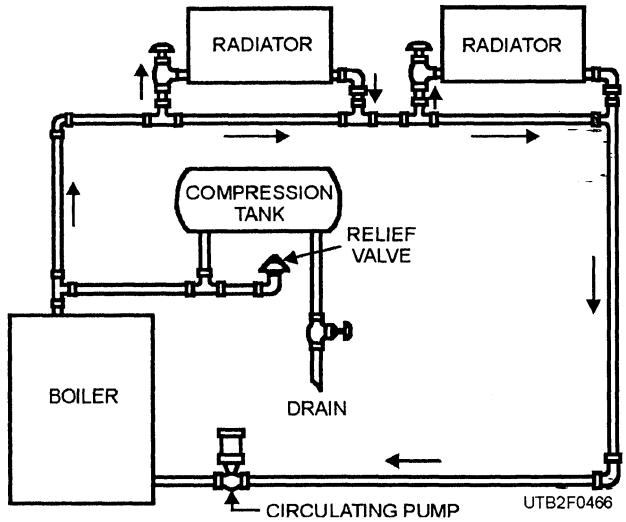


Figure 4-66.—A one-pipe, closed-tank distribution system with a circulating pump.

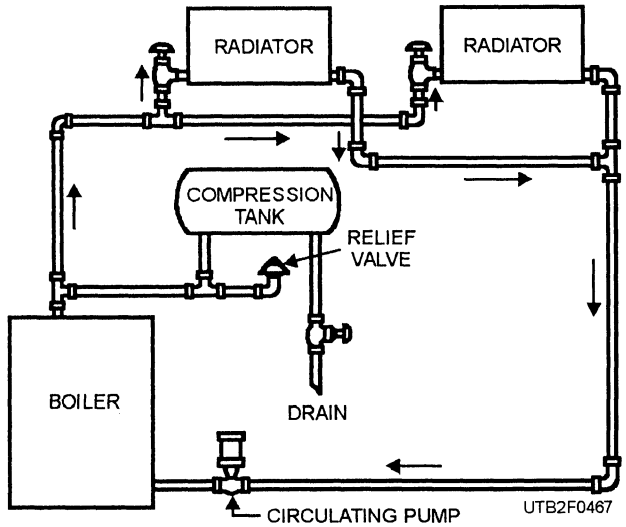


Figure 4-67.—A two-pipe, closed-tank, forced-circulation system.

circulating pumps, reducing valves, flow-control valves, and special tlow fittings.

Pipelines

The piping system constitutes the closed passageway for the delivery of hot water to the points where it is used. Pipelines are made of lengths of pipe fastened by screwed, flanged, or welded joints. They have valves and fittings, such as tees, unions, and elbows, according to the needs of the installation. Pipelines are supported by hangers and fastened by anchors. Expansion joints or loops allow for expansion.

Mains and branches of the pipeline should be pitched so the air in the system can be discharged through open expansion tanks, radiators, and relief

valves. The pitch is generally not less than 1 inch for every 10 feet. The piping arrangements for a new system should provide for draining the entire system.

Radiators

The radiator transfers heat from the hot water in the pipes of a hot-water heating system into the surrounding air in a room. A radiator is usually of two types. Cast-iron radiators are constructed and assembled in sections, as shown in figure 4-68, view A. Damaged radiator sections can be replaced without replacing the entire radiator assembly. Fin-tube radiators (fig. 4-68, view B) are constructed of steel pipe and fins, which are welded to the pipe.

Radiators usually rest on the floor. However, they can be either mounted on a wall or hung from the ceiling. The location of a radiator depends on the type of room to be heated and its location with respect to the location of the boiler. For instance, in a forced-circulation hot-water distribution system, the radiators may be on the same level with the boiler.

Convectors

Convectors are supported on the wall much in the same way as a pipe. The convectors consist of a fin-tube radiator mounted in a metal cabinet and transfer heat much in the same way, although a damaged section must be welded or the entire convector must be replaced (fig. 4-68, view C).

Hot-water heating system radiators and high points in the distribution lines must have some type of vent that releases air from the system. Air trapped in the system prevents the circulation of water. For this purpose, a manually operated key-type air vent, as shown in figure 4-69, can be used.

Manually operated key-type air vents can be replaced by automatic air vents. One type of automatic air vent is shown in figure 4-70. It automatically allows the air that forms in the system to escape. When air vents fail, replace them.

Radiators also have shutoff valves, as shown in figure 4-71, which reduce or stop the flow of hot water through a radiator. They are installed in the piping next to the inlet side of the radiator. Occasionally, you must tighten the packing nut on these valves to prevent the water from leaking around the valve stem.

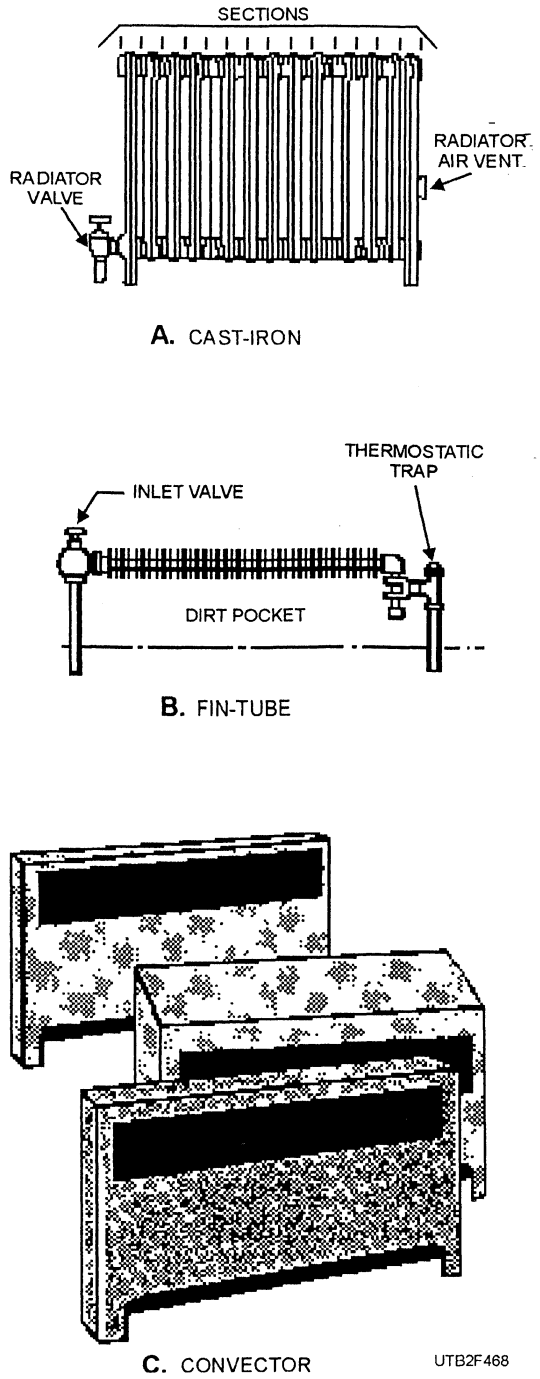


Figure 4-68.—Radiators: A. Cast iron; B. Fin tube; C. Convector.

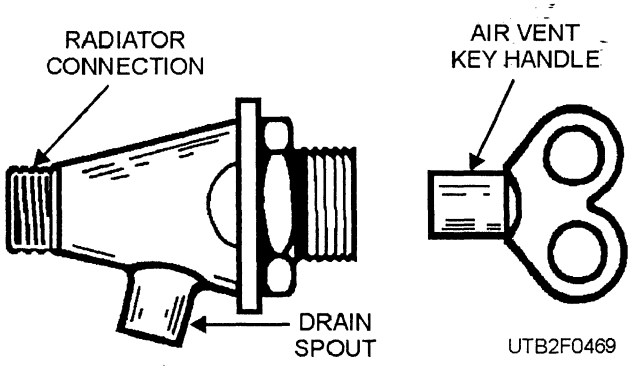


Figure 4-69.—A manually operated key-type air vent.

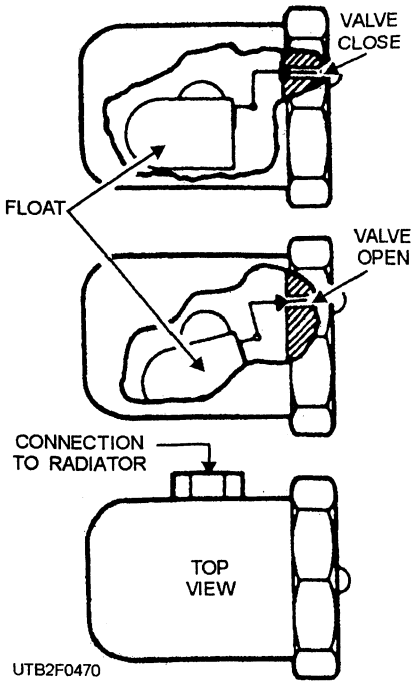


Figure 4-70.—One type of automatic air vent.

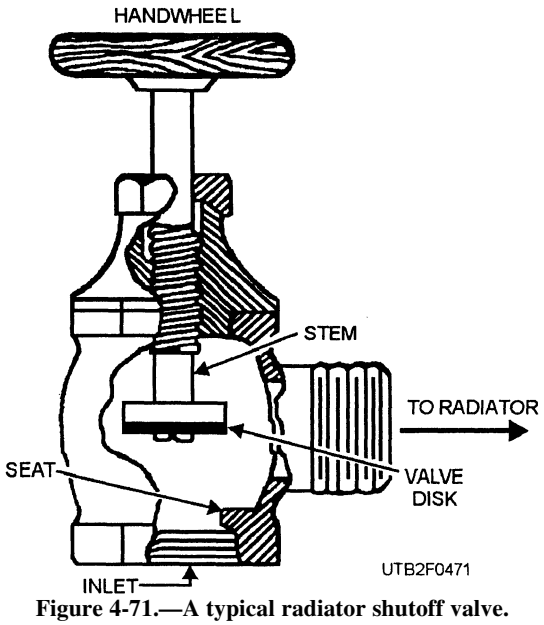


Figure 4-71.—A typical radiator shutoff valve.

Unit Heaters

Unit heaters are the same as those used in warm-air heating, except hot water is used vice coils for the heating medium. The heater consists of a heating coil supplied with hot water. The coil is usually of the finned type, and an electric fan circulates air over it. A unit heater installed in a distribution main is shown in figure 4-72.

Servicing unit heaters includes a monthly inspection. Each month, check for water leaks, cleanliness of the finned coils, and the operation of the

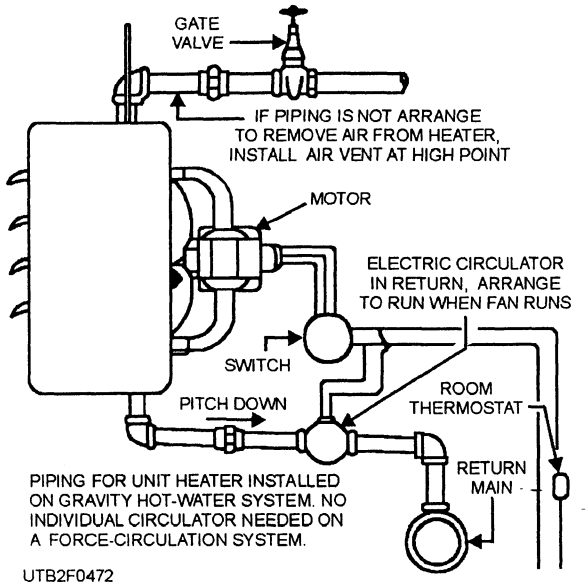


Figure 4-72.—A typical hot-water unit heater installation.

fan motor. Other accessories which you also should inspect are traps, air vents, fan blades, and valves. Make any needed repairs. Lubricate the electric fan monthly.

Circulating Pumps

A forced hot-water heating system has a water-circulating pump in the return line near the boiler. This pump ensures the positive flow of water regardless of the height of the system or the drop in the water temperature. Greater velocities of water flow are obtainable with forced circulation than with gravity circulation.

Circulating pumps are free of valves and float control elements. They are operated under a sufficiently high water inlet temperature to eliminate the difficulties caused by vapor binding. The pumps are usually operated by electric motors.

During maintenance servicing, check the pump carefully for proper rotation, and lubricate the electric motor and pump according to the manufacturer's instructions. Also, periodically clean the pump of sand, rust, and other foreign matter that has collected in the pump casing. Be sure the pump rotates freely and the shaft packing glands, if there are any, are not drawn up so tight that they score the shaft.

Reducing Valves

A reducing valve is normally installed in the cold-water line going to the boiler. It automatically keeps the closed system supplied with water at a predetermined safe system pressure. These valves are

usually set at the factory, but you may adjust them in the shop to a desired pressure. You should install this valve at approximately the same level as the top of the boiler.

Flow-Control Valves

Forced hot-water circulating systems use the flow-control valve shown in figure 4-73. It is normally installed in the distribution main. This valve prevents gravitational flow of water through the system. The valve does not offer any serious resistance to the flow of water when the circulating pump is in operation. However, when the pump is not operating, the small gravitational head of water cannot open the valve. Each week you should check the flow-control valve for proper operational down-free movement. Examine the valve for water leaks and repair it when necessary.

Special Flow Fittings

Various types of special tees designed to deflect main-line water into the radiator branches are used in one-pipe and two-pipe forced-circulation systems. These fittings are designed and calibrated to the size of the radiator and system-operating temperature. Fittings of this type are required with one-pipe, forced-flow systems, and they do equally well for radiators above and below the distribution mains.

MAINTAINING AND TROUBLESHOOTING HOT-WATER HEATING SYSTEMS

Hot-water heating systems require little maintenance other than periodic checks to make certain that all air is out of the system and all radiators are full of water. The circulating pumps should be oiled regularly according to the manufacturer's instructions, and the pressure-relief valves should be checked periodically.

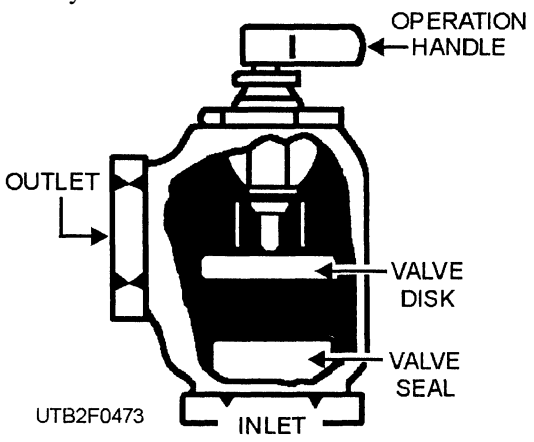


Figure 4-73.—One type of flow-control valve.

Some of the common discrepancies encountered when troubleshooting hot-water heating systems are contained in appendix II, table O.

Operator maintenance on the electrically driven feed pump consists mostly of cleaning the pump and motor. However, the pump motor is lubricated according to the manufacturer's specifications. Remember that not using enough lubricant can result in the bearings running dry or seizing on the motor shaft. But, too much lubricant causes the motor to become dirty, and it can result in the motor windings becoming saturated with oil and burning out.

When a water leak develops around the pump shaft, tighten the packing-gland nuts or repack the stuffing box as necessary. The strainer, installed between the pump and the condensate receiver, should be kept clean to avoid any restriction of the flow of water to the pump.

The maintenance of feed-water heaters and economizers normally includes removing solid matter that accumulates in the unit; stopping steam and water leaks; and repairing inoperative traps, floats, valves, pumps, and other such associated equipment.

Q27. What is the main reason to install a two-pipe, open tank, gravity distribution system over a one-pipe, open-tank, gravity distribution system?

Q28. The operations of what component of the one-pipe, closed-tank distribution system results in higher heat emission from the radiators?

Q29. Air vents release trapped air in the system. If the air is not released, how would this affect the system?

HIGH-TEMPERATURE HOT-WATER SYSTEMS

Learning Objective: Recognize different types of high-temperature hot-water systems, their components, and understand their application and installation.

High-temperature hot-water (HTHW) systems operate at high pressure to maintain water temperature that exceeds the normal boiling temperature of 212°F (at atmospheric pressure) used in other types of heating systems.

High-temperature hot-water systems consist of standard and heavy-duty equipment, including boilers (sometimes referred to as generators), expansion drums, system circulator pumps, distribution piping, and heat-consuming equipment.

High-temperature hot-water systems have the hot water pumped from the generator throughout the distribution system. The circulator pumps are large enough to deliver the water at sufficient pressure to overcome any drop in the distribution system and the heat-consuming equipment. The major advantages of the HTHW heating system are makeup requirements, minimum maintenance, high thermal efficiency, and safe, easy operation and control.

The HTHW system is a closed system, so the only water waste is the normal leakage at the pump and valve packing glands. Consequently, little water is consumed during system operation. This means only a small amount of makeup water is used, practically eliminating boiler blowdowns. The closed re-circulating system operates at high thermal efficiency. All of the heat not used by heat-consuming devices in the system or lost through pipe radiation is returned to the boiler plant. Because few boiler blowdowns are required, the heat loss from blowdowns is kept to a minimum.

TYPES OF HTHW SYSTEMS

The high-temperature range for most military and federal heating plants is 350°F to 450°F which corresponds to saturated pressures of 135 psi to 425 psi. However, some types of plants operate at higher pressures and therefore have higher water temperatures. The installation of HTHW plants that operate at temperatures above 400°F must be approved by the Naval Facilities Engineering Command. Costs usually determine the maximum water temperature used, because the types of HTHW systems using the higher pressures require more expensive piping, valves, fittings, and heat exchangers.

The degree of complexity of HTHW systems varies according to the size, type, and heat load requirement of the installation. Since methods used to maintain pressure and to assure uniform flow rates depend upon the amount of heat load, they affect the complexity of the heating system. There are two methods of circulating the HTHW through the system—the one-pump system and the two-pump system.

The one-pump system uses only one pump to circulate the hot water throughout the system, which includes the generator. The two-pump system uses one pump to circulate the water through the distribution system, and a second pump to circulate the water through the generator for positive circulation. Figure 4-74 shows some typical pumps that are used for circulation in the HTHW system. Note that the pumps are of the centrifugal type. Each pump shown is used to circulate the water to different areas in the distribution systems.

There are two common ways of heating the water in the HTHW system—one way is to use hot-water boilers or generators and the other way is to use the cascade or direct contact heater. The water in the HTHW generator is heated as low-temperature hot water is heated. In the cascade heater, however, the water is forced through spray nozzles and comes into direct contact with the steam. The steam condenses into the circulating water. A typical spray nozzle head is shown in figure 4-75. The spray nozzles are installed in a combination cascade heater expansion drum. A typical cascade heater expansion drum installation is shown in figure 4-76. In the paragraphs that follow, some ways of pressurizing the HTHW system are discussed.

PRESSURIZING THE HTHW SYSTEM

Since water volume varies with changes in temperature, the extra water must be taken care of when the water is heated. It is desirable to operate with the water above the boiling temperature of 212°F; therefore, the pressure in the system must be maintained equal to, or greater than, the corresponding saturation (steam or vaporization) temperature. An expansion tank is required because the water, which is not compressible to a smaller volume, expands when it is heated. Also, the pressurization prevents the formation of saturated steam or vaporization when the water temperature is raised. There are two basic designs used for pressurizing HTHW systems—first, the saturated steam cushion, and second, the mechanical gas cushion. Although both des igns have a variety of modifications, their characteristics are still typical of the basic pressurized system design.

Saturated Steam Cushion

Pressurizing the heating system with steam in the expansion tank is a natural method. Firing the HTHW generator to maintain the system pressure corresponding to the required saturation (steam or vaporization) temperature pressurizes the system. Excess heat is generated to offset the radiant heat loss from the expansion tank. All of the HTHW in the steam-pressurized system flows through the expansion tank and thereby maintains the saturation (steam or vaporization) temperature there.

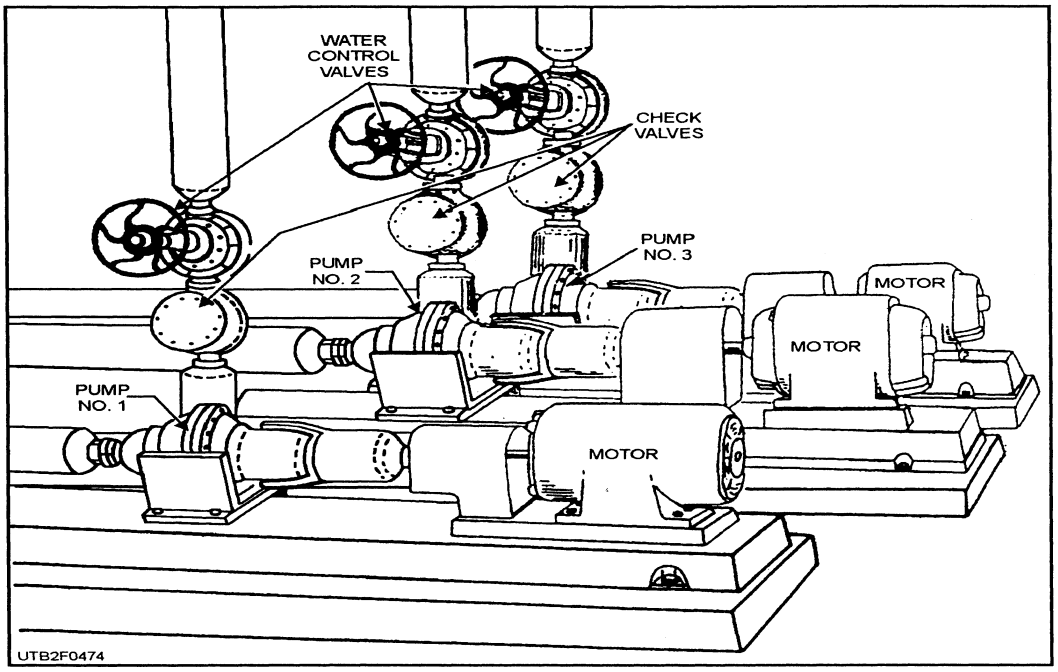


Figure 4-74.—Typical high-temperature hot-water circulation pumps.

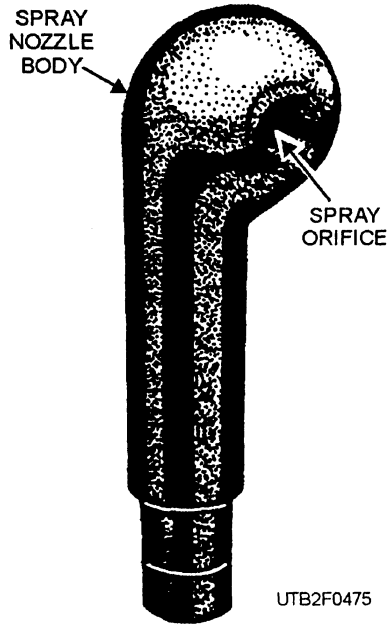


Figure 4-75.—A typical cascade heater spray nozzle head.

The steam in the space in the expansion tank provides the pressure or cushion for the system. The pressure maintained is that of the saturated steam. The water in the lower portion of the tank will be approximately saturation (steam or vaporization) temperature corresponding to this pressure. The water to be used in the HTHW heating system is drawn from the lower part of the expansion tank, mixed with the system return water, and circulated throughout the system. The mixing is necessary to prevent cavitation (steam flashing) at the pump suction.

Here are some conditions that are typical of the saturated-steam cushion design. The expansion tank, either integral or separate, is a part of the HTHW system. The entire amount of hot water flowing in the heating system passes through the expansion tank and exposes the tank to maximum system heat and any form of contamination which, in turn, subjects the expansion tank to thermal stresses and corrosion. There are explosion hazards typical of a steam boiler in the system, and good water-level control is important in maintaining proper operating conditions. Load variations, causing supply pressure changes, create flashing of saturated liquid in the system and produce water hammer.

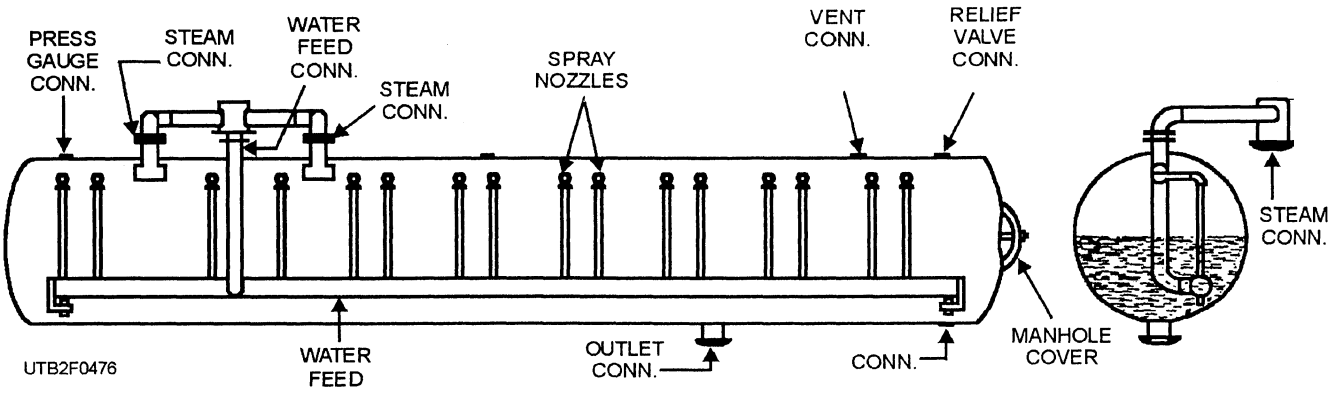


Figure 4-76.—A combination cascade heater expansion drum installation.

Mechanical Gas Cushion

The expansion tank contains the mechanical-gas cushion and is connected to the HTHW system return line just ahead of the circulating pump suction connection. The tank contains an inert gas (usually nitrogen) and is the source of pressure in this method. When the system has been pressurized by the nitrogen, pressure in excess of saturation must be maintained; that is, the water temperature throughout the system must always be less than its saturation temperature. In the nitrogen-pressurized system, the expansion tank is installed in the system as a standpipe arrangement so the water does not flow through it. The water in the lower part of this tank is stagnant, except for the changes caused by expansion and contraction brought on by load fluctuations. If you assume the water is virtually incompressible, the tank provides the space available for these changes in the water volume of the system.

Here are some characteristics that are typical of this design. The expansion tank is independent of the generator and remains cool. Corrosion is practically eliminated because the heating system is flooded with the exception of the nitrogen space in the expansion (cushion) tank. When properly designed, the system is sealed with its fixed charge of water and nitrogen. However, this design does not contain a steam drum or any steam spaces that permit the accumulation of steam. The generator tubes are the weakest link in this entire system. An explosion caused by the dissociation of hydrogen and oxygen cannot occur. The formation of steam cools the otherwise red-hot metal surfaces. Hot-water conditions do not allow the flashing of steam.

Operation

To ensure normal operation, fill the system with treated water taken from the water softener. To prevent oxygen corrosion, add the chemicals for treating the water to furnish 20 to 40 parts of sodium sulfite per million parts (ppm) of water. You thereby maintain a pH value of 9.3 to 9.9. While the water is circulating in the generator and in the system, you should fire the boiler at about 25 percent of its rated capacity to bring the system up to normal operating temperature. You should allow the expansion drum vent in steam-pressurized systems to blow for about 1 hour to rid the system of all oxygen and other non-condensable gases.

The start-up and firing of HTHW boilers or generators arc done in much the same manner as for domestic hot water and steam boilers, depending upon the type of fuel-burning equipment used. The specific start-up and operating procedures vary with different installations. Therefore, this information is furnished by your local supervisor and the manufacturer of the equipment.

Coal, oil, and gas are the types of fuels normally used to fire the boilers of HTHW systems. The specific type of fuel used depends upon the type of firing equipment installed in the plant. Each type of fuel requires designated inspections be made -and certain precautions be taken to eliminate fire and safety hazards.

When you are transferring fuel oil from one tank to another, be sure both tanks are grounded. Checks must then be made to ensure excessive oil pressures are not generated in the tanks by the expansion of the fuel. Although natural gas is not normally stored on a base ashore, liquid petroleum (LP) gas is often stored near the heating plant. You should check the areas where

this gas is stored often to ensure there is no leakage. Liquid petroleum gas is heavier than air, settles in low areas, and creates explosive hazards. When checking for gas leaks, use a standard soap solution.

Because of the large heat storage capacity of HTHW systems, the load demand change for the boiler is slow and smooth. This characteristic provides for improved and safer operation than that provided by the saturated-steam cushion.

PIPING SYSTEM INSTALLATION

All piping in an HTHW system should be welded. No screwed joints should be permitted, and flanges should be allowed only where necessary, such as at expansion joints, pumps, and generator connections. Only schedule 40 black steel piping or better is used for HTHW systems. Upon completion, the entire heating system is subjected to a test of 450 psi that lasts for not less than 24 hours.

The possibilities of line failure are remote when the construction recommended above is used. The system piping material is subjected to a minimum factory test of 700 psi. The generator tubes are subjected to an ASME test of 900 psi. All valves and accessories are rated at working pressures of 540 to 1,075 psi at 400°F. The weakest link in the piping network lies within the generator tubing. The worst likely failure is the loss of tubes, and therefore the generator. The safety of the piping system is maintained over the life of the installation because of the absence of corrosion in the hot-water heating systems due to boiler water treatment.

Q30. What is the high-temperature range for most military and federal heating plants?

Q31. What are the two common ways of heating water in HTHW systems?

Q32. To prevent oxygen corrosion in an HTHW system, treat the water with chemicals to produce whatppm of sodium sulfite?

Q33. Should all piping in an HTHW system be welded? True/False

CHAPTER 5

GALLEY AND LAUNDRY EQUIPMENT

Learning Objective: Recall the procedures required for the maintenance of galley equipment and the procedures for installing, maintaining, troubleshooting, and repairing laundry equipment.

Most stateside galleys and laundries, as well as many overseas, are now operated and maintained through civilian contracts. But there are still installations maintained by overseas Public Works Departments, which require military personnel. This chapter presents information on the maintenance of common types of galley and laundry equipment. Because of the contracted galley and laundry facilities and differences in types of equipment you are expected to maintain, only general information is presented in this chapter. Remember you should study the manufacturer's manual that comes with a new piece of equipment before you attempt to install or maintain it.

GALLEY EQUIPMENT

Learning Objective: Identify different types of galley equipment and recall the procedures required for their maintenance.

Galley equipment must be maintained in a safe, sanitary, and economical way. Utilitiesmen not only install and maintain the equipment but they also supervise others who perform work on the equipment. It is always a good practice to post operating instructions near the various pieces of equipment in a galley or a bakeshop. This action should reduce the number of operators who abuse the machines. This is particularly important where messmen and strikers are working. As a further safeguard, you should conduct periodic preventive maintenance inspections as required for the equipment at your location or as called for in the manufacturer's instructions. After the inspection, you should attach a tag to each piece of equipment that contains pertinent information, such as the date, the type of inspection, and by whom the inspection was made.

The maintenance of food preparation equipment may vary. In peacetime, most types of equipment are located in a permanent galley or bakeshop. While deployed to an island or an overseas shore station, a construction battalion might have either a permanent galley or a semi-permanent galley, using either field units or fixed types of equipment.

Whatever the need or the location, your most important duty is to keep all items of equipment in a condition of readiness to ensure safe, sanitary, and excellent operation at all times. The medical department is responsible for conducting sanitary inspections, and the supply department is responsible for preparing food and keeping food-handling equipment and spaces clean. Coordinate your maintenance efforts in conjunction with these departments. Once any maintenance or repair is completed on equipment, ensure that it is inspected before it is put back into service for food preparation. Field galley range is briefly covered in this chapter. For more information on its operation, refer to chapter 2 of *Utilitiesman Basic,* volume 1, NAVEDTRA 11019.

STEAM KETTLES

Steam kettles, more commonly called "coppers," are either direct-steam or self-contained type units. Self-contained units generate their own steam though either a gas burner or electrical connections. Direct-steam coppers are supplied with steam from a central boiler located in the galley. Because direct-steam units are more common than self-contained units, this chapter mainly covers direct-steam coppers.

Maintenance requirements for coppers are small when compared to other pieces of galley equipment. You should consider this fact when you are developing a preventive maintenance inspection schedule. The maintenance schedule for coppers requires monthly inspections and an annual preventive maintenance inspection. When conducting monthly or annual

inspections, talk to galley personnel about the operation of the coppers. These personnel can give you information that will assist you in diagnosing possible operational or maintenance problems. A few factors for inspecting direct-steam coppers (fig. 5-1) are as follows:

MONTHLY inspection:

- Check the faucets, valves, and piping for leaks.
- Check the steam pressure-reducing valve to ensure it is in good condition and functions properly.
- Lubricate the hinges of the cover with mineral oil.

ANNUAL inspection:

- Check the copper for leaks, cracks, and dents.
- Examine the cover, hinges, and latch for warp and alignment.
- Check the steam and condensate piping, valves, and traps for leaks and obstructions.
- Remove the safety valves and remove any rust and corrosion using Navy-approved solvents. Then, lubricate and calibrate the valves before replacing them.

Other than visual inspections, each individual piece of galley equipment requires its own type of preventive maintenance. Recommended schedules for inspection and maintenance of coppers are provided in table P of appendix II.

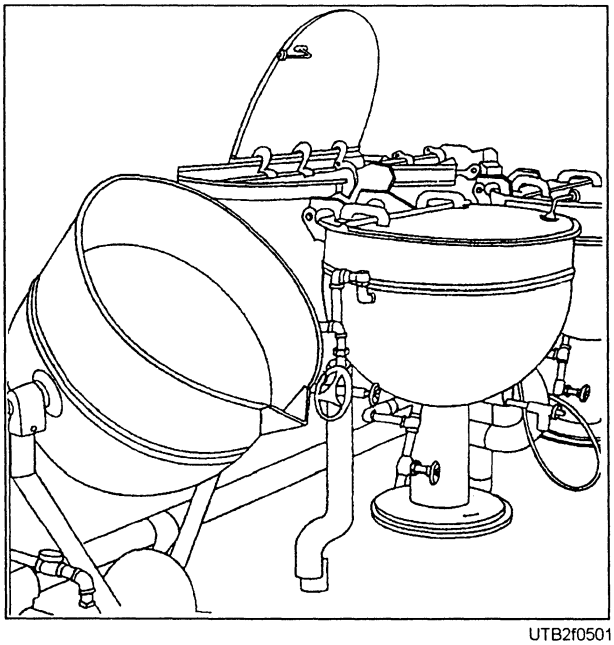


Figure 5-1.—A pedestal and a trunnion or tilt type of direct-steam coppers.

STEAM CHESTS

Steam chests are used to cook food through a steaming process. The escape of steam from a steam chest harms the food being prepared and also poses a safety hazard to personnel. To ensure steam-tight operation, ensure the door latches, hinges, and gaskets are kept close fitting. A physical preventive maintenance inspection of the steam chests (fig. 5-2) should be made each week.

The weekly inspection should ensure the following:

- The compartment drains are free of obstructions.
- The door hinges, locking devices, and shelf drawbars work well.
- The pressure setting of the gauge pressure is correct.

When a plunger type of valve is used with the locking device, the plunger must be adjusted so the valve is fully depressed when the door is closed. This action allows a full measure of steam to enter the compartment. When the door is opened, the valve must function to stop the steam supply completely. To ensure a tight fit of the doors, replace hinge pins and bushings when they show too much wear. Some full-floating doors are adjustable by means of hexagon-head bolts extending through the door near each corner. When door gaskets must be replaced, you must remove the door from the unit because this makes it easier to remove the worn gasket and to clean the channel. Failure to complete these actions can provide a path for steam leakage. Apply gasket cement, and then force the new gasket into the channel at the corners, working it in toward the center of the sides and ends. You are now ready to hang the door; but first, place paper along the edge of the door opening to prevent excess cement from adhering to the mating surfaces when the door is closed. Any surplus cement can be cleaned off after it has hardened. When the door has hexagon-head bolts, adjust them so the closed door touches the steamer evenly without binding at the corners. Unless you have a good fit, the gasket will cut by the corners of the door and steam will escape. For inspection and preventive maintenance of the steam service and condensate system, include those items that apply in table P of appendix II.

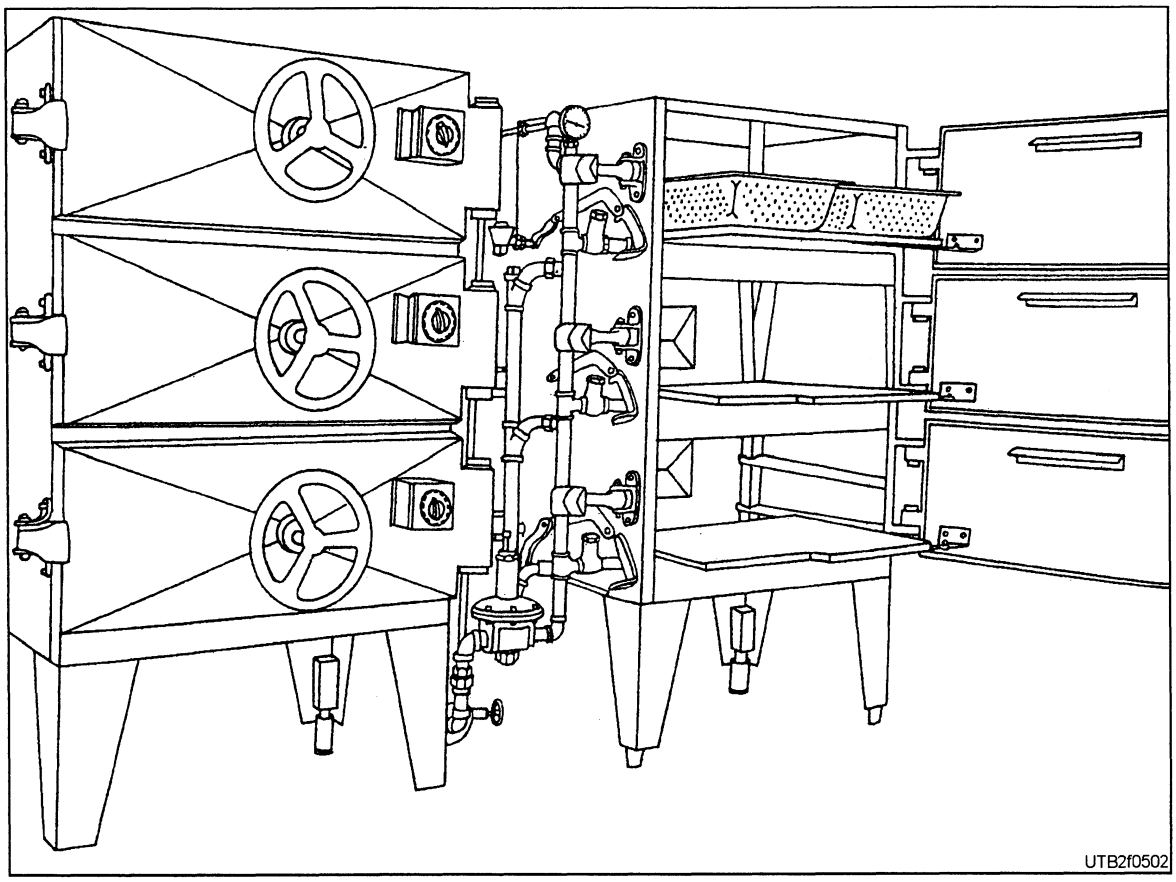


Figure 5-2.—Direct-connected steam chests.

STEAM TABLES

Steam tables are used to keep food hot during serving by use of steam and hot water. Steam tables (fig. 5-3) should be carefully inspected monthly and yearly.

The MONTHLY inspection should include the following:

- Check the water compartment, steam coil, valves, and piping for leaks and corrosion.
- Check the steam pressure on the gauge, keeping in mind that the PRESSURE SHOULD NOT EXCEED MAXIMUM PRESSURE SHOWN ON THE NAMEPLATE.
- Check and calibrate the temperature control, if needed.

The ANNUAL inspection should include the following:

- Descale the water compartment, examine the top and frame for scale, and check the level of the steam tabletop.

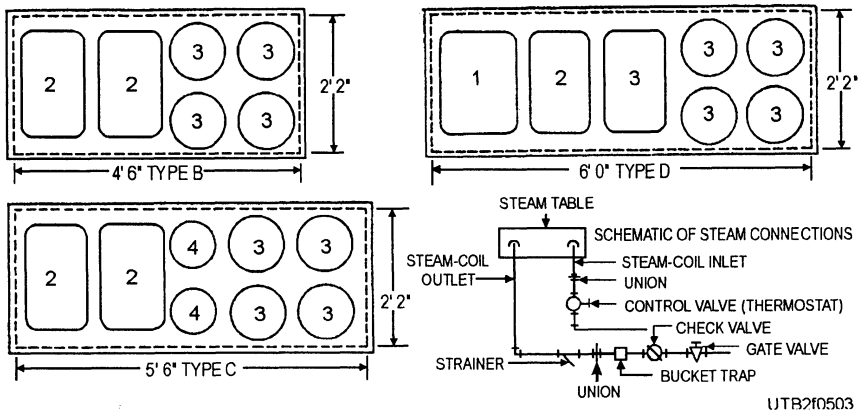


Figure 5-3.—Schematic drawing of a steam table.

- Remove the rust and corrosion within the water compartment, as necessary, with solvent, and paint the bare spots with heat-resistant aluminum paint.
- Check the thermostat with a mercury thermometer. The thermostat must be accurate to within either plus or minus 5°F.

NOTE

Use table P of appendix II to check other items that apply to this equipment.

DISHWASHERS

From time to time, you may be called upon to adjust dishwashing machines that have become defective (figs. 5-4 and 5-5). Some of the most common difficulties, the usual reasons for their occurrence, and possible remedies for them are listed in table Q of appendix II.

Now and then, descaling deposits from within the machine, the piping, and the pumps will be required. You can fill the tank halfway with hot water, add an approved cleaning solution, fill the tanks to overflowing, and then operate the machine for 30 minutes at high temperature with trays, spray arms, and curtains in place. Next, drain the tanks and fill them with hot water and run the machine for 5 minutes. This rinsing action should be repeated several times to make sure all of the cleaning solution is removed from the unit.

Dishwashing machines and accessories should be lubricated according to the manufacturer's instructions. This is especially true in the selection of

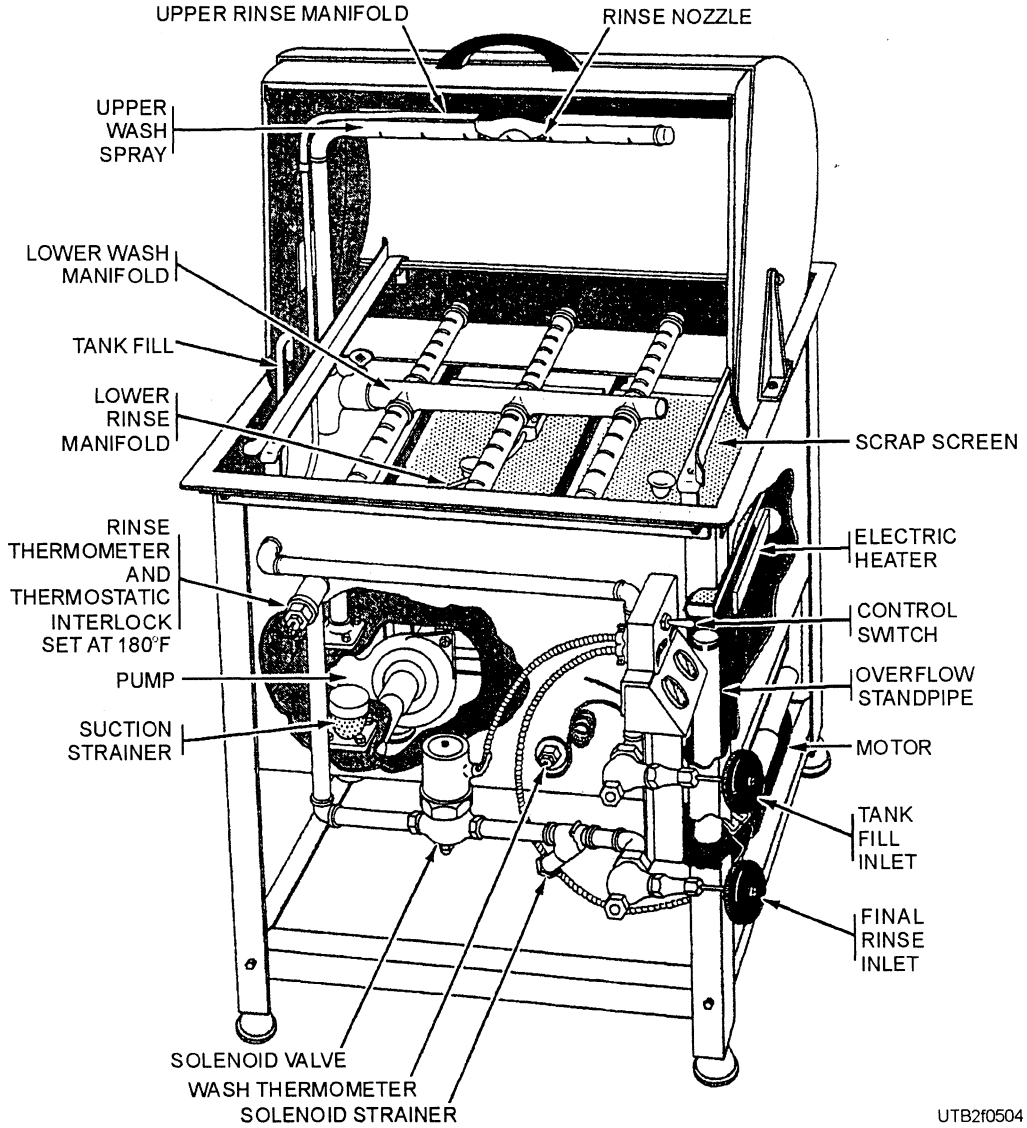


Figure 5-4.—A semiautomatic single-tank dishwasher.

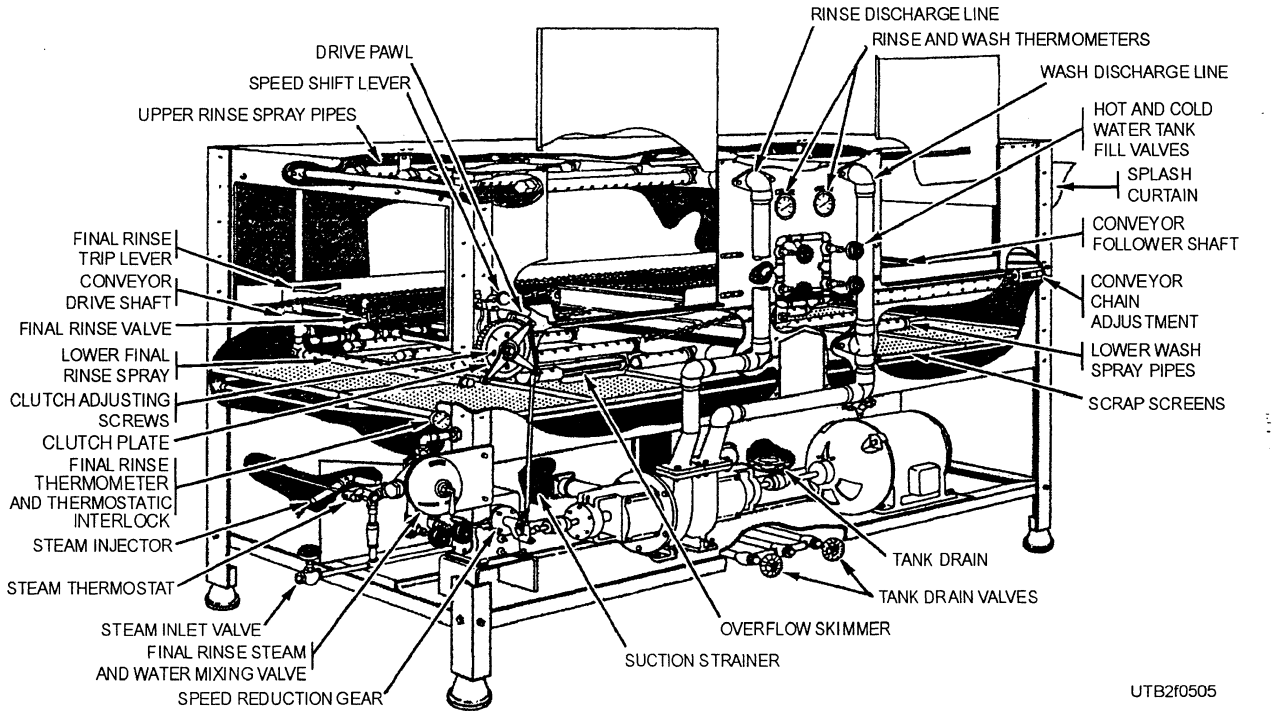


Figure 5-5.—A cutaway view of a double-tank automatic dishwasher.

grades and viscosities of the oil used, the levels at which the oil is to be maintained, and the places to be oiled. All damaged or missing lubrication fittings should be replaced. The grease cups on the drive end, connecting rod, and the rinse lever should be turned once each quarter and be refilled when empty. Also, the revolving wash arms and valve stems should have a few drops of light oil applied to them about once each quarter.

CAUTION

Be sure to turn off the power before lubricating the equipment.

Because of limited space, this chapter does not attempt to provide all the necessary details concerning the parts and accessories of dishwashing machines. Study the manufacturer's manual for the type and make of machine concerned. Some of the machine parts and accessories of the dishwasher that should be maintained and serviced regularly are as follows:

- Repair or replace the torn or worn curtains.
- Straighten the warped pans so they stay flat in the machine.
- Replace the packing with new material of the same type and size. Do not overpack the packing gland because this condition causes binding of the shaft.
- Replace the broken or damaged thermometers. Check the accuracy of the thermometer by measuring the water temperature with a high-grade thermometer and comparing results with a thermostat setting. The thermostat should be set for a wash water temperature between 138°F to 145°F and rinse water for a temperature of 180°F or above.
- Defective conveyors should be properly adjusted or replaced. Check the nylon covering of steel parts and replace the coverings when they are worn or torn.
- The inspection doors of wash and rinse compartments should be kept tight at all times.
- Straighten or replace bent or loose doors.
- Check the chains and pulleys of counterbalanced doors. Apply oil regularly to moving parts.
- Check the dish racks for bent or warped surfaces and replace broken parts.

- Inspect the utility fittings, such as steam coils, traps, heating elements, gas burners, and all thermostats. Follow the manufacturer's repair instructions. Usually, you have to detach these component parts and take them to the maintenance shop for repairs.
- Frequently check the ventilating hoods (if installed), the hood fans, and fan accessories, such as baffles, clampers, vanes, access doors, louvers, registers, protective grilles, and bird or insect screens for corrosion and rust.
- Check the ventilating hood fans for grease and other impurities that should be scraped off with a knife. Tighten any items that have become loosened by vibration.
- Remove the rust from dishwashers with solvents and paint over corroded areas with two coats of rust-resistant paint. In selecting a solvent, use the air-inhibited sulfamic acid type according to the manufacturer's instructions.

CAUTION

Never use steel wool for cleaning interior surfaces of dishwashers because small particles may contact dishes and eventually become embedded in food.

With regular inspection and lubrication, with repairs and adjustments made as necessary, and with strict observance of the manufacturer's operating instructions, these machines will last along time. To ensure they receive the required attention, set up a regular schedule of inspection. Monthly and annual inspections may be satisfactory in many cases.

MONTHLY inspect ion and maintenance should include the following:

- Check the lubrication of bearings, gearboxes, chains, and sprockets; lubricants should be added, if required.
- Check the drive V-belt tension and alignment, flexible couplings, chains, and sprockets.
- Check the electrical components for proper functioning and safety features, including proper grounding.
- Ensure the machine and the tables are level; check for misalignment of parts, loose parts and leaks, and unusual noises.
- Check the piping system for faults.

During ANNUAL inspections, give careful attention to the following:

- Check the frames for adequacy of support; tightness of casings, seams, joints, and counterweights; evidence of corrosion; watertightness of doors, hinges, and gaskets; and correctness of clearance and alignment.
- Check the pumps and impellers for corrosion or extreme wear of parts. Disassemble them, clean all parts thoroughly, and repair or replace badly worn parts. Reassemble and adjust.
- Lubricate all parts requiring lubrication.
- Be sure to tag the dishwasher, stating the date of the current inspection, repairs made, and the date of the next inspection.

RANGES

Observing a schedule of monthly and annual inspections ensures the safe and efficient operation of a range, including the oven, broiler, griddle, and so on. Some of the major items that should be covered as part of the MONTHLY inspection are as follows:

- Check the pipe for leaks.
- Clean and lubricate the motors.
- Check the burner flame. Remember, the burner should give off a blue flame when the air-oil mixture is correct. A flue-gas analysis should be performed to find the proper fuel-air mixture.
- Check the equipment for alignment and fit of doors, for sliding action of racks, and for levelness.

The ANNUAL inspection of oil- and gas-fired equipment should include the following:

- Check on all the parts for damage, corrosion, and lack of paint. Remove the rust with solvents, and paint the bare spots with heat-resistant aluminum paint. (**NOTE:** If bare spots total more than 20 percent of the entire surface, paint the equipment.)
- Check the thermostat. If the accuracy of the thermostat cannot be adjusted to within 5°F accuracy, replace it with a new thermostat.
- Clean soot deposits and jet openings and repair or replace leaking piping. Clean and tighten the nuts and bolts.

NOTE

Refer to table R of appendix II for a trouble-shooting chart covering the maintenance of ranges, ovens, and broilers.

FIELD RANGE

As a Utilitiesman, you need to know how to maintain, repair, and troubleshoot the field range. Unfortunately, this manual can NOT cover all you need to know about the field range; therefore, you should have your supervisor refer you to other sources of pertinent information. A gas-fired field range is shown in figure 5-6 and the procedures for setting up and operating the range burner unit is detailed in chapter 2, *Utilitiesman Basic,* volume 1, NAVEDTRA 11019.

Keeping the field range in a constant state of readiness is important to everyone in the field. This is accomplished by performing preventive maintenance checks and services quarterly or after every 250 hours of operation, whichever occurs first. Table R of appendix II provides a listing of possible malfunctions that may occur in the field range outfit. This listing will help vou in diagnosing and correcting unsatisfactory operation or failure of the field range outfit. Also, an excellent source of information is listed in the references listed in appendix IV.

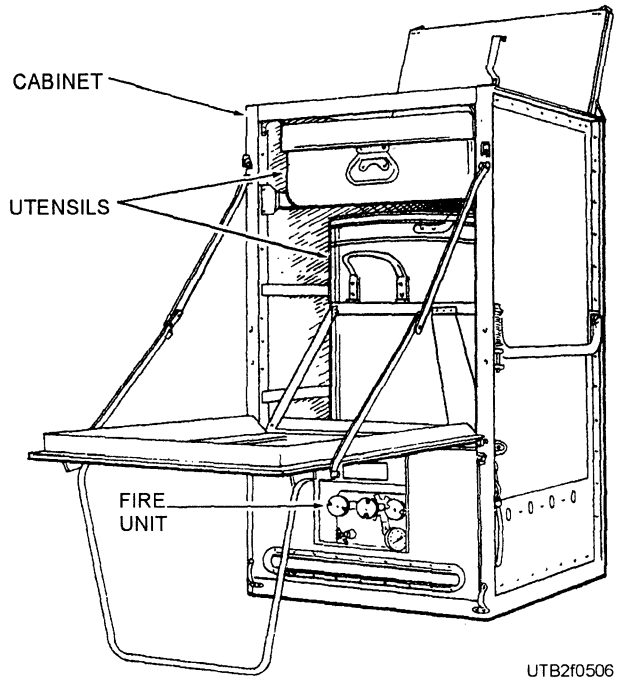


Figure 5-6.—Field range with fire unit in position for cooking.

BAKERY OVENS

Routine maintenance of bakery ovens (fig. 5-7) requires weekly, monthly, and annual inspections.

The WEEKLY inspections should include the following:

- Adjust the heating units for proper fuel-air mixtures and constant operating temperature.
- Check the pilot flame of the gas-fired ovens and adjust it, if necessary, so the burner gas ignites without wasting fuel and the flame is not blown out by the flue draft. Adjust the fuel-air mixture to produce a blue flame.
- Check the operation of the purging fan and the flame failure devices.
- Clean the soot and dirt from the pilot and gas burner.
- Check the oil supply for eaks and stoppages and clean the strainer basket of oil-fired ovens.
- Examine the operation of the electric-ignition and flame-failure devices, and repair them if necessary.
- Adjust the oil burner for proper spread of fuel across the combustion chamber and for proper fuel-air mixture to maintain a blue flame.
- Examine the operation of dampers and clean and adjust them if required.
- Check the settings of automatic temperature and humidity controls; reset the settings of the thermostat and humidistat if necessary.

The MONTHLY inspections should include the following:

- Inspect the conveyor and drive and adjust loose chains, belt tension, and any other component that may be misaligned.
- Adjust the chains of the V-belt tension by moving the idler sprocket or sliding motor base.
- Check the lubrication of gearboxes, bearings, and moving parts.
- Examine the oven top and walls for cracks and breaks; make the repairs if necessary to ensure tightness.

The ANNUAL inspections should include the following:

- Drain, flush, and renew the lubricant in the gearboxes. Check the sprockets, gears, and

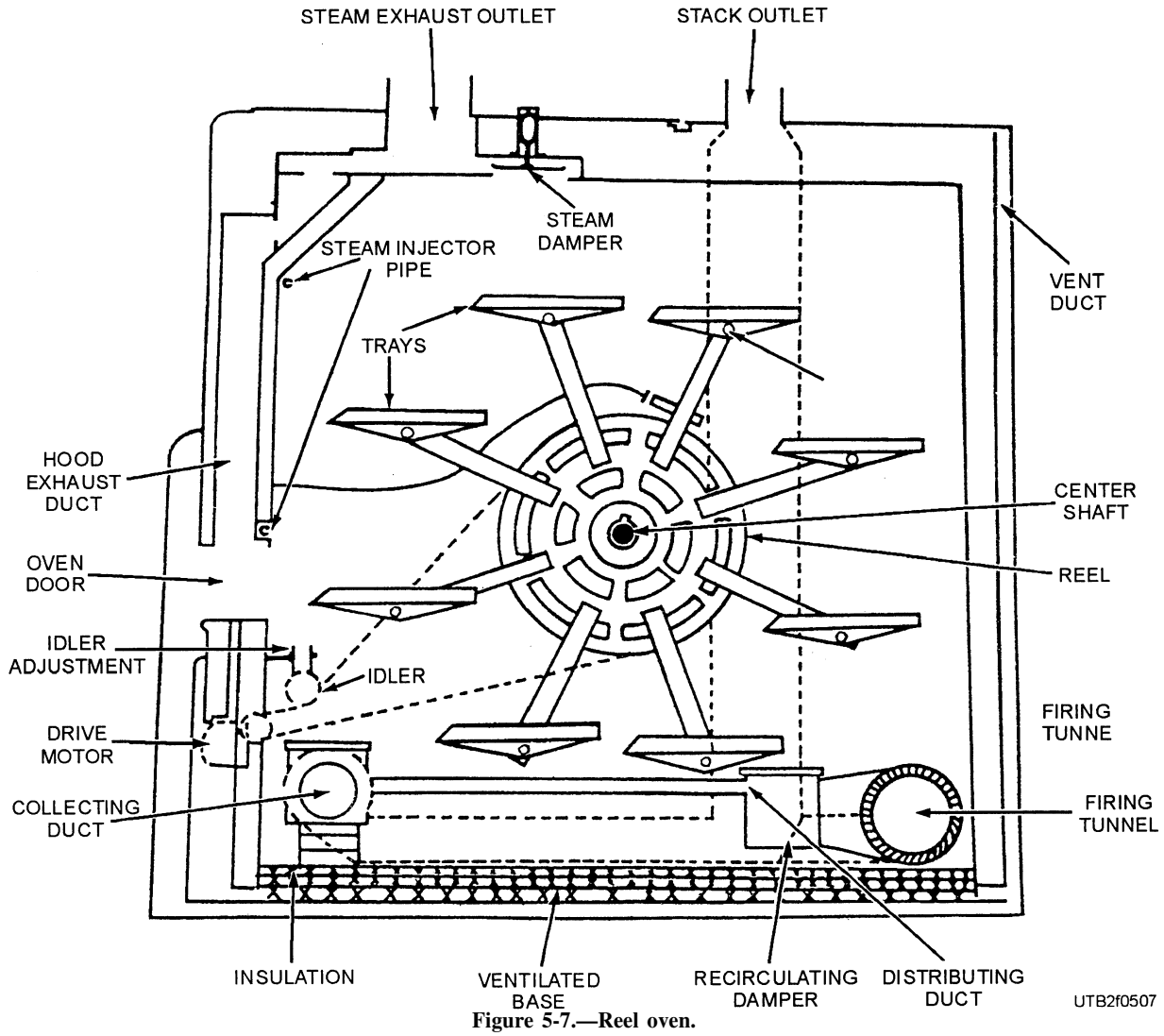


Figure 5-7.—Reel oven.

bearings and renew the lubricant according to the manufacturer's instructions.

- Conduct electrical checks of the insulation resistance of motor windings, controls, and wiring. Clean all contacts of the controls.

INTERCEPTORS AND GREASE TRAPS

Removal of grease from greasy wastes is necessary if the sewage system is to function properly. One way grease is collected is by ceramic or cast-iron grease interceptors installed inside mess halls. Among the types of interceptors you may encounter is the Zurn interceptor shown in figure 5-8. Another way of collecting grease is to use concrete or brick grease traps outside of buildings. Mess personnel usually clean the inside interceptors but you may have to clean the outside traps. When inside grease interceptors are maintained properly, they should collect most of the grease from the waste. They may need cleaning once each day.

Remember that outside grease traps are intended to serve kitchen plumbing fixtures and equipment only. So they should never be connected to soil and waste lines from toilet rooms. To help ensure proper functioning, clean grease traps at least once a week. Since accumulated odor-forming solids cause septic action within a short time, remove all solids each time the traps are cleaned.

The steps of the procedure for cleaning outside grease traps include the following:

1. Skim grease from the surface of the trap using an ordinary perforated sewer scoop, and place it in suitable containers for disposal.
2. Remove as much odor-forming material as possible with the same scoop. Treat this refuse as disposable.

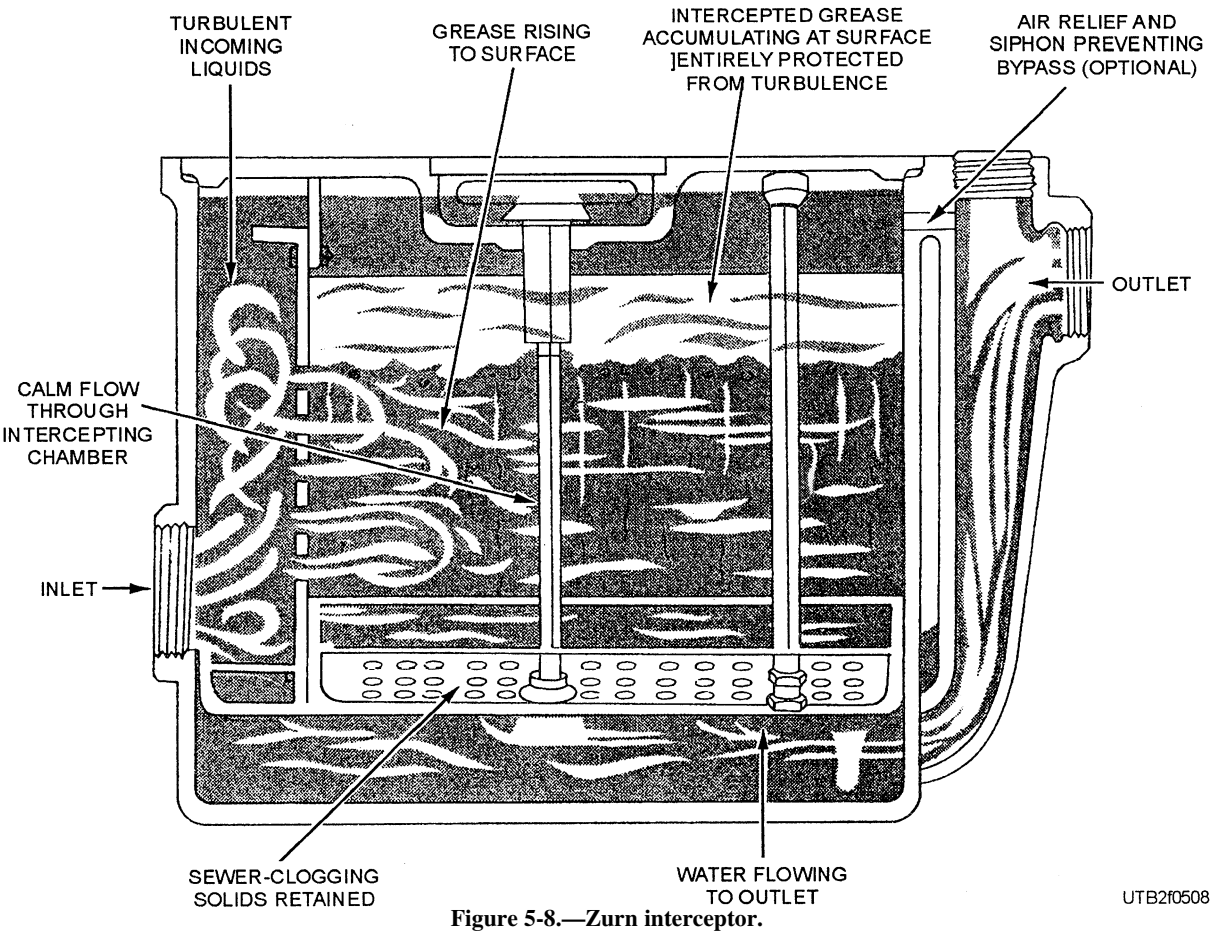


Figure 5-8.—Zurn interceptor.

3. Pump out the liquid from the traps every 3 months, and remove all sediment from the sidewalls and the bottom if necessary.

Q1. *What person is responsible for conducting sanitary inspections of galley equipment?*

Q2. *What type of steam kettle generates its own steam?*

Q3. *When a plunger type of valve is used on steam chests, the valve must be fully depressed when the steam chest compartment door is closed. True/False.*

Q4. *How often should the temperature control on a steam table be calibrated?*

Q5. *A steam table thermostat must be accurate within plus or minus how many degrees. in Fahrenheit?*

Q6. *The wash water temperature of a dishwasher should be maintained within what temperature range, in degrees Fahrenheit?*

Q7. *Steel wool should never be used to clean interior surfaces of dishwashers for what reason?*

Q8. When the proper air-oil mixture is present, a range burner will have a flame that is what color?

Q9. *How often should the pilot and gas burner be inspected for soot and dirt?*

Q10. Other than ceramic or cast iron, what types of grease traps are used?

Q11. How often should liquid be pumped from a grease trap?

LAUNDRY EQUIPMENT

Learning Objective: Recall the procedures for installation, maintenance, and repair of laundry equipment.

Laundry equipment varies from one activity to another, depending upon such factors as the size of the laundry and the differences in individual types of equipment produced by various manufacturers, such as Pellen-Milnor, Bock, Cissell, or Huebsch. Some common types of equipment used in most laundries are washers, extractors, and drying tumblers.

One type of laundry unit you may encounter in your work is shown in views A, B, and C of figure 5-9. This laundry unit is mounted on three skids that are fitted together in assembling; the unit. On one skid is the washer unit, which consists of two, 75-pound, 26- by 26-inch end-loading washers, and one 30-inch top-loading extractor. View C shows the extractor and the back of the washers more clearly. The middle skid has the dryer unit, which consists of two 42- by 42-inch steam-heated drying tumblers, one air compressor, an electric-driven motor, and one stainless steel surge tank. The other skid has the boiler unit; it consists of an oil-fired 33-horsepower steam generator with a return hot well, a water softener, and a 350-gallon hot-water storage tank. This laundry unit can wash and fluff dry 225 pounds (dry weight) of laundry per hour.

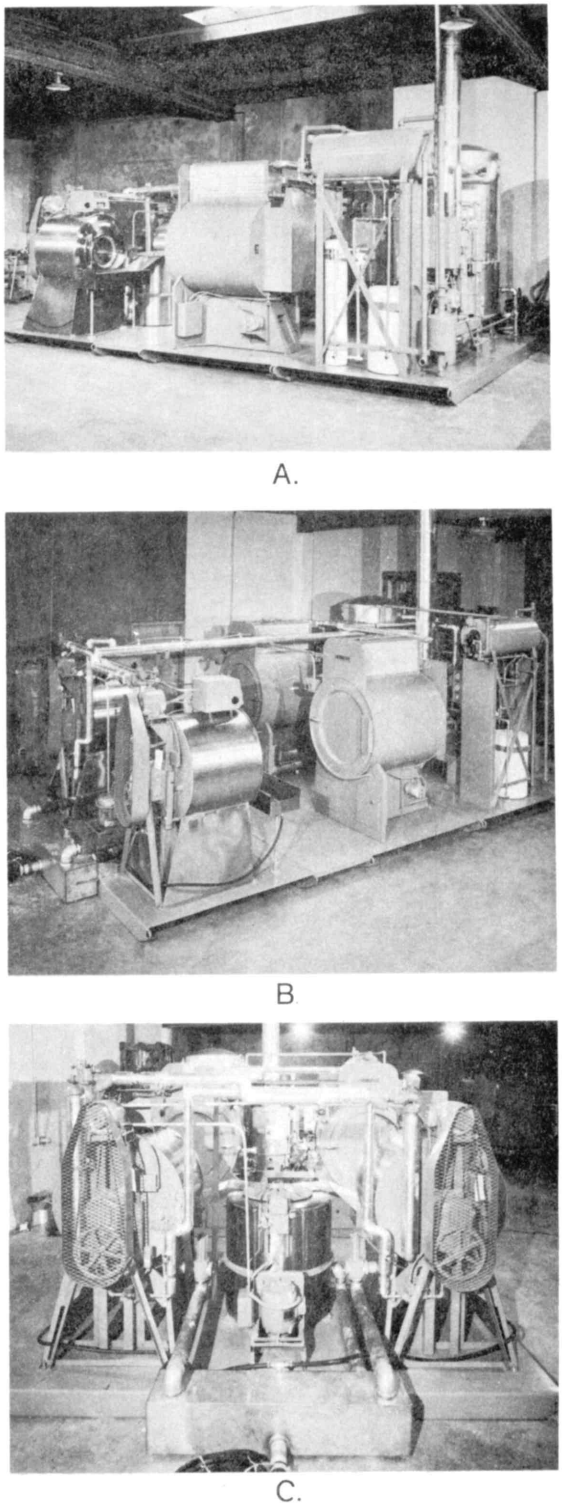


Figure 5-9.—Skid-mounted laundry unit.

In the following sections, information is provided about the installation, maintenance, and minor repair of laundry equipment. This information is not intended to furnish all the details you need to know concerning installation, maintenance, and repair of washers, extractors, drying tumblers, and steam generators. For specific information, you should always refer to the instruction manual provided by the manufacturer of the equipment.

WASHER

The purpose of a washer is to wash clothes and other suitable materials. The washing process is a series of baths during which soil is loosened from the materials, suspended in the water, and finally rinsed away. Several baths are usually necessary to remove the soil completely.

Operation

The type of washer most often used at Navy activities is the Pellerin-Milnor end-loaded, fully automatic washer (fig. 5-10) that is often referred too simply as the "Milnor." This washer is provided with a removable FORMULA CHART, which can be easily changed at the discretion of the operator. Each formula chart provides a full 88 minutes of operation if desired. Marker labels affixed to the formula show the operation in progress and which supplies are needed when the timer signals. The Milnor washer is also equipped with a Miltrol timer to carry the washer through a complete cycle by following the formula cut in the chart.

The Milnor washer has an automatic supply injector unit that consists of five compartments. Various supplies are placed into these compartments at the start of the washing cycle. At a designated time, the supplies are flushed from each compartment into the washer.

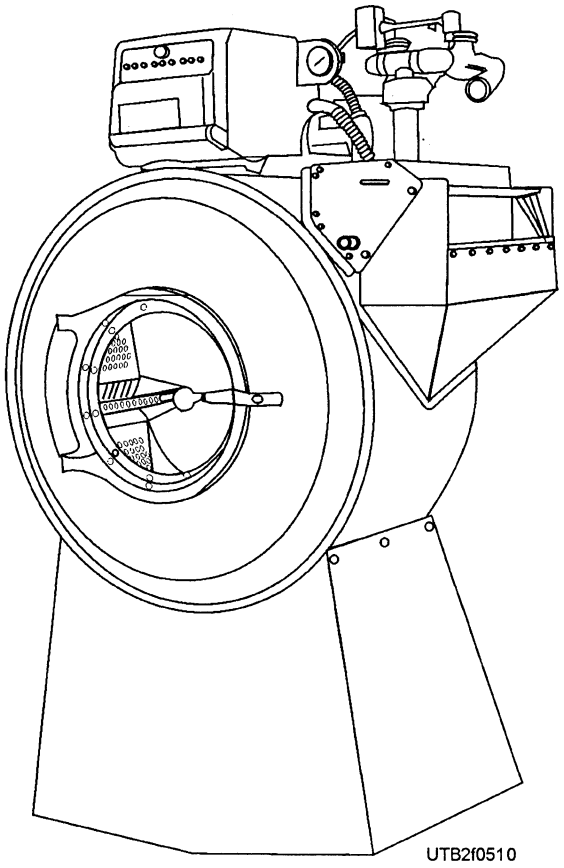


Figure 5-10.—Washer.

Machines equipped with automatic supply injection may also be operated manually at any time. To operate manually, however, you must turn the chart to the uncut position. When required, the Milnor washer can be supplied with an electrically operated tempering control to thermostatically control the temperature of the water for the washer.

Milnor washers, when required, can be furnished with a device to inject supplemental steam automatically when called for by the formula chart and raise the water temperature above that available from the hot-water source. This device can also be used to maintain minimum hot-water temperature in the washer when the normal hot-water source is unable to generate enough hot water to keep up with the hot-water demand of the plant or to raise the water tern perature near the boiling point.

Installation

The steps required to install the Milnor washer are as follows:

1. Install the washer on a steady, level floor, or foundation. Make sure the machine is properly bolted down to prevent vibration.
2. Assemble the water inlet valves on the rear shell of the washer. (The water inlet valve assembly and two water inlet valve strainers are shipped inside of the washer.) Assembling the inlet valves consists of plugging in a twist-lock connection to the rear of the Miltrol timer or plugging bullet connectors into rubber sleeves, as shown on the inside of the Miltrol box.

NOTE

On some models, the inlet valves are permanently attached and wired to the control and do not require installation.

3. Connect the hot and cold waterlines to the hot- and cold-water inlet valves. (The hot-water valve is on the left, and the cold-water valve is on the right when you face the front of the washer.)
4. Install one of the strainers in each of the waterlines just ahead of the solenoid valve. Note that some machines have water valves that do not require strainers, so when this type of valve is used, no strainers are shipped inside of the washer cylinder.
5. Some models are furnished with a "Steam Boil" circuit to allow any or all of the washing operations at boiling temperature. In such cases, connect the steam line to the steam solenoid valve near the bottom of the washer shell at the rear of the machine.
6. To eliminate water hammer when the inlet valves close, connect the inlet valves to the water main with a short piece of rubber hose (about 15 to 24 inches long) between the water main and the upstream side of the strainers. The elasticity of the rubber hose prevents the pounding noise that might otherwise occur every time an inlet valve is closed.
7. Water inlet valves are rated to handle a maximum of 90-psi pressure. A pressure-reducing valve should be used to limit water pressure when the pressure exceeds this figure. The steam valve (when furnished) is rated to handle a maximum of 110-psi pressure, and a pressure-reducing valve should be used to limit steam pressure when it exceeds this figure.
8. Connect the pressure supply for the automatic drain valve to the air line or to the cold waterline. The automatic drain valve requires a minimum of 25-psi pressure AT ALL TIMES.

NOTE

Some models are equipped with electric drain valves that do not require air or water pressure connections.

9. Connect the drain line to the connection in the BOTTOM of the automatic drain valve. The threaded connection in the side of the automatic drain valve is a cleanout hole only.

10. The Miltrol timer is equipped with a step-down transformer to lower the voltage at the contact fingers to 24 volts. Some electrical components in the timer operate on 24 volts (the lamps, timer relays, water valves, etc.). Provide a line disconnect switch for each washer, so any washer in your installation can be turned off for repairs without affecting the operation of the others.

11. Adjust the level control for the desired high- and low-water levels. The level control is set at the factory to deliver the approximate water depths. However, the final adjustment must be made in the field.

12. Connect the supply injector unit to a source of water for flushing. Use one size larger if the pipe run is more than 5 feet. When the water piping for the supply injector is too small, the supply injector does hot flush the supplies properly. When available, hot water should be used for flushing but only if your hot-water source is dependable, has at least 20-psi pressure, and does not occasionally boil over and produce steam in the hot waterline. If hot water is not available, use cold water.

13. Five solenoid valves are within the supply injector. These valves can handle a maximum of 30 psi. They are adequately protected against higher pressure by the pressure-reducing valve that has been properly set at the factory to deliver between 25 to 28 psi. Be sure to check the pressure gauge and reset it to 25 to 28 pounds, as vibration and/or handling in shipment may cause the regulator to get out of adjustment.

Maintenance and Repair

The Milnor washer should be inspected at regular intervals to ensure that it works properly. If an inspection reveals adjustments or repairs are needed, they should be made promptly.

The inspection of a washer should ensure that proper conditions exist. These conditions include the following:

The machine is level.

- All bolts, nuts, and screws are tight.
- Latches on cylinder doors work properly.
- The thermometers are accurate.
- Switches are properly adjusted and working correctly.
- Timers are in good working order.
- Water level gauges are correct.
- All electric controls are working.

In addition to the regular scheduled inspections, you should make special inspections as follows:

EVERY 2 MONTHS:

- Check the gearbox oil level and replenish with fresh oi I, if necessary.

SEMIANNUALLY:

- Lubricate the clutch drag spring with two or three drops of light machine oil between the left-hand chassis end frame and the chart drag spring holder, a shown by arrow (1) in figure 5-11.

ANNUALLY:

- Drain the gearbox and replenish it with fresh oil. The drain plug in the bottom of the gearbox has a small magnet in its end to attract metallic particles in the oil. Be sure to clean off the magnet each time the gearbox is drained and before reinserting the drain plug.
- Clean the motor clutch assembly, as shown by arrow 2 in figure 5-11, with one or two squirts of Navy-approved nonflammable cleaning fluid. Wipe the fluid off with a clean, dry rag and lubricate with two or three drops of light machine oil to prevent the clutch spring from "gumming up" and allowing the clutch to slip. Wipe off excess lubricant.

Troubleshooting

The washer is a rugged machine, but from time to time you can expect trouble. A troubleshooting chart for the Milnor washer is contained in table X of appendix II of this TRAMAN.

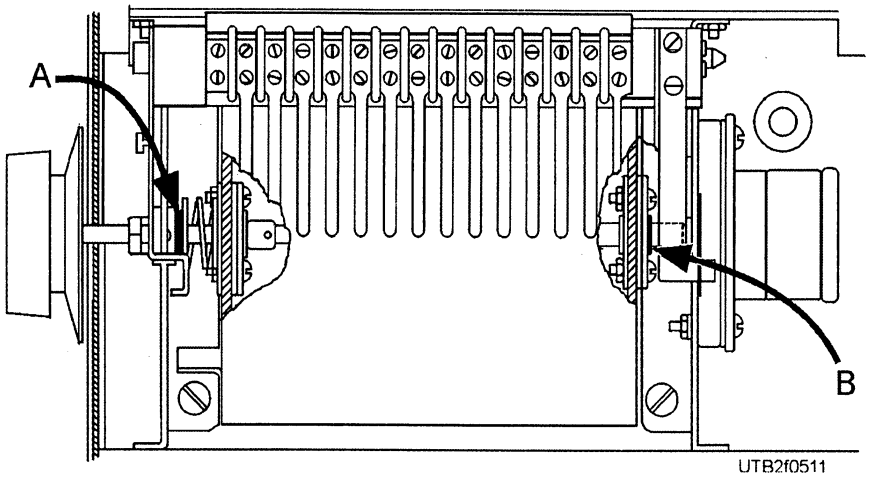


Figure 5-11.—Lubrication and cleaning points on timer.

EXTRACTOR

The purpose of the extractor is to extract water from clothes after rinsing. Water is extracted by spinning the clothes at a high speed, applying centrifugal force, pushing the water to the outer surface, and discharging it through small holes in the basket of the extractor to drain.

Extractors may be equipped with a manual brake (fig. 5-12) or an automatic brake. An assembly drawing of a manual brake stainless steel extractor is shown in figure 5-13.

Installation

The procedure for installing extractors varies with different makes and models. Consult the manufacturer's manual for specific instructions on the model that you are installing. These machines may be installed on any good floor or foundation, and they operate without excessive vibration if properly leveled and bolted down.

When installing the extractor, you should pay special attention to the following:

- Support the extractor so it is 1 inch above the foundation. Ensure there is 100 percent contact between the hold-down pads and the grout for leveling the extractor.
- Check the nameplate before connecting the electrical source to ensure the proper power source is connected.
- If the extractor is equipped with an automatic brake, which is operated by air, ensure the proper air supply pressure is connected.
- When connecting the drain piping, you should install a short piece of hose on the drain line near the extractor to avoid possible problems due to vibration of the unit.
- Ensure the rotation of the basket is in the clockwise direction as shown on the nameplate.
- Once installation is complete, thoroughly clean the inside of the basket to remove the dust and grime that have accumulated during shipment.

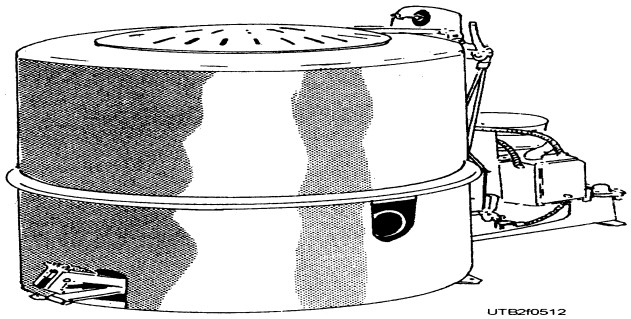


Figure 5-12.—A manual brake extractor.

Maintenance and Repair

If the extractor is to give satisfactory service for a long period of time, it should be properly maintained and repaired promptly. Maintenance and upkeep of the Milnor extractor requires the following:

- The extractor rubbers should be checked at regular intervals. When necessary, the rubbers should be tightened or replaced.

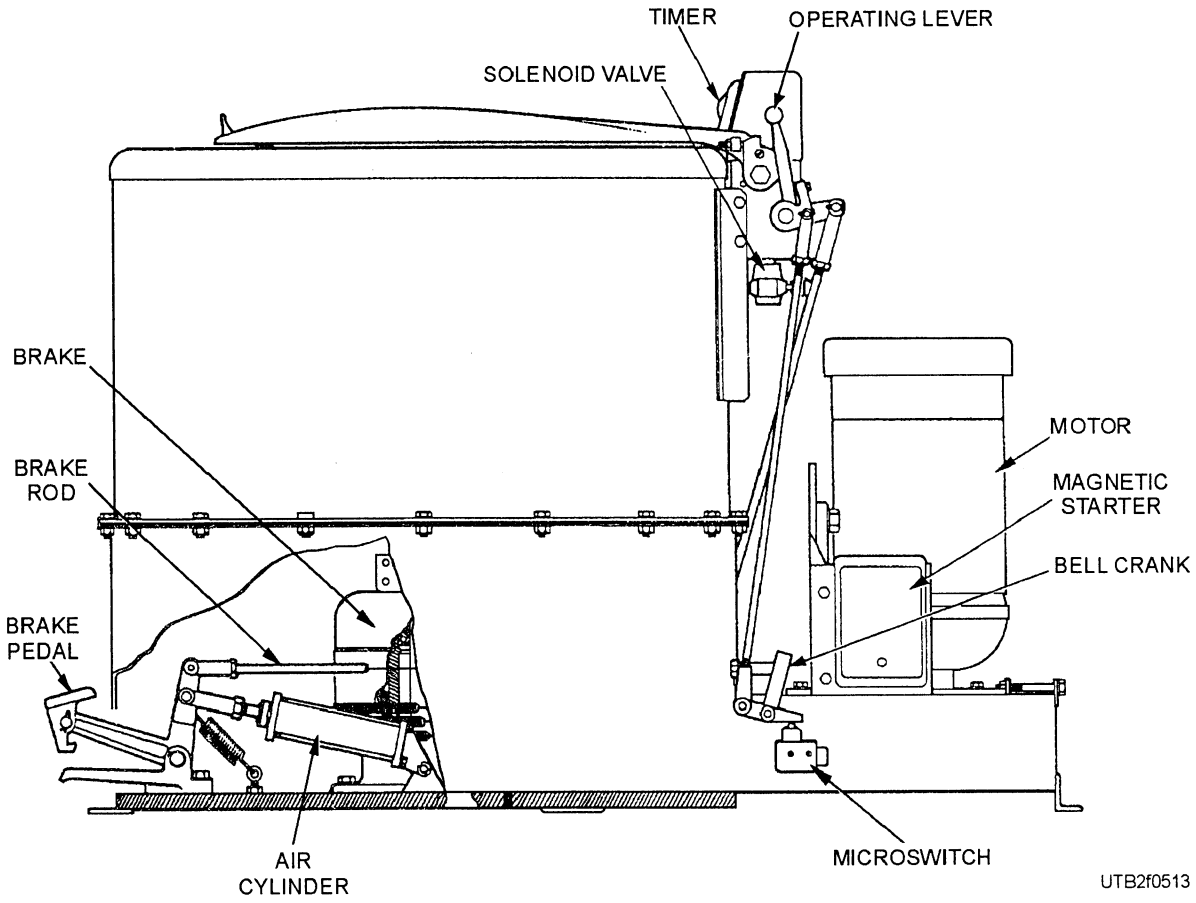


Figure 5-13.—An assembly drawing of a manual brake stainless steel extractor.

- Remove the basket from the spindle. The basket is held to the spindle with a locknut on the inside of the basket, and the shaft and basket are fitted together with a taper. The basket may be removed from the spindle by "jolting" it off of the spindle or, if the extractor has been in service for a long period of time, you may have to press the basket off of the spindle. Next, remove the pulley, loosen the packing nut, and remove the bearing housing assembly with its shaft and bearings, after which new rubbers may be installed and the extractor assembled in reverse order. When installing new rubbers, be sure to place the flat face of the rubbers so they face the flange on the bearing housing; this will ensure that the concave side of the rubbers is down on the lower rubber and up on the upper rubber.

- Ensure the extractor is lubricated at all points recommended by the manufacturer. Also, use lubricants approved by the manufacturer. As for the frequency, lubricate every 30 days or as experience dictates.

Troubleshooting

In troubleshooting the extractor, you must be able to recognize common troubles and know the possible causes of the trouble. Obviously, a lot of time may often be saved if the cause is found before any corrective action is started. Table X of appendix II will be useful to you as a guide in finding the sources of troubles in Milnor extractors.

TUMBLER

The tumbler, also called the "drying tumbler," is the machine used in Navy laundries to remove moisture from materials. The efficient removal of moisture by the tumbler provides material that can be ironed properly. There are various brands of tumblers manufactured by such companies as Cissell and Huebsch.

The Huebsch Loadmaster model 42-inch tumbler is often used at Navy activities. This is a commercial type of tumbler with a drying capacity of 100 pounds (dry weight) of laundry per hour. A two-motor drive system provides independent fan and cylinder operation. A one-way cylinder rotation and a door safety switch are standard.

Another type of tumbler used at Navy activities is the Cissell model 36-inch tumbler. This tumbler has a drying capacity of 50 pounds (dry weight) of laundry per hour. This tumbler can have heat for drying supplied by a oil-fired burner attached to the unit or supplied by a permanent plant source. It also has a "cool down" feature for permanent press and other modern-day fabrics.

Installation

The following instructions on the installation, maintenance, and repair of tumblers apply to the Huebsch Loadmaster model 42-inch tumbler. Always consult the manufacturer's instructions for the brand and model that you are installing.

When installing the tumbler, you should ensure the following:

- Ensure the tumbler is level and properly secured to the floor. In leveling, use shims of adequate size to avoid weight concentration.
- The dryer room must be well ventilated. An opening of 2 square feet to the atmosphere must be supplied for each 1,700-cubic-feet per minute (cfm) model and 4 square feet for each 3,000-cfm model. Allow adequate clearance on all sides for servicing and efficient loading and dispatching of dried materials.
- On steam-heated laundry tumblers, a minimum of 100 psi should be maintained for efficient performance. Connect 3/4-inch steam supply and return lines to the coils as marked on the coil housing.
- Laundry tumblers are factory-wired for operation and require only a power supply connection.
- A fused disconnect should be installed. For multiple-tumbler installations, each unit should be equipped with a disconnect switch.
- Ensure the fan rotation is correct.
- For maximum efficiency of single- or multiple-unit installation, air discharge must be ducted individually to the atmosphere by the shortest possible route. For runs less than 20 feet, the duct size must equal the discharge spout or be larger. For each additional 30 feet of duct run, increase the entire duct diameter by one tenth for round duct or the entire duct area by one fifth for rectangle duct. Discharge to the atmosphere must be constructed to get rid of too much back pressure and to prevent the entrance of weather. The end of the duct should be at least one diameter away from any obstacle.
- Check for correct cylinder, belt, and chain adjustment before starting the unit, as described later in this chapter. Turn the power on and start the tumbler to check the cylinder and fan rotation and the door switch adjustment.
- Turn the steam on. Place a load of damp rags in the cylinder and run until dry. Check the cylinder adjustment under load and check for vibration or unusual noise. Reversing models must be checked for correct time delay betweeh reversing cycles. Correct any adjustment before placing the tumbler in service.

Maintenance and Repair

Two views of the tumbler are shown in figures 5-14 and 5-15. Try to keep the tumblers operating at peak efficiency.

Some general maintenance and minor repair procedures in the care and upkeep of tumblers are as follows:

MONTHLY:

- Loose wire connections can cause tumbler failure and possible damage. Remove the control box cover and check the controls.
- Replace the contactor points when pitted or worn. Check and tighten all wire connections, including thermal overload heating coils. Check for secure mounting of controls to the control box.

ANNUALLY:

- Ensure that electric motors are removed and cleaned thoroughly. Frequent tripping of the thermal overload circuit breakers may be caused by low voltage, loose connections, reversed fan, or high ambient temperature. Never increase thermal overload heater size without complete investigation.
- The door switch, thermostat, and other optional electrical equipment require replacement upon failure. After exchange, check the wiring diagram before turning on the power. Check with the power on. Adjust if necessary before returning to service.

ADJUSTMENTS.—In servicing the tumbler, you may have to adjust the belt, chain, cylinder, and

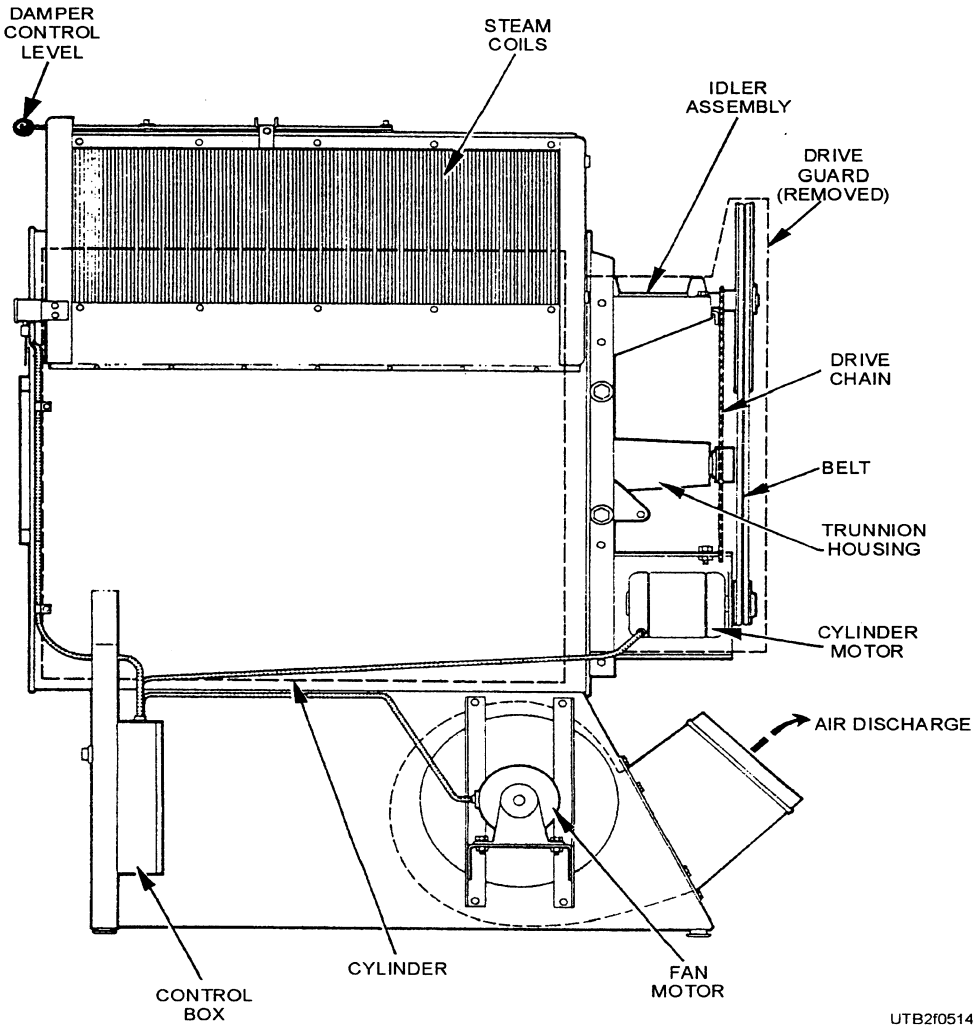


Figure 5-14.—Right side view of tumbler.

reversing timer (on machines so equipped), and door safety switch at various times. To make these adjustments, refer to the manufacturer's instructions for specific procedures.

LUBRICATION.—Once a month, remove the circular cover on the drive guard and oil the chain, using SAE-30 oil. The pillow block, trunnion, and motor bearings are sealed and require no service.

STEAM GENERATOR

The purpose of the steam generator is to provide enough steam to operate tumblers, as well as to provide a continuous supply of hot water to the washers under constant operation. One type of steam generator frequently used in laundries at Navy activities is the Clayton steam generator, Model RO-33-PL.

NOTE

Some portable skid-mounted units use a self-contained oil-fired water heater to supply hot water for washers instead of a steam generator.

The Clayton steam generator is a water-tube boiler that delivers its rated output of 99 percent quality steam (containing less than 1 percent moisture) per hour from 60°F feedwater. The generator develops its full-rated pressure within 5 minutes from a cold start.

The generator features a continuous circulating feedwater system with a constant capacity pump that ensures a wet tube in the generator-heating unit at all times. Automatic controls regulate the feedwater rate

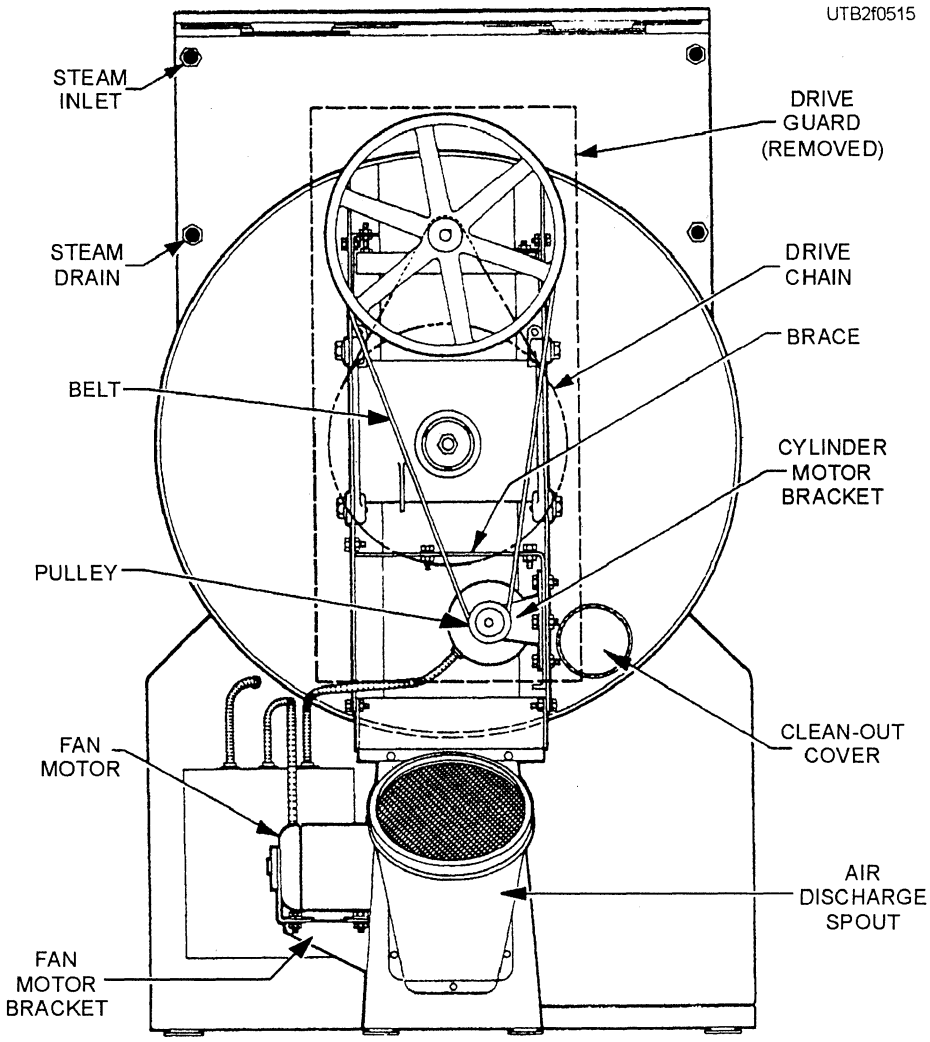


Figure 5-15.—Rear view of tumbler.

and modulate or stop the burner by steam demand. Standard equipment includes safety devices for protection against water fai I ure, burner failure, too much pressure, and electrical overload. A flow diagram of the water and steam circuit of the generator is shown in figure 5-16. Supply water enters the feedwater section of the water pump from the hot well/feedwater tank and is pumped directly to the steam accumulator. The circulating liquid is drawn from the accumulator by the circulating section of the water pump and pumped into the single-passage heating coil, and then back to the accumulator where the steam is separated.

The pump is driven directly by an electric motor and contains no packing boxes. It is arranged in two sections—the feedwater section and the circulating section. The pump diaphragms are operated hydraulically by oil displaced by reciprocating pistons within the pump. A built-in solenoid-operated bypass valve is on the hydraulic pressure section of the feedwater pump to prevent the feedwater section from pumping when the valve is open. The valve is actuated by the water level control according to the liquid level in the accumulator.

Installation

When installing a steam generator, always use the manufacturer's instructions. Pay attention to the fuel, water, electrical, and venting facilities when installing the boiler and ensure the following:

- Ample clearance should be allowed on all sides to make operation and maintenance easier.
- When installing external piping, use pipe unions next to the boiler connections to allow easy removal of parts for inspection and cleaning.
- The boiler is equipped to burn No. 2 diesel fuel oil. Connect the fuel supply line to the inlet connection on the fuel filter. Connect the return

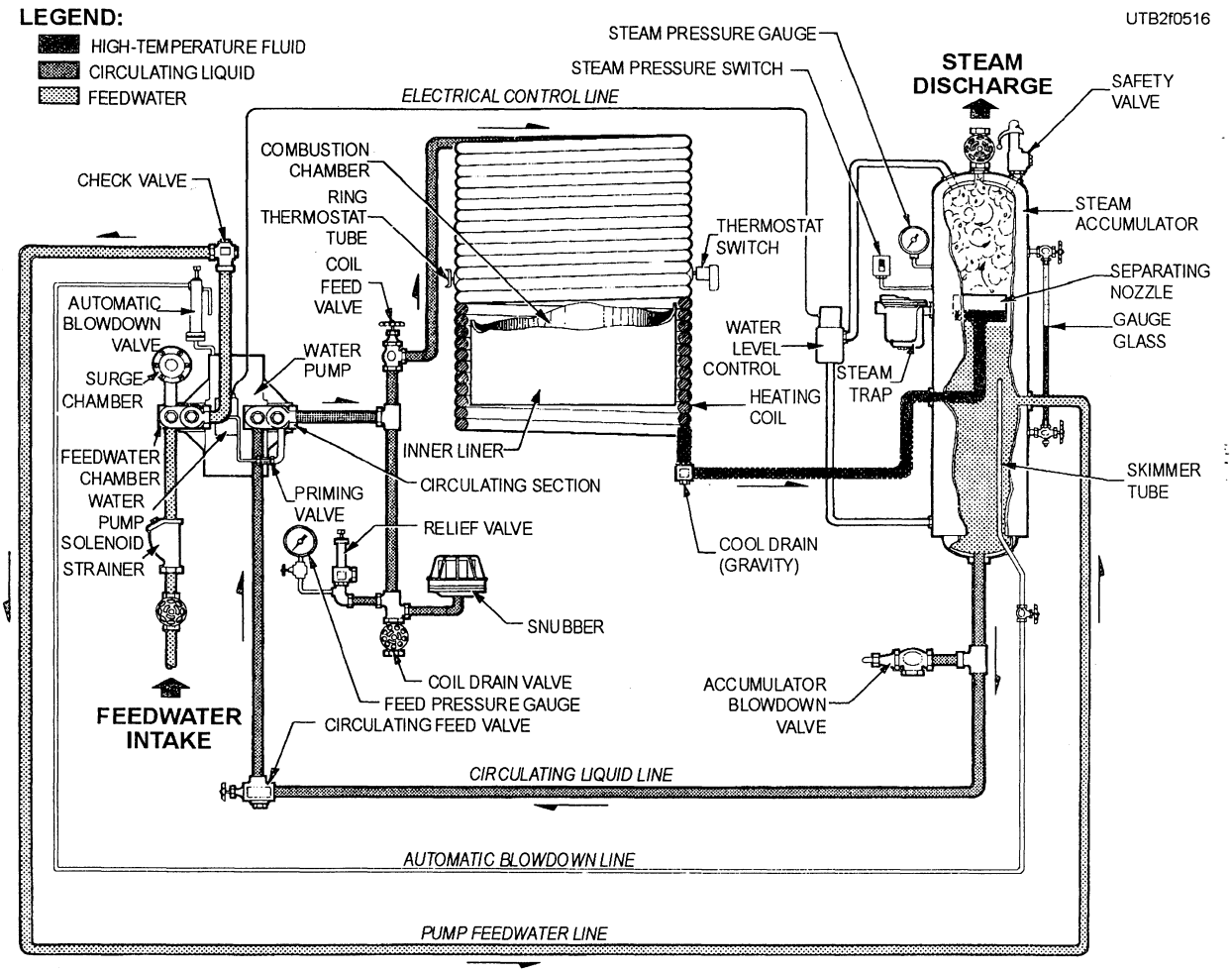


Figure 5-16.—Flow diagram of the water and steam circuit in a generator.

line to the return connection below the fuel pump. The return line must be a separate line back to the fuel tank and NOT connected to the fuel suction line to prevent locking of air in the fuel system that will cause erratic burner operation. Do NOT install a shutoff valve in the return line; however, a swing check valve may be installed if the fuel pump is below the fuel tank.

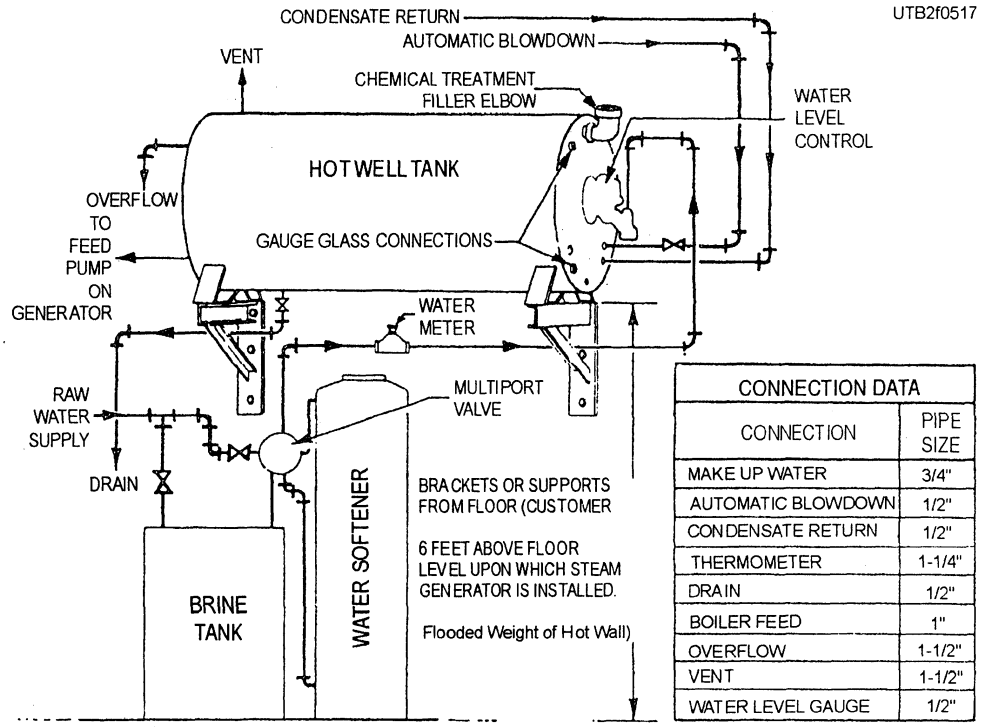
- Install a stack adapter (supplied with the steam generator) directly on the heater cover stack outlet. Install a stack extension if desired, using 12-inch-diameter flue pipe (minimum), and install a weather cap (supplied with the unit) at the top of the flue pipe. If the unit is operated in an enclosed building, extend the flue pipe through the roof and install a weather cap.

- Typical hot-well installation and connection data are shown in figure 5-17. The hot well must be elevated on a suitable stand or bracket to allow a 60-inch gravity feed to the inlet of the feedwater pump check valve housing for hot-well temperatures up to 180°F. If higher hot-well temperatures are anticipated, a higher gravity feed is required to prevent vapor locking of the feedwater pump. For hot-well temperatures of 180°F to 200°F, a 72-inch gravity feed is necessary. Temperatures above 200°F require a gravity feed of 84 inches.

- The feedwater connection is made by connecting a line between the feed pump connection on the hot well and the feedwater intake valve. The connection is made by using a minimum of 1-inch-diameter pipe.

- The steam header should be connected to the steam discharge valve. Ensure that the header pipe size is not smaller than the steam discharge valve.

- A valve bleed line to the atmosphere should be installed at the steam discharge. This design



CONNECTION DATA	
CONNECTION	PIPE SIZE
MAKE UP WATER	3/4"
AUTOMATIC BLOWDOWN	1/2"
CONDENSATE RETURN	1/2"
THERMOMETER	1-1/4"
DRAIN	1/2"
BOILER FEED	1"
OVERFLOW	1-1/2"
VENT	1-1/2"
WATER LEVEL GAUGE	1/2"

Figure 5-17.—A typical installation of horizontal hot-well tank and connection data.

allows the release of steam to permit the steam generator to operate under full load when adjustments are made.

- Connect the pipe accumulator blowdown valve and coil drain valve to waste. These lines may be manifolded into a common line of not less than 1-inch-diameter pipe. Connect the pipe discharge from the steam safety valve to the atmosphere. You should provide a 1/4-inch-diameter (minimum) pipe drain at the lowest point in the safety valve vent line piping.

- The pipe outlet from the accumulator steam trap should be connected to the condensate return connection on the hot well with 3/4-inch-diameter pipe.

- To permit periodic checking of the automatic blowdown valve adjustment, you should install a shutoff valve and a flow test valve, as shown in figure 5-18. Pipe the discharge from the shutoff valve to the automatic blowdown connection on the hot well.

- Make electrical connections to terminals in the electrical control box. Install a disconnect switch in the line next to the steam generator to ease the isolation of electrical components from the line if service is necessary. Start the motor momentarily to check rotation. Rotation should be clockwise as viewed from the front of the plant.

Preventive Maintenance and Repair

Like any piece of mechanical equipment, the steam generator requires proper maintenance and some repairs will be needed to maintain the efficiency and service it is designed to provide. The following discussion covers some of the maintenance and repair requirements for the Clayton steam generator, Model RO-33-PL. For detailed information on the maintenance and upkeep of this and other types of

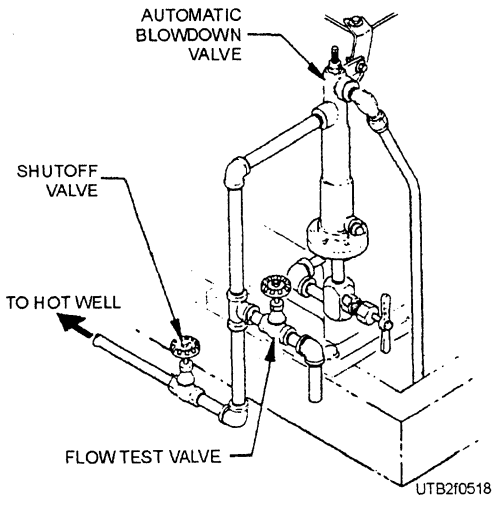
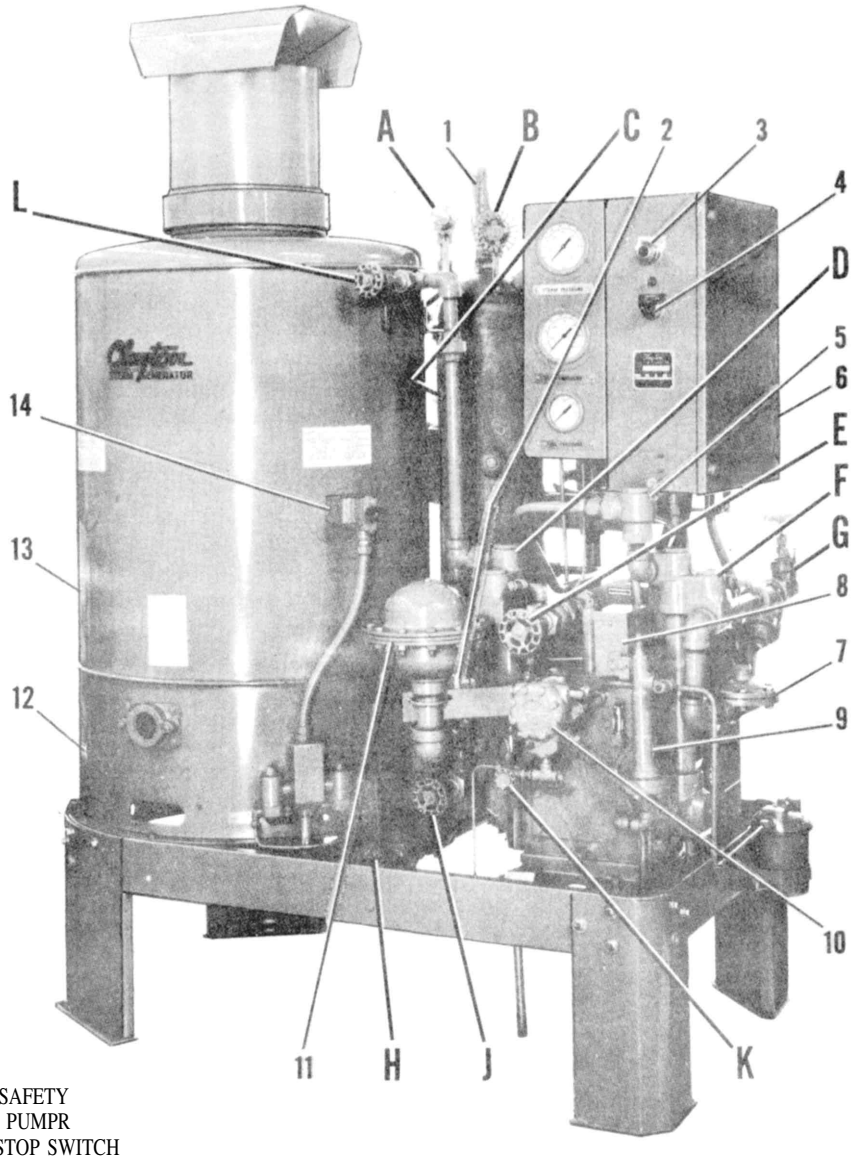


Figure 5-18.—Suggested automatic blowdown valve discharge piping.

generators, consult the manufacturer's instruction manual. Before proceeding, observe that figure 5-19 shows the operating controls and parts as seen from the front of the generator, and figure 5-20 shows the operating controls and parts as viewed from the rear. The letters and numbers shown in parentheses in the sections that follow refer to the name and location of operating controls and parts in figures 5-19 and 5-20.

Some general maintenance and repair requirements for the steam generator are as follows:

- If dirt or lint accumulates on the cupped sides of the blower rotor blades, a shortage of air to the



1. STEAM SAFETY
2. WATER PUMPR
3. START-STOP SWITCH
4. EMERGENCY RUN SWITCH
5. CHECK VALVE
6. ELECTRICAL CONTROLS BOX
7. INTAKE SURGE CHAMBER
8. WATER PUMP SOLENOID
9. AUTOMATIC BLOWDOWN VALVE
10. FUEL PUMP
11. WATERPUMP DISCHARGE SNUBBER
12. BURNER BASE
13. HEATING UNIT
14. THERMOSTAT SWITCH

A. SOOT BLOWER VALVE
B. STEAM DISCHARGE VALVE
C. ACCUMULATOR GAUGE GLASS
D. CIRCULATING PUMP HOUSING
E. CIRCULATING FEED VALVE
F. FEEDWATER PUMP HOUSING
G. FEEDWATER INTAKE VALVE
H. ACCUMULATOR BLOWDOWNVALVE
J. COIL DRAIN VALVE
K. BURNER CONTROL VALVE
L. COIL FEED VALVE

Figure 5-19.—Operating controls and component identification of Clayton steam generator, Model RO-33.PL, front view.

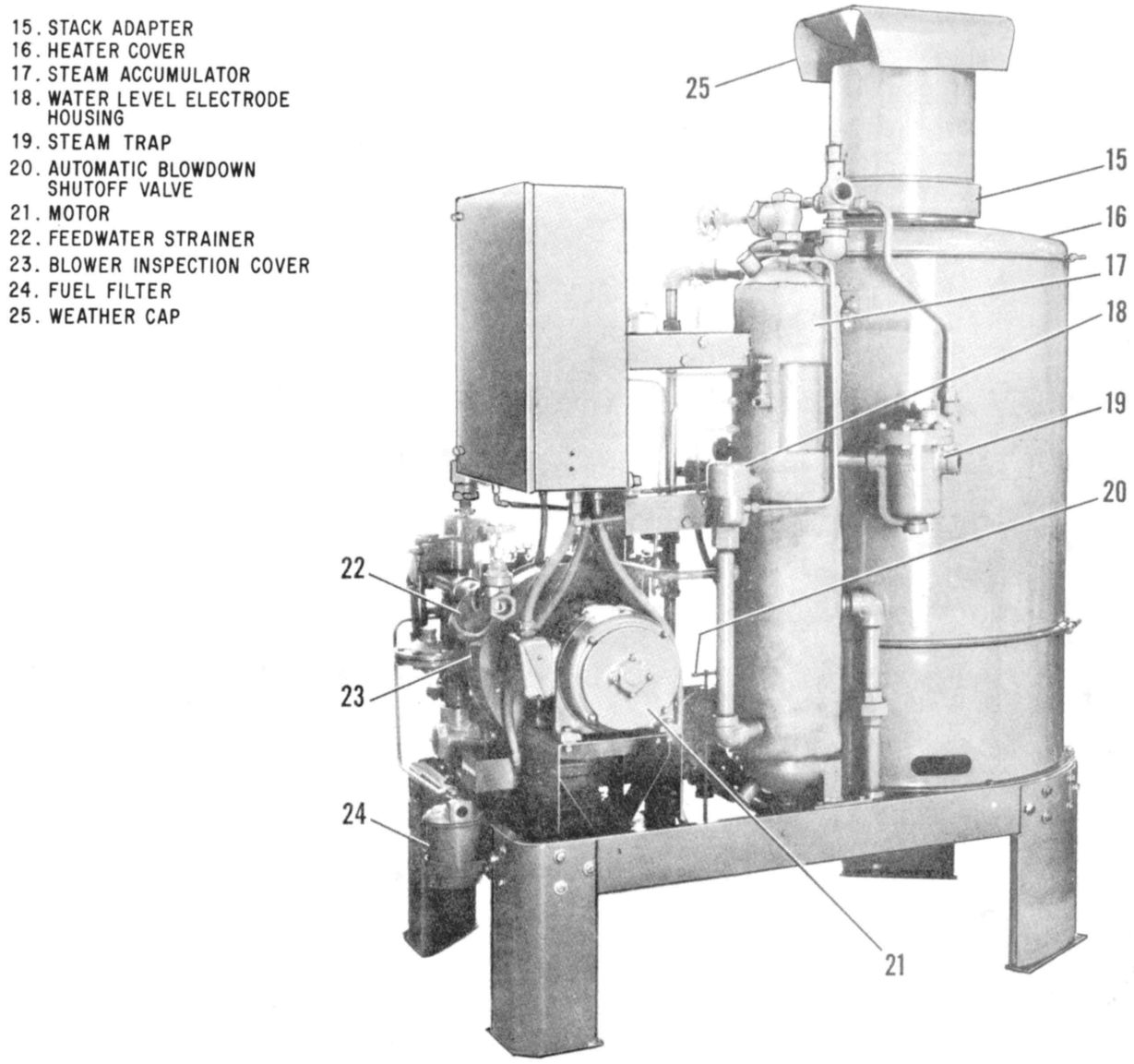


Figure 5-20.—Operating controls and component indentification of Clayton steam generator, Model RO-33-PL, rear view.

burner causes reduced burner efficiency. The frequency of cleaning depends on the amount of dirt or lint in the air at the installation.

- Check the operation of the thermostat control every 100 operating hours. Consult the manufacturer's instructions for test procedures.
- When a water pump is noisy, the trouble is sometimes due to a restricted heating coil that causes excessive feed pressure. The feed pressure should be checked for coil restriction. When checking for coil restriction, compare the reading on the feed pressure gauge with that on the steam pressure gauge. Normal feed pressure may vary slightly with each installation. Carefully note the pressure right after the steam generator is installed, so an accurate check of coil restriction can be made for the unit. The coil is restricted if feed pressure is 30 pounds or more above the normal feed pressure noted immediately after installation or when the coil was completely clean.

The steps of the procedure used to blowdown the system are as follows:

1. With the plant operating at normal steam pressure, close the circulating feed valve (E) and open the coil drain valve (J). Start a time check. After 30 seconds, shut off the burner and close the steam discharge valve (B).

NOTE

If the burner is shut down by the thermostat control during the time check, immediately open the burner control valve (K); then close the steam discharge valve.

2. Open the accumulator blowdown valve (H).

3. When the steam pressure drops to zero, close the coil drain valve (J) and the accumulator blowdown valve (H).

4. Open the circulating feed valve (E).

5. To resume operation, allow the plant to fill with water and start the burner in the normal manner. You may have to reprime the circulating pump after the blowdown. To prime the feedwater pump, refer to the manufacturer's instructions.

Additional inspection and maintenance factors for the steam generator are as follows:

- When the electric motor is equipped with sealed bearings, the bearings are prelubricated for the life of the bearings. However, motors equipped with oil-wick-lubricated bearings should have 1 teaspoon of good grade oil added to the reservoirs every 6 months.

- If the motor is equipped with pressure grease fittings, remove the plug below the motor shaft every 6 months and force a light grade of grease into the port at the top until the clean grease appears at the plug outlet. To prevent rupture of the grease seals, run the motor for 4 or 5 minutes before replacing the plug below the motor shaft.

- Every year (more often under severe operations), drain and refill the water pump crankcase with a good grade of SAE 20 motor oil (about 5 quarts required). With the pump running, oil should show at least halfway in the sight gauge.

- The water pump check valves should also be inspected and cleaned when you remove scale from a restricted heating coil. Check the disks, springs, and valve seats for scale and pitting.

- The relief valve (fig. 5-21) of the water pump should be adjusted to open at about 500-psi feed pressure but remain driptight during operation. Leakage from this valve results in a lack of water to the heating unit and causes overheating. Sometimes when the unit is started, the feed pressure may temporarily rise enough to cause the relief valve to release a small amount of water; however, the feed pressure will return to normal after the unit heats and the system becomes stabilized.

- The water pump discharge snubber (fig. 5-22) is nonadjustable. If the rubber insert has to be replaced, the old insert must be cut away from the retainer. To ease assembly, lubricate the new insert with glycerine (do not use oil) to allow it to be pushed into the retainer and bottom housing.

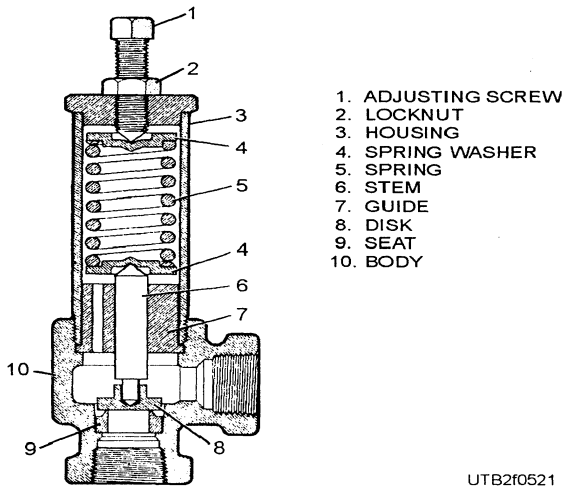


Figure 5-21.—Pump relief valve.

- To keep the ring thermostat control of the generator (fig. 5-23) at peak operation, you may have to adjust the thermostat switch and the thermostat ring channel. The plant must be operated long enough to be thoroughly heated before you adjust the thermostat switch. In making these adjustments, refer to the manufacturer's instructions.

- Adjust the thermostat ring channel (Number 23 of fig. 5-23) when replacing the heating coil or if the original assembly has been disturbed. A careful check of the adjustment must also be made if the thermostat switch cannot be adjusted without erratic response.

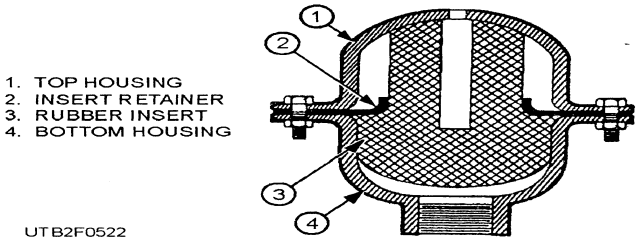


Figure 5-22.—Water pump discharge snubber.

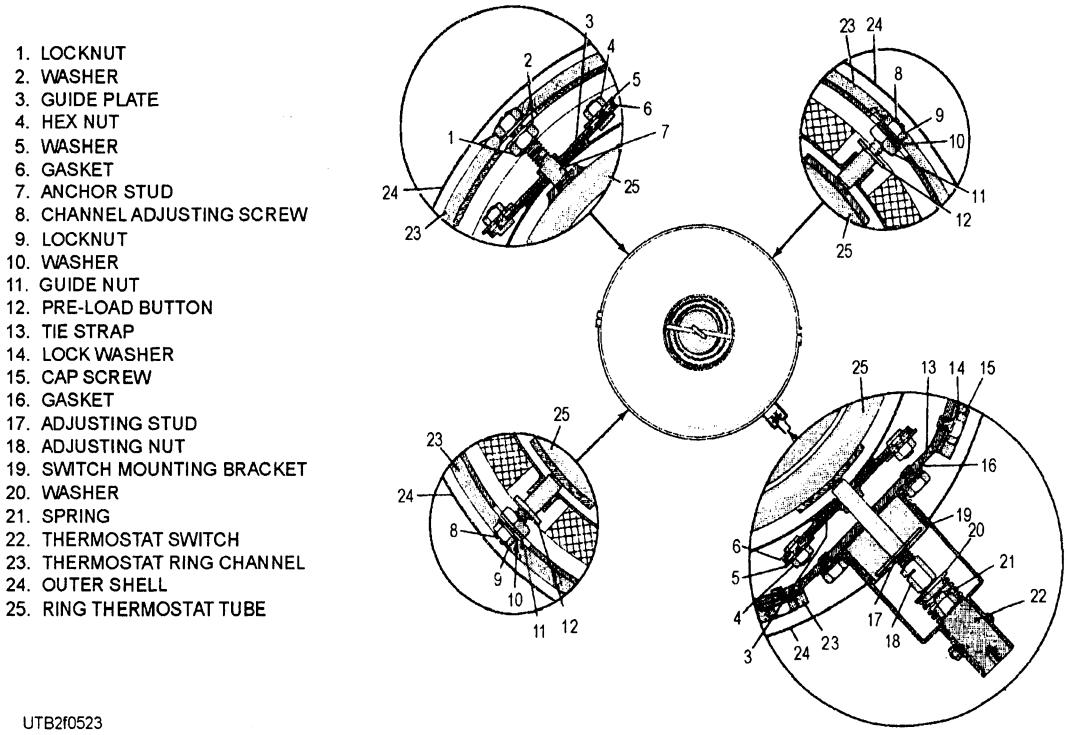


Figure 5-23.—Ring thermostat control.

- The automatic damper should be kept in proper adjustment to ensure a proper supply of air to the burner.
- The burner manifold (fig. 5-24) requires cleaning and adjusting at times to keep it in good shape. Remove the manifold. Scrape carbon deposits from the manifold and ignition electrodes. Clean the burner nozzles and strainer.

CAUTION

When cleaning, you should NOT use a sharp instrument that can scratch or disfigure the tip orifice or slots in the distributor. A slight scratch on these parts can seriously impair nozzle operation.

- Adjust the ignition electrodes to conform with the dimensions shown in figure 5-24. The gap must be positioned as accurately as possible, so it is at the immediate edge of the nozzle spray. Be careful when bending and adjusting the electrodes to avoid cracking the insulators. The insulators may develop an invisible short due to such a fracture, resulting in ignition failure.
- The fuel pressure to the burner must be properly maintained. Excessive fuel pressure causes the burner to smoke and results in sooting of the heating coil. However, if fuel pressure is too low, the plant comes up to pressure slowly and does not maintain adequate steam pressure during periods of maximum steam demand. Adjust the pressure as needed.
- Figure 5-25 shows a drawing of a fuel pressure switch. To adjust the switch, close the light and fuel indicator pilot when fuel pressure rises to about 70 psi by turning the adjusting screw (1) clockwise to increase or counterclockwise to decrease pressure at which the switch closes. This step allows enough pressure to induce proper atomization when fuel is admitted to the burner. Secure the adjusting screw with the locknut after adjustment.
- The steam pressure switch (SPS) can be adjusted to open and stop the burner at any maximum pressure between 65 and 195 psi. The switch closes and restarts the burner when steam pressure drops about 8 psi below that point.
- The modulating pressure switch (MPS) is normally adjusted to modulate the burner to "low-fire" operation when steam pressure reaches 10 psi below maximum and to return the burner to "high-fire" operation when steam pressure drops about 8 psi below that point. The recommended setting of 10 psi below the maximum, in most cases, provides both stable operation and stable steam pressure during fluctuating demand.

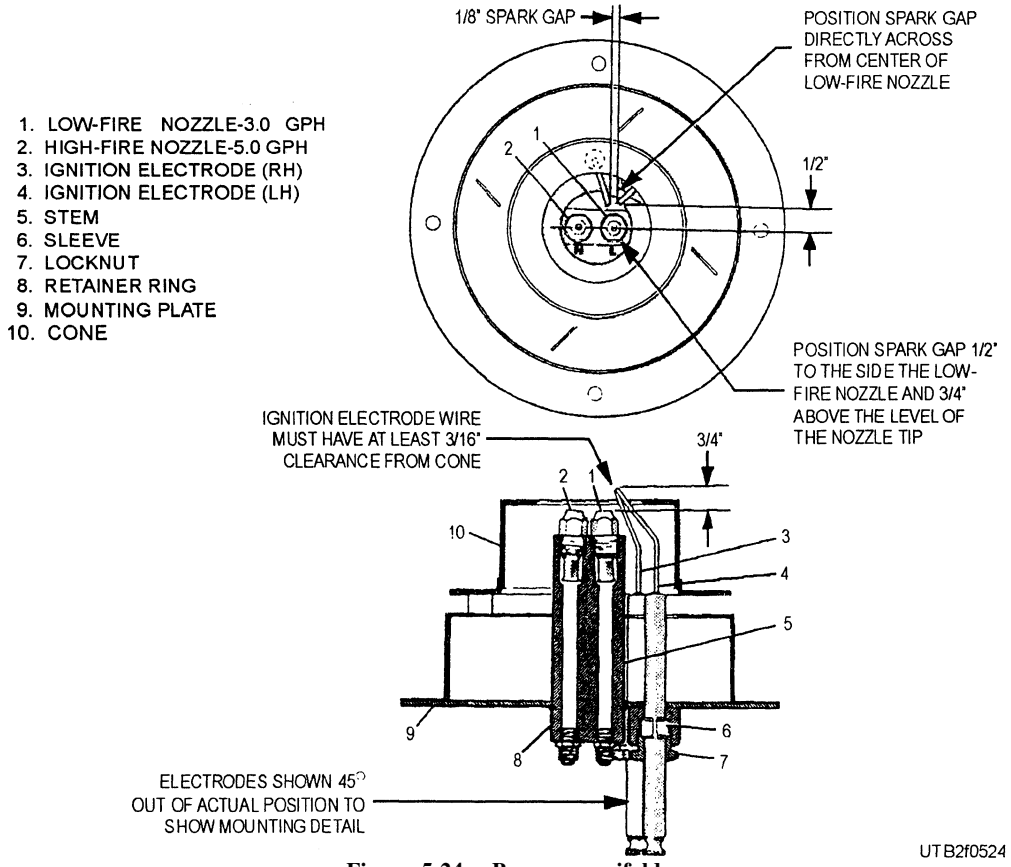


Figure 5-24.—Burner manifold.

- The automatic blowdown valve (fig. 5-26) is operated by oil pressure from the water pump. If the blowdown valve diaphragm gets ruptured, oil will likely appear in the waste discharge. Replace a ruptured valve diaphragm immediately to prevent the loss of oil from the pump crankcase.

- As preventive maintenance, replace the blowdown valve diaphragm whenever the water pump diaphragms are replaced. Since wear may affect the operation of the blowdown valve, dissemble the valve each time the diaphragm is replaced.

Troubleshooting

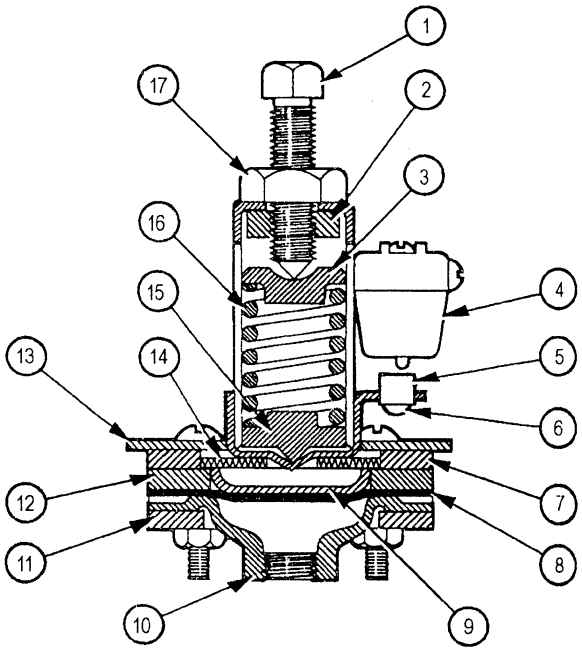
A troubleshooting chart for the Clayton steam generator, Model RO-33-PL, is provided in table S of appendix II. This chart will guide you in finding and correcting troubles in that make and model of generator. You will find similar charts in the instruction manuals provided by the manufacturers of other makes of steam generators. Make sure you are familiar with the manufacturer's manual for the generator used at your activity, and follow the procedures prescribed for the maintenance and repair of the equipment.

RESIDENTIAL WASHING MACHINES

The automatic washer (fig. 5-27), described in this chapter, is typical of the machines on the market today. The circuits and timing diagrams are composites of the more common features found in several different models. For the equipment you are installing or working on, follow the manufacturer's instruction manual.

The automatic clothes washing cycle can be broken down into four basic operations—fill, agitate, spin, and drain. Nearly all of these operations are repeated two or more times throughout a complete washing cycle and, for the most part, are controlled by a timing assembly.

The FILL operation begins immediately after starting the washer, but the timer does not start until the water level is at the proper height. Some models use timed-fill operations that start and end under the control of the timer of the washer. Also, note that there are no timed-fill operations. This type of washer uses a no timed-fill feature initiated by the timer but



LEGEND:

1. ADJUSTING SCREW
2. NUT PLATE
3. SPRING WASHER
4. SWITCH
5. LEAF SPRING
6. SPRING GUIDE
7. GUIDE RING
8. DIAPHRAGM
9. DIAPHRAGM WASHER
10. BASE
11. RING
12. GUIDE RING
13. COVER
14. WASHER
15. PIVOT WASHER
16. SPRING
17. LOCKNUT

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Figure 5-25.—Fuel pressure switch.

terminates whenever the water level sensing switch closes. When the water level sensing switch is finally activated, the timer starts running and the agitation operation commences.

The AGITATION operation function is to provide washing and rinsing of the laundry once the tub is filled with water. There are two basic methods of washing action in general use. One is a reciprocating agitator that swirls the water and clothes back and forth in a tank. The other is a rotating drum that picks up the clothes and allows them to drop into a pool or stream of water. Most automatic washers are of the agitator, top-loading variety.

The SPIN operation function is to remove excess water from the laundry fabrics. During this operation, the main drive motor spins the laundry tub at a relatively high rate of speed, forcing water out of the tub and laundry fabrics by means of centrifugal force. The drain pump removes this spun-out water from the washer; therefore, the DRAIN operation function is to pump the used wash water and rinse water out of the washer and into the wastewater system.

Modern automatic clothes washers include a number of optional features that do not appear as necessary parts of the timing diagram. The more common options are as follows:

- Most washers have a high/low water level selector switch; some give the user a choice of high, medium, and low water levels; and a few washers have an "infinite" water level adjustment that lets the user set the water to any desired level. The purpose of such a switch is to conserve water whenever the laundry tub is only partially filled with laundry. Some washers do not have a water level selector switch, and all wash and rinse phases run with the tub filled to capacity.

- In most washers you normally have access to a set of switches, push buttons, or a dial that allows a choice of water temperatures. Newer and better washers have separate selector switches for the wash water and rinse water phases; hot water, warm water, or cold water for the washing phase; and warm water or cold water for the rinsing phase. In the simplest washers, the switch might only permit a selection of either hot or cold water for both the washing and rinsing phases of the wash cycle.

- The agitation speed selector lets you select a normal or gentle speed for the agitation action. The gentle speed is used only in instances where there is a chance that normal speed might harm certain types of fabrics. It is important to note that this speed selector switch does not influence the timing in any way. For example, if you set up a 10-minute washing operation, the operation occupies a full 10 minutes whether the agitator speed is set to normal or gentle.

Operation

An automatic washer can be an elaborate piece of electromechanical equipment. Most modern washers have a number of basic electrical and mechanical parts that work much the same way in every make and model. The primary parts include the following:

1. a timer assembly,
2. solenoids for controlling the inflow of hot and cold water,
3. a transmission and a main drive motor for providing the powerful agitation and spin actions,

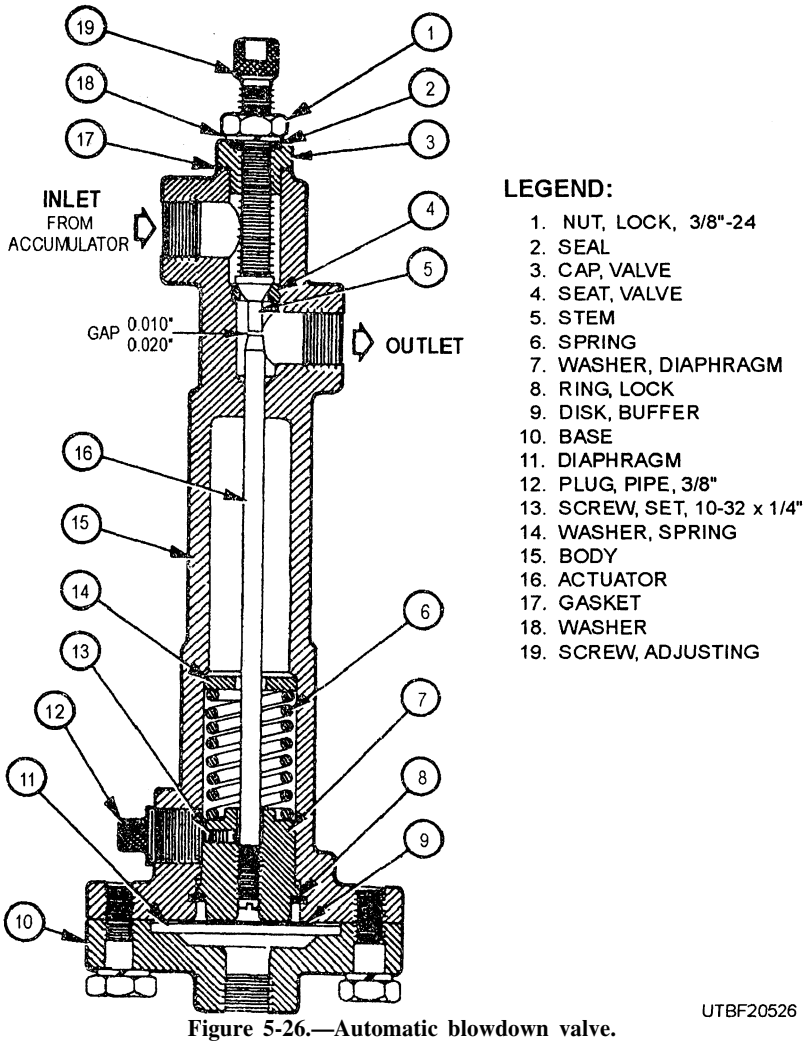


Figure 5-26.—Automatic blowdown valve.

4. a water pump assembly for recirculating and removing water from the washer, and

5. a host of controls and switches.

These components are discussed in terms of what they do and how they do it in the following paragraphs.

TIMER ASSEMBLY.—The timer assembly is the "brain" of the automatic washer. The timers found in automatic washers are not much different from those found in some other major appliances, including automatic dryers and dishwashers. The cam-operated switch contacts are responsible for starting and stopping most of the basic washer operations.

The basic elements of a timing switch assembly are a split-phase motor, a set of cams, and some contact switches. The motor, usually geared down to a speed of about one-half revolution per hour, turns a set of cams that open and close banks of switch contacts. The switch contacts control the flow of line power to the various electrical devices in the washer.

TRANSMISSON ASSEMBLY.—The transmission in an automatic washer is the most complex piece of mechanical machinery in the appliance industry. The transmission is wholly responsible for converting the rotary motion of the main drive motor into either an agitating motion or spinning action. Although there is often a direct linkage between the drive motor shaft and the cam assembly that produces the agitating motion, the motor is connected to the spin section of the transmission by means of a friction clutch that lets the laundry tub reach its normal spinning speed gradually without overloading the motor.

In some current models, the transmission is shifted from one type of action to another by means of a solenoid-operated gearshift. The majority, however, shift between agitate and spin according to the

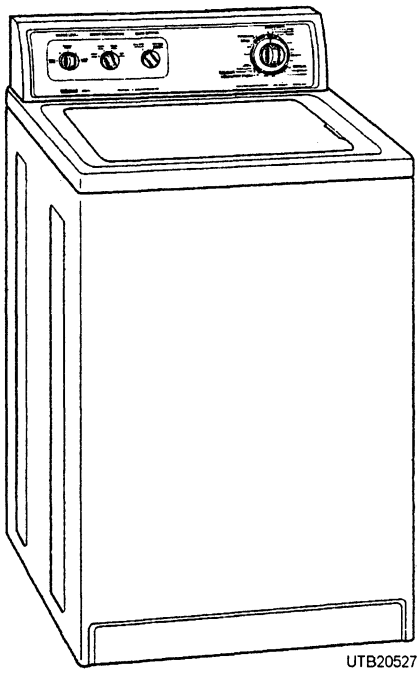


Figure 5-27.—A typical automatic residential washer.

direction the drive motor spins. Whenever the drive motor turns in one particular direction, the transmission is shifted to the spin gear. Reversing the motor then automatically shifts the transmission to its agitate gear.

Some washing machine transmissions also have a neutral gear that allows the drive motor to turn without causing either the spin or agitation action to occur. This feature is used during drain operations that call for running the water pump by itself.

MAIN DRIVE MOTOR.—The main drive motor is responsible for converting electrical energy into the kind of mechanical power that is necessary for carrying out the agitation, spin, and pumping actions of the washer. The motor is normally a split-phase induction motor that is rated at about one-half horsepower. Washer motors, almost without exception, operate on 120-volt line power.

A capacitor-start feature is not necessary for washing machines using fractional horsepower drive motors, but a centrifugal switch or relay-start mechanism is always an integral part of the control system of the main drive motor. In some cases, you will find that washer motors are also reversible and they sometimes have built-in speed control windings.

WATER PUMP ASSEMBLY.—The primary purpose of the water pump is to draw used water out of the washer at the end of the washing and rinsing steps and during spin operations. The pump is also used to recirculate the wash and rinse water with the use of a lint filter. The water pump is mechanically driven by the transmission and main drive motor and is operating anytime the main drive motor is running. Consider now the fact that the main drive motor is reversible in most models. It runs in one direction for agitation operations and in the opposite direction for spin operations. This means the water pump runs in both directions as well; and the logical conclusion is the pump moves water in two different directions, depending on which way the main drive motor is turning.

It is possible to take advantage of this two-direction characteristic of the water pump by using it in conjunction with a two-way flapper-valve assembly. The idea is to recirculate the wash or rinse water during agitation operations and to pump the water out of the system during spin operations. By turning the drive motor and pump in the agitation direction (fig. 5-28, view A), valve A is opened and valve B is closed. The water is thus routed through the water recirculation system inside the machine. By turning the drive motor and pump in the spin direction (fig. 5-28, view B), valve A is closed and valve B is opened. Since valve B leads to the wastewater system, moving the water in that direction effectively drains it all out of the washer. This makes it possible to use a flapper-valve assembly for routing the water without using extra electrical controls and timer switches. Some washers control the routing of the pump water by means of solenoid valves.

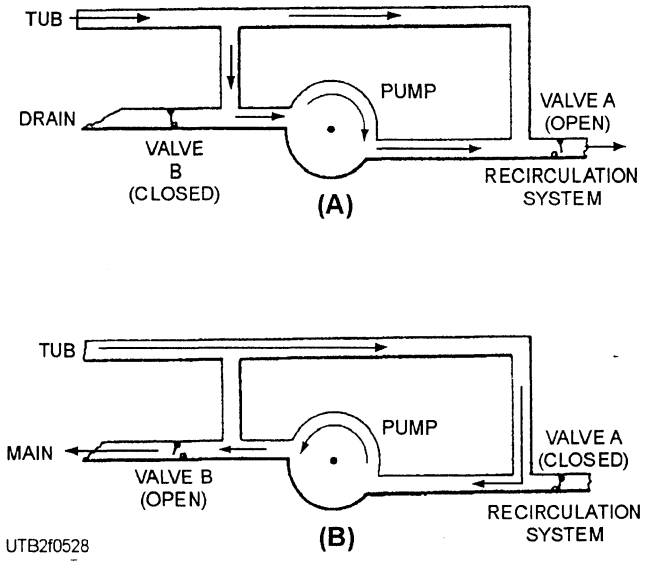


Figure 5-28.—Operation of a flapper-valve water control system: A. Pump turning in the agitate direction to recirculate the water; B. Pump turning in the spin direction to pump water out of the washer.

WATER VALVES.—The water valves control the inflow of hot and cold water during fill operations. The valves are electrically operated, as shown in figure 5-29. The solenoids are turned off most of the time, keeping their respective valve ports closed. The ports open only when electrical power is sent to the solenoid windings.

The two water valve solenoids can be operated individually or at the same time. Activating the "hot" valve, for instance, fills the washer with hot water. Energizing the "cold" valve fills the washer with cold water, and energizing both valves at the same time fills the washer with warm water—a mixture of hot and cold.

The water temperature selector switch determines the water valves to be operated during any given fill operation; timer contacts are responsible for energizing the selected solenoids at the appropriate times.

A typical water-fill circuit for modern automatic washers is shown in figure 5-30. The hot- and cold-water solenoid valves are energized through several sets of timer contacts and a water temperature selector switch assembly.

WATER LEVEL SENSING SWITCH.—Washers that do not use a timed-fill interval must have provisions for sensing the water level and turning off the water supply whenever a given water level is reached. This sensor normally takes the form of a pressure switch that is activated either directly by the water pressure on the bottom of the laundry tub or indirectly activated by air pressure in a tube located at the rear of the washer.

The diagram in figure 5-31 shows the operation of the indirect, or air pressure, sensing mechanism. The water level in the tub is always the same as the water level in the washer. As the water level rises, the air pressure at the top of the tub increases. A pressure switch at the top of the tub can be adjusted to close at various pressure levels, representing different water levels in the washer.

DOOR INTERLOCK SWITCH.—The door interlock switch is a safety feature that completely shuts down the washer whenever the door or lid is opened during a spin operation. Opening the door during any other part of the cycle does not affect the ongoing operation.

The diagram in figure 5-32 shows how the door interlock switch is bypassed by a timer contact. The timer contact is closed throughout most cycles of the washer, allowing the lid switch to be opened without interrupting current flow to the motor circuit. During every spin operation, however, the timer opens the bypass switch, letting the lid switch interrupt the complete circuit to the motor whenever the lid is opened during that particular operation.

This list of mechanical and electrical components is not complete as far as the full range of modern clothes washer models is concerned. This list is complete, however, in the sense that it describes the most critical components and those that are unique to clothes washers.

Installation

Satisfactory performance of an automatic washing machine depends on a carefully planned and properly designed first installation. The place where the laundry is done should be well lighted and adequately equipped with convenient electrical outlets. The plumbing connections must be anchored to the floor to prevent movement.

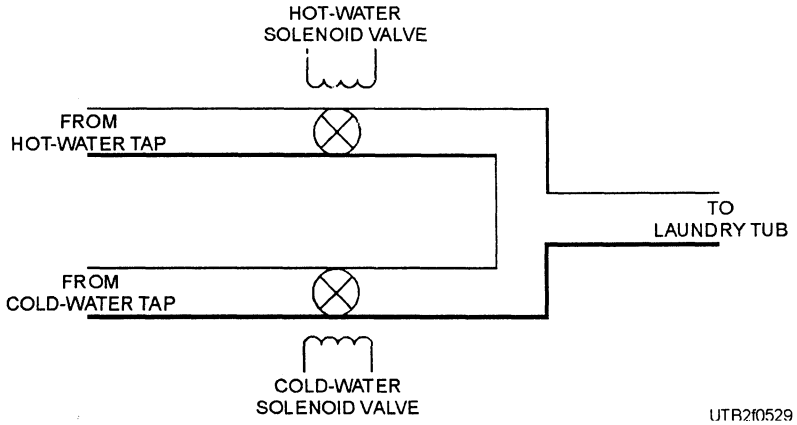
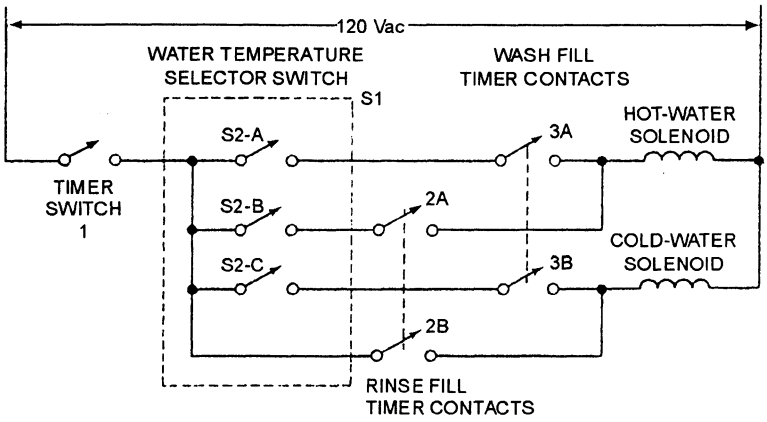


Figure 5-29.—Hot- and cold-water solenoid valve control system.



SELECTED WATER TEMPERATURE		S1 CONTACT CONFIGURATION		
WASH	RINSE	S1-A	S1-B	S1-C
HOT	WARM	X	X	0
HOT	COLD	X	0	0
WARM	WARM	X	X	X
WARM	COLD	X	0	X
COLD	WARM	0	X	X
COLD	COLD	0	0	X

X = CLOSED
0 = OPEN

(B)

UTB2f0530

Figure 5-30.—Water temperature selector circuit: A. Circuit diagram; B. Switch closes for different combinations of wash and rinse water temperatures.

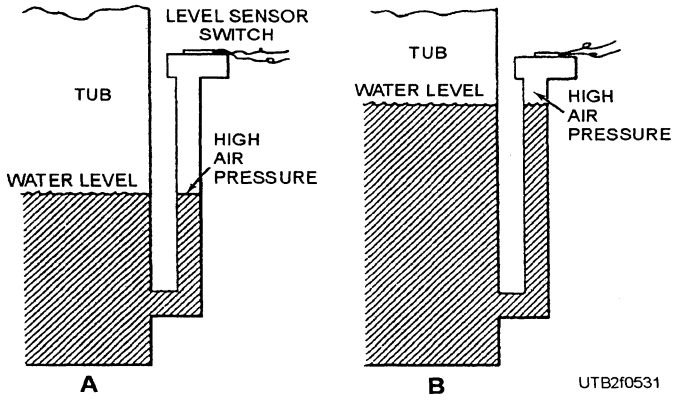


Figure 5-31.—A water level sensor scheme: A. Water level below the set point on the sensor; B. Water level at the set point.

Various local code regulations apply in most communities to permanent plumbing and electrical installations; however, local codes and military specifications can vary. The National Plumbing Code and NAVFACENGCOM guide specifications also provide installation requirements. Figure 5-33 shows an installation that meets the requirements of the National Plumbing Code. In summary, installation depends upon where you are. In a conflict, what the ROICC (Resident Officer in Charge of Construction) says is the final word.

Troubleshooting

Now you know what the components in a washing machine do and how they do it. Use the trouble-shooting chart in table T of appendix II as a guide or checklist for some of the common problems, causes, and ways to fix them.

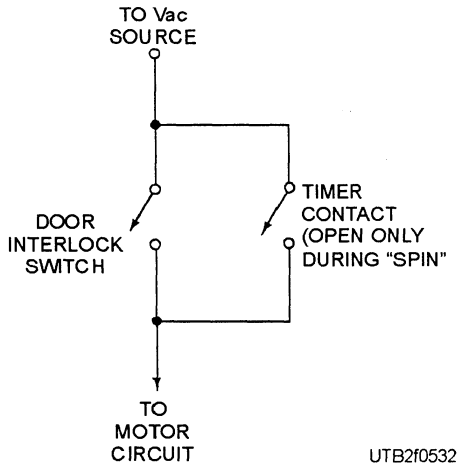


Figure 5-32.—Door switch and override circuit.

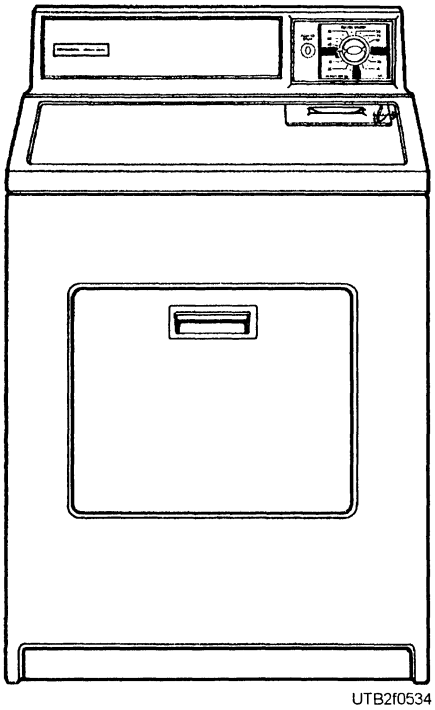


Figure 5-34.—A typical residential dryer.

RESIDENTIAL CLOTHES DRYERS

Automatic clothes dryers (fig. 5-34) have two primary advantages over the old clothesline process. First, the laundry drying job is much faster with the automatic dryer. The user does not spend as much time setting up the process and the actual drying operation takes less time. The other advantage of an automatic drying scheme is that it can be used at any time of the day, in any season of the year, and under any sort of weather conditions.

Depending on the type of heat energy used, clothes dryers may be divided into two general classes—electric dryers and gas dryers. The source of heat in the electric dryer is obtained electrically by a heating element mounted in the dryer. A centrally located thermostat and timer control the heating element. In a gas dryer, the source of heat is derived from ignited gas, which is obtained by turning on the gas flow; however, a pilot light must first be burning in the combustion chamber. This pilot ignition is automatic; lighting takes place when a spark is created by turning a knob usually on the dryer control panel.

All dryers, irrespective of heating methods used, are equipped with a forced-air blower to draw in fresh air, force it through a heating assembly, and then

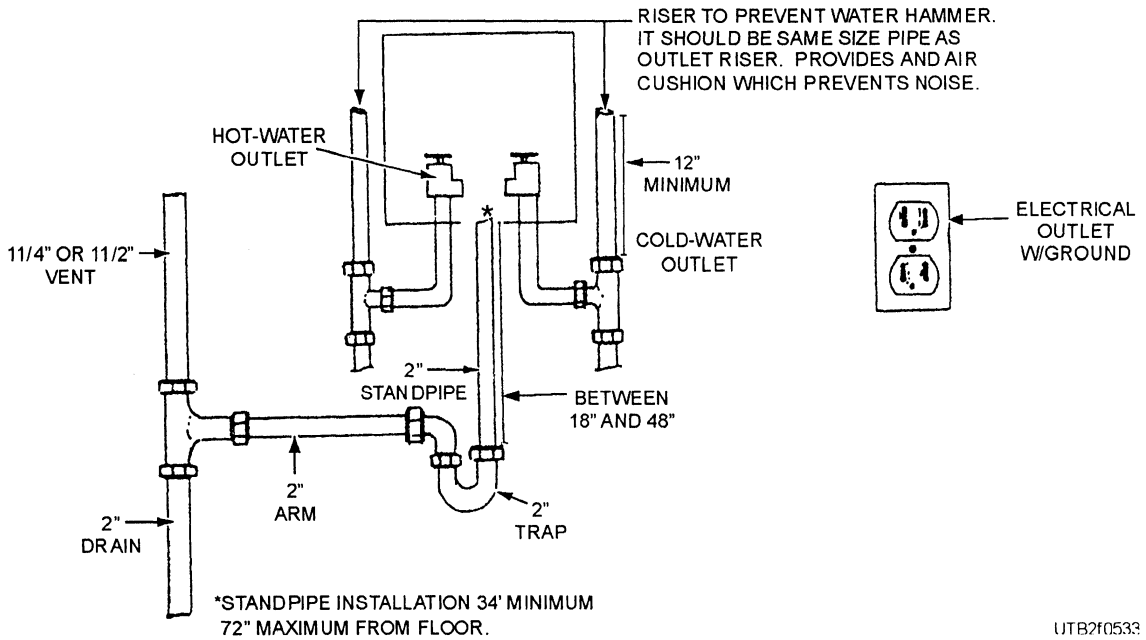


Figure 5-33.—Automatic washer installation.

channel it into the rotating hamper. The warmed air picks up moisture from the laundry, as it passes through the hamper. The blower finally directs the moisture-laden air through a lint filter that traps most of the dry, lightweight particles of lint and other foreign materials picked up by the moving air before the air is discharged from the dryer.

The heating assembly in an all-electric dryer consists of a set of nichrome heating elements situated in the forced-air steam. The heating assembly in a gas dryer performs exactly the same function, but it uses gas flame heat.

The electrical sections of modern clothes dryers can be rather simple compared to some other kinds of modern appliances. The basic electrical units of a dryer include heating controls that maintain a fairly constant drying temperature and a timer mechanism that turns off the dryer at the end of a selected drying interval. The essential differences between the simpler dryer models and the top-of-the-line versions can be found in the number and types of heat and timer controls.

All automatic dryers include a basic cycle that is normally labeled a "Timed Cycle"" on the timer control knob. When operation is done in this mode, the dryer tumbles the laundry continually and regulates the level of the forced air throughout the entire drying interval. The tumbling and heating actions both stop at the end of the selected drying time. You can set the drying interval to any point between zero and about 180 minutes, depending on the amount and wetness of the load.

Operation

Automatic clothes dryers operate on a simple principle, involving the following essential parts:

- An exhaust fan
- Automatic controls
- A perforated metal drum
- An electric motor to rotate the drum
- A source of heat—either gas or electric.

In operation, wet or damp clothes are placed into the drum, and after the door is closed, the thermostatic control is set to the correct heat level; the timer is also set to the desired running time. The best temperature and running time combination depends on the type of clothing, the material of which it is made, the weight of the clothing, and the amount of water it contains. The correct combination for various loads is normally indicated on a chart near the control knobs; if not, consult the owner's manual.

Once the correct control combination has been set, the drum begins to rotate at about 50 revolutions per minute, and the heat turns on to start the drying function. Air circulation is provided simultaneously by the motor-driven fan, circulating the heated air through the clothing. Baffles on the sides of the drum tend to carry the clothes to the top of the dryer drum, at which time they drop to the bottom. These baffles prevent the clothes from lumping together and provide a tumbling action that speeds up the drying process. The door may be opened at any time during the cycle. When the controls are functioning properly, any opening of the dryer door stops the dryer cycle, turning off the heater and other motors. If more time remains in the cycle, the drying action resumes when the door is closed; in some cases, the start button must be pressed.

Although a motor drive belt may break from time to time or a bearing becomes jammed, most problems involving automatic clothes dryers are in the automatic controls. In most cases, the contacts become worn, wiring becomes short-circuited or open, and so on.

Installation

When installing a dryer, either a new one or one that has been repaired, observe all codes and ordinances that apply to the particular dryer. The information below will help you in installing, repairing, and locating a dryer. Leave enough space around the dryer for ease of installation, use, and service.

If the dryer is to be installed in a confined area, such as a closet or bathroom, it must be exhausted to the outside. Furthermore, it must have enough space around it and enough air circulation to operate properly.

The electric service should conform with the National Electric Code as well as local codes and ordinances. When gas is used as the heat source, the installation must conform to the National Fuel Gas Code and local codes and ordinances.

Never exhaust the dryer into a chimney or any other duct or vent. The dryer must have its own exhaust system. Before putting a dryer into use after installing or servicing, replace all access and service panels. If still attached, read and follow all caution and direction labels attached to the dryer.

While servicing, review the wiring diagram that accompanies the dryer. This diagram is usually

attached to the access panel. The dryer vent should not exceed a maximum length of 4 feet primarily because the buildup of condensation increases the time required to dry the clothes.

Troubleshooting

You need to be acquainted with the operation and functioning of both the mechanical and electrical systems. Although the various types of clothes dryers may differ in appearance and location of controls, they all operate on the same principles and are fundamentally similar in servicing. Clothes dryer timers are quite similar to those on an automatic washing machine, while thermostats used in automatic dryers are the same type as those used on electric ranges.

Since the only moving parts consist of the motor, drive, drum, and exhaust fan, the clothes dryer, when properly installed, should give years of trouble-free service. When called on, the service personnel should be familiar with the recommendations and specifications of the particular manufacturer's service manual to replace any worn-out or faulty component correctly. When a dryer does not operate properly, always try the service manual first. However, table U of appendix II may be used for further troubleshooting and repair should it become necessary.

Q12. What is the maximum operation time that can be provided by the formula chart on the Milnor washer?

Q13. The automatic supply injector of a washer consists of how many compartments?

Q14. The automatic drain valve for a washer requires a minimum of whatpsi?

Q15. The supply injector solenoid valves can handle what maximum psi?

Q16. How often should the gearbox oil level be checked?

Q17. Extractors are eq uipped with either an automatic or manual brake. True/False.

Q18. When installing an extractor, you should check the equipment nameplate before connecting the power source for what reason?

Q19. An opening of how many square feet must be provided for a 3,000 cfm dryer for proper ventilation?

Q20. The electric motors on a tumbler should be cleaned and inspected annually.' True/False.

Q21. The Clayton steam generator can develop its full-rated capacity from a cold start in what length of time?

Q22. When. installing a boiler, you should always use what manual?

Q23. Reduced burner efficiency can be caused by dirt or lint on what device?

Q24. What are the four basic operations of a residential washer?

Q25. What component converts electrical energy into mechanical power necessary to carry out washer operations?

Q26. What are the two classes of residential dryers?

CHAPTER 6

REFRIGERATION

Learning Objective: Describe the stages of heat theory and the principles involved in heat transfer, and recognize various components of refrigeration systems and their application. Recognize the characteristics and procedures required to service and troubleshoot rcfri gerat ion systems.

Modern refrigeration has many applications, such as preserving medicine, blood, and the most important application, the preservation of food. Most foods kept at room temperature spoil rapidly. This is due to the rapid growth of bacteria. Refrigeration preserves food by keeping it cold, which greatly slows down the growth of bacteria. In days past, blocks of ice were used in iceboxes to refrigerate food and other items. These iceboxes were small and not very practical. Today, mechanical refrigeration systems make transportation, storage, and use of refrigerated goods easy and practical.

The installation, operation, adjustment, and repair of refrigeration equipment are the primary responsibility of the Utilitiesman rating. To perform these duties required of a refrigeration mechanic, you need to understand the principles and theory of refrigeration and recognize system components and understand the way they work within the system.

Methods of installing, maintaining, and repairing refrigeration equipment and maintaining, servicing, and repairing domestic refrigerators and freezers are also covered in this chapter.

HEAT AND REFRIGERATION PRINCIPLES

Learning Objective: Explain the basics of heat theory and the basic principles of refrigeration.

REFRIGERATION is the process of removing heat from an area or a substance and is usually done by an artificial means of lowering the temperature, such as the use of ice or mechanical refrigeration. MECHANICAL REFRIGERATION is defined as a mechanical system or apparatus so designed and constructed that, through its function, heat is transferred from one substance to another. Since refrigeration deals entirely with the removal or transfer of heat, some knowledge of the nature and effects of heat is necessary for a clear understanding of the subject.

NATURE OF HEAT

Heat is a form of energy contained to some extent in every substance on earth. All known elements are made up of very small particles, known as atoms, which, when joined together, form molecules. These molecules are particular to the form they represent. For example, carbon and hydrogen in certain combinations form sugar and in others form alcohol.

Molecules are in a constant state of motion. Heat is a form of molecular energy that results from the motion of these molecules. The temperature of the molecules dictates to a degree the molecular activity within a substance. For this reason, substances exist in three different states or forms—solid, liquid, and gas. Water, for example, may exist in any one of these states. As ice, it is a solid; as water, it is a liquid; and as steam, it is a gas (vapor).

When heat is added to a substance, the rate of molecular motion increases, causing the substance to change from a solid to a liquid, and then to a gas (vapor). For example, in a cube of ice, molecular motion is slow, but as heat is added, molecular activity increases, changing the solid "ice" to a liquid "water" (fig. 6-1). Further application of heat forces the molecules to greater separation and speeds up their motion so that the water changes to steam. The steam formed no longer has a definite volume, such as a solid or liquid has, but expands and fills whatever space is provided for it.

Heat cannot be destroyed or lost. However, it can be transferred from one body or substance to another or to another form of energy. Since heat is not in itself a substance, it can best be considered in relation to its

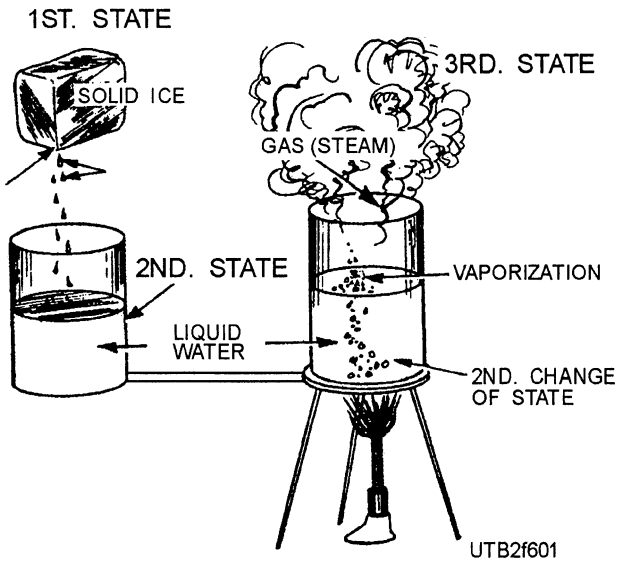


Figure 6-1.—The three states of matter.

effect on substances or bodies. When a body or substance is stated to be cold, the heat that it contains is less concentrated or less intense than the heat in some warmer body or substance used for comparison.

UNITS OF HEAT

In the theory of heat, the speed of the molecules indicates the temperature or intensity of heat, while the number of molecules of a substance indicates the quantity of heat.

The intensity and quantity of heat may be explained in the following simple way. The water in a quart jar and in a 10-gallon container may have the same intensity or temperature, but the quantity of heat required to raise these amounts of water to a higher uniform temperature (from their present uniform temperature) will differ greatly. The 10 gallons of water will absorb a greater amount of heat than the quart jar of water.

The amount of heat added to, or subtracted from, a body can best be measured by the rise or fall in temperature of a known weight of a substance. The standard unit of heat measure is the amount of heat necessary to raise the temperature of 1 pound of water 1°F at sea level when the water temperature is between 32°F and 212°F. Conversely, it is also the amount of heat that must be extracted to lower by 1°F the temperature of a pound of water between the same temperature limits. This unit of heat is called a British thermal unit (Btu). The Btu's equivalent in the metric system is the calorie, which is the amount of heat required to raise one gram of water 1° Celsius.

Suppose that the temperature of 2 pounds of water was raised from 35°F to 165°F. To find the number of Btu required to increase the temperature, subtract 35 from 165. This equals a 130° temperature rise for 1 pound of water. Since 2 pounds of water were heated, multiply 130 by 2, which equals 260 Btu required to raise 2 pounds of water from 35°F to 165°F.

MEASUREMENT OF HEAT

The usual means of measuring temperature is a thermometer. It measures the degree or intensity of heat and usually consists of a glass tube with a bulb at the lower portion of the tube that contains mercury, colored alcohol, or a volatile liquid. The nature of these liquids causes them to rise or fall uniformly in the hollow tube with each degree in temperature change. Thermometers are used to calibrate the controls of refrigeration. The two most common thermometer scales are the Fahrenheit and the Celsius.

On the Fahrenheit scale, there is a difference of 180° between freezing (32°) and the boiling point (212°) of water. On the Celsius scale, you have only 100° difference between the same points (0° freezing and 100° boiling point).

Of course, a Celsius reading can be converted to a Fahrenheit reading, or vice versa. This can be expressed in terms of the following formula:

$$F = (C \times 1.8) + 32$$

To change Fahrenheit to a Celsius reading, the terms of the formula are as follows:

$$C = (F-32) \div 1.8$$

TRANSFER OF HEAT

Heat flows from a substance of higher temperature to bodies of lower temperature in the same manner that water flows down a hill, and like water, it can be raised again to a higher level so that it may repeat its cycle.

When two substances of different temperatures are brought in contact with each other, the heat will immediately flow from the warmer substance to the colder substance. The greater the difference in temperature between the two substances, the faster the heat flow. As the temperature of the substances tends to equalize, the flow of heat slows and stops completely when the temperatures are equalized. This

characteristic is used in refrigeration. The heat of the air, of the lining of the refrigerator, and of the food to be preserved is transferred to a colder substance, called the refrigerant.

Three methods by which heat may be transferred from a warmer substance to a colder substance are conduction, convection, and radiation. These principles are explained in chapter 4 of this TRAMAN.

SPECIFIC HEAT

SPECIFIC HEAT is the ratio between the quantity of heat required to change the temperature of 1 pound of any substance 1°F, as compared to the quantity of heat required to change 1 pound of water 1°F. Specific heat is equal to the number of Btu required to raise the temperature of 1 pound of a substance 1°F. For example, the specific heat of milk is .92, which means that 92 Btu will be needed to raise 100 pounds of milk 1°F. The specific heat of water is 1, by adoption as a standard, and specific heat of another substance (solid, liquid, or gas) is determined experimentally by comparing it to water. Specific heat also expresses the heat-holding capacity of a substance compared to that of water.

A key RULE to remember is that .5 Btu of heat is required to raise 1 pound of ice 1°F when the temperature is below 32°F; and .5 Btu of heat is required to raise 1 pound of steam 1°F above the temperature of 212°F.

SENSIBLE HEAT

Heat that is added to, or subtracted from, a substance that changes its temperature but not its physical state is called SENSIBLE HEAT. It is the heat that can be indicated on a thermometer. This is the heat human senses also can react to, at least within certain ranges. For example, if a person put their finger into a cup of water, the senses readily tell that person whether it is cold, cool, tepid, hot, or very hot. Sensible heat is applied to a solid, a liquid, or a gas/vapor as indicated on a thermometer. The term *sensible heat* does not apply to the process of conversion from one physical state to another.

LATENT HEAT

LATENT HEAT, or hidden heat, is the term used for the heat absorbed or given off by a substance while it is changing its physical state. When this occurs, the heat given off or absorbed does NOT cause a temperature change in the substance. In other words, sensible heat is the term for heat that affects the temperature of things; latent heat is the term for heat that affects the physical state of things.

To understand the concept of latent heat, you must realize that many substances may exist as solids, as liquids, or as gases, depending primarily upon the temperatures and pressure to which they are subjected. To change a solid to a liquid or a liquid to a gas, ADD HEAT; to change a gas to a liquid or a liquid to a solid, REMOVE HEAT. Suppose you take an uncovered pan of cold water and put it over a burner. The sensible heat of the water increases and so does the temperature. As you continue adding heat to the water in the pan, the temperature of the water continues to rise until it reaches 212°F. What is happening? The water is now absorbing its latent heat and is changing from a liquid to a vapor. The heat required to change a liquid to a gas (or, the heat that must be removed from a gas to condense it to a liquid) without any change in temperature is known as the LATENT HEAT OF VAPORIZATION.

Now suppose you take another pan of cold water and put it in a place where the temperature is below 32°F. The water gradually loses heat to its surroundings, and the temperature of the water drops to 32°F until all the water has changed to ice. While the water is changing to ice, however, it is still losing heat to its surroundings. The heat that must be removed from a substance to change it from a liquid to a solid (or, the heat which must be added to a solid to change it to a liquid) without change in temperature is called the LATENT HEAT OF FUSION. Note the amount of heat required to cause a change of state (or the amount of heat given off when a substance changes its state) varies according to the pressure under which the process takes place. Figure 6-2 shows the relationship between sensible heat and latent heat for one substance – water at atmospheric pressure. To raise the temperature of 1 pound of ice from 0°F to 32°F, you must add 16 Btu. To change the pound of ice at 32°F to a pound of water at 32°F, you add 144 Btu (latent heat of fusion). There is no change in temperature while the ice is melting. After the ice is melted, however, the temperature of the water is raised when more heat is applied. When 180 Btu are added, the water boils. To change a pound of water at 212°F to a pound of steam at 212°F, you must add 970 Btu (latent heat of vaporization). After the water is converted to steam at 212°F, the application of additional heat causes a rise in the temperature of the steam. When you add 44 Btu

to the steam at 212°F, the steam is superheated to 300°F.

TOTAL HEAT

TOTAL HEAT is the sum of sensible heat and latent heat. Since measurements of the total heat in a certain weight of a substance cannot be started at absolute zero, a temperature is adopted at which it is assumed that there is no heat; and tables of data are constructed on that basis for practical use. Data tables giving the heat content of the most commonly used refrigerants start at 40°F below zero as the assumed point of no heat; tables for water and steam start at 32°F above zero. Tables of data usually contain a notation showing the starting point for heat content measurement.

DAY-TON OF REFRIGERATION

A day-ton of refrigeration (sometimes incorrectly called a ton of refrigeration) is the amount of refrigeration produced by melting 1 ton of ice at a temperature of 32°F in 24 hours. A day-ton is often used to express the amount of cooling produced by a refrigerator or air-conditioner. For example, a 1-ton air-conditioner can remove as much heat in 24 hours as 1 ton of 32°F ice that melts and becomes water at 32°F. It is a rate of removing heat, rather than a quantity of heat. A rate can be converted to Btu per day, hour, or minute. To find the rate, proceed as follows:

- Per Day: Multiply 2,000 (number of pounds of ice in 1 ton) by 144 (latent heat of fusion per pound) = 288,000 Btu per day
- Per Hour: 288,000 (Btu per day) ÷ 24 (hours in a day) = 12,000

So, a "1-ton" air-conditioner would have a rating of 12,000 Btu per hour.

PRESSURE

PRESSURE is defined as a force per unit area. It is usually measured in pounds per square inch (psi). Pressure may be in one direction, several directions, or in all directions, as shown in figure 6-3. The ice (solid) exerts pressure downward. The water (fluid) exerts pressure on all wetted surfaces of the container. Gases exert pressure on al I inside surfaces of their containers.

Pressure is usually measured on gauges that have one of two different scales. One scale is read as so many pounds per square inch gauge (psig) and indicates the pressure above atmospheric pressure surrounding the gauge. The other type of scale is read as so many pounds per square inch absolute (psia) and indicates the pressure above absolute zero pressure (a perfect vacuum).

Atmospheric Pressure

Atmospheric pressure is the pressure of the weight of air above a point on, above, or under the earth. At sea level, ATMOSPHERIC PRESSURE is 14.7 psia, as shown in figure 6-4. As one ascends, the atmospheric pressure decreases about 1.0 psi for every 2,343 feet. Below sea level in excavations and depressions, atmospheric pressure increases. Pressures underwater differ from those under air only because the weight of the water must be added to the pressure of the air.

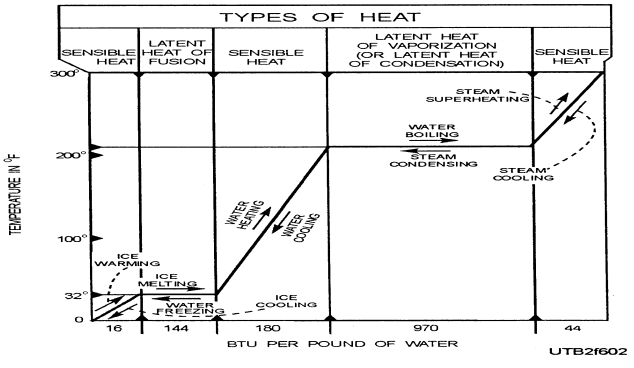


Figure 6-2.—Relationship between temperature and the amount of heat required per pound (for water at atmospheric pressure).

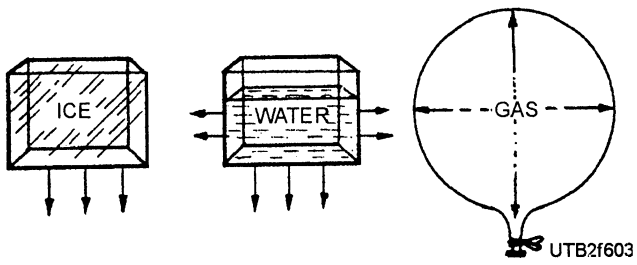


Figure 6-3.—Exertion of pressures.

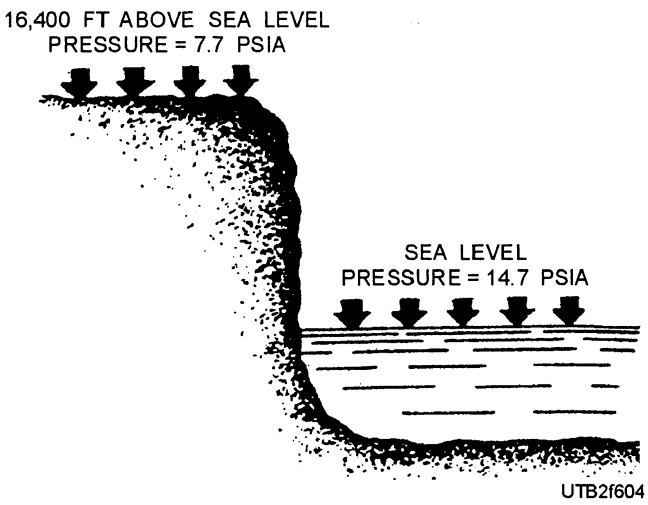


Figure 6-4.—Atmospheric pressure.

Scale Relationships

A relationship exists between the readings of a gauge calibrated in psig and calibrated in psia. As shown in figure 6-5, when the psig gauge reads 0, the psia gauge reads the atmospheric pressure (14.7 psia at sea level). In other words, the psia reading equals the psig reading plus the atmospheric pressure (7.7 psia at 16,400 feet), or, a psig reading equals the psia reading minus the atmospheric pressure.

ABSOLUTE SCALE (PSIA)	GAUGE SCALE (PSIG)	INCHES OF MERCURY	INCHES OF WATER
44.7	30	NOT USED	NOT USED
24.7	10	NOT USED	NOT USED
14.7	0	0	0
0	NOT USED	-30	-408

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Figure 6-5.—Pressure relationship.

For pressure less than the atmospheric pressure (partial vacuums), a measuring device with a scale reading in inches of mercury (Hg) or in inches of water (H_2O) is used. A perfect vacuum is equal to -30 inches of mercury or -408 inches of water (fig. 6-5). In refrigeration work, pressures above atmospheric are measured in pounds per square inch, and pressures below atmospheric are measured in inches of mercury.

Effects of Pressure on Gases

The exertion of pressure on a substance with a constant temperature decreases its volume in proportion to the increase of pressure. For example, suppose that a given amount of gas is placed in a cylinder that is sealed on one end and has a movable piston on the other end. When 60 psi of absolute pressure is exerted on the piston, as shown in view A of figure 6-6, the volume of the gas is compressed to 3 cubic feet. When 90 psi of absolute pressure is exerted on the piston, as shown in view B, the volume of the gas is compressed to 1.5 cubic feet. Finally, when 180 psi of absolute pressure is exerted on the piston, as shown in view C, the volume of the gas is compressed to 1 cubic foot. Thus, if a given amount of gas is confined in a container and subject to changes of pressure, its volume changes, so the product of volume multiplied by absolute pressure is always the same.

Pressure has a relationship to the boiling point of a substance There is a definite temperature at which a liquid boils for everv definite pressure exerted upon it.

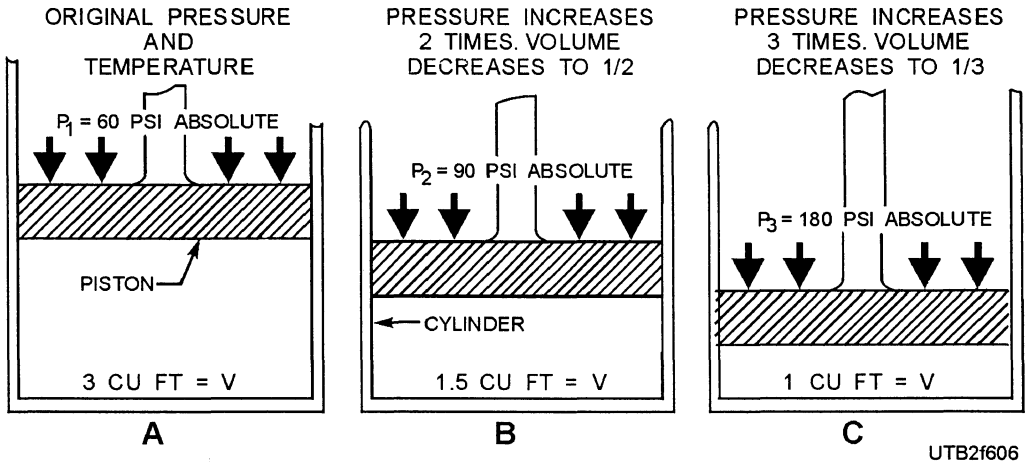


Figure 6-6.—Pressure-volume relationship.

For instance, water boils at 212°F at atmospheric pressure (14.7 psia), as shown in view A, figure 6-7. The same water boils at 228°F if the pressure is raised 5.3 psig (20 psia), as shown in view B, figure 6-7. On the other hand, the same water boils at 32°F in a partial vacuum of 29.74 inches of mercury (Hg), as shown in figure 6-8.

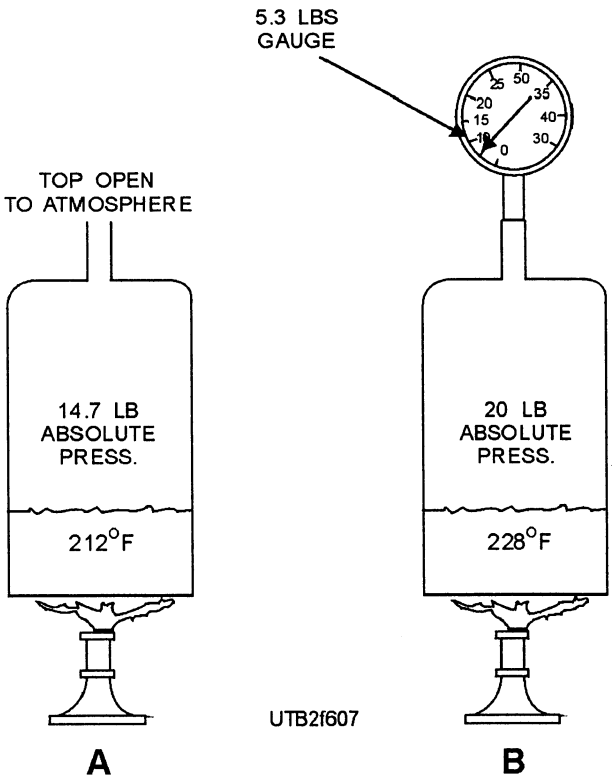


Figure 6-7.—A. Water boils at atmospheric pressure; B. Water boils at 20-psia absolute pressure.

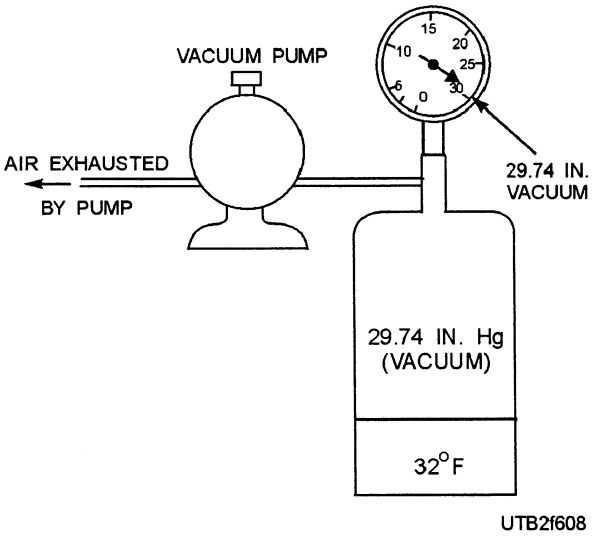


Figure 6-8.—Water boils quicker in a vacuum.

This effect of reduced pressure on the boiling temperature of refrigerants makes the operation of a refrigeration system possible. The pressure temperature relationship chart in figure 6-9 gives the pressures for several different refrigerants.

An increase in the temperature of a refrigerant results in an increase in pressure, and a decrease in temperature causes a decrease in pressure. By the same token, a decrease in pressure results in a corresponding decrease in temperature.

This means that as the pressure of a refrigerant is increased, so is the temperature at which the refrigerant boils. Thus, by regulating the pressure of the refrigerant, the temperature at which evaporation takes place and at which the latent heat of evaporation is used can be controlled.

VAPORIZATION

VAPORIZATION is the process of changing a liquid to vapor, either by evaporation or boiling. When a glass is filled with water, as shown in figure 6-10, and exposed to the rays of the sun for a day or two, you should note that the water level drops gradually. The loss of water is due to evaporation. Evaporation, in this case, takes place only at the surface of the liquid. It is gradual, but the evaporation of the water can be speeded up if additional heat is applied to it. In this case, the boiling of the water takes place throughout the interior of the liquid. Thus the absorption of heat by a liquid causes it to boil and evaporate.

Vaporization can also be increased by reducing the pressure on the liquid, as shown in figure 6-11. Pressure reduction lowers the temperature at which liquid boils and hastens its evaporation. When a liquid evaporates, it absorbs heat from warmer surrounding objects and cools them. Refrigeration by evaporation is based on this method. The liquid is allowed to expand under reduced pressure, vaporizing and extracting heat from the container (freezing compartment), as it changes from a liquid to a gas. After the gas is expanded (and heated), it is compressed, cooled, and condensed into a liquid again.

CONDENSATION

CONDENSATION is the process of changing a vapor into a liquid. For example, in figure 6-12, a warm atmosphere gives up heat to a cold glass of water, causing moisture to condense out of the air and form on the outside surface of the glass. Thus the removal of heat from a vapor causes the vapor to condense.

PRESSURE TEMPERATURE CHART												
Temp °F	113	141b	123	11	114	124	134a	12	500	22	502	125
-40.0	29.5	29.0	28.8	28.4	26.1	22.8*	14.7	11.0	7.6	0.6	4.1	4.9
-35.0	29.4	28.8	28.6	28.1	25.4		12.3	8.4	4.6	2.6	6.5	
-30.0	29.3	28.6	28.3	27.8	24.7	20.2*	9.7	5.5	1.2	4.9	9.2	10.6
-25.0	29.2	28.3	28.1	27.4	23.8		6.8	2.3	1.2	7.5	12.1	
-20.0	29.0	28.1	27.7	27.0	22.9	16.9*	3.6	0.6	3.2	10.2	15.3	17.4
-15.0	28.8	27.7	27.3	26.6	21.8		0.0	2.5	5.4	13.2	18.8	
-10.0	28.7	27.3	26.9	26.0	20.6	12.7*	2.0	4.5	7.8	16.5	22.6	25.6
-5.0	28.4	26.9	26.4	25.4	19.3		4.1	6.7	10.4	20.1	26.7	
0.0	28.2	26.4	25.8	24.7	17.8	7.6*	6.5	9.2	13.3	24.0	31.1	35.1
5.0	27.9	25.8	25.2	23.9	16.2		9.1	11.8	16.4	28.3	35.9	
10.0	27.5	25.2	24.5	23.1	14.4	1.4*	12.0	14.7	19.7	32.8	41.0	46.3
15.0	27.2	24.5	23.7	22.1	12.4		15.1	17.7	23.3	37.8	46.5	
20.0	26.7	23.7	22.8	21.1	10.2	3.0	18.4	21.1	27.2	43.1	52.5	59.2
25.0	26.3	22.8	21.8	19.9	7.8		22.1	24.6	31.4	48.8	58.8	
30.0	25.7	21.8	20.7	18.6	5.1	7.5	26.1	28.5	36.0	54.9	65.6	74.1
35.0	25.1	20.7	19.5	17.1	2.2		30.4	32.6	40.8	61.5	72.8	
40.0	24.4	19.5	18.1	15.6	0.4	12.7	35.0	37.0	46.0	68.5	80.5	91.2
45.0	23.7	18.1	16.6	13.8	2.1		40.0	41.7	51.6	76.1	88.7	
50.0	22.9	16.7	15.0	12.0	3.9	18.8	45.4	46.7	57.5	84.1	97.4	110.6
55.0	21.9	13.1	13.1	9.9	5.9		51.2	52.1	63.8	92.6	106.6	
60.0	20.9	13.4	11.2	7.7	8.0	25.9	57.4	57.8	70.6	101.6	116.4	132.8
65.0	19.8	11.5	9.0	5.2	10.3		64.0	63.8	77.7	111.3	127.6	
70.0	18.6	9.4	6.6	2.6	12.7	34.1	71.1	70.2	85.3	121.4	137.6	157.8
75.0	17.3	7.2	4.1	0.1	15.3		78.6	77.0	93.4	132.2	149.1	
80.0	15.8	4.8	1.3	1.6	18.2	43.5	86.7	84.2	101.9	143.7	161.2	186.0
85.0	14.2	2.3	0.9	3.3	21.2		95.2	91.7	110.9	155.7	174.0	
90.0	12.5	0.2	2.5	5.0	24.4	54.1	104.3	99.7	120.5	168.4	187.4	217.5
95.0	10.6	1.7	4.2	6.9	27.8		113.9	108.2	130.5	181.8	201.4	
100.0	8.6	3.2	6.1	8.9	31.4	66.2	124.1	117.0	141.1	196.0	216.2	252.7
105.0	6.4	4.8	8.1	11.1	35.3		134.9	126.4	152.2	210.8	231.7	
110.0	4.0	6.6	10.2	13.4	39.4	79.7	146.3	136.2	163.9	226.4	247.9	291.6
115.0	1.4	8.4	12.6	15.9	43.8		158.4	146.5	176.3	242.8	264.9	
120.0	0.7	10.4	15.0	18.5	48.4	94.9	171.1	157.3	189.2	260.0	282.7	334.3

Vapor pressures in psig, except (*) which are inches of mercury (Hg). UTBf609

Figure 6-9.—Pressure temperature chart.

An increase in pressure on a confined vapor also causes the vapor to change to a liquid. This fact is shown in figure 6-13. When the compressor increases the pressure on the vapor, the condensing vapor changes to a liquid and gives up heat to the cooler surrounding objects and atmosphere.

These conditions exist when the vaporized refrigerant is compressed by the compressor of a refrigeration system and forced into the condenser. The condenser removes the superheat, latent heat of vaporization, and, in some cases, sensible heat from the refrigerant.

Q1. When two substances of different temperatures are brought in contact with each other, heat will flow from the colder substance to the warmer substance. True/False.

Q2. What is specific heat?

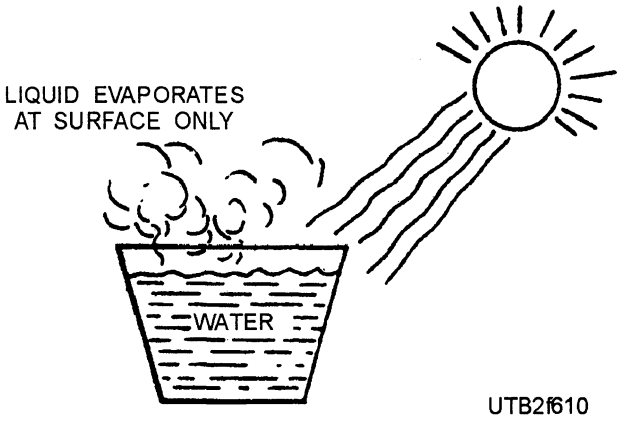


Figure 6-10.—Normal surface evaporation.

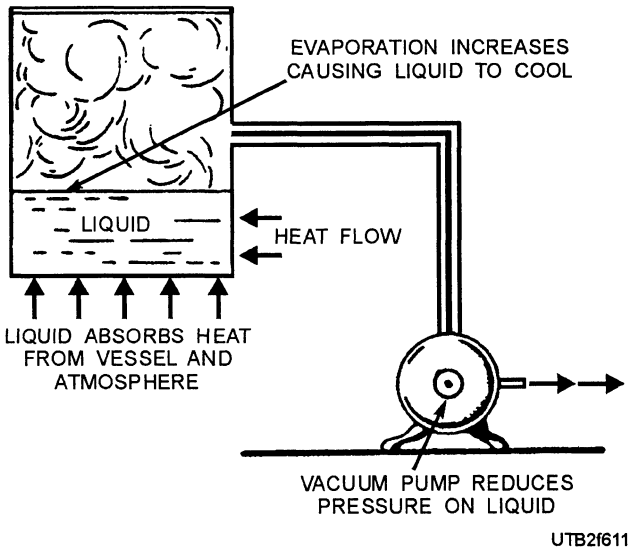


Figure 6-11.—Evaporation by pressure reduction.

Q3. What is the difference between "sensible heat" and "latent heat"?

Q4. What is the atmospheric pressure at 4,686 feet?

Q5. Exertion of *pressure on a substance with a constant pressure does what to the substance?*

Q4. Removal of *heat from a vapor causes what change to occur?*

MECHANICAL REFRIGERATION SYSTEMS

Learning Objective: Identify and understand different types of refrigeration system components and their operation.

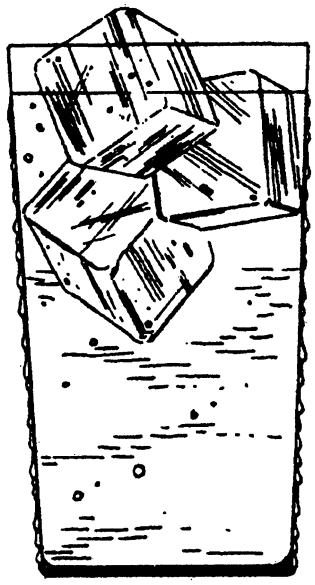


Figure 6-12.—Condensation of moisture on a glass of cold water.

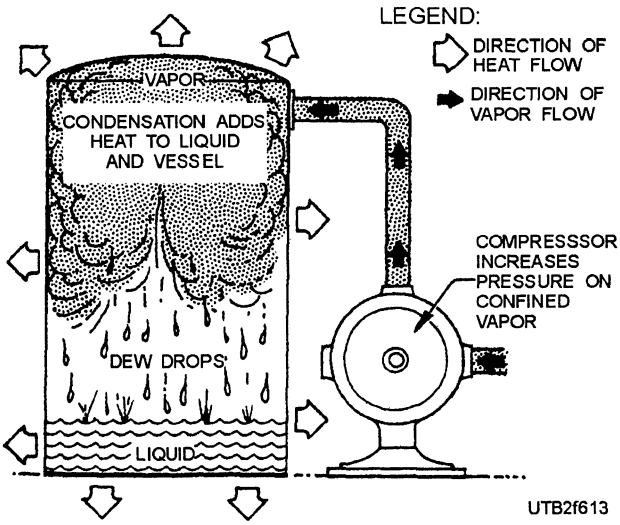


Figure 6-13.—Pressure causes a vapor to condense.

Mechanical refrigeration systems are an arrangement of components in a system that puts the theory of gases into practice to provide artificial cooling. To do this, you must provide the following: (1) a metered supply of relatively cool liquid under pressure; (2) a device in the space to be cooled that operates at reduced pressure so that when the cool, pressurized liquid enters, it will expand, evaporate, and take heat from the space to be cooled; (3) a means of repressurizing (compressing) the vapor; and (4) a means of condensing it back into a liquid, removing its

superheat, latent heat of vaporization, and some of its sensible heat.

Every mechanical refrigeration system operates at two different pressure levels. The dividing line is shown in figure 6-14. The line passes through the discharge valves of the compressor on one end and through the orifice of the metering device or expansion valve on the other.

The high-pressure side of the refrigeration system comprises all the components that operate at or above condensing pressure. These components are the discharge side of the compressor, the condenser, the receiver, and all interconnected tubing up to the metering device or expansion valve.

The low-pressure side of a refrigeration system consists of all the components that operate at or below evaporating pressure. These components comprise the low-pressure side of the expansion valve, the evaporator, and all the interconnecting tubing up to and including the low side of the compressor.

Refrigeration mechanics call the pressure on the high side discharge pressure, head pressure, or high-side pressure. On the low side, the pressure is called suction pressure or low-side pressure.

The refrigeration cycle of a mechanical refrigeration system may be explained by using figure 6-14. The pumping action of the compressor (1) draws vapor drawn from the evaporator (2). This action reduces the pressure in the evaporator, causing the liquid particles to evaporate. As the liquid particles evaporate, the evaporator is cooled. Both the liquid and vapor refrigerant tend to extract heat from the warmer objects in the insulated refrigerator cabinet. The ability of the liquid to absorb heat as it vaporizes is very high in comparison to that of the vapor. As the liquid refrigerant is vaporized, the low-pressure vapor is drawn into the suction line by the suction action of the compressor (1). The evaporation of the liquid refrigerant would soon remove the entire refrigerant from the evaporator if it were not replaced. The replacement of the liquid refrigerant is usually controlled by a metering device or expansion valve (3). This device acts as a restrictor to the flow of the liquid refrigerant in the liquid line. Its function is to change the high-pressure, subcooled liquid refrigerant to low-pressure, low-temperature liquid particles, which will continue the cycle by absorbing heat.

The refrigerant low-pressure vapor drawn from the evaporator by the compressor through the suction line, in turn, is compressed by the compressor to a high-pressure vapor, which is forced into the

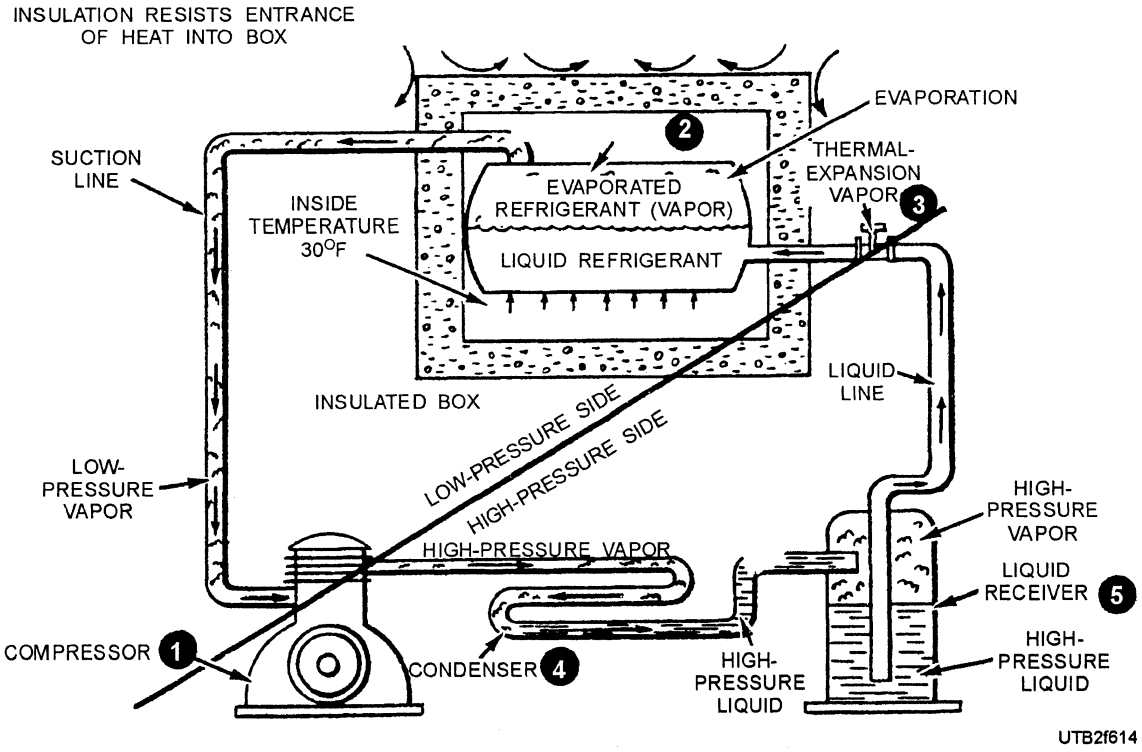


Figure 6-14.—Refrigeration cycle.

condenser (4). In the condenser, the high-pressure vapor condenses to a liquid under high pressure and gives up heat to the condenser. The heat is removed from the condenser by the cooling medium of air or water. The condensed liquid refrigerant is then forced into the liquid receiver (5) and through the liquid line to the expansion valve by pressure created by the compressor, making a complete cycle.

Although the receiver is indicated as part of the refrigeration system in figure 6-14, it is not a vital component. However, the omission of the receiver requires exactly the proper amount of refrigerant in the system. The refrigerant charge in systems without receivers is to be considered critical, as any variations in quantity affects the operating efficiency of the unit.

The refrigeration cycle of any refrigeration system must be clearly understood by a mechanic before repairing the system. Knowing how a refrigerant works makes it easier to detect faults in a refrigeration system.

COMPONENTS

The refrigeration system consists of four basic components - the compressor, the condenser, the liquid receiver, the evaporator, and the control devices. These components are essential for any system to operate on the principles previously discussed. Information on these components is described in the following sections.

Compressors

Refrigeration compressors have but one purpose—to withdraw the heat-laden refrigerant vapor from the evaporator and compress the gas to a pressure that will liquefy in the condenser. The designs of compressors vary, depending upon the application and type of refrigerant. There are three types of compressors classified according to the principle of operation— reciprocating, rotary, and centrifugal.

You may recall that material on compressors was presented in chapter 6, *Utilitiesman Basic,* volume 1. They will not be explained further here except to discuss the special methods used to seal compressors to prevent escape of refrigerant. Many refrigerator compressors have components besides those normally found on compressors, such as unloaders, oil pumps, mufflers, and so on. These devices are too complicated to explain here. Before repairing any compressor, check the manufacturer's manual for an explanation of their operation, adjustment, and repair.

EXTERNAL DRIVE COMPRESSOR.—An external drive or open-type compressor is bolted together. Its crankshaft extends through the crankcase and is driven by a flywheel (pulley) and belt, or it can be driven directly by an electric motor. A leakproof seal must be maintained where the crankshaft extends out of the crankcase of an open-type compressor. The seal must be designed to hold the pressure developed inside of the compressor. It must prevent refrigerant and oil from leaking out and prevent air and moisture from entering the compressor. Two types of seals are used—the stationary bellows seal and the rotating bellows seal.

An internal stationary crankshaft seal shown in figure 6-15 consists of a corrugated thin brass tube (seal bellows) fastened to a bronze ring (seal guide) at one end and to the flange plate at the other. The flange plate is bolted to the crankcase with a gasket between the two units. A spring presses the seal guide mounted on the other end of the bellows against a seal ring positioned against the shoulder of the crankshaft. As the pressure builds up in the crankcase, the bellows tend to lengthen, causing additional force to press the seal guide against the seal ring. Oil from the crankcase lubricates the surfaces of the seal guide and seal ring. This forms a gastight sea whether the compressor is operating or idle.

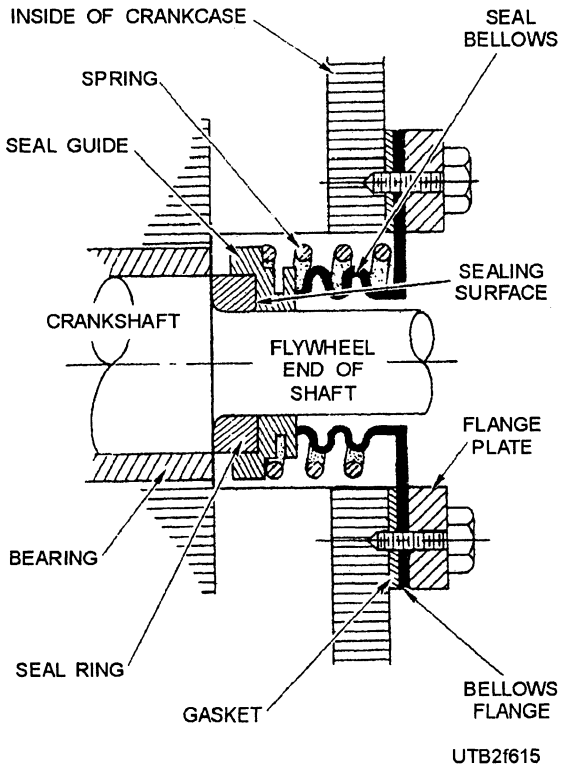


Figure 6-15.—An internal stationary bellows crankshaft seal.

An external stationary bellows crankshaft seal is shown in figure 6-16. This seal is the same as the internal seal, except it is positioned on the outside of the crankcase.

An external rotating bellows crankcase seal is shown in figure 6-17. This seal turns with the crankshaft. This seal also consists of a corrugated thin brass tube (seal bellows) with a seal ring fastened to one end and a seal flange fastened to the other. A seal spring is enclosed within the bellows. The complete bellows assembly slips on the end of the crankshaft and is held in place by a nut. The seal ring that is the inner portion of the bellows is positioned against a nonrotating seal fastened directly to the crankcase. During operation, the complete bellows assembly rotates with the shaft, causing the seal ring to rotate against the stationary seal. The pressure of the seal spring holds the seal ring against the seal. The expansion of the bellows caused by the pressure from the crankcase also exerts pressure on the seal ring. Because of this design, double pressure is exerted against the seal ring to provide a gastight seal.

HERMETIC COMPRESSOR.—In the hermetically sealed compressor, the electric motor and compressor are both in the same airtight (hermetic) housing and share the same shaft. Figure 6-18 shows a hermetically sealed unit. Note that after assembly, the two halves of the case are welded together to form an airtight cover. Figure 6-19 shows an accessible type of hermetically sealed unit. The compressor, in this case, is a double-piston reciprocating type. Other compressors may be of the centrifugal or rotary types.

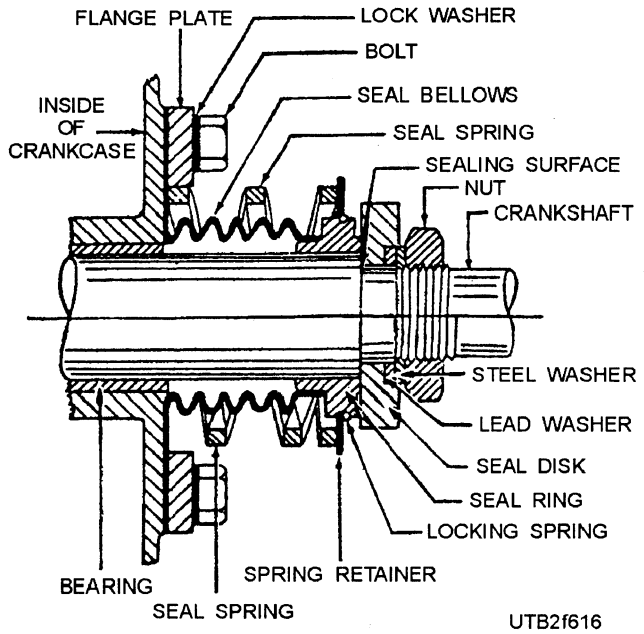


Figure 6-16.—An external stationary bellows crankshaft seal.

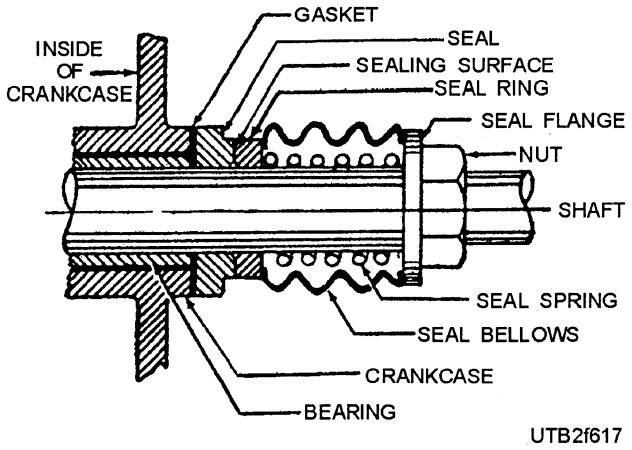


Figure 6-17.—An external rotating bellows crankcase seal.

Cooling and lubrication are provided by the circulating oil and the movement of the refrigerant vapor throughout the case.

The advantages of the hermetically sealed unit (elimination of pulleys, belts and other coupling methods, elimination of a source of refrigerant leaks) are offset somewhat by the inaccessibility for repair and generally lower capacity.

Condensers

The condenser removes and dissipates heat from the compressed vapor to the surrounding air or water to

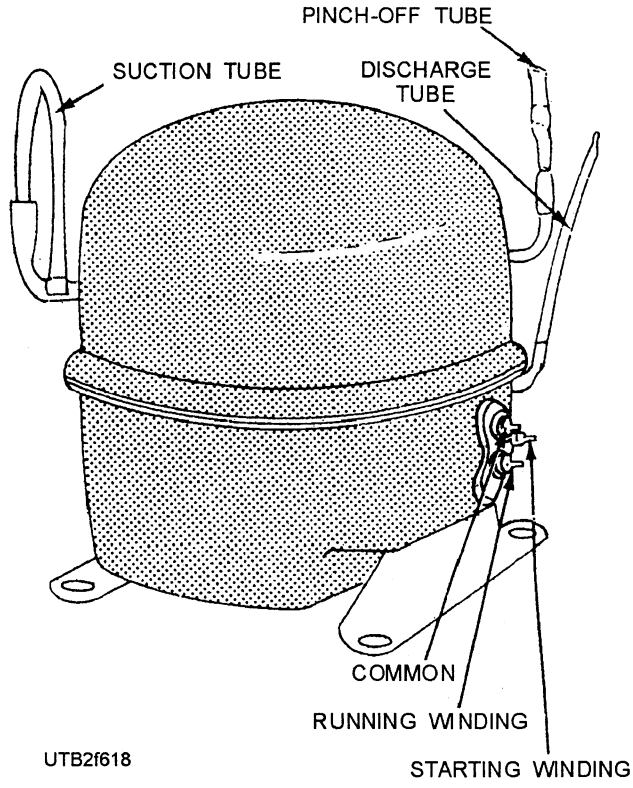


Figure 6-18.—Hermetic compressor.

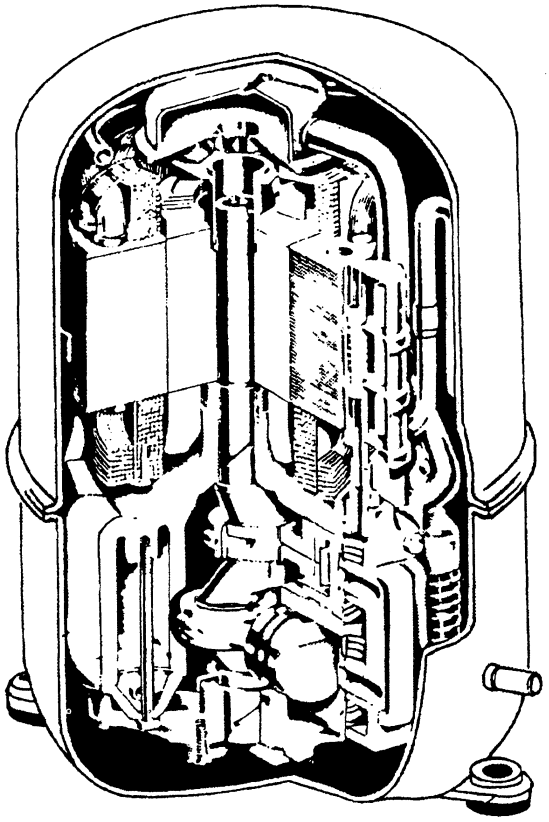


Figure 6-19.—A cutaway view of a hermetic compressor and motor.

condense the refrigerant vapor to a liquid. The liquid refrigerant then falls by gravity to a receiver (usually located below the condenser), where it is stored, and available for future use in the system.

There are three basic types of condensers—air-cooled, water-cooled, and evaporative. The first two are the most common, but the evaporative types are used where low-quality water and its disposal make the use of circulating water-cooled types impractical.

AIR-COOLED CONDENSERS.—The construction of air-cooled condensers makes use of several layers of small tubing formed into flat cells. The external surface of this tubing is provided with fins to ease the transfer of heat from the condensing refrigerant inside the tubes to the air circulated through the condenser core around the external surface of the tubes (fig. 6-20). Condensation takes place as the refrigerant flows through the tubing, and the liquid refrigerant is discharged from the lower ends of the tubing coils to a liquid receiver on the condensing unit assembly.

WATER-COOLED CONDENSERS.—Water-cooled condensers are of the multipass shell and tube type, with circulating water flowing through the tubes. The refrigerant vapor is admitted to the shell

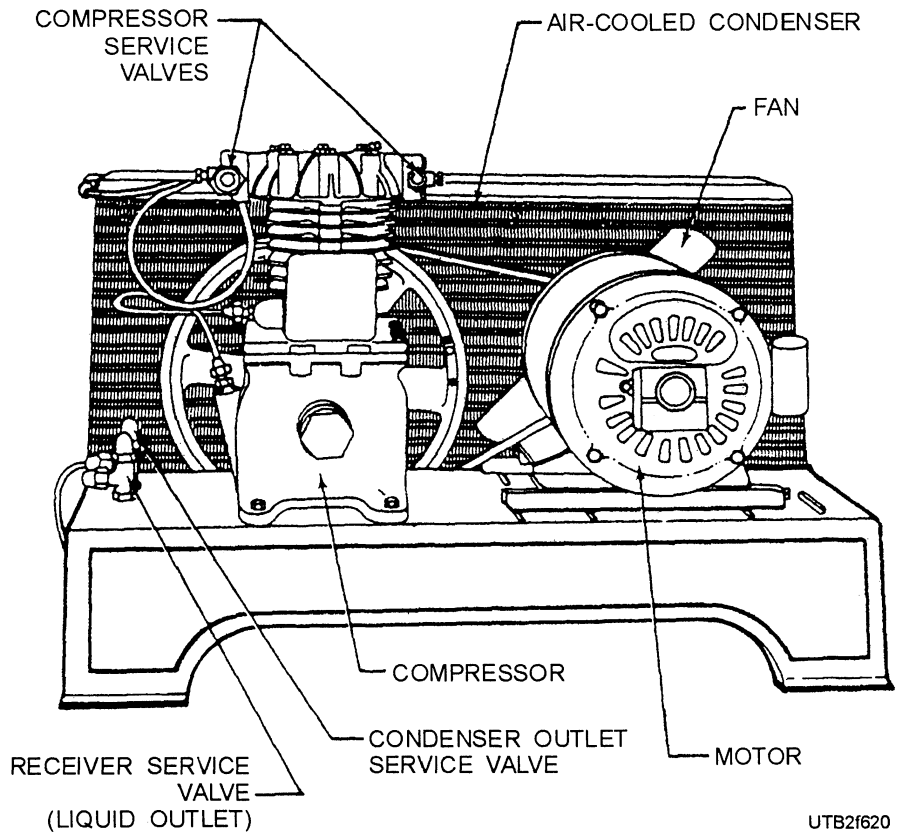


Figure 6-20.—Air-cooled condenser mounted on a compressor unit.

and condensed on the outer surfaces of the tubes (fig. 6-21).

The condenser is constructed with a tube sheet brazed to each end of a shell. Copper-nickel tubes are inserted through drilled openings in the tube sheet and are expanded or rolled into the tube sheet to make a gastight seal. Headers, or water boxes, are bolted to the tube sheet to complete the waterside of the condenser. Zinc-wasting bars are installed in the water boxes to minimize electrolytic corrosion of the condenser parts.

A purge connection with a valve is at the topside of the condenser shell to allow manual release of any accumulated air in the refrigerant circuit.

The capacity of the water-cooled condenser is affected by the temperature of the water, quantity of water circulated, and the temperature of the refrigerant gas. The capacity of the condenser varies whenever the temperature difference between the refrigerant gas and the water is changed. An increased temperature difference or greater flow of water increases the capacity of the condenser. The use of colder water can cause the temperature difference to increase.

EVAPORATIVE CONDENSERS.—An evaporative condenser operates on the principle that heat can be removed from condensing coils by spraying them with water or letting water drip onto them and then forcing air through the coils by a fan. This evaporation of the water cools the 'coils and condenses the refrigerant within.

Liquid Receiver

A liquid receiver as shown at position (5) on figure 6-14, serves to accumulate the reserve liquid refrigerant, to provide a storage for off-peak operation, and to permit pumping down of the system. The receiver also serves as a seal against the entrance of gaseous refrigerant into the liquid line. When stop valves are provided at each side of the receiver for confinement of the liquid refrigerant, a pressure relief valve is generally installed between the valves in the receiver and condenser equalizing line to protect the receiver against any excessive hydraulic pressure being built up.

Evaporators

The evaporator is a bank or coil of tubing placed inside the refrigeration space. The refrigerant is at a low-pressure and low-temperature liquid, as it enters the evaporator.

As the refrigerant circulates through the evaporator tubes, it absorbs its heat of vaporization from the surrounding space and substances. The absorption of this heat causes the refrigerant to boil. As the temperature of the surrounding space (and

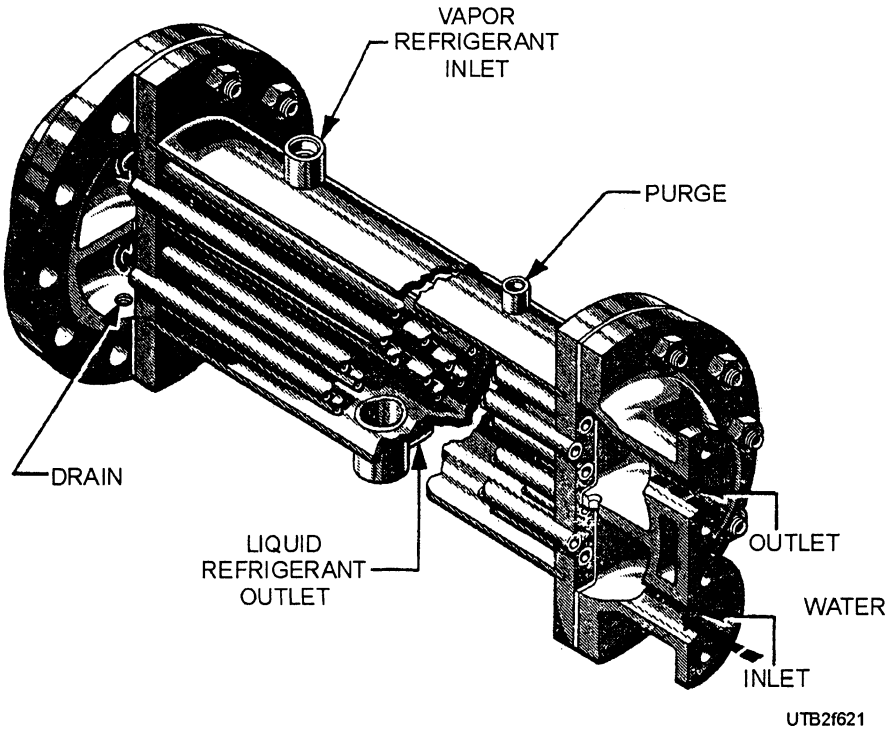


Figure 6-21.—Water-cooled condenser.

contents) is lowered, the liquid refrigerant gradually changes to a vapor. The refrigerant vapor then passes into the suction line by the action of the compressor.

Most evaporators are made of steel, copper, brass, stainless steel, aluminum, or almost any other kind of rolled metal that resists the corrosion of refrigerants and the chemical action of the foods.

Evaporators are mainly of two types—dry or flooded. The inside of a dry evaporator refrigerant is fed to the coils only as fast as necessary to maintain the temperature wanted. The coil is always filled with a mixture of liquid and vapor refrigerant. At the inlet side of the coil, there is mostly liquid; the refrigerant flows through the coil (as required); it is vaporized until, at the end, there is nothing but vapor. In a flooded evaporator, the evaporator is always filled with liquid refrigerant. A float maintains liquid refrigerant at a constant level. As fast as the liquid refrigerant evaporates, the float admits more liquid, and, as a result, the entire inside of the evaporator is flooded with liquid refrigerant up to a certain level determined by the float.

The two basic types of evaporators are further classified by their method of evaporation, either direct expanding or indirect expanding. In the direct-expanding evaporator, heat is transferred directly from the refrigerating space through the tubes and absorbed by the refrigerant. In the indirect-expanding evaporator, the refrigerant in the evaporator is used to cool some secondary medium, other than air. This secondary medium or refrigerant maintains the desired temperature of the space. Usually brine, a solution of calcium chloride is used as the secondary refrigerant.

Natural convection or forced-air circulation is used to circulate air within a refrigerated space. Air around the evaporator must be moved to the stored food so that heat can be extracted, and the warmer air from the food returned to the evaporator. Natural convection can be used by installing the evaporator in the uppermost portion of the space to be refrigerated, so heavier cooled air will fall to the lower food storage and the lighter food-warmed air will rise to the evaporator. Forced-air circulation speeds up this process and is usually used in large refrigerated spaces to ensure all areas are cooled.

Control Devices

To maintain correct operating conditions, control devices are needed in a refrigeration system. Some of the control devices are discussed in this chapter.

METERING DEVICES.—Metering devices, such as expansion valves and float valves, control the flow of liquid refrigerant between the high side and the low side of the system. It is at the end of the line between the condenser and the evaporator. These devices are of five different types: an automatic expansion valve (also known as a constant-pressure expansion valve), a thermostatic expansion valve, low-side and high-side float valves, and a capillary tube.

Automatic Expansion Valve.—An automatic expansion valve (fig. 6-22) maintains a constant pressure in the evaporator. Normally this valve is used only with direct expansion, dry type of evaporators. In operation, the valve feeds enough liquid refrigerant to the evaporator to maintain a constant pressure in the coils. This type of valve is generally used in a system where constant loads are expected. When a large variable load occurs, the valve will not feed enough refrigerant to the evaporator under high load and will overfeed the evaporator at low load. Compressor damage can result when slugs of liquid enter the compressor.

Thermostatic Expansion Valve.—Before discussing the thermostatic expansion valve, let's explain the term SUPERHEAT. A vapor gas is superheated when its temperature is higher than the boiling point corresponding to its pressure. When the boiling point begins, both the liquid and the vapor are at the same temperature. But in an evaporator, as the gas vapor moves along the coils toward the suction line, the gas may absorb additional heat and its temperature rises. The difference in degrees between the saturation temperature and the increased temperature of the gas is called superheat.

A thermostatic expansion valve (fig. 6-22) keeps a constant superheat in the refrigerant vapor leaving the coil. The valve controls the liquid refrigerant, so the evaporator coils maintain the correct amount of refrigerant at all times. The valve has a power element that is activated by a remote bulb located at the end of the evaporator coils. The bulb senses the superheat at the suction line and adjusts the flow of refrigerant into the evaporator. As the superheat increases (suction line), the temperature, and therefore the pressure, in the remote bulb also increases. This increased pressure, applied to the top of the diaphragm, forces it down along with the pin, which, in turn, opens the valve, admitting replacement refrigerant from the receiver to flow into the evaporator. This replacement has three effects. First, it provides additional liquid

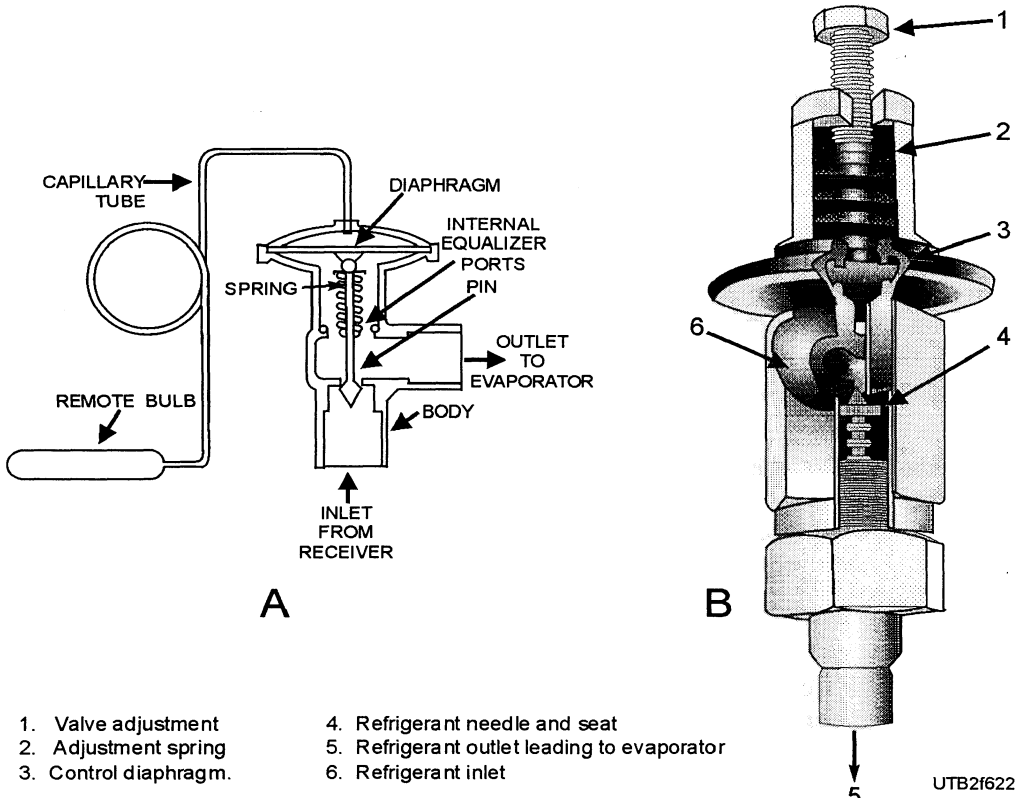


Figure 6-22—A. Thermostatic expansion valve; B. Automatic expansion valve.

refrigerant to absorb heat from the evaporator. Second, it applies higher pressure to the bottom of the diaphragm, forcing it upward, tending to close the valve. And third, it reduces the degree of superheat by forcing more refrigerant through the suction line.

Low-Side Float Expansion Valve.—The low-side float expansion valve (fig. 6-23) controls the liquid refrigerant flow where a flooded evaporator is used. It consists of a ball float in either a chamber or the evaporator on the low-pressure side of the svstem.

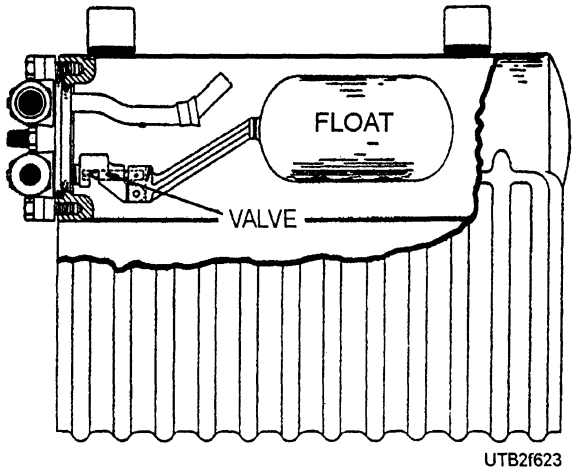


Figure 6-23.—A low-side float expansion valve.

The float actuates a needle valve through a lever mechanism. As the float lowers, refrigerant enters through the open valve; when it rises, the valve closes.

High-Side Float Expansion Valve.—In a high-side float expansion valve (fig. 6-24), the valve float is in a liquid receiver or in an auxiliary container on the high-pressure side of the system. Refrigerant from the condenser flows into the valve and immediately opens it, allowing refrigerant to expand and pass into the evaporator. Refrigerant charge is critical. An overcharge of the system floods back and damages the compressor. An undercharge results in a capacity drop.

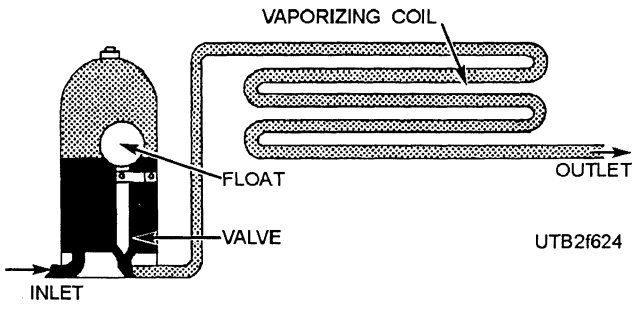


Figure 6-24.—A high-side float expansion valve.

Capillary Tube.—The capillary tube consists of a long tube of small diameter. It acts as a constant throttle on the refrigerant. The length and diameter of the tube are important; any restrictions cause trouble in the system. It feeds refrigerant to the evaporator as fast as it is produced by the condenser. When the quantity of refrigerant in the system is correct or the charge is balanced, the flow of refrigerant from the condenser to the evaporator stops when the compressor unit stops. When the condensing unit is running, the operating characteristics of the capillary tube equipped evaporator are the same as if it were equipped with a high-side float.

The capillary tube is best suited for household boxes, such as freezers and window air-conditioners, where the refrigeration load is reasonably constant and small horsepower motors are used.

Accessory Devices

The four basic or major components of a refrigeration system just described are enough for a refrigeration unit to function. However, additional devices, such as the receiver already described, make for a smoother and more controlled cycle. Some of the accessory devices used on a refrigeration unit are described in this section. Before proceeding, take a close look at figure 6-25 that shows one type of refrigeration system with additional devices installed. Some of the devices and their functions are explained to help you understand installation and troubleshooting of a refrigeration unit.

RELIEF VALVE.—A refrigeration system is a sealed system in which pressures vary. Excessive pressures can cause a component of the system to explode. The National Refrigeration Code makes the installation of a relief valve mandatory. A spring-loaded relief valve is most often used and it is installed in the compressor discharge line between the compressor discharge connection and the discharge line stop valve to protect the high-pressure side of the system. No valves can be installed between the compressor and the relief valve. The discharge from the relief valve is led to the compressor suction line.

DISCHARGE PRESSURE GAUGE AND THERMOMETER. —A discharge pressure gauge and thermometer are installed in the compressor discharge line (liquid line) to show the pressure and temperature of the compressed refrigerant gas. The temperature indicated on the gauge is always higher than that corresponding to the pressure when the compressor is operating.

COMPRESSOR MOTOR CONTROLS.—The starting and stopping of the compressor motor is usually controlled by either a pressure-actuated or temperature-actuated motor control. The operation of the pressure motor control depends on the relationship

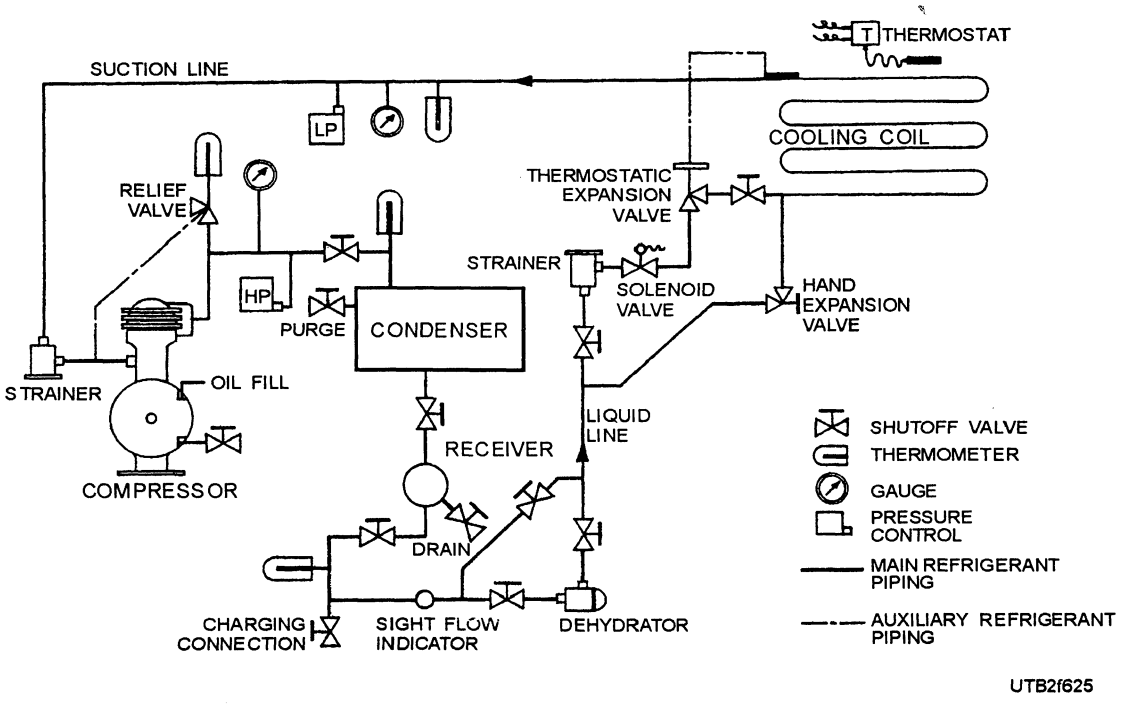


Figure 6-25.—A basic refrigeration system.

between pressure and temperature. A pressure motor control is shown in figure 6-26. The device consists of a low-pressure bellows, or, in some cases, a low-pressure diaphragm, connected by a small diameter tube to the compressor crankcase or to the suction line. The pressure in the suction line or compressor crankcase is transmitted through the tube and actuates the bellows or diaphragm. The bellows move according to the pressure, and its movement causes an electric switch to start (cut in) or stop (cut out) the compressor motor. Adjustments can be made to the start and stop pressures under the manufacturer's instruction. Usually the cutout pressure is adjusted to correspond to a temperature a few degrees below the desired evaporator coil temperature, and the cut-in pressure is adjusted to correspond to the temperature of the coil.

The tem perature-actuated motor control is similar to the pressure device. The main difference is that a temperature-sensing bulb and a capillary tube replace the pressure tube. The temperature motor control cuts in or cuts out the compressor according to the temperature in the cooled space.

The refrigeration system may also be equipped with a high-pressure safety cutout switch that shuts off the power to the compressor motor when the high-side pressure exceeds a preset limit.

SOLENOID STOP VALVES.—Solenoid stop valves, or magnetic stop valves, control gas or liquid flow. They are most commonly used to control liquid refrigerant to the expansion valve but are used throughout the system. The compressor motor and solenoid stop valve are electrically in parallel; that is, the electrical power is applied or removed from both at the same time. The liquid line is open for passage of refrigerant only when the compressor is in operation and the solenoid is energized. A typical solenoid stop valve is shown in figure 6-27.

Improper operation of these valves can be caused by a burned-out solenoid coil or foreign material lodged between the stem and the seat of the valve, allowing fluid to leak. Carefully check the valve before replacing or discarding. The valve must be installed so that the coil and plunger are in a true vertical position. When the valve is cocked, the plunger wi II not reseat properly, causing refrigerant leakage.

THERMOSTAT SWITCH.—Occasionally, a thermostat in the refrigerated space operates a solenoid stop valve, and the compressor motor is controlled independently by a low-pressure switch. The solenoid control switch, or thermostat, makes and breaks the electrical circuit, thereby controlling the liquid refrigerant to the expansion valve. The control bulb is charged with a refrigerant so that temperature changes of the bulb itself produce like changes in pressure within the control bulb. These pressure changes are transmitted through the tubing to the switch power element to operate the switch. The switch opens the contacts and thus releases the solenoid valve, stopping the flow of refrigerant to the cooling coil when the temperature of the refrigerated space has reached the desired point. The compressor continues to operate until it has evacuated the evaporator. The resulting low

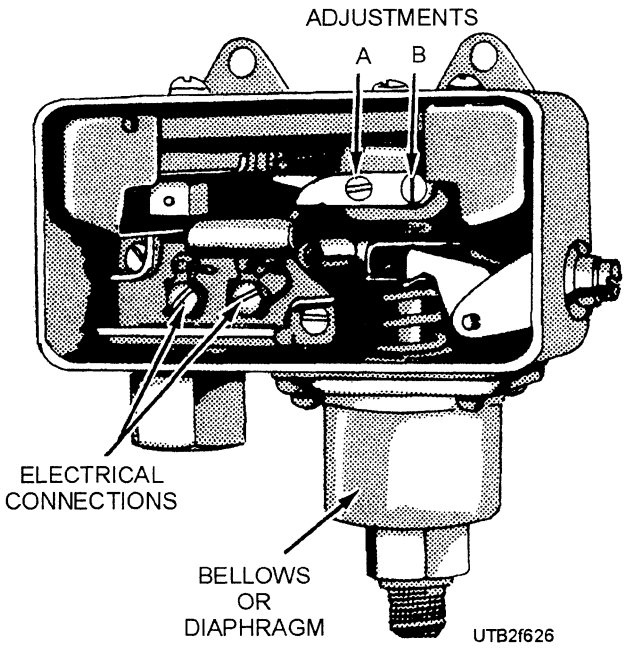


Figure 6-26.—Pressure-actuated motor control.

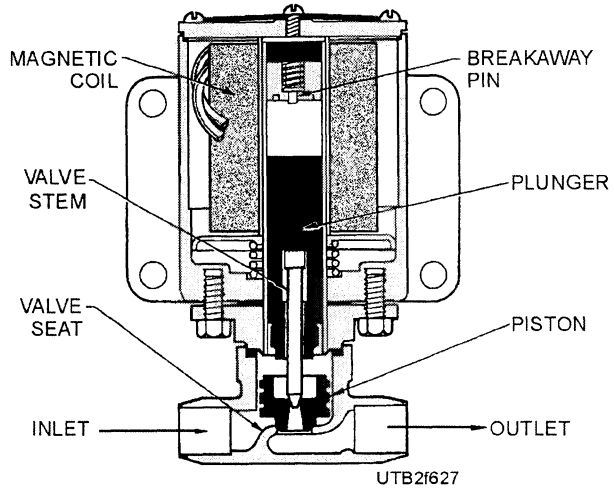


Figure 6-27.—A solenoid stop valve.

pressure in the evaporator then activates the low-pressure switch, which stops the compressor. As the temperature rises, the increase in bulb pressure closes the switch contacts, and the refrigerant is supplied to the expansion valve.

LIQUID LINE.—The refrigerant accumulated in the bottom of the receiver shell is conveyed to the cooling coils through the main refrigerant liquid line. A stop valve and thermometer are usually installed in this line next to the receiver. Where the sight-flow indicator, dehydrator, or filter-drier is close to the receiver, the built-in shutoff valves may be used instead of a separate shutoff valve.

LIQUID LINE FILTER-DRIER OR DEHYDRATOR.—A liquid line filter-drier (fig. 6-28) prevents or removes moisture, dirt, and other foreign materials from the liquid line that would harm the system components and reduce efficiency. This tank like accessory offers some resistance to flow. and, for this reason, some manufacturers install it in a bypass line. A filter-drier consists of a tubular shell with strainers on the inlet and outlet connections to prevent escape of drying material into the system. Some filter-driers are equipped with a sight-glass indicator, as shown in figure 6-28. A dehydrator is similar to a filter-drier, except that it mainly removes moisture.

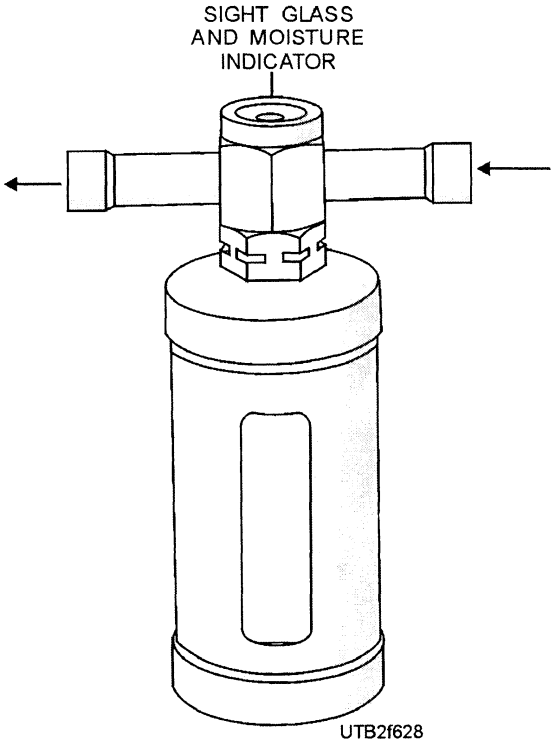


Figure 6-28.—A liquid line filter-drier with sight-glass indicator.

SIGHT-FLOW INDICATOR.—The sight-flow indicator, also known as a sight glass (fig. 6-29), is a special fitting provided with a gasketed glass, single or double port, and furnished with or without seal caps for protection when not in use. The double-port unit permits the use of a flashlight background. The refrigerant may be viewed passing through the pipe to determine the presence and amount of vapor bubbles in the liquid that would indicate low refrigerant or unfavorable operating conditions. Some filter-driers are equipped with built-in sight-flow indicators, as shown in figure 6-29.

SUCTION LINE.—Suction pressure regulators are sometimes placed between the outlet of the evaporator and the compressor to prevent the evaporator pressure from being drawn down below a predetermined level despite load fluctuations. These regulators are usually installed in systems that require a higher evaporator temperature than usual.

PRESSURE CONTROL SWITCHES.—Pressure control switches (fig. 6-30), often called low-pressure cutouts, are essentially a single-pole, single-throw electrical switch and are mainly used to control starting and stopping of the compressor. The suction pressure acts on the bellows of the power element of the switch and produces movement of a lever mechanism operating electrical contacts. A rise in pressure closes the switch contacts and thereby completes the circuit of the motor controller, which, in turn, starts the compressor automatically. As the operation of the compressor gradually decreases the suction pressure, the movement of the switch linkage

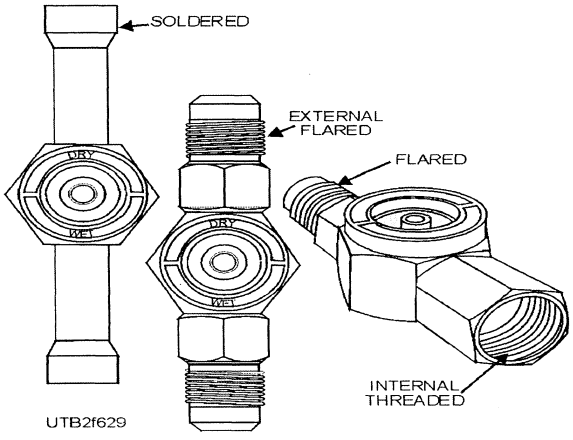


Figure 6-29.—Sight-flow indicators with different types of connections.

reverses until the contacts are separated at a predetermined low-suction pressure, thus breaking the motor controller circuit and stopping the compressor.

SUCTION LINE FILTER-DRIER.—Some systems include a low-side filter-drier (fig. 6-31) at the compressor end of the suction line. The filter-drier used in the suction line should offer little resistance to flow of the vaporized refrigerant, as the pressure difference between the pressure in the evaporator and the inlet of the compressor should be small. These filter-driers function to remove dirt, scale, and moisture from the refrigerant before it enters the compressor.

GAUGES AND THERMOMETERS.—Between the suction line stop valve and the compressor, a pressure gauge and thermometer may be provided to show the suction conditions at which the compressor is operating. The thermometer shows a higher temperature than the temperature corresponding to the suction pressure indicated on the gauge, because the refrigerant vapor is superheated during its passage from the evaporator to the compressor.

ACCUMULATORS AND OIL SEPARATORS.—Liquid refrigerant must never be allowed to enter the compressor. Liquids are noncompressible; in other words, their volume remains the same when compressed. An accumulator (fig. 6-32) is a small tank accessory; that is, a safety device designed to prevent liquid refrigerant from flowing into the suction line and into the compressor. A typical accumulator has an outlet at the top. Any liquid refrigerant that flows into the accumulator is evaporated, and then the vapor will flow into the suction line to the compressor.

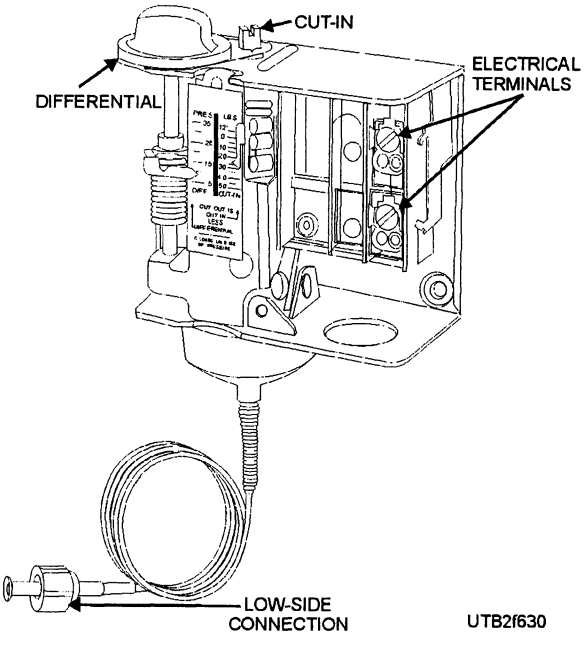


Figure 6-30.—Pressure type cut-in, cutout control switch.

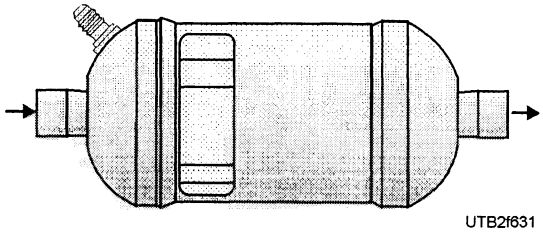


Figure 6-31.—A suction line filter-drier.

Oil from the compressor must not move into the rest of the refrigeration system. Oil in the lines and evaporator reduces the efficiency of the system. An oil separator (fig. 6-33) is located between the compressor discharge and the inlet of the condenser. The oil separator consists of a tank or cylinder with a series of baffles and screens, which collect the oil. This oil settles to the bottom of the separator. A float arrangement operates a needle valve, which opens a return line to the compressor crankcase.

Q7. What are the three types of compressors used in refrigeration systems?

Q8. What is the difference between the internal and external bellows crankshaft seal?

Q9. What are the two drawbacks of a hermetic compressor?

Q10. What are the two primary types of evaporators?

Q11. A capillary tube-metering device is most commonly used on what type of refrigeration equipment?

Q12. What is the function of a sight-flow indicator?

REFRIGERANTS

Learning Objective: Understand and identify classification of common refrigerants and their application. Understand the requirements for ozone protection and the Clean Air Act.

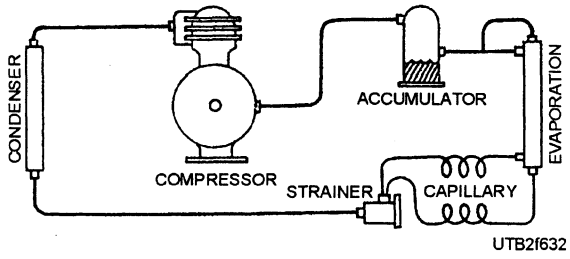


Figure 6-32.—Accumulator location.

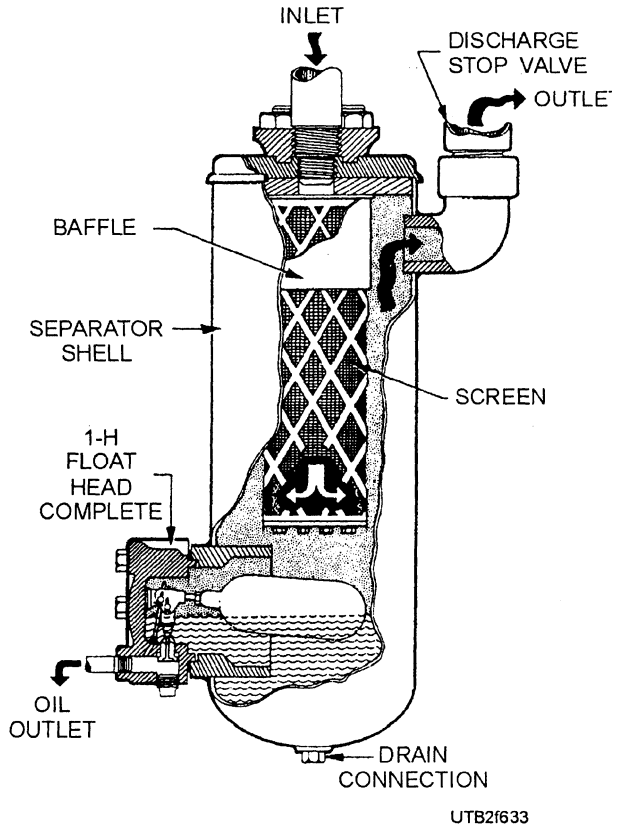


Figure 6-33.—A cutaway view of an oil separator.

Refrigerants are fluids that change their state upon the application or removal of heat within a system and, in this act of change, absorb or release heat to or from an area or substance. Many different fluids are used as refrigerants. In recent years, the most common has been air, water, ammonia, sulfur dioxide, carbon dioxide, and methylchloride.

Today, there are three specific types of refrigerants used in refrigeration and air-conditioning systems—(1) Chlorofluorocarbons or CFCs, such as R-11, R-12, and R-114; (2) Hydrochlorofluorocarbons or HCFCs, such as R-22 or R-123; and (3) Hydrofluorocarbons or HFCs, such as R-134a. All these refrigerants are "halogenated," which means they contain chlorine, fluorine, bromine, astatine, or iodine.

Refrigerants, such as Dichlorodifluoromethane (R-12), Monochlorodifluoromethane (R-22), and Refrigerant 502 (R-502), are called PRIMARY REFRIGERANTS because each one changes its state upon the application or absorption of heat, and, in this act of change, absorbs and extracts heat from the area or substance.

The primary refrigerant is so termed because it acts directly upon the area or substance, although it may be enclosed within a system. For a primary refrigerant to cool, it must be placed in a closed system in which it can be controlled by the pressure imposed upon it. The refrigerant can then absorb at the temperature ranges desired. If a primary refrigerant were used without being controlled, it would absorb heat from most perishables and freeze them solid.

SECONDARY REFRIGERANTS are substances, such as air, water, or brine. Though hot refrigerants in themselves, they have been cooled by the primary refrigeration system; they pass over and around the areas and substances to be cooled; and they are returned with their heat load to the primary refrigeration system. Secondary refrigerants pay off where the cooling effect must be moved over a long distance and gastight lines cost too much.

Refrigerants are classified into groups. The National Refrigeration Safety Code catalogs all refrigerants into three groups—Group I – safest of the refrigerants, such as R-12, R-22, and R-502; Group II – toxic and somewhat flammable, such as R-40 (Methyl chloride) and R-764 (Sulfur dioxide); Group III – flammable refrigerants, such as R-170 (Ethane) and R-290 (Propane).

R-12 DICHLORODIFLUOROMETHANE ($CC1_2F_2$)

Dichlorodifluoromethane, commonly referred to as R-12, is colorless and odorless in concentrations of less than 20 percent by volume in air. In higher concentrations, its odor resembles that of carbon tetrachloride. It is nontoxic, noncorrosive, nonflammable, and has a boiling point of -21.7°F (-29°C) at atmospheric pressure.

WARNING

Because of its low-boiling point at atmospheric pressure, it prevents liquid R12 from contacting the eyes because of the possibility of freezing.

One hazard of R-12 as a refrigerant is the health risk should leakage of the vapor come into contact with an open flame of high temperature (about 1022°F) and be decomposed into phosgene gas, which is highly toxic. R-12 has a relatively low latent heat value, and, in smaller refrigerating machines, this is an advantage. R-12 is a stable compound capable of undergoing the physical changes without decomposition to which it is

commonly subjected in service. The cylinder code color for R-12 is white.

R-22 MONOCHLORODIFLUOROMETHANE ($CHCIF_2$)

Monochlorodifluoromethane, normally called R-22, is a synthetic refrigerant developed for refrigeration systems that need a low-evaporating temperature, which explains its extensive use in household refrigerators and window air conditioners. R-22 is nontoxic, noncorrosive, nonflammable, and has a boiling point of -41°F at atmospheric pressure. R-22 can be used with reciprocating or centrifugal compressors. Water mixes readily with R-22, so larger amounts of desiccant are needed in the filter-driers to dry the refrigerant. The cylinder code color for R-22 is green.

R-502 REFRIGERANT ($CHCIF_2/CCIF_2CF_3$)

R-502 is an azeotropic mixture of 48.8 percent R-22 and 51.2 percent R-115. Azeotropic refrigerants are liquid mixtures of refrigerants that exhibit a constant maximum and minimum boiling point. These mixtures act as a single refrigerant. R-502 is noncorrosive, nonflammable, practically nontoxic, and has a boiling point of -50°F at atmospheric pressure. This refrigerant can only be used with reciprocating compressors. It is most often used in refrigeration applications for commercial frozen food equipment, such as frozen food walk-in refrigerators, frozen food display cases, and frozen food processing plants. The cylinder color code for R-502 is orchid.

R-134a TETRAFLUOROETHANE (CH_2FCF_3)

R-134a, tetrafluoroethane, is very similar to R-12, the major difference is that R-134a has no harmful influence on the ozone layer of the earth's atmosphere and is a replacement for R-12 applications. Noncorrosive, nonflammable, and nontoxic, it has a boiling point of -15°F at atmospheric pressure. Used for medium-temperature applications, such as air conditioning and commercial refrigeration, this refrigerant is now used in automobile air-conditioners. The cylinder color code for R-134a is light (sky) blue.

ADDITIONAL REFRIGERANTS

In addition to the previously mentioned refrigerants, other less common refrigerants are used in a variety of applications.

R-717 Ammonia (NH_3)

Ammonia, R-717, is commonly used in industrial systems. It has a boiling point of -28°F at atmospheric pressure. This property makes it possible to have refrigeration at temperatures considerably below zero without using pressure below atmospheric in the evaporator. Normally it is a colorless gas, is slightly flammable, and, with proper portions of air, it can form an explosive mixture, but accidents are rare. The cylinder color code for R-717 is silver.

R-125 Pentafluoroethane ($CHCF_5$)

Pentafluoroethane, R-125, is a blend component used in low- and medium-temperature applications. With a boiling point of -55.3°F at atmospheric pressure, R-125 is nontoxic, nonflammable, and noncorrosive. R-125 is one replacement refrigerant for R-502.

All refrigerants have their own characteristics. It is extremely important to charge a system with the refrigerant specified. Use of an incorrect refrigerant can lead to reduced efficiency, mechanical problems, and dangerous conditions.

OZONE PROTECTION AND THE CLEAN AIR ACT

Several scientific studies conducted in the 1970s showed that chlorine was a leading cause of holes in the ozone. In 1987, 30 countries signed the Montreal Protocol, which mandated the phase out of the production, and eventual use, of all harmful CFCs. In 1990, the most significant piece of legislation affecting the air conditioning and refrigeration industry, the Clean Air Act, was passed. Regulated by the Environmental Protection Agency (EPA), Title VI of the Clean Air Act states fully halogenated refrigerants (CFCs) will be phased out. It also calls for the phase out of HCFCs by the year 2030. Both of these types of refrigerants adversely affect the atmosphere, and as of July 1992, it is illegal to discharge refrigerant to the atmosphere. The production of R-12 was discontinued in December 1995, and the production of R-11, R-113, R-114, and R-115 is scheduled to be discontinued by

January 2000. Depending on the rate of depletion of the ozone layer, these timetables could be accelerated.

As a result of the Clean Air Act of 1990, there has been a determined effort by manufacturers to develop alternative refrigerants to replace those to be discontinued. CFCs, R-11, and R-12, primarily used in chillers, residential, and automotive refrigeration, can be substituted with HCFC R-123 and HFC R-134a. Future replacements include HCFC R-124 in place of CFC, R-114, in marine chillers, and HFC R-125, in place of CFC R-502, used in stores and supermarkets.

These replacement refrigerants have slightly different chemical and physical properties; thus they cannot just be "dropped" into a system designed to use CFCs. Loss of efficiency and improper operation could be the result. When changing the refrigerant in an existing system, parts of the system specifically designed to operate with a CFC refrigerant may need to be replaced or retrofitted to accommodate the new refrigerant.

Q13. What are CFCs and HCFCs?

Q14. What can happen if improper refrigerant is used in a refrigeration system?

Q15. What types of refrigerants are to be phased out by the Clean Air Act in 2030?

Q16. What refrigerant has been developed to replace R-12?

REFRIGERANT SAFETY

Learning Objective: Recall the safety requirements for handling and storage of refrigerants and refrigerant cylinders.

Safety is always paramount and this is especially true when you are working with refrigerants. Major safety concerns are discussed in this section.

PERSONAL PROTECTION

Since R-12, R-22, and R-502 are nontoxic, you will not have to wear a gas mask; however, you must protect your eyes by wearing splashproof goggles to guard against liquid refrigerant freezing the moisture of your eyes. When liquid R-12, R-22, and R-502 contact the eyes, get the injured person to the medical officer at once. Avoid rubbing or irritating the eyes. Give the following first aid immediately:

- Drop sterile mineral oil into the eyes and irrigate them.
- Wash the eyes when irrigation continues with a weak boric acid solution or a sterile salt solution not to exceed 2 percent salt.

Should the refrigerant contact the skin, flush the affected area repeatedly with water. Strip refrigerant-saturated clothing from the body, wash the skin with water, and take the patient immediately to the dispensary. Should a person be overcome in a space which lacks oxygen due to a high concentration of refrigerant, treat the victim as a person who has experienced suffocation; render assistance through artificial respiration.

HANDLING AND STORAGE OF REFRIGERANT CYLINDERS

Handling and storage of refrigerant cylinders are similar to handling and storage of any other type of compressed gas cylinders. When handling and storing cylinders, keep the following rules in mind:

- Open valves slowly; never use any tools except those approved by the manufacturer.
- Keep the cylinder cap on the cylinder unless the cylinder is in use.
- When refrigerant is discharged from a cylinder, immediately weigh the cylinder.
- Record the weight of the refrigerant remaining in the cylinder.
- Ensure only regulators and pressure gauges designed for the particular refrigerant in the cylinder are used.
- Do use different refrigerants in the same regulator or gauges.
- Never drop cylinders or permit them to strike each other violently.
- Never use a lifting magnet or a sling. A crane may be used when a safe cradle is provided to hold the cylinders.
- Never use cylinders for any other purpose than to carry refrigerants.
- Never tamper with safety devices in the cylinder valves.
- Never force connections that do not fit. Ensure the cylinder valve outlet threads are the same as what is being connected to it.

- Never attempt to alter or repair cylinders or valves.
- Cylinders stored in the open must be protected from extremes of weather and direct sunlight. A cylinder should never be exposed to temperature above 120°F.
- Store full and empty cylinders apart to avoid confusion.
- Never store cylinders near elevators or gangways.
- Never store cylinders near highly flammable substances.
- Never expose cylinders to continuous dampness, salt water, or spray.

Q17. Goggles are not required when working with refrigerants. True/False

Q18. How often should you weigh a refrigerant cylinder?

Q19. Why are full and empty refrigerant cylinders stored separately?

REFRIGERATION EQUIPMENT

Learning Objective: Understand and recognize the basic types of commercial and domestic refrigeration equipment.

Refrigeration equipment can be classified as either self-contained or remote units. Self-contained equipment houses both the insulated storage compartments (refrigerated), in which the evaporator is located, and an uninsulated compartment (nonrefrigerated), in which the condensing unit is located, in the same cabinet. This type of equipment can be designed with a hermetically sealed, semisealed, or an open condensing unit. These units are completely assembled and charged at the factory and come ready for use with little or no installation work. Self-contained refrigerating equipment includes such equipment as domestic refrigerators and freezers, water coolers, reach-in and walk-in refrigerators, small cold-storage plants, and ice plants.

Remote refrigerating equipment has the condensing unit installed in a remote location from the main unit. These types of units are used where the heat liberated from the condenser cannot enter the space where the unit is installed or space is limited for installation.

REACH-IN REFRIGERATORS

Reach-in refrigerators have a storage capacity of 15 cubic feet or greater. At Navy installations, they are used to store perishable foods in galleys and messes. Also, at Navy hospitals and medical clinics they are used to store biologicals, serums, and other medical

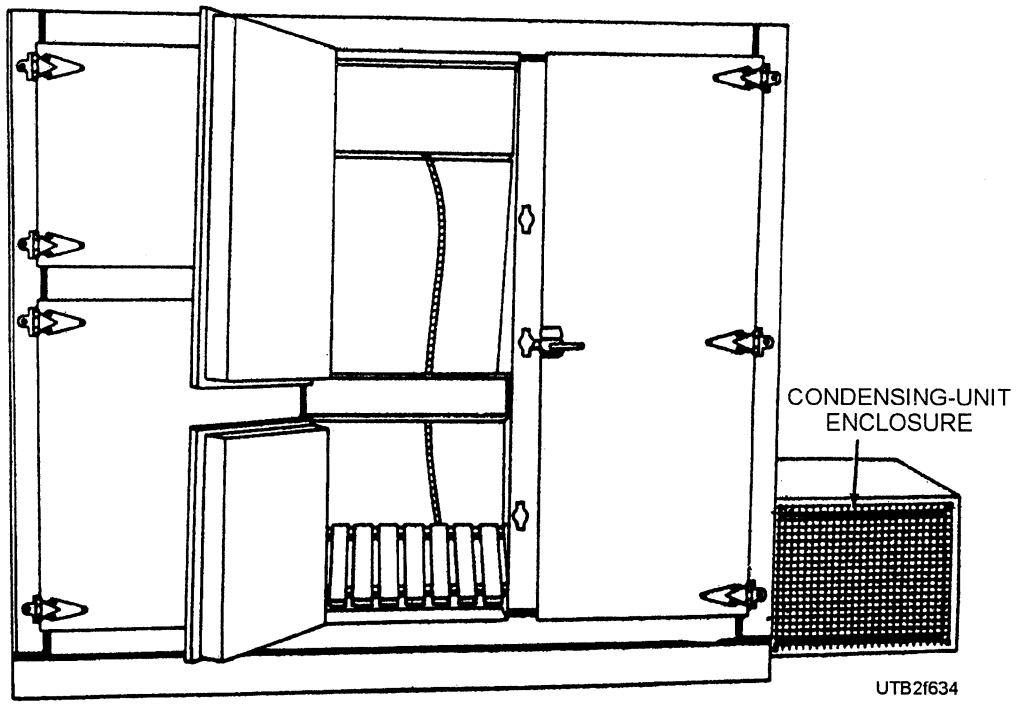


Figure 6-34.—A reach-in refrigerator with a remote condensing unit.

supplies requiring temperatures between 30°F and 45°F. Standard-size units most frequently used are those with storage capacities between 15 and 85 cubic feet. Figure 6-34 shows a typical reach-in refrigerator with a remote (detached) condensing unit.

Exterior finishes for reach-in refrigerators are usually of stainless steel, aluminum, or vinyl, while the interior finishes are usually metal or plastic, and the refrigerator cabinet is insulated with board or batten type polystyrene or urethane. Reach-in refrigerators are normally self-contained, with an air-cooled condenser, but in larger refrigerators, with remote condensers, water-cooled condensers are sometimes used. A typical self-contained unit is shown in figure 6-35. The evaporator is mounted in the center of the upper portion of the food compartment. In operation, warm air is drawn by the fan into the upper part of the unit cooler, where it passes over the evaporator coils, is cooled, and then is discharged at the bottom of the cooler. The air then passes up through the interior and around the contents of the refrigerator. The cycle is completed when the air again enters the evaporator. The low-pressure control is set to operate the evaporator on a self-defrosting cycle, and temperature is thus control led. Another type of control system uses both temperature and low-pressure control or defrost on each cycle. The evaporator fan is wired for continuous operation within the cabinet.

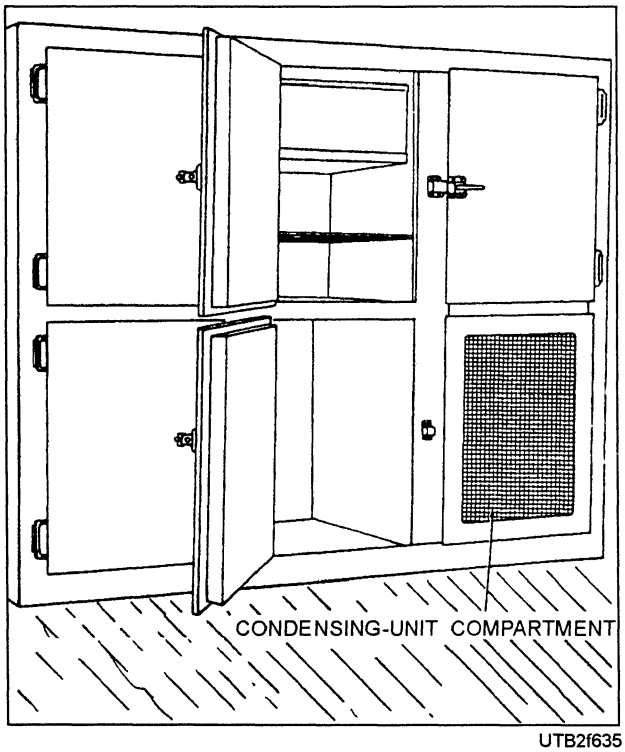


Figure 6-35.—A self-contained reach-in refrigerator.

Evaporators in reach-in refrigerators are generally the unit cooler type with dry coils (fig. 6-36). In smaller capacity refrigerators, ice-making coils, similar to those used in domestic refrigerators, are often used as well as straight gravity coils. R-12 and R-502 are normally used in these units.

WALK-IN REFRIGERATORS

Walk-in refrigerators are normally larger than reach-in types and are either built-in or prefabricated sectional walk-in units. They are made in two

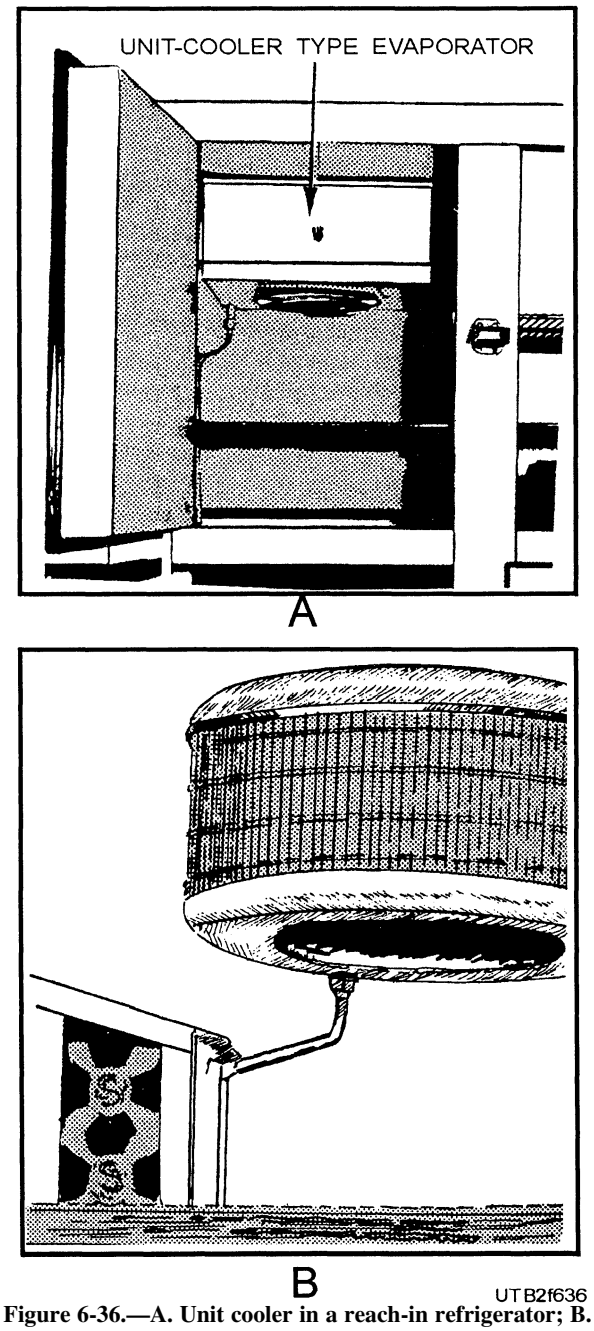


Figure 6-36.—A. Unit cooler in a reach-in refrigerator; B. Dome cooler in a reach-in refrigerator.

types—one for bulk storage of fresh meats, dairy products, vegetables, and fruits requiring a temperature from 35°F to 38°F and the other for the storage of frozen food at temperatures of 10°F or below. The 35°F to 38°F refrigerators are built and shipped in sections and assembled at the location they are installed. They can be taken apart, moved, and reassembled in another area if needed. Standard-size coolers can be from 24 square feet up to 120 square feet in floor area. A walk-in refrigerator with reach-in doors is shown in figure 6-37.

The exterior and interiors of these units are normally galvanized steel or aluminum. Vinyl, porcelain, and stainless steel are also used. Most walk-in refrigerators use rigid polyurethane board, batten, or foamed insulation between the inner and outer walls. For storage temperatures between 35°F to 40°F, 3 to 4 inches of insulation is generally used. For low-temperature applications, 5 inches or more of insulation is used. These refrigerators are equipped with meat racks and hooks to store meat carcasses. Walk-in refrigerators also have a lighting system inside the refrigerator compartment. Most systems have the compressor and condenser outside the main structure and use either a wall-mounted forced-air or gravity-type evaporator that is separated from the main part of the cabinet interior by a vertical baffle.

The operation of the walk-in refrigerator is similar to that of the reach-in units. The evaporator must have sufficient capacity (Btu per hour) to handle the heat load from infiltration and product load.

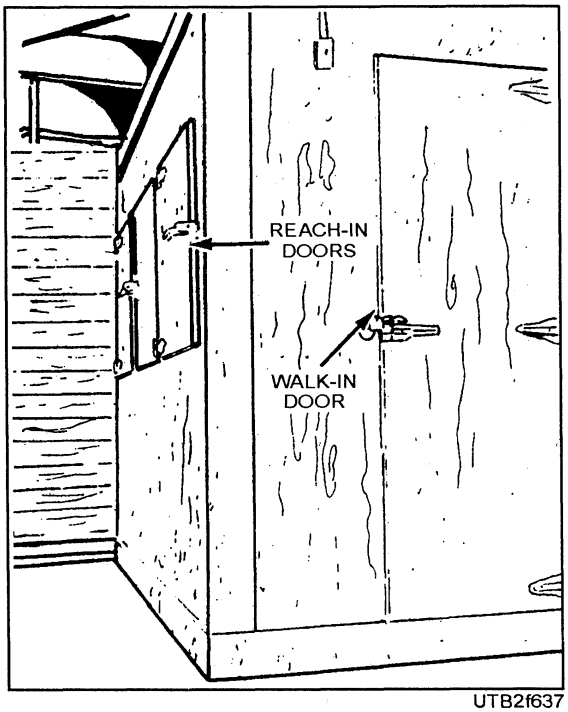


Figure 6-37.—A walk-in refrigerator with reach-in doors.

DOMESTIC REFRIGERATORS

Domestic refrigerators are used in most facilities on a Navy installation. Most domestic refrigerators are of two types—either a single door fresh food refrigerator or a two-door refrigerator-freezer combination, with the freezer compartment on the top portion of the cabinet, or a vertically split cabinet (side-by-side), with the freezer compartment on the left side of the cabinet. They are completely self-contained units and are easy to install. Most refrigerators use R-22 refrigerant, normally maintaining temperatures of 0°F in the freezer compartment and about 35°F to 45°F in the refrigerator compartment. The Utilitiesman must be able to perform various duties in the maintenance and repair of domestic refrigerators, water coolers, and ice machines at Navy activities. This section provides information to aid you in handling some of the more common types of troubles. But let us remind you that the information given here is intended as a general guide and should, therefore, be used with the manufacturer's detailed instructions. For troubleshooting guidance, see table Y in appendix II at the back of this TRAMAN.

Single Door Fresh Food Refrigerator

A single door fresh food refrigerator (fig. 6-38) consists of an evaporator placed either across the top or in one of the upper corners of the cabinet. The

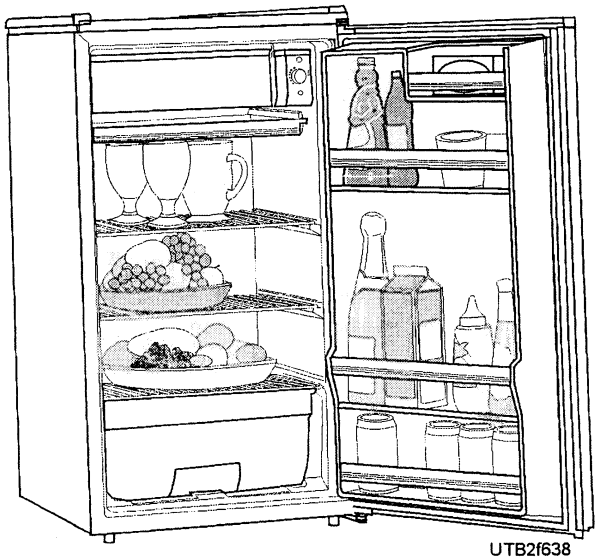


Figure 6-38.—Single door fresh food refrigerator.

condenser is on the back of the cabinet or in the bottom of the cabinet below the hermetic compressor. During operation, the cold air from the evaporator flows by natural circulation through the refrigerated space. The shelves inside the cabinet are constructed so air can circulate freely past the ends and sides, eliminating the need for a fan. This refrigerator has a manual defrost, which requires that the refrigerator be turned off periodically (usually overnight) to enable the buildup of frost on the evaporator to melt. Both the outside and inside finish is usually baked-on enamel. Porcelain enamel is found on steel cabinet liners. The interior of the unit contains the shelves, lights, thermostats, and temperature controls.

Two-Door Refrigerator-Freezer Combination

The two-door refrigerator-freezer combination is the most popular type of refrigerator. It is similar to the fresh food refrigerators in construction and the location of components except it sometimes has an evaporator for both the freezer compartment and the refrigerator compartment. Also, if it is a frost-free unit, the evaporators are on the outside of the cabinet. Because of the two separate compartments (refrigerator-freezer) and the larger capacity, these types of refrigerators use forced air (fans) to circulate the air through the inside of both compartments. The two-door refrigerator also has one of the following three types of evaporator defrost systems: manual defrost, automatic defrost, or frost-free.

There are two types of automatic defrosting: the hot gas system or the electric heater system. The hot gas system, through the use of solenoid valves, uses the heat in the vapor from the compressor discharge line and the condenser to defrost the evaporator. The other system uses electric heaters to melt the ice on the evaporator surface.

A frost-free refrigerator-freezer (fig. 6-39) has the evaporator located outside the refrigerated compartment. On the running part of the cycle, air is drawn over the evaporator and is forced into the freezer and refrigerator compartments by a fan. On the off part of the cycle, the evaporators automatically defrost.

Refrigerator-freezer cabinets are made of pressed steel with a vinyl or plastic lining on the interior wall surfaces and a lacquer exterior finish. Most domestic refrigerators have urethane foam or fiber glass insulation in the cabinet walls. The side-by-side refrigerator-freezer arrangement has a number of features not found in other refrigerators. In addition to the automatic icemaker in the freezer compartment, it has an option for a cold water dispenser, a cube or crushed ice dispenser, and a liquid dispenser built into the door.

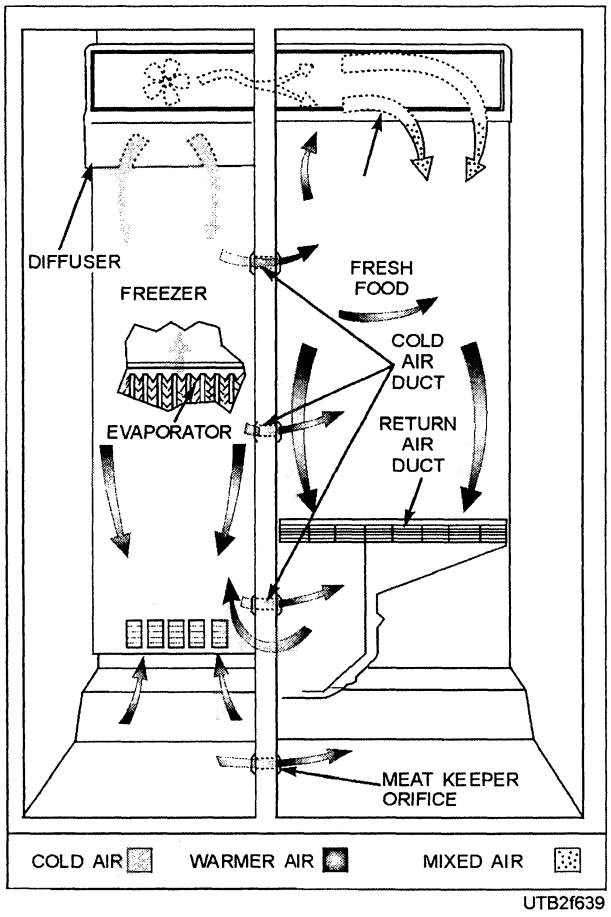


Figure 6-39.—Frost-free refrigerator airflow diagram.

WATER COOLERS AND ICE MACHINES

Water coolers provide water for drinking at a temperature under 50°F. Two types of water coolers are instantaneous and storage. The instantaneous type only cools water when it is being drawn; the storage type maintains a reservoir of cooled water. One instantaneous method used places coils in a flooded evaporator through which the water flows. A second instantaneous method uses double coils with water flowing through the inner coil with refrigerant flowing in the space between the inner coil and the outer coil. A third instantaneous method is to coil the tubing in a water storage tank. This allows refrigerant to flow through it (fig. 6-40).

Water coolers are of two basic designs—wall mounted or floor mounted. Both types are the same in construction and operation; the only difference is in the

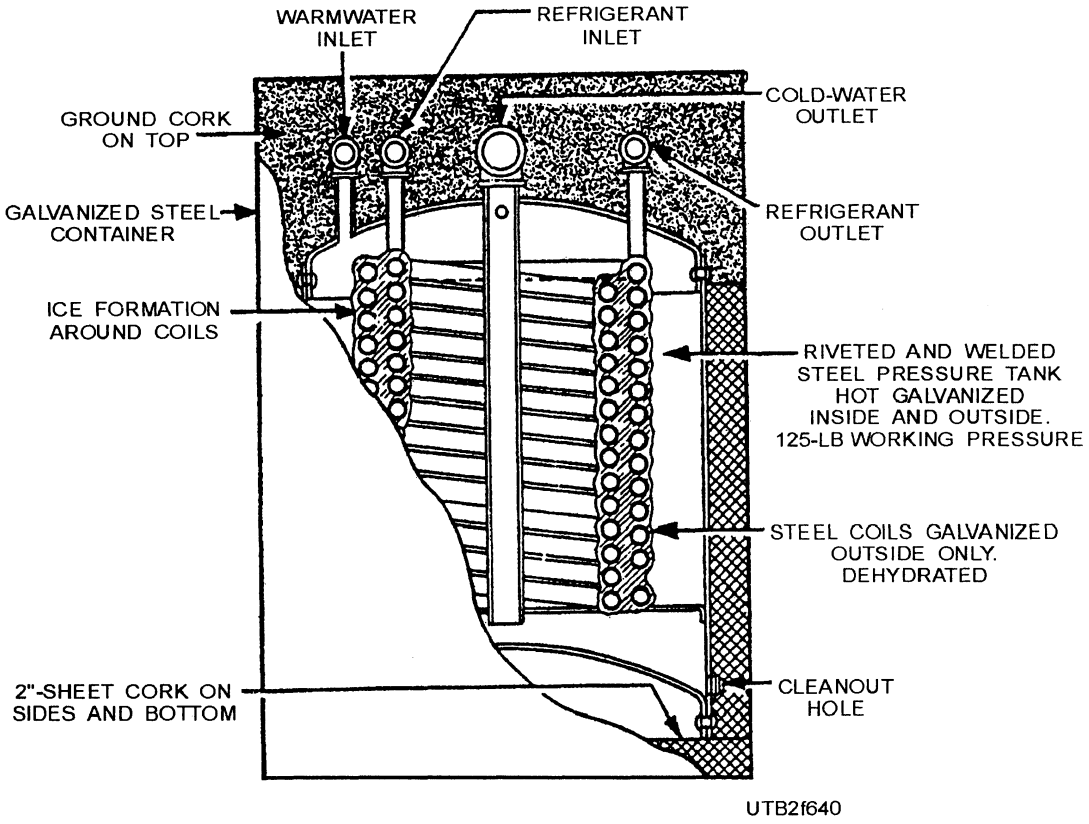


Figure 6-40.—Storage type of water cooler.

method of installation. Water cooler cabinets have a sheet metal housing attached to a steel framework. The condenser and hermetic compressor are located in the housing base, and the evaporator is located in the cabinet depending on its type of evaporator, but normally under the drain basin. Most water coolers use a heat exchanger or precooler, which precools the fresh water line to the evaporator, reducing cooling requirements for the evaporator. A thermostat, which is manually set and adjusted, is located in the cooler housing close to the evaporator.

Automatic ice machines, similar to the units shown in figures 6-41 and 6-42, are often used in galleys, barracks, gymnasiums, and other public areas. Ice machines are self-contained, automatic machines, ranging from a small unit producing 50 pounds of ice per day to a commercial unit producing 2,400 pounds of ice per day. The primary difference in the design of these machines is the evaporator. They automatically control water feed to the evaporator, freeze the water in an ice cube mold, heat the mold and empty the ice into a storage bin, and shut down when the storage bin is full. Floats and solenoids control water flow, and switches operate the storing action when ice is made. Electrical heating elements, hot water, hot gas defrosting, or mechanical devices remove the ice from the freezing surfaces depending on the unit. Figures 6-43 and 6-44 show the freezing and defrost cycle of a typical ice cube machine. In recent years, many companies have begun to manufacture their units to use HFC R-404a refrigerant instead of HCFC R-22.

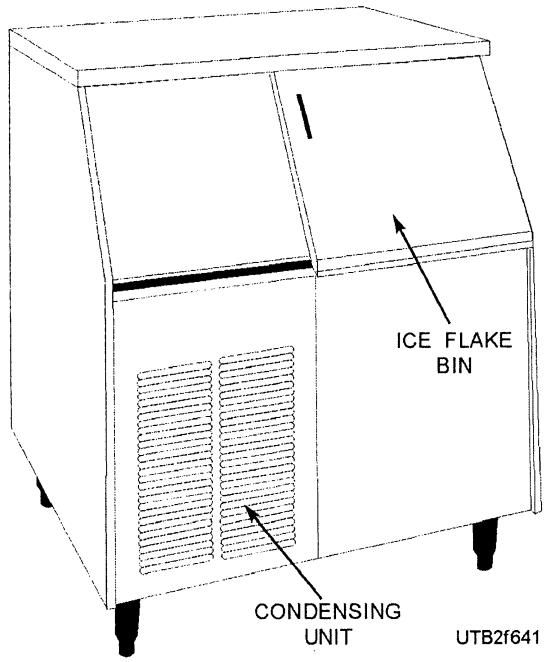
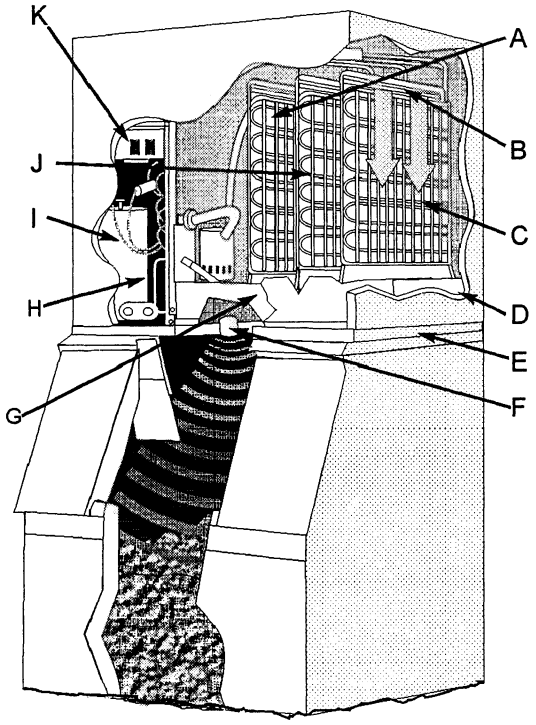


Figure 6-41.—Flake or chipped-ice machine.



A. Modular evaporator plate
B. Water distribution tubes
C. Evaporator plate
D. Insulated cabinet
E. Base
F. Sonar bin control
G. Frontal access for service
H. Suction line accumulator
I. Compressor - R-22 refrigeran
J. Water control
K. Adjustable bin control

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Figure 6-42.—A cutaway view of an automatic ice machine.

Q20. What design factor makes remote refrigeration equipment different from self-contained equipment?

Q21. Reach-in refrigerators are operated at a temperature that falls within what range, in degrees Fahrenheit?

Q22. Reach-in refrigeration units are equipped with what type of evaporator?

Q23. Why are walk-in refrigerators manufactured and constructed in sections?

Q24. Domestic refrigerators come in what two design configurations?

Q25. What are the two types of automatic defrosting in the two-door refrigerator-freezer combination unit?

Q26. What component of a water cooler precools the fresh water line to the evaporator?

Q27. What design factor is the primary difference in the different types of ice machines?

INSTALLATION OF REFRIGERATION EQUIPMENT

Learning Objective: Recall refrigeration requirements and the types of installation for refrigeration equipment.

Utilitiesman are often tasked to installation refrigeration systems. Therefore, it is important for you to understand the basic requirements applicable to the installation of the various types of the equipment.

When installing a refrigeration or air-conditioning plant, you must not allow dirt, scale, sand, or moisture to enter any part of the refrigerant system. Since air contains moisture, its entrance into the circuit should be controlled as much as possible during installation. Most maintenance problems come from careless erection and installation. All openings to the refrigerant circuit—piping, controls, compressor, condensers, and so on—must be adequately sealed when work on them is not in progress. The R-12 refrigerant is a powerful solvent that readily dissolves foreign matter and moisture that may have entered the system during installation. This material is soon carried to the operating valves and the compressor. It becomes a distinct menace to bearings, pistons, cylinder walls, valves, and the lubricating oil. Scoring of moving parts frequently occurs when the equipment is first operated, starting with minor scratches that increase until the operation of the compressor is seriously affected.

Under existing specifications, copper tubing and copper piping needed for installation should be cleaned, deoxidized, and sealed. When there is a question about cleanliness of tubing or piping to be used, each length of pipe should be thoroughly blown out. Use a strong blast of dry air when blowing out, and clean the tubing with a cloth swab attached to copper wire pulled back and forth in the tube until it is clean and shiny. Then the ends of the tubes should be sealed until connected to the rest of the system.

EFFECTS OF MOISTURE

As little as 15 to 20 parts of moisture per million parts of R-12 can cause severe corrosion in a system. The corrosion results from hydrochloric acid formed by R-12 in contact with water. A chemical reaction takes place between the acid and the iron and copper in

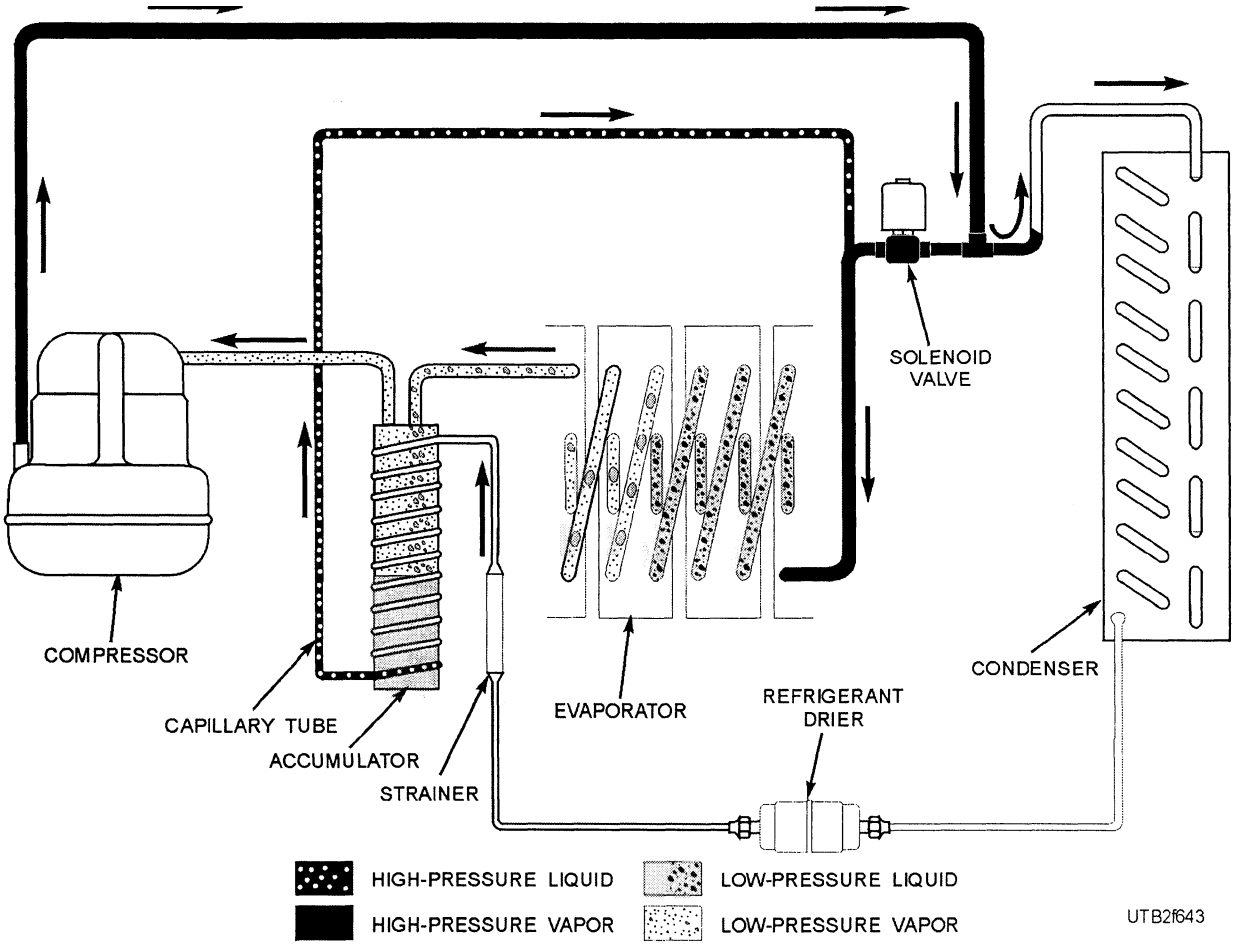


Figure 6-43.—An ice cube machine refrigeration cycle during the freezing process.

the system to form corrosion products. A strong acid combined with high discharge and compressor temperature can cause decomposition of lubricating oil and produce a sludge of breakdown products. Either the corrosion or the oil breakdown products can plug valves, strainers, and dryers and cause a serious casualty.

NOTE: The formation of ice from a minute quantity of moisture in expansion valves and capillary tubes can occur when operating below 32°F.

LOCATION OF EQUIPMENT

Adequate space should always be left around major portions of equipment for servicing purposes; otherwise, the equipment must be moved after installation so serviceable parts are accessible (figs. 6-45 and 6-46). Compressors require overhead clearance for removal of the head, discharge valve plate, and pistons with side clearance to permit removal of the flywheel and crankshaft where necessary. Water-cooled condensers require a free area equal to the length of the condenser at one end to provide room for cleaning tubes, installing new tubes, or removal of the condenser tube assembly. Space is needed for servicing valves and accessory equipment. Service openings and inspection panels on unitary equipment require generally at least 18 inches of clearance for removal of the panel. Air-cooled condensing units should be placed in a location that permits unrestricted flow of air for condensing, whether the condenser is in a unitary piece of equipment or separate. Inadequate ventilation around air-cooled condensers can cause overloading of the motor and loss of capacity.

REFRIGERANT PIPING

Certain general precautions for the installation of refrigerant lines should be followed. When the receiver is above the cooling coil, the liquid line should be turned up before going down to the evaporator. This inverted loop prevents siphoning of the liquid from the receiver over into the cooling coil through an open or leaking expansion valve during compressor

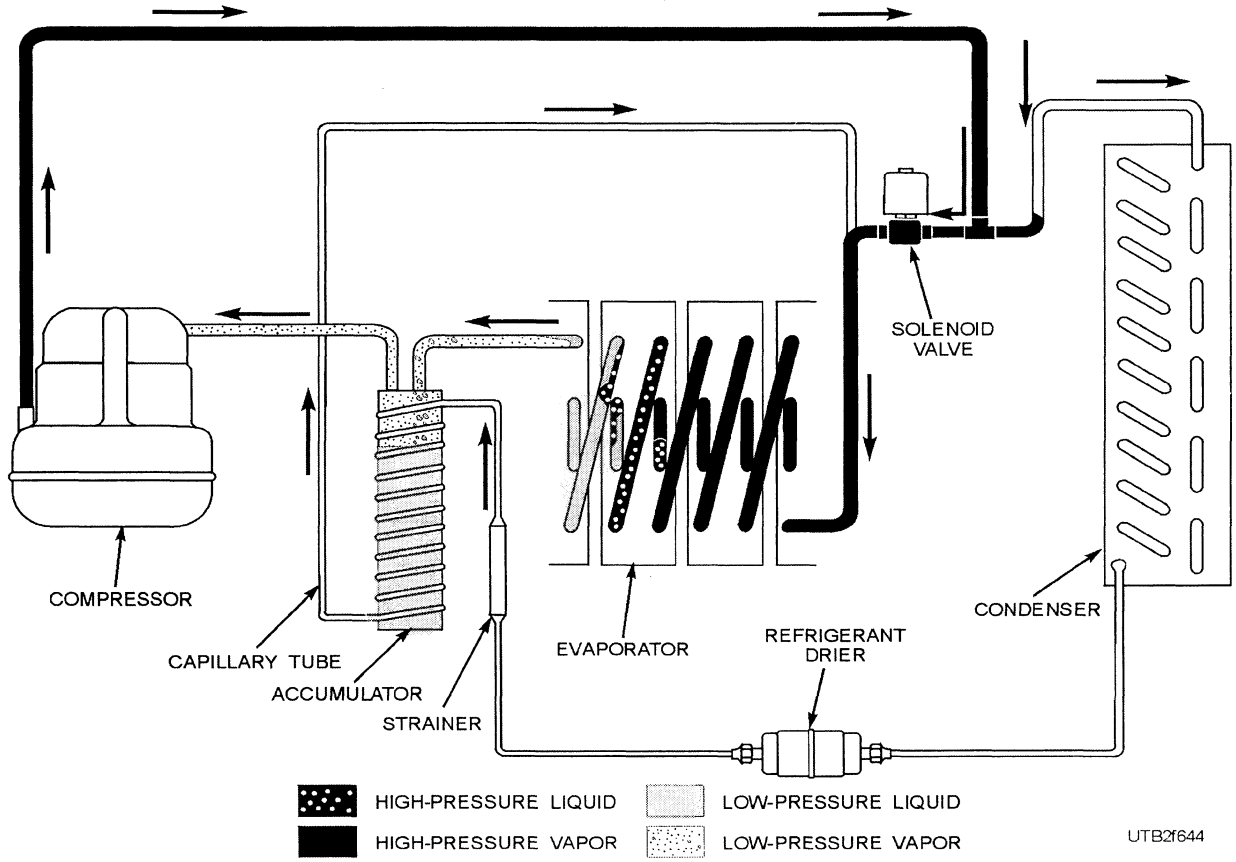


Figure 6-44.—The defrost cycle of an ice cube machine.

shutdown periods. If siphoning starts, the liquid refrigerant flashes into a gas at the top of the loop, breaking the continuity of the liquid volume and stopping the siphoning action. Where the cooling coils and compressors are on the same level, both the suction and liquid lines should be run to the overhead and then down to the condensing unit, pitching the suction line toward the compressor to ease oil return. On close-coupled installations, running both lines up to the overhead helps to eliminate vibration strains as well as provide the necessary trap at the cooling coil.

Prepare pipe and fittings with care, particularly when cutting copper tubing or pipe to prevent filings or cuttings from entering the pipe. The small particles of copper should be completely removed since the finely divided copper may pass through the suction strainer. The tube should be cut square, and all burrs and dents should be removed to prevent internal restrictions and to permit proper fit with the companion fittings. If a hacksaw is used to cut, a fine-toothed blade should be used, preferably 32 teeth per inch. The use of a hacksaw should be avoided whenever possible. When making silver-solder joints, brighten up the ends of the tubing or pipe with a wire brush or crocus cloth to make a good bond. Do not use sandpaper, emery cloth, or steel wool for this cleansing, as this material may enter the system and cause trouble.

Acid should never be used for soldering, nor should flux be used if its residue forms an acid. Use flux sparingly so no residue will enter inside the system and eventually be washed back to the compressor crankcase. If tubing and fittings are improperly fitted because of distortion, too much flux, solder, and brazing material may enter the system.

The temperature required to solder or braze pipe joints causes oxidation within the tubing. The oxidation eventually will be removed by the refrigerant flow after the system is in operation. The oxide breaks up into a fine powder to contaminate the lubricant in the compressor and to plug strainers and driers. To eliminate this possibility, provide a neutral atmosphere within the tube being soldered or brazed. Use gas-bled nitrogen through the tubing during soldering or brazing and for a sufficient time after the

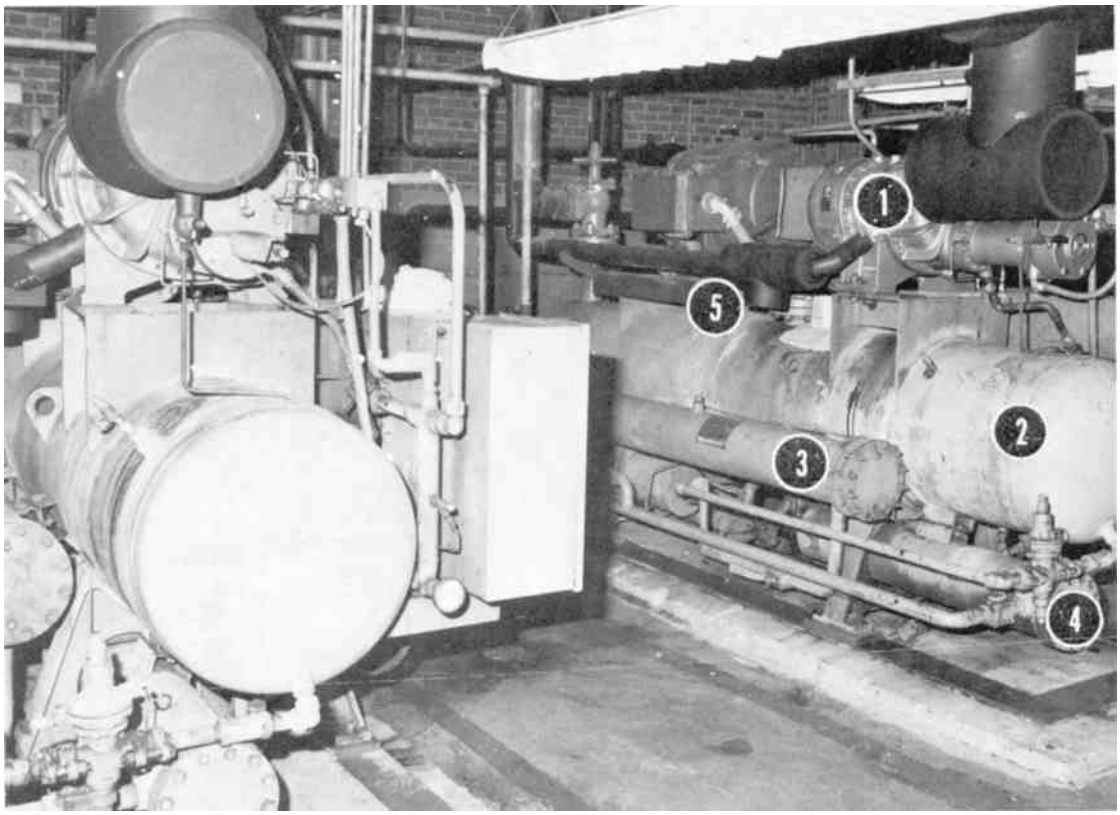


Figure 6-45.—A low-temperature screw or helix compressor system. (1) Compressor; (2) Oil separator and reservoir; (3) Oil coller; (4) Oil filters (5) Hot -gas discharge line.

bond is made until the heat of the copper has been reduced below the temperature of oxidation.

All joints should be silver-soldered and kept to a minimum to reduce leaks. Special copper tube fittings designed for refrigeration service should be used since these are manufactured with close tolerances to assure tight capillary joints in the brazing process.

SAE flare joints are generally not desired, but when necessary, care should be taken in making the joint. The flare must be of uniform thickness and should present a smooth, accurate surface, free from tool marks, splits, or scratches. The tubing must be cut square, provided with a full flare, and any burrs and saw filings removed. The flare seat of the fitting connector must be free from dents or scratches. The flare can best be made with a special swivel head flaring tool, available as a general stores item, which remains stationary and does not tear or scar the face of the flare in the tubing. Oil should not be used on the face of the flare, either in making up the flare or in securing it to the fitting, since the oil will eventually be dissolved by the refrigerant in the system and cause a leak through the displacement of the oil. The flare joint should always be tightened with two wrenches—one to turn the nut and the other to hold the connecting piece to avoid strain on the connection and cause a leak.

Where pipe or tubing has to be bent, bends should be made with special tools designed for this type of work. Do not use rosin, sand, or any other filler inside the tubing to make a bend. Threaded joints should be coated with a special refrigerant pipe dope. In an emergency, use a thread compound for making up a joint; remember R-12 and R-22 are hydrocarbons, which dissolve any compound containing oil. A compound containing an acid or one whose residual substance forms an acid should not be used. The use of

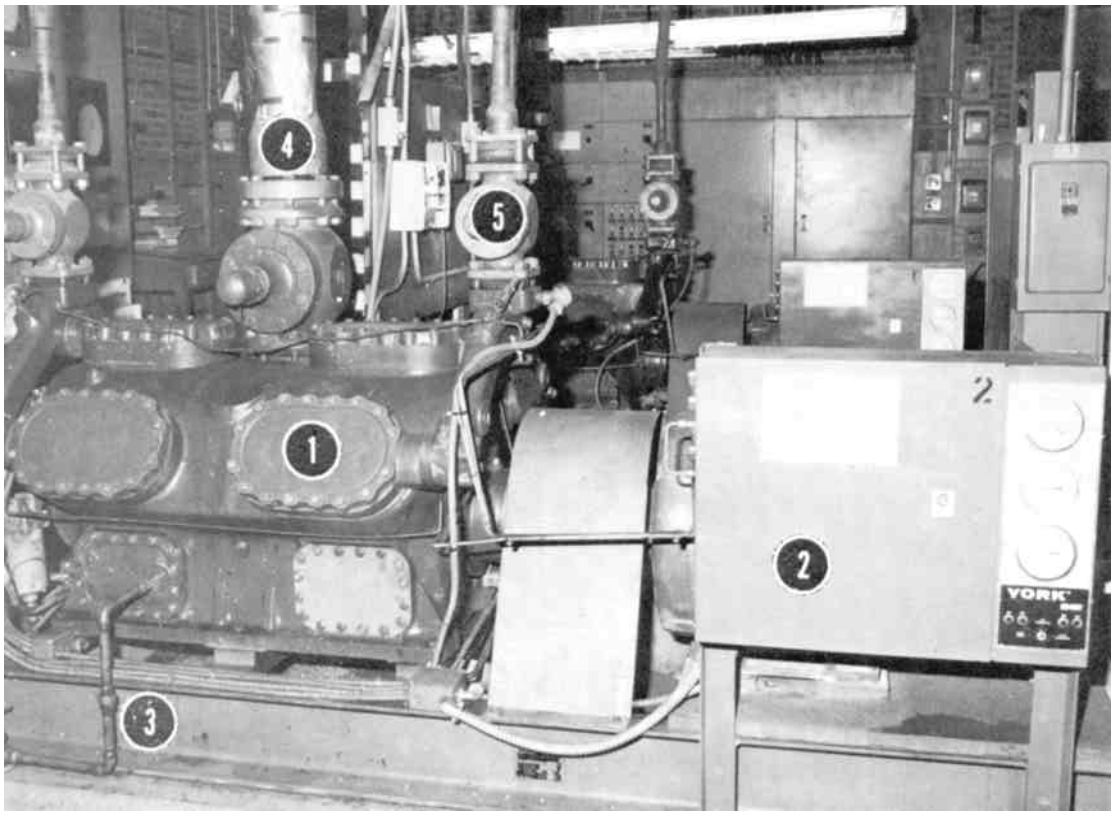


Figure 6-46.—A twelve-cylinder semihermetic reciprocating direct drive compressor. (1) Compressor; (2) control Panel; (3) Oil Return from Reservoir; (4) Suction Line; (5) Hot Gas Discharge Line.

a thick paste made of fresh lethargy and glycerin makes a satisfactory joint compound; however, the joint should be thoroughly cleaned with a solvent to eliminate oil or grease. Thread compounds should be applied to the male part of the thread after it has entered the female coupling one and one-half to two threads to prevent any excess compound from entering the system.

When securing, anchoring, or hanging the suction and liquid lines, be sure and allow enough flexibility between the compressor and the first set of hangers or points where the lines are secured to permit some degree of freedom. This flexibility relieves strain in the joints of these lines at the compressor due to compressor vibration.

MULTIPLE COMPRESSORS

Parallel operation of two or more reciprocating compressors should be avoided unless there are strong and valid reasons for not using a single compressor. In a situation where two compressors must be used, extreme care in sizing and arranging the piping system is essential.

An acceptable arrangement of two compressors and two condensers is shown in figure 6-47. An equalizer line connects the crankcase at the oil level of each machine. Therefore, the oil in both machines will be at a common level. If machines of different sizes are used, the height of the bases beneath the machines must be adjusted so the normal oil level of both machines is at the same elevation; otherwise, the oil accumulates in the lower machine.

This arrangement is called a single-pipe crankcase equalizer. It can be used only on those machines with a single equalizer tapping entering the crankcase in such a position that the bottom of the tapping just touches the normal oil level.

Another method of piping to maintain proper oil level in two or more compressors uses two equalizer lines between the crankcase—one above the normal oil

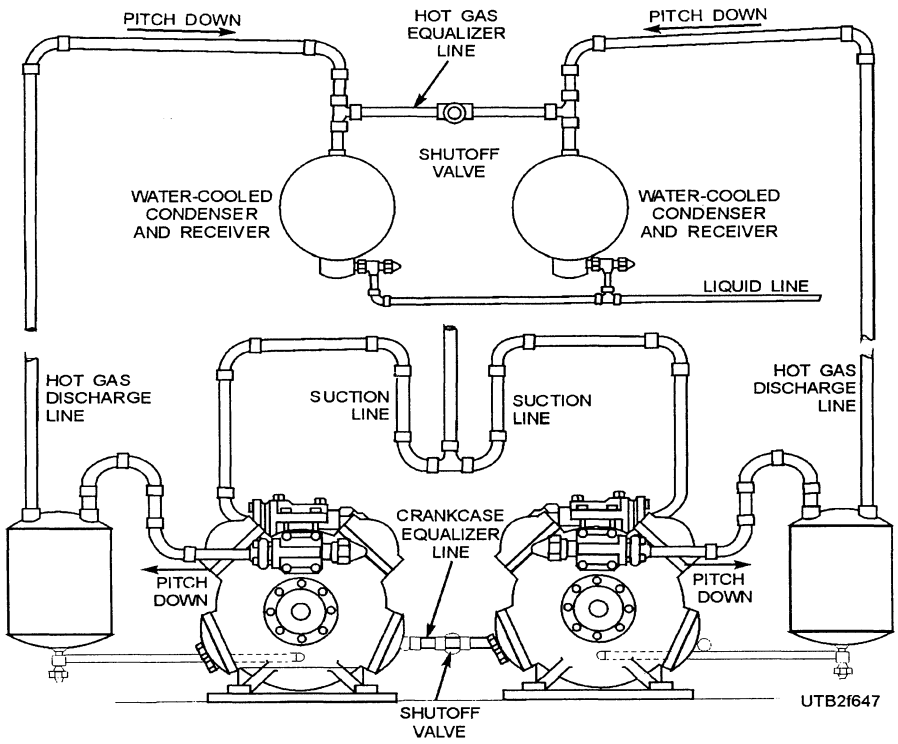


Figure 6-47.—Parallel compressors with separate condensers.

level and one below. The double equalizer system must be used on compressors having two equalizer tappings. A single equalizer line on machines having two equalizer tappings should never be used.

The lower oil equalizer line must not rise above the oil level in the crankcase and should be as level as possible. This is important since the oil builds up in one crankcase if the line rises. The upper equalizer line is a gas line intended to prevent any difference in crankcase. pressure that would influence the gravity flow of oil in the lower equalizer line or the level of oil in the crankcase. This upper line must not dip, and care should be taken to eliminate pockets in which oil could accumulate to block the flow of gas. Valves in the crankcase equalizer lines are installed with the stems horizontal, so no false oil levels are created by oil rising over the valve seat and minimize flow resistance.

It is poor practice to skimp on piping when making up these equalizer lines. Oversize piping is preferred to undersize piping. General practice indicates the use of oil equalizer lines equal to the full size of the tapping in the compressor.

The discharge lines from the compressors are also equalized before they enter the condensers. This, in effect, causes the individual condensers to function as a single unit. This is the most critical point in the piping system. It is here that pressure drop is extremely important—a pressure drop of 0.5 psi being equal to a 1.0 foot head of liquid. Excessive pressure drop in the equalizer line may rob one condenser of all liquid by forcing it into the other condenser. One of the results may be the pumping of large quantities of hot refrigerant vapor into the liquid lines from the condenser of the operating compressor. This could reduce the capacity of the system materially. For this reason, the equalizer line should be just as short and level as possible. A long equalizer line introduces an unequal pressure in condensers if one of the compressors is not operating. The refrigerant then accumulates in the condenser of the nonoperating compressor. The equalizer line should also be generously sized and should be equal to or larger than the discharge 1 ine of the largest compressor being used.

If the condensers are more than 10 feet above the compressor, U-traps or oil separators should be installed in the horizontal discharge line where it comes from each compressor.

The traps or separators prevent the oil from draining back to the compressor head on shutdown. Should a single compressor or multiple compressors with capacity modulation be used in an instance of this kind, another solution may be dictated. When a compressor unloads, less refrigerant gas is pumped through the system. The velocity of flow in the refrigerant lines drops off as the flow decreases. It is necessary to maintain gas velocities above some minimum value to keep the entrained oil moving with the refrigerant. The problem becomes particularly acute in refrigerant gas lines when the flow is upward. It does not matter whether the line is on the suction or discharge side of the compressor; the velocity must not be allowed to drop too low under low refrigerant flow conditions. Knowing the minimum velocity, 1,000 feet per minute (fpm), for oil entrainment up a vertical riser and the minimum compressor capacity, the designer of the piping can overcome this problem using a double riser.

The smaller line in the double riser is designed for minimum velocity, at the minimum step, of compressor capacity. The larger line is sized to assure that the velocity in the two lines at full load is approximately the same as in the horizontal flow lines. A trap of minimum dimensions is formed at the bottom of the double-riser assembly, which collects oil at minimum load. Trapped oil then seals off the larger line so the entire flow is through the smaller line.

If an oil separator is used at the bottom of a discharge gas riser, the need for a double riser is eliminated. The oil separator will do as its name implies—separate the major part of the oil from the gas flowing to it and return the oil to the compressor crankcase. Since no oil separator is 100 percent effective, the use of an oil separator in the discharge line does not eliminate the need for double risers in the suction lines of the same system if there are vertical risers in the suction lines. When multiple compressors with individual condensers are used, the liquid lines from the condenser should join the common liquid line at a level well below the bottoms of the condensers. The low liquid line prevents gas from an "empty" condenser from entering the line because of the seal formed by the liquid from other condensers.

NOTE: A common water-regulating valve should control the condenser water supply for a multiple system using individual condensers, so each condenser receives a proportional amount of the condenser water.

Frequently, when multiple compressors are installed, only one condenser is provided. Such installations are satisfactory only as long as all of the compressors are operating at the same suction pressure. However, several compressors may occasionally be installed which operate at different suction pressures—the pressures corresponding, of course, to the various temperatures needed for the different cooling loads. When this is the case, a separate condenser must be installed for each compressor or group of compressors operating at the same suction pressure. Each compressor, or group of compressors, operating at one suction pressure must have a complete piping system with an evaporator and condenser, separate from the remaining compressors operating at other suction pressures. Separate systems are required because the crankcase of compressors operating at different suction pressures cannot be interconnected. There is no way of equalizing the oil return to such compressors.

The suction connection to a multiple compressor system should be made through a suction manifold, as shown in figure 6-47. The suction manifold should be as short as possible and should be taken off in such a manner that any oil accumulating in the header returns equally to each machine.

Evaporative condensers can be constructed with two or more condensers built into one spray housing. This is accomplished quite simply by providing a separate condensing coil for each compressor, or a group of compressors, operating at the same suction pressure. All of the condensing coils are built into one spray housing; this provides two or more separate condensers in one condenser housing.

Q28. What type of acid is formed when R-12 is mixed with water?

Q29. Air-cooled condensers should be located in areas that provide plenty of clear space around them for what reason?

Q30. On close-coupled systems, running refrigerant lines up to the overhead helps eliminate what problem?

Q31. To eliminate possible oxidation from occurring while conducting soldering or brazing operations, you should ensure what condition exists within the tube or pipe?

Q32. U-traps or oil separators should be installed on multiple compressor systems when the condensers are how many feet above the compressor?

Q33. If an oil separator is used at the bottom of a discharge riser on multiple compressor applications, the need for a double riser is eliminated. True/False.

MAINTENANCE, SERVICE, AND REPAIR OF REFRIGERATION EQUIPMENT

Learning Objective: Understand different types of maintenance equipment and methods for basic maintenance, service, and repair of refrigeration systems and components.

As a Utilitiesman, you must be able to maintain, service, and repair refrigeration equipment. This phase of our discussion provides information on different jobs that you may be assigned. When information here varies from that in the latest federal or military specifications, the specifications apply. You will find the "Troubleshooting Checklist–Refrigeration Systems," which is presented in table V, appendix II, at the end of this book, helpful in locating and correcting troubles. It is not intended to be all encompassing. Manufacturers also provide instruction manuals to aid you in maintaining and servicing their equipment.

SERVICING EQUIPMENT

Repair and service work on a refrigeration system consists mainly of containing refrigerant and measuring pressures accurately. One piece of equipment is the refrigerant gauge manifold set (fig. 6-48). It consists of a 0-500 psig gauge for measuring pressure at the compressor high side, a compound gauge (0-250 psig and 0 to -30 inches of mercury) to measure the low or suction side, and valves to control admission of the refrigerant to the refrigeration system. It also has the connections and lines required to connect the test set to the system. Depending on test and service requirements, the gauge set can be connected to the low side, the high side, a source of vacuum, or a refrigerant cylinder. A swiveling hanger allows the test set to be hung easily, and the three additional blank connections allow for securing the open ends of the three lines when the gauge set is not in use. There is always a path from the low-side and high-side input to the low-side and high-side gauge (fig. 6-49).

Another important piece of equipment is the portable vacuum pump. The type listed in the Seabee

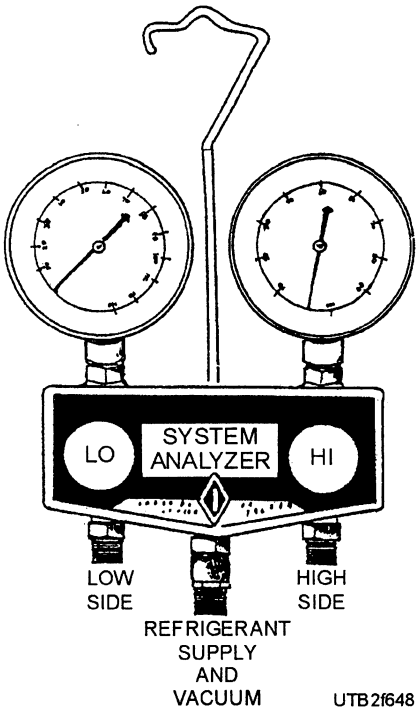


Figure 6-48.—Refrigerant gauge manifold set.

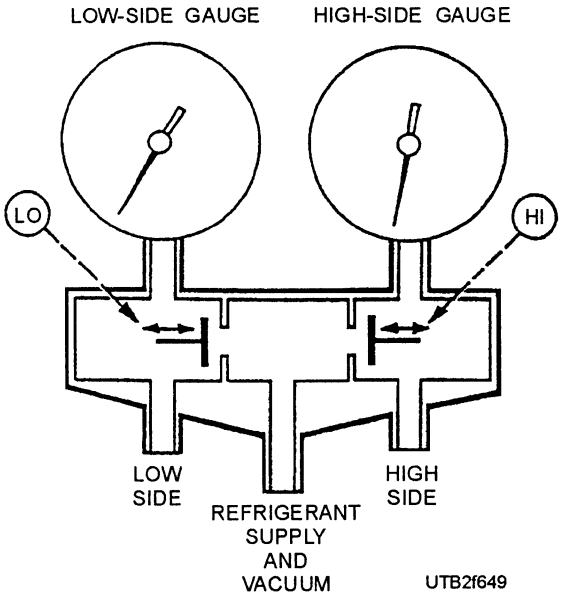


Figure 6-49.—Internal view of a refrigerant gauge manifold set.

Table of Allowance is a sealed unit consisting of a single-piston vacuum pump driven by an electric motor. A vacuum pump is the same as a compressor, except the valves are arranged so the suction valve is opened only when the suction developed by the downward stroke of the piston is greater than the vacuum already in the line. This vacuum pump can develop a vacuum close to -30 inches of mercury, which can be read on the gauge mounted on the unit

(fig. 6-50). The pump is used to reduce the pressure in a refrigeration system to below atmospheric pressure.

Various manufacturers manufacture hermetic refrigeration systems used by the Navy; therefore, the connectors and size of tubing vary. The Table of Allowance provides for a refrigeration service kit that contains several adapters, wrenches, and other materials to help connect different makes of systems to the refrigerant manifold gauge set and the vacuum pump lines. A table affixed to the lid of the storage container identifies the adapter you should use for a particular refrigeration unit.

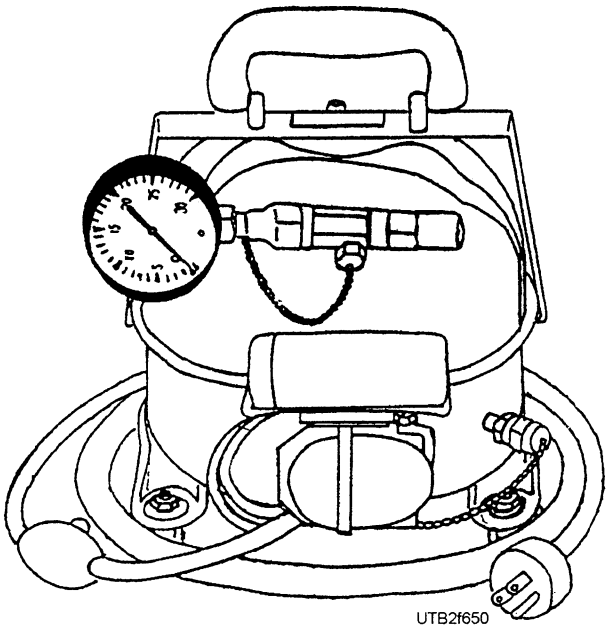


Figure 6-50.—Portable vacuum pump.

TRANSFERRING REFRIGERANTS

Refrigerants are shipped in compressed gas cylinders as a liquid under pressure. Liquids are usually removed from the shipping containers and transferred to a service cylinder (fig. 6-51).

Before attempting transfer of refrigerants from a container to a cylinder, precool the receiving cylinder until its pressure is lower than that of the storage container or cylinder. Precool by placing the cylinder in ice water or a refrigerated tank. You must also weigh the service cylinder, including cap, and compare it with the tare weight stamped or tagged on the cylinder. The amount of refrigerant that may be placed in a cylinder is 85 percent of the tare weight (the weight of a full cylinder and its cap minus the weight of the empty cylinder and its cap).

To transfer refrigerants, connect a flexible charging line on a 1/4-inch copper tube several feet long with a circular loop about 8 to 10 inches in diameter. Be sure to install a 1/4-inch refrigerant shutoff valve (fig. 6-51) in the charging line to the service cylinder. This valve should be inserted so no more than 3 inches of tubing is between the last fitting and the valve itself. This arrangement prevents the loss of refrigerant when the service drum is finally disconnected. The entire line must be cleared of air by leaving the flare nut on the service cylinder loose and cracking the storage cylinder valve. This arrangement allows refrigerant to flow through the tubing, clearing it. After clearing, tighten the flare nut and then open the valve on the service cylinder, the valve on the

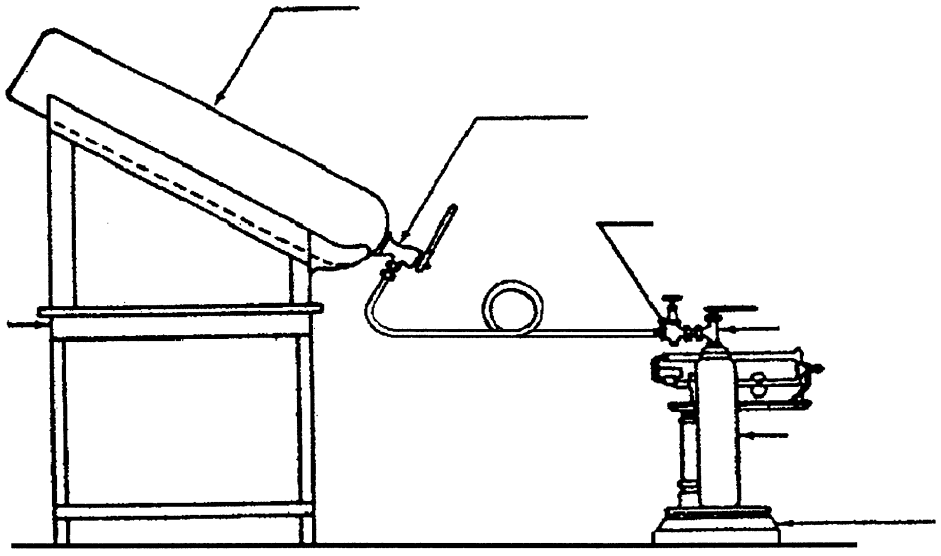


Figure 6-51.—Method of transferring refrigerants to service cylinders.

storage cylinder, and then the 1/4-inch valve in the refrigerant line. When the weight of the service cylinder shows a sufficient amount of refrigerant is in the serviced cylinder, close all valves tightly, and disconnect the charging line at the service cylinder.

CAUTION

To warm refrigerant containers or cylinders for more rapid discharge, use care to prevent a temperature above 120°F because the fusible plugs in the cylinder and valve have a melting point of about 157°F.

EVACUATING AND CHARGING A SYSTEM

One of your duties will be charging a system with refrigerant. If a system develops a leak, you must repair it first, then charge the system. Similarly, if a component of the system becomes faulty and must be replaced, some refrigerant will be lost and the system will require charging.

Evacuation

Before a system can be charged, all moisture and air must be eliminated from the components by drawing a vacuum on the system. To draw a vacuum on the system, proceed as follows:

1. Connect the portable vacuum pump to the vacuum fitting on the refrigerant manifold gauge set (fig. 6-48).
2. Connect the LO line (suction) to the suction service valve of the compressor, using appropriate connectors if required.
3. Turn the suction service valve to mid-position, so vacuum draws from the compressor crankcase and suction line back through the evaporator, expansion valve, and liquid line. When the receiver service valve, condenser service valve, and discharge service valve are open, the pump draws back through the receiver and condenser to the compressor.
4. Attach one end of a 1/4-inch copper tube to the vacuum pump discharge outlet (fig. 6-52). Allow the vacuum pump to draw a vacuum of at least 25 inches. Submerge the other end of the copper tubing under 2 or 3 inches of clean compressor oil contained in a bottle.

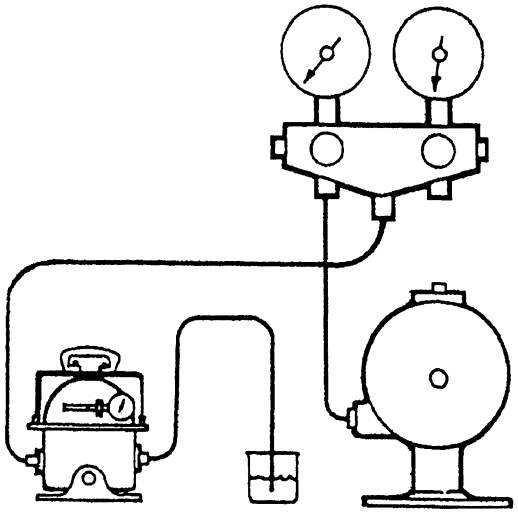


Figure 6-52.—Connections for drawing a vacuum.

5. Continue to operate the vacuum pump until there are no more bubbles of air and vapor in the oil, which indicates that a deep vacuum has been obtained.
6. Maintain the deep vacuum operation for at least 5 minutes, and then stop the vacuum pump. Leaking discharge valves of a vacuum pump cause oil to be sucked up into the copper discharge tube. Keep the vacuum pump off at least 15 minutes to allow air to enter the system through any leaks. Then start the vacuum pump. A leaky system causes bubbling of the oil in the bottle.
7. Examine and tighten any suspected joints in the line, including the line to the vacuum pump. Repeat the test.

Charging

In most small refrigerating systems, low-side charging (fig. 6-53) is generally recommended for adding refrigerant after repairs have been made. After the system has been cleaned and tested for leaks, the steps to charge the system are as follows:

1. Connect a line from a refrigerant cylinder to the bottom center connection on the refrigerant gauge manifold set. Be certain the refrigerant cylinder is in a vertical position, so only refrigerant in the form of gas, not liquid, can enter the system. Leave the connection loose and crack the valve on the cylinder. This fills

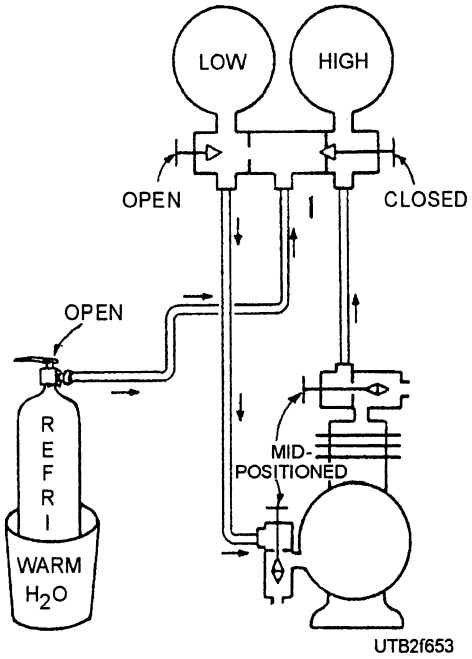


Figure 6-53.—Connections for low-side charging.

the line with gas and clears the air from the line. After clearing, tighten the connection.

2. Connect a line from the LOW (LO) valve (suction) on the gauge manifold set to the suction service valve of the compressor.

3. Start the compressor.

4. Open the valve on the cylinder and the LOW (LO) valve (suction) on the gauge manifold set.

5. Open the suction service valve on the compressor to permit the gas to enter the compressor where it will be compressed and fed to the high side. Add the refrigerant slowly and check the liquid level indicator regularly until the system is fully charged. It is easy to check the receiver refrigerant level in some makes of condensing units because the receiver has minimum and maximum liquid level indicator valves which show the height of the liquid level when opened. If a liquid line sight glass is used, the proper charge may be determined when there is no bubbling of refrigerant as it passes by the glass. The sight glass will appear empty.

Again, be certain the refrigerant cylinder is in the vertical position at all times; otherwise, the liquid refrigerant will enter the compressor and, liquid not being compressible, damage the piston or other parts of the compressor.

REFRIGERANT LEAKS

The best ti me to test joints and connections in a system is when there is enough pressure to increase the rate at which the refrigerant seeps from the leaking joint. There is usually enough pressure in the high-pressure side of the system; that is, in the condenser, receiver, and liquid line, including dehydrators, strainers, line valves, and solenoid valves. This is not necessarily true of the low-pressure side of the system, especially if it is a low-pressure installation, such as for frozen foods and ice cream, where pressures may run only slightly above zero on the gauge. When there is little pressure, increase the pressure in the low-pressure side of the system by bypassing the discharging pressure from the condenser to the low-pressure side through the service gauge manifold Small leaks cannot be found unless the pressure inside the system is at least 40 to 50 psi, regardless of the method used to test for leaks.

Halide Leak Detector

The use of a halide leak detector (fig. 6-54) is the most positive method of detecting leaks in a refrigerant system using halogen refrigerants (R-12, R-22, R-11, R-502, etc.). Such a detector consists essentially of a torch burner, a copper reactor plate, and a rubber exploring hose.

Detectors use acetylene gas, alcohol, or propane as a fuel. A pump supplies the pressure for a detector that uses alcohol. If a pump-pressure type of alcohol-burning detector is used, be sure that the air pumped into the fuel tank is dry.

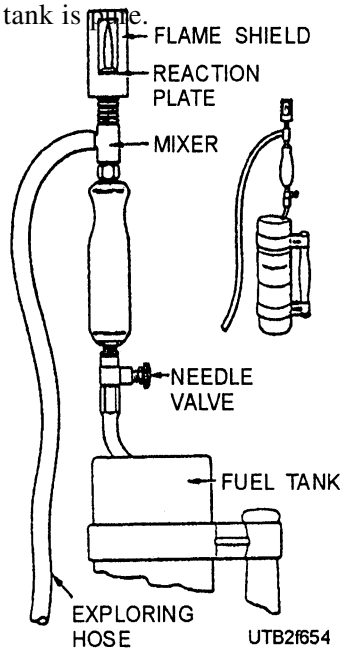


Figure 6-54.—Halide leak detector.

An atmosphere suspected of containing a halogen vapor is drawn through the rubber exploring hose into the torch burner of the detector. Here the air passes over the copper reactor plate, which is heated to incandescence. If there is a minute trace of a halogen refrigerant present, the color of the torch flame changes from blue (neutral) to green as the halogen refrigerant contacts the reactor plate. The shade of green depends upon the amount of halogen refrigerant; a pale green color shows a small concentration and a darker green color, a heavier concentration. Too much of a halogen refrigerant causes the flame to burn with a vivid purple color. Extreme concentrations of a halogen refrigerant may extinguish the flame by crowding out the oxygen available from the air.

Normally, a halide leak detector is used for R-12 and R-22 systems. In testing for leaks always start at the highest point of the system and work towards the lowest point because halogen refrigerants are heavier than air.

When using a leak detector, you will obtain the best results by following the Precautions listed below.

1. Be sure the reactor plate is properly in place.
2. Adjust the flame so it does not extend beyond the end of the burner. (A small flame is more sensitive than a large flame. If it is hard to light the torch when it is adjusted to produce a small flame, block the end of the exploring hose until the fuel ignites; then gradually open the hose.)
3. Clean out the rubber exploring hose if the flame continues to have a white or yellow color. (A white or yellow flame is an indication that the exploring tube is partially blocked with dirt.)
4. Check to see that air is being drawn into the exploring tube; this check can be made from time to time by holding the end of the hose to your ear.
5. Hold the end of the exploring hose close to the joint being tested to prevent dilution of the sample by stray air currents.
6. Move the end of the exploring hose slowly and completely around each joint being tested. (Leak testing cannot be safely hurried. There is a definite time lag between the moment when air enters the exploring hose and the moment it reaches the reactor plate; permit enough time for the sample to reach the reactor plate.)

If a greenish flame is noted, repeat the test in the same area until the source of the refrigerant is located.

Always follow a definite procedure in testing for refrigerant leaks, so none of the joints are missed. Even the smallest leaks are important. However slight a leak may seem, it eventually empties the system of its charge and causes faulty operation. In the long run, the extra time spent in testing each joint will be justified. A refrigerant system should never be recharged until all leaks are discovered and repaired.

Electronic Leak Detector

The most sensitive leak detector of all is the electronic type. The principle of operation is based on the dielectric difference of gases. In operation, the gun is turned on and adjusted in a normal atmosphere. The leak-detecting probe is then passed around the surfaces suspected of leaking. If there is a leak, no matter how tiny, the halogenated refrigerant is drawn into the probe. The leak gun then gives out a piercing sound, or a light flashes, or both, because the new gas changes the resistance in the circuit.

When using an electronic leak detector, minimize drafts by shutting off fans or other devices that cause air movement. Always position the sniffer below the suspected leak. Because refrigerant is heavier than air, it drifts downward. Always remove the plastic tip and clean it before each use. Avoid clogging it with dirt and lint. Move the tip slowly around the suspected leak.

Soap and Water Test

Soap and water may be used to test for leakage of refrigerant with a pressure higher than atmospheric pressure. Make a soap and water solution by mixing a lot of soap with water to a thick consistency. Let it stand until the bubbles have disappeared, and then apply it to the suspected leaking joint with a soft brush. Wait for bubbles to appear under the clear, thick soap solution.

Find extremely small leaks by carefully examining suspected places with a strong light. If necessary, use a mirror to view the rear side of joints or other connections suspected of leaking.

PUMPING DOWN

Quality refrigeration repair includes preventing loss of refrigerant in the system. Whenever a component is removed from the system, the normally

closed system is opened and, unless precautions are taken, refrigerant is lost to the atmosphere. The best way to contain the refrigerant (gas and liquid) is to trap it in the condenser and receiver by pumping down the system.

To pump down the system, proceed as follows:

1. Secure electric power to the unit and connect the refrigerant manifold test set, as shown in figure 6-55.
2. Close the receiver stop (king) valve (by turning the valve stem inwards as far as it will go), and close both gauges on the gauge manifold (LO and HI valves).
3. Start the compressor and mid-seat the discharge and suction service valves.
4. Operate the compressor until the pressure on the suction (LO) gauge on the manifold shows a vacuum at 0 to 1 psi.
5. Stop the compressor. If the pressure rebuilds appreciably, operate the unit again until pressure registers between 0 to 1 psi. Repeat this step until the pressure no longer rebuilds appreciably.
6. When suction pressure remains at about 0 to 1 pound as read on the compound gauge, then front-seat the suction and discharge service valves (fig. 6-56). This procedure traps practically all the refrigerant in the condenser and receiver.

RECOVERY, RECYCLING, AND RECLAIMING REFRIGERANT

Laws governing the release of chlorofluorocarbon refrigerants (CFCs) into the atmosphere have resulted in the development of procedures to recover, recycle, and reuse these refrigerants. Many companies have developed equipment necessary to prevent the release of CFCs into the atmosphere. Refrigerant recovery management equipment can be divided into three categories—recovery, recycle, and reclaiming equipment.

Recovery

Removing refrigerant from a system in any condition and storing it in an external container is called "recovery." Removal of refrigerant from the system is necessary, in some instances, when repair of a system is needed. To accomplish this, you can use special recovery equipment, which is now a requirement when removing refrigerant from a system. This equipment ensures complete removal of the refrigerant in the system.

Recovery is similar to evacuating a system with the vacuum pump and is accomplished by either the vapor recovery or liquid recovery method. In the vapor

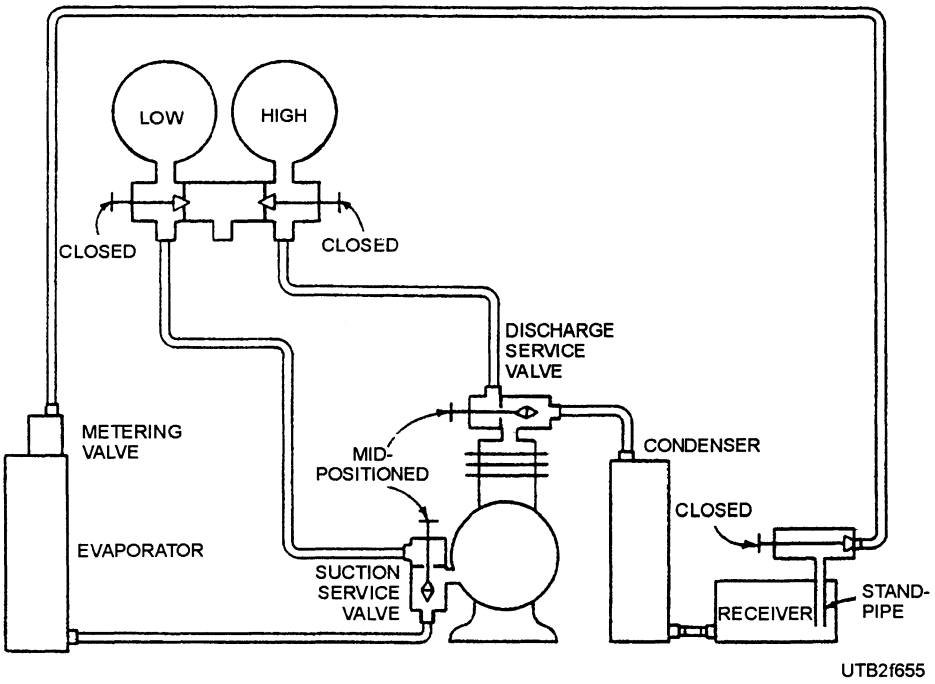


Figure 6-55.—Connections for pumping down a system.

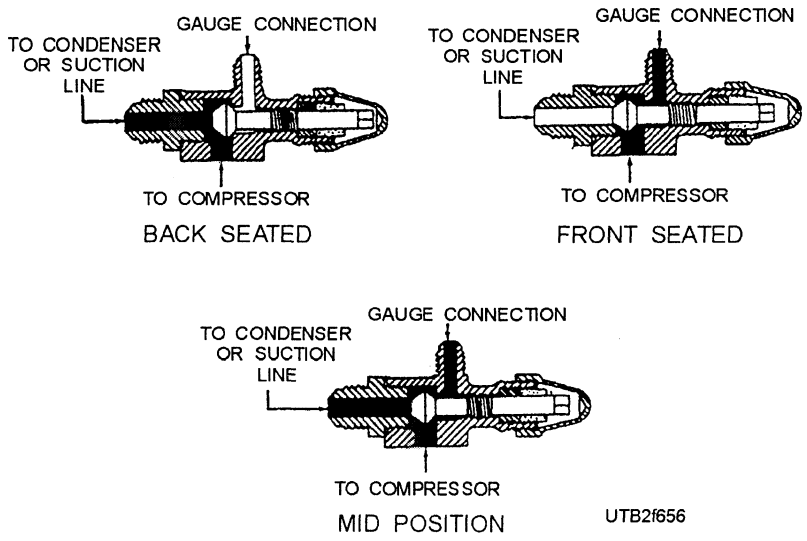


Figure 6-56.—Three-way service valve positions.

recovery method (fig. 6-57), a hose is connected to the low-side access point (compressor suction valve) through a filter-drier to the transfer unit, compressor suction valve. A hose is then connected from the transfer unit, compressor discharge valve to an external storage cylinder. When the transfer unit is turned on, it withdraws vapor refrigerant from the system into the transfer unit compressor, which, in turn, condenses the refrigerant vapor to a liquid and discharges it into the external storage cylinder.

In the liquid recovery method (fig. 6-58), a hose is connected to the low-side access point to the transfer unit compressor discharge valve. A hose is then connected from the transfer unit compressor suction valve through a filter-drier to a two-valve external storage cylinder. A third hose is connected from the high-side access point (liquid valve at the receiver) to the two-valve external storage cylinder. When the transfer unit is turned on, the transfer unit compressor pumps refrigerant vapor from the external storage cylinder into the refrigeration system, which pressurizes it. The difference in pressure between the system and the external storage cylinder forces the liquid refrigerant from the system into the external cylinder. Once the liquid refrigerant is removed from the system, the remaining vapor refrigerant is removed using the vapor recovery method as previously described.

Most recovery units automatically shut off when the refrigerant has been completely recovered, but check the manufacturer's operational manual for specific instructions. You should make sure that the

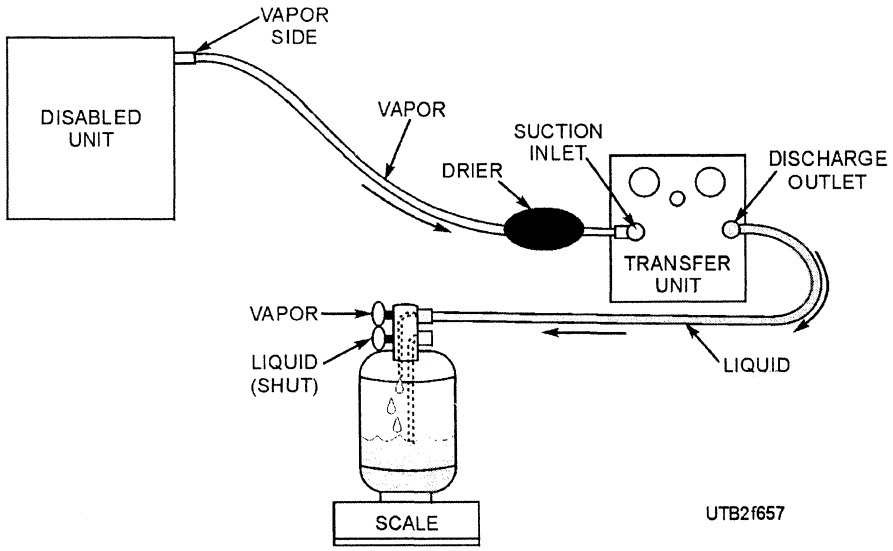


Figure 6-57.—The vapor recovery method.

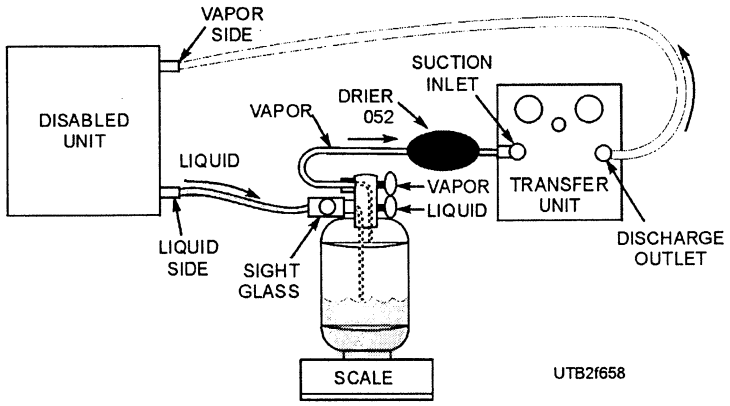


Figure 6-58.—The liquid recovery method.

external storage cylinder is not overfilled. Eighty percent capacity is normal. If the recovery unit is equipped with a sight-glass indicator, any changes that may occur should be noted.

Recycling

The process of cleaning refrigerant for reuse by oil separation and single or multiple passes through filter-driers which reduce moisture, acidity, and matter is called "recycling." In the past, refrigerant was typically vented into the atmosphere. Modern technology has developed equipment to enable reuse of old, damaged, or previously used refrigerant. Refrigerant removed from a system cannot be simply reused—it must be clean. Recycling in the field as performed by most recycling machines reduces the contaminants through oil separation and filtration. Normally recycling is accomplished during the recovery of the vapor or liquid refrigerant by use of equipment that does both recovery and recycling of refrigerant.

Recycling machines use either the single-pass or multiple-pass method of recycling. The single-pass method (fig. 6-59) processes refrigerant through a filter-drier and/or uses distillation. It makes only one pass through the recycling process to a storage cylinder. The multiple-pass method (fig. 6-60) recirculates refrigerant through the filter-drier many times, and after a period of time or number of cycles, the refrigerant is transferred to a storage cylinder.

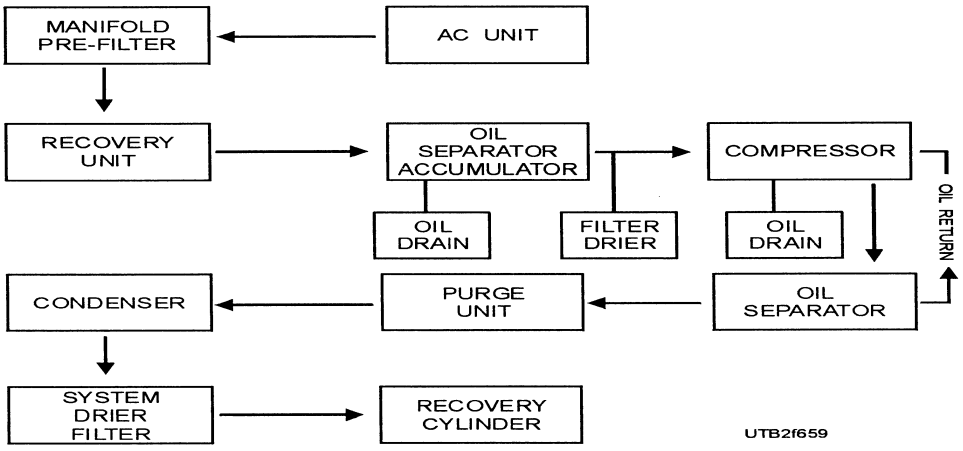


Figure 6-59.—Single-pass method of recycling.

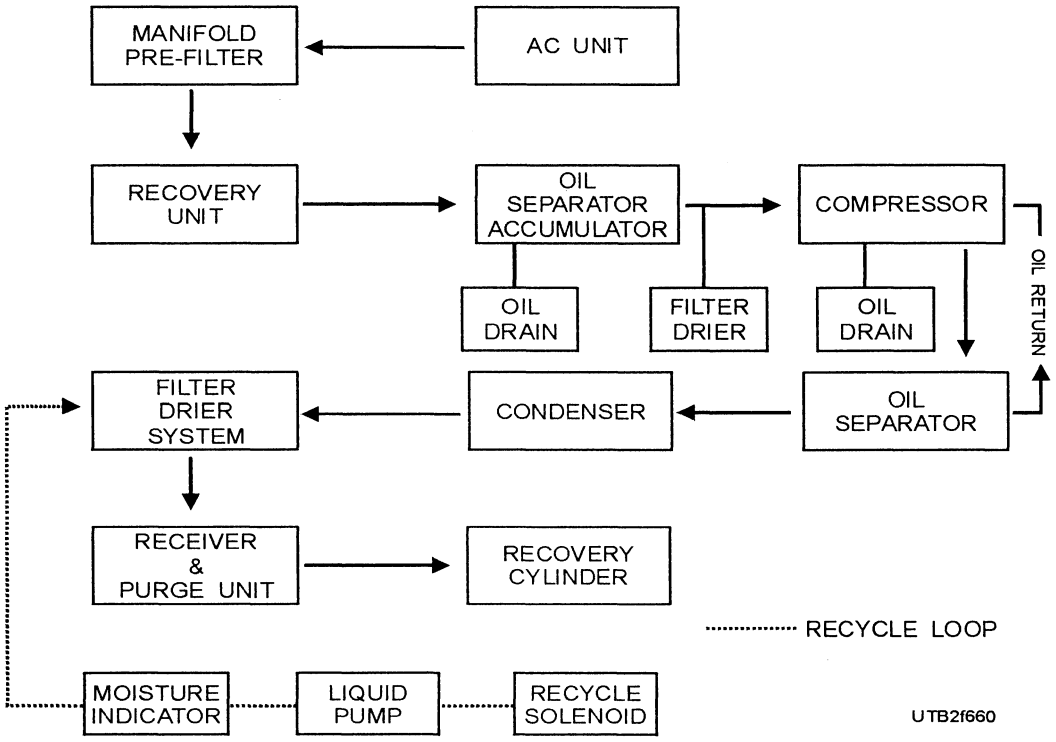


Figure 6-60.—Multiple-pass method of recycling.

Reclaiming

The reprocessing of a refrigerant to original production specifications as verified by chemical analysis is called "reclaiming." Equipment used for this process must meet SAE standards and remove 100 percent of the moisture and oil particles.

Most reclaiming equipment uses the same process cycle for reclaiming refrigerant. The refrigerant enters the unit as a vapor or liquid and is boiled violently at a high temperature at extreme high pressure (distillation). The refrigerant then enters a large, unique separator chamber where the velocity is radically reduced, which allows the high-temperature vapor to rise. During this phase all the contaminants, such as copper chips, carbon, oil, and acid, drop to the bottom of the separator to be removed during the "oil out" operation. The distilled vapor then leaves the separator and enters an air-cooled condenser where it is converted to a liquid. Then the liquid refrigerant passes through a filter-drier into a storage chamber where the refrigerant is cooled to a temperature of 38°F to 40°F by an evaporator assembly.

COMPONENT REMOVAL OR REPLACEMENT

To maintain a refrigerant system at a optimum operating condition sometimes requires removal or replacement of some component. Procedures for removal and replacement of some of the components most often requiring action are covered in this section.

Removing Expansion or Float Valves

To help ensure good results in removing expansion or float valves, you should pump the system down to a suction pressure of just over zero. You should do this at least three times before removing the expansion valve. Plug the opened end of the liquid line and evaporator coil to prevent air from entering the system. Repair or replace the expansion valve and connect it to the liquid valve. Crack the receiver service valve to clear air from the liquid line and the expansion valve. Connect the expansion valve to the evaporator coil inlet and tighten the connection. Pump a vacuum into the low side of the system to remove any air.

Replacing an Evaporator

To replace an evaporator, pump down the system and disconnect the liquid and suction lines. Then remove the expansion valve and the evaporator. Make the necessary repairs or install a new evaporator as required. Replace the expansion valve and connect the liquid and suction lines. Remove moisture and air by evacuating the system. When the evaporator is back in place, pump a deep vacuum as in starting a new installation for the first time. Check for leaks and correct them if they occur. If leaks do occur, be certain to repair them; then pump the system into a deep vacuum. Repeat the process until no more leaks are found.

Removing the Compressor

Using the gauge manifold and a vacuum pump, pump down the system. Most of the refrigerant will be trapped in the condenser and the receiver. To remove the compressor from service, proceed as follows:

1. Once the pump down is complete, the suction valve should already be closed and the suction gauge should read a vacuum. Mid-seat the discharge service valve. Open both manifold valves to allow high-pressure vapor to build up the compressor crankcase pressure to 0 psi.
2. Front-seat (close) the discharge service valve. Then crack the suction service valve until the compound gauge reads 0 to 1 psi to equalize the pressures and then front-seat the valve.
3. Joints should be cleaned with a grease solvent and dried before opening. Unbolt the suction service and discharge service valves from the compressor. DO NOT remove the suction or discharge lines from the compressor service valves.
4. Immediately plug all openings through which refrigerant flows using dry rubber, "cork" stoppers, or tape.
5. Disconnect the bolts that hold the compressor to the base and remove the drive belt or disconnect the drive coupling. You can now remove the compressor.

Removing Hermetic Compressors

Systems using hermetic compressors are not easily repaired, as most of the maintenance performed on them consists of removal and replacement.

1. Disconnect the electrical circuit including the overload switch.
2. Install a gauge manifold. Use a piercing valve (Schraider) if needed.
3. Remove the refrigerant using an EPA approved recovery/recycling unit.
4. Disconnect the suction and discharge lines. Using a pinching tool, pinch the tubing on both the suction and discharge lines, and cut both lines between the compressor and the pinched area.
5. Disconnect the bolts holding the compressor to the base and remove the compressor.

Do not forget to pump down the system and equalize the suction and head pressure to the atmosphere, if applicable. Wear goggles to prevent refrigerant from getting in your eyes. After replacement, the procedures given for removing air and moisture and recharging the system can be followed; however, the procedures may have to be modified because of the lack of some valves and connections. Follow the specific procedures contained in the manufacturer's manual.

Q34. What are the two major pieces of maintenance equipment used for refrigeration work?

Q35. Before attempting transfer of refrigerantfrom a container to a cylinder, you should precool the receiving cylinder for what reason?

Q36. What is the purpose of evacuating a refrigeration system?

Q37. You should continue to operate the vacuum pump during evacuation of a system until what condition is obtained?

Q38. What method of charging a system is generally recommended?

Q39. What are the three methods used to detect refrigerant leaks?

Q40. When you pump down a system, where is the refrigerant stored?

Q41. What are the two methods of refrigerant recovery?

Q42. Recycling refrigerant reduces contaminants through what two processes?

MAINTENANCE OF COMPRESSORS

Learning Objective: Recall the inspection points for open-type compressors and repair procedures for common problems in open-type refrigeration compressors.

Inspection points for open-type compressors and repair procedures for common problems in open-type refrigeration compressors are covered in this section.

OPEN TYPES OF COMPRESSORS

Figure 6-61 shows a vertical single-acting reciprocating compressor. Some of the duties you may perform in maintaining this and other open-type compressors are discussed below.

Shaft Bellows Seal

Refrigerant leakage often occurs at the shaft bellows seal with consequent loss of charge. Install a test gauge in the line leading from the drum to the compressor. Attach a refrigerant drum to the suction end of the shutoff valve outlet port. Apply the proper amount of pressure, as recommended in the manufacturer's instructions. Test for leaks with a halide leak detector around the compressor shaft, seal gasket, and seal nut. Slowly turn the shaft by hand. When a leak is located at the seal nut, replace the seal plate, gasket, and seal assembly; when the leak is at the gasket, replace the gasket only. Retest the seal after reassembly. (This procedure is typical for most shaft seals on reciprocating open-type compressors.)

Valve Obstructions

Obstructions, such as dirt or corrosion, may be formed under seats of suction or discharge valves. To locate the source of trouble, proceed as follows:

When the suction side is obstructed, the unit tends to run continuously or over long periods. Connect the gauge manifold and start the unit. This pressure gauge (HI) will not indicate an increase in pressure. The low-side gauge (LO) will fluctuate and will not indicate any decrease in pressure. Clean out any obstructions and recheck again by using the test gauge assembly.

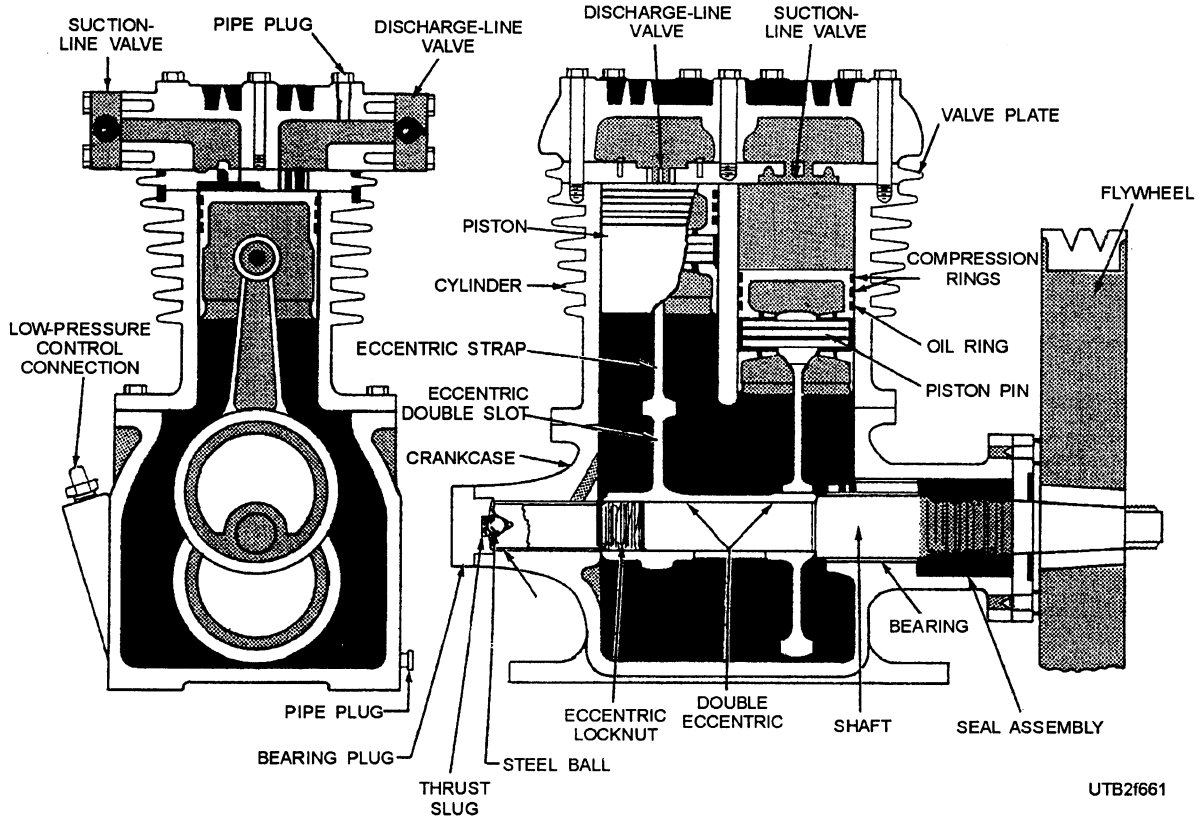


Figure 6-61.—Vertical single-acting reciprocating compressor.

To determine if there is a discharge valve leak, connect the gauge manifold and start the unit. Run it until the low-side (LO) pressure gauge indicates normal pressure for the unit. Stop the unit. With an ear near the compressor housing, listen for a hissing sound. Also, watch the gauges. When leaking caused by an obstruction is present, the low-side pressure rises, and the high side decreases until the pressures are equalized. A quick equalization of pressures indicates a bad leak that should be repaired immediately or the compressor replaced.

Compressor Lubrication

The oil level in the compressor crankcase should be checked by the procedure in the following manufacturer's manual. This procedure normally includes the following steps:

1. Attach the gauge manifold to the suction and discharge service valves.
2. Pump the system down.
3. Close the suction and discharge valves, isolating the compressor.
4. Remove the oil filter plug and measure the oil level as per the manufacturer's manual.

Compressor Knocks

When the compressor knocks, you may have to disassemble the compressor to determine whether the cause is a loose connecting rod, piston pin, or crankshaft. Sometimes a loose piston can be detected without the complete disassembly. In cases requiring disassembly, you should take the following steps:

First, remove the cylinder head and valve plate to expose the top of the piston. Start the motor and press down with your finger on top of the piston. Any looseness can be felt at each stroke. The loose part should be replaced.

Check the oil level because oil levels that are too high often cause knocks. Always make sure that a low oil level is actually the result of a lack of oil, rather than a low charge.

Stuck or Tight Compressor

A stuck or tight compressor often occurs as a result of poor reassembly after a breakdown repair. In such cases, determine where the binding occurs and reassemble the unit with correct tolerances; avoid uneven tightening of screws or seal covers.

INSPECTION OF COMPRESSORS

An inspection should be performed on a refrigeration unit from time to time for knocks, thumps, rattles, and so on, while the unit is in operation. When any of the external parts have excessive grease, dirt, or lint, they should be cleaned. Before cleaning, you should always ensure the power is off.

A careful check of the entire system with instruments or tools is essential to determine if there has been any loss of refrigerant. NO LEAK IS TOO SMALL TO BE FIXED. Each leak must be stopped immediately.

Some specific conditions to look for during the inspection of a refrigeration system are as follows:

Inadequate lubrication of bearings and other moving parts.

Rusty or corroded parts discovered during the inspection should be cleaned and painted.

Hissing sounds at the expansion valve, low readings on the discharge pressure gauge, and bubbles in the receiver sight glass, all indicate a weak refrigerant charge.

Loose connections and worn or pitted switch contacts result in inoperative equipment or reduced reliability. Thermostats with burned contacts may produce abnormal temperatures in the cooled compartment.

Fans difficult to rotate by hand, with bent blades, or loose or worn belts are a source of trouble easy to locate and correct during inspection.

Air filters clogged with dirt should be cleaned or replaced during the inspection.

Hermetically sealed units should be inspected for signs of leaks and high temperatures and for too much noise or vibration.

Q43. On compressors, refrigerant leaks most often occur at what location?

Q44. Hissing sounds at the expansion valves, low discharge pressure, and bubbles in the receiver sight glass during inspections indicate what possible problems?

Q45. When inspecting hermetic compressors, you should look for what type of *problems?*

MAINTENANCE OF MOTORS

Learning Objective: Understand basic maintenance of motors and methods of electrical troubleshooting of motors.

Troubles with the electrical motors used to drive the compressors of mechanical refrigeration systems fall into two classes—mechanical and electrical.

MECHANICAL PROBLEMS

Some compressors are belt-driven from the electrical motor. For proper operation, both the belt tension and pulley alignment adjustments must be made. Belt tension should be adjusted so a l-pound force on the center of the belt, either up or down, does not depress it more than one-half inch. To adjust the alignment, loosen the setscrew on the motor pulley after tension adjustment is made. Be sure the pulley turns freely on the shaft; add a little oil if necessary. Turn the flywheel forward and backward several times. When it is correctly aligned, the pulley does not move inward or outward on the motor shaft. Tighten the setscrew holding the pulley to the shaft before starting the motor.

Compressors may also be driven directly by a mechanical coupling between the motor and compressor shafts. Be sure the two shafts are positioned so they form a straight line with each other. The coupling on direct drive units should be realigned after repair or replacement. Clamp a dial indicator to the motor half coupling with its pointer against the outer edge of the compressor half coupling. Rotate the motor shaft, and observe any fluctuations of the indicator. Move the motor or compressor until the indicator is stationary when revolving the shaft one full turn. Secure the hold-down bolts and then recheck.

Moisture in the System

When liquid refrigerant that contains moisture vaporizes, the moisture separates from the vapor. Because the vaporization of the refrigerant causes a cooling effect, the water that has separated can freeze. Most of the expansion and vaporization of the refrigerant occurs in the evaporator. However, a small amount of the liquid refrigerant vaporizes in the expansion valve, and the valve is cooled below the freezing point of water. As a result, ice can form in the expansion valve and interfere with its operation. If the needle in the valve freezes in a slightly off-seat position, the valve cannot permit the passage of enough refrigerant. If the needle freezes in a position far from the seat, the valve feeds too much refrigerant. In either case, precautions must be observed to assure a moisture-free system.

A dehydrator is filled with a chemical known as a desiccant, which absorbs moisture from the refrigerant passing through the dehydrator. Dehydrators are installed in the liquid line to absorb moisture in the system after the original installation. An arrow on the dehydrator indicates the direction of flow. Desiccants are granular and are composed of silica gel, activated alumina, or calcium sulfate. Do not use calcium chloride or chemicals that form a nonfreezing solution. These solutions may react with moisture to form undesirable substances, such as gums, sludges, or waxes. Follow the manufacturer's instructions as to limitations of dehydrators, as well as operation, recharging, replacing, and servicing.

Loose Copper Tubing

In sealed units, loose copper tubing is usually detected by the sound of rattling or metallic vibration. Bending the tubing carefully to the position of least vibration usually eliminates the defect. Do not touch it against other tubing or parts at a point of free movement, and do not change the tubing pitch or the tubing diameter by careless bending.

In open units, lengths of tubing must be well supported by conduit straps or other devices attached to walls, ceilings, or fixtures. Use friction tape pads to protect the copper tubing from the metal of the strap. When two tubes are together in a parallel position, wrapping and binding them together with tape can prevent vibration. When two lines are placed in contact for heat exchange, they should be soldered to prevent rattling and to permit better heat transfer.

Doors and Hardware

When hinges must be replaced because of lack of lubrication or other reasons, the use of exact duplicates is preferable. Loose hinge pins must be securely braided. When thrust bearings are provided, they are held in place by a pin.

The latch or catch is usually adjusted for proper gasket compression. Shims or spacers may be added

or removed for adjustment. Latch mechanisms should be lubricated and adjusted for easy operation. Latch rollers must not bind when operated. Be sure to provide sufficient clearance between the body of the latch and catch, so no contact is made. The only contact is made between the catch and the latch bolt or roller. These instructions also apply to safety door latches, when they are provided for opening the door from the inside, although it is locked from the outside. Warping of the door usually causes lack of complete gasket contact between the door overlap and the doorframe. Correct the condition by installing a long, tapered wooden shim or splicer rigidly in place under the door seal. If this does not tighten the door to the frame, remove the door and either reline or rebuild it.

Repair or replace missing, worn, warped, or loose door gaskets. If the gasket is tacked on, rustproof tacks or staples should be used. If the gasket is clamped or held in place by the doorframe or the door panel, an exact replacement is necessary. In either case, the gasket should be installed so when the door is closed a complete and uniformly tight seal results. If doors freeze closed due to condensation and subsequent freezing, apply a light coat of glycerine on the gaskets.

Defrosting

Cooling units in the 35°F to 45°F reach-in or walk-in refrigerators or cold storage rooms are generally defrosted automatically by setting the low-pressure control switch to a predetermined level. If this setting causes overload with consequent heavy frosting of the coil, manual defrosting is necessary. Cooling units of 35°F and lower temperatures are defrosted manually. The most common method for manual defrosting is to spray water over the cooling coil, although warm air, electric heating, or hot gas refrigerant defrosts too. In any case, the fans must not be in operation during the defrosting. Defrost plate-type evaporator banks in below-freezing refrigerators when the ice has built up to a thickness of one-half inch or when the temperature of the fixtures or the suction pressure is affected by the buildup of ice. Before removing frost from the plates, place a tarpaulin on the floor or over the contents of the refrigerator to catch the frost under the bank.

ELECTRICAL DEFECTS

The control systems for modern refrigeration systems are composed of many components that use or pass electrical power, including compressor drive motors, pressure switches, thermostats, and solenoid stop valves. Although as a Utilitiesman second class you are not responsible for troubleshooting these electrical components, you must be able to use the multimeter for locating opens, shorts, and grounds, and measuring voltage and current. Module 3 of the Navy Electricity and Electronics Training Series, NAVEDTRA 172-03-00-93 *(Introduction to Circuit Protection, Control, and Measurement),* will help you in learning to use electrical meters and testing equipment. When you have finished studying the module, return to this chapter and learn how to locate opens, shorts, and grounds in refrigeration control circuits.

Opens

Figure 6-62 shows a simple refrigeration control system. You have learned the basics of electricity and how to use meters. Using this figure, you will put that knowledge to work. Remember one fact—if you are

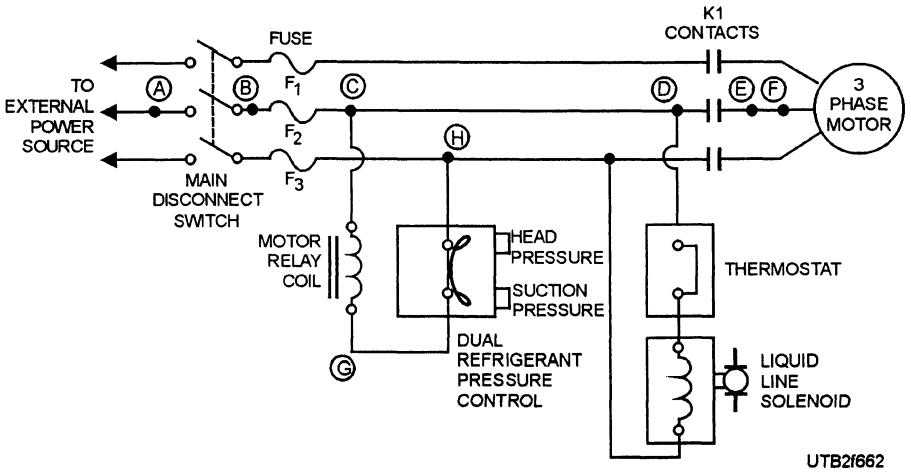


Figure 6-62.—Simple refrigeration control system.

not sure what you are doing, call your supervisor or arrange for a Construction Electrician to assist you.

An "open" is defined as the condition of a component that prevents it from passing current. It may be a broken wire, a burned or pitted relay contact, a blown fuse, a broken relay coil, or a burned-out coil winding. An open can be located in one of two ways. For the components in series, such as the main disconnect switch, fuses, the wire from Point C to Point D (fig. 6-62), the relay contacts, and the wire from Point E to Point F, a voltmeter should be used. Set up the voltmeter to measure the source voltage (120 volts ac, in this case). If the suspected component is open, the source will be measured across it. To check part of the main disconnect switch, close the switch and measure from Point A to Point B. If the meter reading is 0 volts, that part of the switch is good; if the voltage equals the source voltage, the switch is open. To check the fuse F2, measure across it, Point B to Point C. Measuring across Points C and D or E and F will check the connecting wires for opens. One set of relay contacts can be checked by taking meter readings at Points D and E. These are just a few examples, but the rule of series components can always be applied. Remember, the three sets of contacts of relay K1 will not close unless voltage is present across the relay coil; the coil cannot be open or shorted. When testing an electrical circuit, follow the safe practices you have been taught and use procedures outlined in equipment manuals.

Opens in components that are in parallel cannot easily be found with a voltmeter because, as you know, parallel components have voltage across them at all times when the circuit is energized. In figure 6-62, the branch with the motor relay K1 and the dual refrigerant pressure control are considered a parallel circuit. Because when the main disconnect switch is closed and the fuses are good, there is voltage between Points C and H, regardless of whether the relay coil and pressure switch are open. To check for opens in these components, use an ohmmeter set at a low range. Disconnect all power by opening (and locking out, if possible) the main disconnect switch. This action removes all power and ensures both personal and equipment safety. To check the motor relay K1 to see if its coil is open, put the ohmmeter leads on Points C and G. A reading near infinity (extremely high resistance) indicates an open. The contacts of the dual refrigerant pressure control can be tested by putting the ohmmeter leads from Point G to Point H. Again, a reading near infinity indicates open contacts. You may need to consult the manufacturer's manual for the physical location of Points G and H. Notice the contacts of the control are normally closed when neither the head pressure nor the suction pressure is above its set limits.

Shorts

Shorts are just the opposite of opens. Instead of preventing the flow of current, they allow too much current to flow, often blowing fuses. The ohmmeter on its lowest range is used to locate shorts by measuring the resistance across suspected components. If the coil of the motor relay K1 is suspected of being shorted, put the leads on Points C and G. A lower than normal reading (usually almost zero) indicates a short. You may have to determine the normal reading by consulting the manufacturer's manual or by measuring the resistance of the coil of a known good relay. If fuses F2 and F3 blow and you suspect a short between the middle and bottom lines (fig. 6-62), put the ohmmeter leads between Points C and H. Again, a low reading indicates a short. Remember, in all operations using an ohmmeter, it is imperative that all power be removed from the circuit for equipment and personal safety. Don't fail to do this!

Grounds

A ground is an accidental connection between a part of an electrical circuit and ground, due perhaps, to physical contact through wearing of insulation or movement. To locate a ground, follow the same procedure you used to locate a short. The earth itself, a cold-water pipe, or the frame of a machine are all examples of ground points. To see whether a component is shorted to ground, put one ohmmeter lead on ground and the other on the point suspected to be grounded and follow the rules for locating a short. Be sure to turn off all power to the unit. It may even be wise to check for the presence of voltage first. Use a voltmeter set to the range suitable for measuring source voltage. If power does not exist, then use the ohmmeter.

The limited amount of instruction presented here is not enough to qualify you as an electrician, but it should enable you to find such troubles as blown fuses, poor electrical connections, and the like. If the trouble appears more complicated than this, call your supervisor or ask for assistance from a Construction Electrician.

Testing the Motor

As a Utilitiesman, you should be able to make voltage measurements in a refrigeration system to ensure the proper voltage is applied to the drive motor, as shown on the rating plate of the motor. If the proper voltage is applied (within 10 percent) to the terminals of the motor and yet it does not run, you must decide what to do. If it is an open system (not hermetically sealed), it is the Construction Electrician's job to repair the motor. If it is a hermetically sealed unit, however, you must use special test equipment to complete further tests and perhaps make the unit operational again.

If the unit doesn't run, it may be because the motor rotor or compressor crankshaft is stuck (remember, in a hermetically sealed unit, they are one and the same). If you apply electrical power to try and move the motor in the correct direction first and then reverse the power, you may be able to rock it free and not have to replace the unit. This is one of the purposes of the hermetic unit analyzer (fig. 6-63). To rock the rotor of an hermetically sealed unit, follow these steps:

1. Determine from the manufacturer's manual whether the motor is a split-phase or a capacitor-start type.
2. Remove any external wiring from the motor terminals.

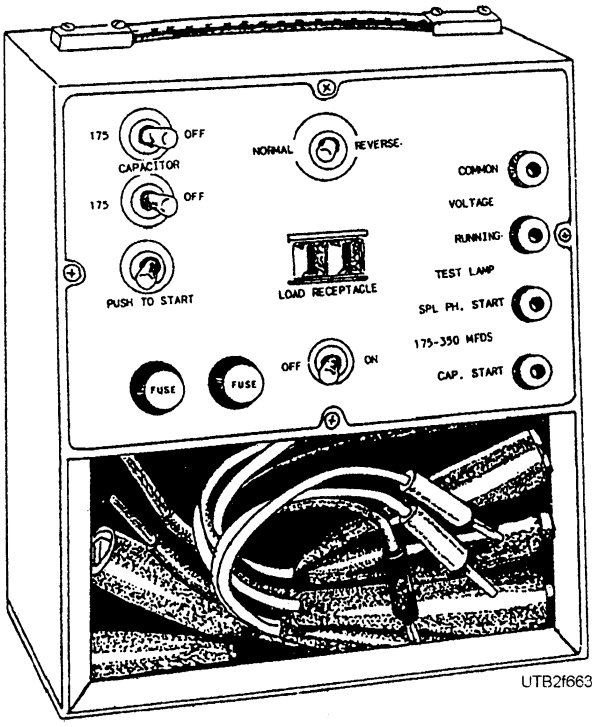


Figure 6-63.—Hermetic unit analyzer.

3. Place the analyzer plugs in the jacks of the same color. If a split-phase motor is used, put the red plug in jack No. 3; if the capacitor-start motor is used, put the red plug in jack No. 4; and select a capacity value close to the old one with the toggle switches.
4. Connect the test clips as follows:

   White to common

   Black to the running winding

   Red to the starting winding
5. Hold the push-to-start button down and at the same time move the handle of the rocker switch from normal to reverse. The frequency of rocking should not exceed five times within a 15-second period. If the motor starts, be certain that the rocker switch is in the normal position before releasing the push-to-start button.
6. More tests can be made with the hermetic unit analyzer, such as testing for continuity of windings and for grounded windings. Procedures for these tests are provided in the manual that comes with the analyzer. Generally, if the rocking procedure does not result in a free and running motor, the unit must be replaced.

TROUBLESHOOTING REFRIGERATION EQUIPMENT

Troubleshooting of any type of refrigeration unit depends, in part, on your ability to compare normal operation with that obtained from the unit being operated. Obviously for you to detect these abnormal operations, you must first know what normal operation is. Climate affects running time. A refrigeration unit generally operates more efficiently in a dry climate. In an ambient temperature of 75°F, the running period usually approximates 2 to 4 minutes, and the off period, 12 to 20 minutes.

It is beyond the scope of this text to cover all of the troubles you may encounter in working with refrigeration equipment. If you apply yourself, you can acquire a lot of additional information through on-the-job training and experience and studying the manufacturer's instruction manuals.

First and foremost, safety must be stressed and safe operating practices followed before and while doing any troubleshooting or service work. All local and

national codes, as well as DoD rules concerning safety, must be observed. Some of the more important safety steps that are often overlooked are as follows:

- Protective equipment, such as eye protection, gloves, hard hats, and so forth, must be available and worn.
- Fire extinguishers must be readily available, in good working order, and adequate for the situation.
- Safety tags with such notations as "Danger," "Hands Off," "Do Not Operate," and "Do Not Throw Switch" should be attached to valves, switches, and at other strategic locations when servicing or making repairs.
- Install machinery guards properly before operating machinery.

The above is only a short list and not intended to be all-inclusive. You will also find table W, appendix II, "Troubleshooting — Industrial Refrigeration," and table Y, appendix II, "Troubleshooting — Domestic Refrigerators and Freezers," useful guides for locating and correcting different troubles in refrigeration equipment.

Q46. Most problems with electrical motors for refrigeration system compressors fall into what classes?

Q47. How often is the coupling on the shafts of direct drive motors realigned?

Q48. What piece of equipment is installed in a refrigeration system just before the expansion valve to remove moisture?

Q49. Manually defrosting is normally required on refrigeration units that operate at what temperature?

Q50. If you suspect a component is open, you should test the source in what way?

Q51. What unit of measurement on a multimeter do you use to test for a short?

Q52. When checking for a ground, you use the same troubleshooting procedure as used for what other problem?

Q53. Troubleshooting a refrigeration system depends partly on your knowledge of how the equipment runs normally. True/False.

LOGS

Learning Objective: Understand the importance and use of maintaining, operating, and inspecting logs for refrigeration equipment.

When maintaining, standing watch, operating, or inspecting refrigerating and air-conditioning equipment, the Utilitiesman may be responsible for keeping operation, inspection, or maintenance logs on the equipment. Try to keep the logs neat and clean. You must ensure that any information recorded in them is accurate and legible.

Operation and maintenance logs may help to spot trouble in the equipment. They also aid in ensuring proper periodic maintenance and inspection are performed on the equipment. Logs may provide a means of self-protection when trouble occurs and the cause can be placed on an individual.

Good judgment must always be used in analysis of service troubles and specific corrections should be followed whenever possible. One of the methods for determining when and what corrective measures are necessary on equipment or a plant which is not operating properly is to compare the pressures and temperatures of various parts of the system with corresponding readings taken in the past when the equipment or plant was operating properly under similar heat load and circulating water temperature conditions.

A typical operating log may contain entries such as the following:

- Date and time of readings
- Ambient temperature
- Suction pressure and temperature readings
- Discharge pressure and tem perature readings
- Condenser pressure and temperature
- Evaporator pressure and temperature
- Oil level in the compressor
- Operating hours

These types of readings give a complete picture of the current and past operating conditions of the equipment or plant and can assist the Utilitiesman in keeping the equipment or plant at its maximum efficiency.

Maintenance logs contain entries of when, what, and who performed routine periodic maintenance on

the equipment or plant. Such logs help ensure that the equipment or plant is well maintained and that the life expectancy of the equipment or plant is fully used. These logs also can assist in determining estimates for future budget requirements for maintenance on the equipment or plant. Maintenance log entries may include the following:

- Date of maintenance
- Type of maintenance
- What was done
- Who did the work
- Cost of the work
- Materials used

It is important to compare operating log readings of the equipment or plant before the maintenance with those taken after the maintenance was completed to ensure maintenance was accomplished properly, and that it had no ill effects on the equipment or plant.

Q54. Operating and maintenance logs can assist in spotting troubles in refrigeration equipment or plants. True/False.

Q55. Maintenance logs can be used to figure future maintenance cost requirements. True /False.

CHAPTER 7

AIR CONDITIONING

Learning Objectives: Understand the principles of air conditioning and the operation of basic air-conditioning systems. Recognize the characteristics and procedures required to install, operate, and maintain air-conditioning systems

Air conditioning is the simultaneous control of temperature, humidity, air movement, and the quality of air in a conditioned space or building. The intended use of the conditioned space is the determining factor for maintaining the temperature, humidity, air movement, and quality of air. Air conditioning is able to provide widely varying atmospheric conditions ranging from conditions necessary for drying telephone cables to that necessary for cotton spinning. Air conditioning can maintain any atmospheric condition regardless of variations in outdoor weather.

This chapter explains the following subjects as they pertain to air conditioning: principles of air conditioning, heat pumps, chilled-water systems, periodic maintenance, cooling towers, troubleshooting, automotive air conditioning, and ductwork.

PRINCIPLES OF AIR CONDITIONING

Learning Objective: Understand the basic principles of temperature, humidity, and air motion in relation to air conditioning.

Air conditioning is the process of conditioning the air in a space to maintain a predetermined temperature-humidity relationship to meet comfort or technical requirements. This warming and cooling of the air is usually referred to as winter and summer air conditioning.

Here, you are introduced to the operating principles of air-conditioning systems, the environmental factors controlled by air conditioning, and their effects on health and comfort. Refrigerative air conditioners and general procedures pertaining to the installation, operation, and maintenance of these systems are examined. Also, the operation and maintenance of the controls used with these systems are explained.

TEMPERATURE

Temperature, humidity, and air motion are interrelated in their effects on health and comfort. The term given to the net effects of these factors is effective *temperature.* This effective temperature cannot be measured with a single instrument; therefore, a psychrometric chart aids in calculating the effective temperature when given sufficient known conditions relating to air temperatures and velocity.

Research has shown that most persons are comfortable in air where the effective temperature lies within a narrow range. The range of effective temperatures within which most people feel comfortable is called the COMFORT ZONE. Since winter and summer weather conditions are markedly different, the summer zone varies from the winter zone. The specific effective temperature within the zone at which most people feel comfortable is called the COMFORT LINE (fig. 7-1).

HUMIDITY

Air at a high temperature and saturated with moisture makes us feel uncomfortable. However, with the same temperature and the air fairly dry, we may feel quite comfortable. Dry air, as it passes over the surface of the skin, evaporates the moisture sooner than damp air and, consequently, produces greater cooling effect. However, air may be so dry that it causes us discomfort. Air that is too dry causes the surface of the skin to become dry and irritates the membranes of the respiratory tract.

HUMIDITY is the amount of water vapor in a given volume of air. RELATIVE HUMIDITY is the amount of water vapor in a given amount of air in comparison with the amount of water vapor the air would hold at a temperature if it were saturated. Relative humidity may be remembered as a fraction or percentage of water vapor in the air; that is, DOES HOLD divided by CAN HOLD.

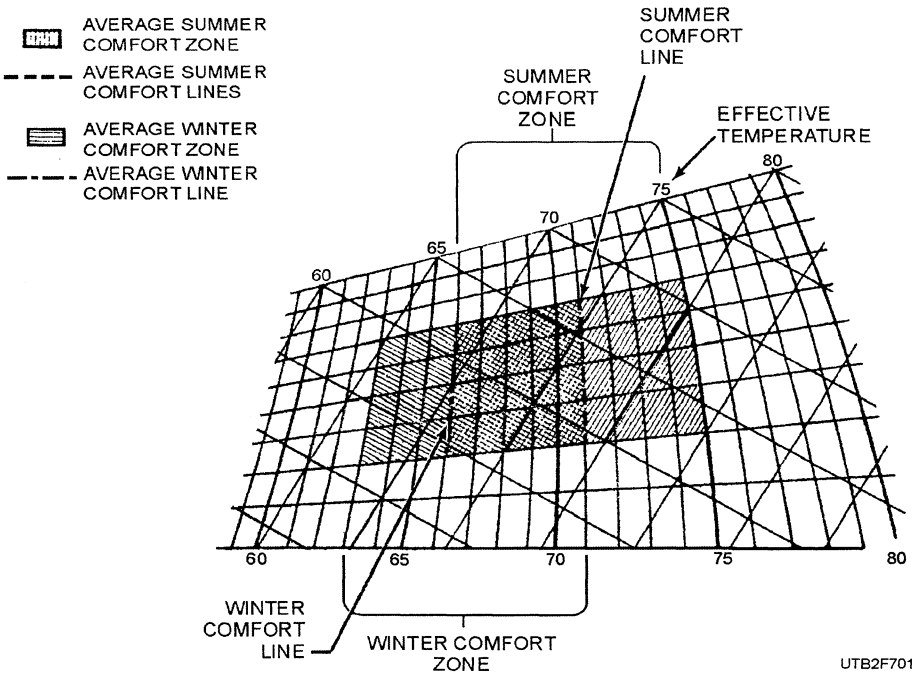


Figure 7-1.—Comfort zones and lines.

Relative humidity is determined by using a sling psychrometer. It consists of a wet-bulb thermometer and a dry-bulb thermometer, as shown in figure 7-2. The wet-bulb thermometer is an ordinary thermometer similar to the dry-bulb thermometer, except that the bulb is enclosed in a wick that is wet with distilled water. The wet bulb is cooled as the moisture evaporates from it while it is being spun through the air. This action causes the wet-bulb thermometer to register a lower temperature than the dry-bulb thermometer. Tables and charts have been designed that use these two temperatures to arrive at a relative humidity for certain conditions.

A comfort zone chart is shown in figure 7-3. The comfort zone is the range of effective temperatures within which the majority of adults feel comfortable. In looking over the chart, note that the comfort zone represents a considerable area. The charts show the wet- and dry-bulb temperature combinations that are comfortable to the majority of adults. The summer comfort zone extends from 66°F effective temperature to 75°F effective temperature for 98 percent of all personnel. The winter comfort zone extends from 63°F effective temperature to 71°F effective temperature for 97 percent of all personnel.

Dew-Point Temperature

The dew point depends on the amount of water vapor in the air. If the air at a certain temperature is not

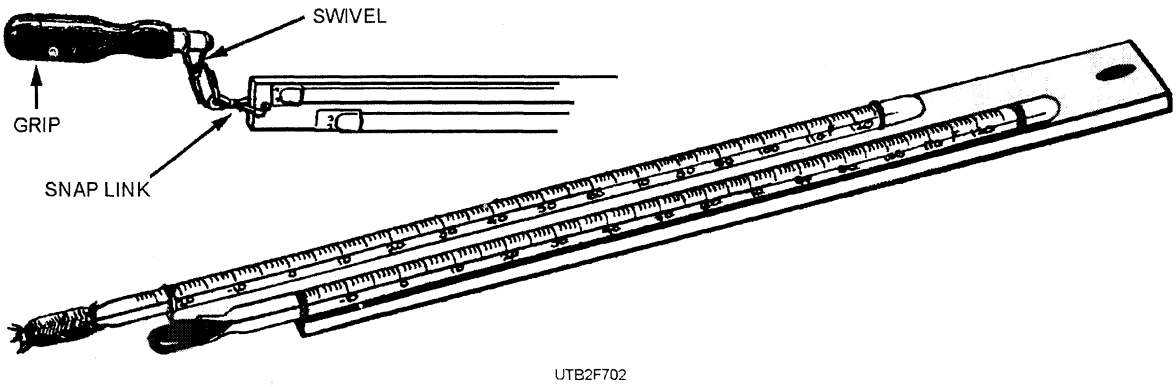


Figure 7-2.—A standard sling psychrometer.

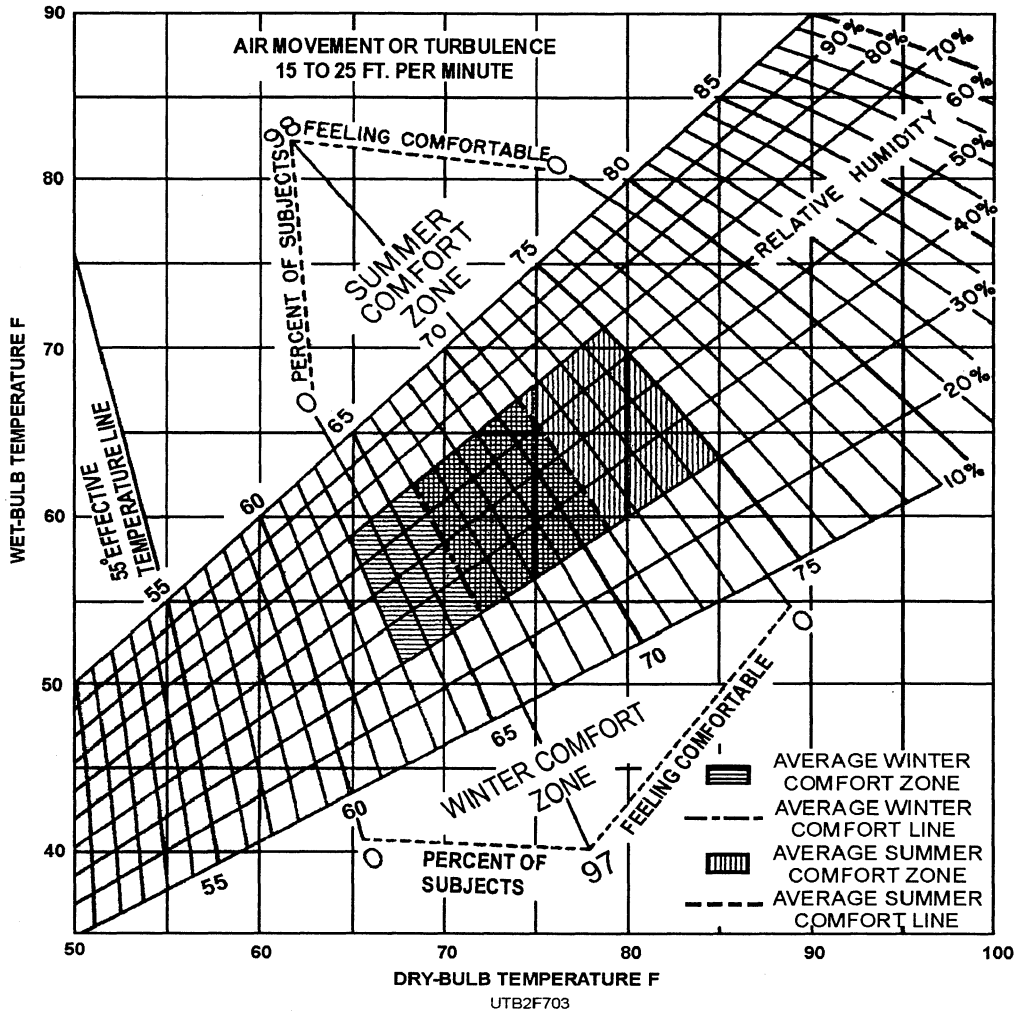


Figure 7-3.—Comfort zone chart.

saturated (maximum water vapor at that temperature) and the temperature of that air falls, a point is finally reached at which the air is saturated for the new and lower temperature, and condensation of the moisture begins. This is the dew-point temperature of the air for the quantity of water vapor present.

Relationship of Wet-Bulb, Dry-Bulb, and Dew-Point Temperatures

A definite relationship exists between the wet-bulb, dry-bulb, and dew-point temperatures. These relationships are as follows:

- When the air is not saturated but contains some moisture, the dew-point temperature is lower than the dry-bulb temperature, and the wet-bulb temperature is in between.
- As the amount of moisture in the air increases, the amount of evaporation (and, therefore, cooling) decreases. The difference between the temperatures becomes less.
- When the air becomes saturated, all three temperatures are the same and the relative humidity is 100 percent.

To HUMIDIFY air is to increase its water vapor content. To DEHUMIDIFY air is to decrease its water vapor content. The device used to add moisture to the air is a humidifier, and the device used to remove the moisture from the air is a dehumidifier. The control device, sensitive to various degrees of humidity, is called a HUMIDISTAT.

Methods for humidifying air in air-conditioning units usually consist of an arrangement that causes air to pick up moisture. One arrangement consists of a

heated water surface over which conditioned air passes and picks up a certain amount of water vapor by evaporation, depending upon the degree of humidifying required. A second arrangement to humidify air is to spray or wash the air as it passes through the air-conditioning unit.

During the heat of the day, the air usually absorbs moisture. As the air cools at night, it may reach the dew point and give up moisture, which is deposited on objects. This principle is used in dehumidifying air by mechanical means.

Dehumidifying equipment for air conditioning usually consists of cooling coils within the air conditioner. As warm, humid air passes over the cooling coils, its temperature drops below the dew point and some of its moisture condenses into water on the surface of the coils. The condensing moisture gives up latent heat that creates a part of the cooling load that must be overcome by the air-conditioning unit. For this reason, the relative humidity of the air entering the air conditioner has a definite bearing on the total cooling load. The amount of water vapor that can be removed from the air depends upon the air over the coils and the temperature of the coils.

PURITY OF AIR

The air should be free from all foreign materials, such as ordinary dust, rust, animal and vegetable matter, pollen, carbon (soot) from poor combustion, fumes, smoke, and gases. These types of pollution are harmful to the human body alone; however, they include an additional danger because they also carry bacteria and harmful germs. So, the outside air brought into a space or the recirculating air within a space should be filtered during air conditioning.

Air in an air conditioner may be purified or cleaned by filters, air washing, or electricity.

Filters may be designed as permanent or throwaway types. They are usually made of fibrous material, which collects the particles of dust and other foreign matter from the air as it passes through the filter. In some cases, the fibers are dry, while in others they have a viscous (sticky) coating. Filters usually have a large dust-holding capacity. When filters become dust-laden, they are either discarded or cleaned. Permanent filters are usually cleaned. Throwaway filters are only one-time filters and are discarded when they become dust-laden.

Often water sprays are used to recondition the air by washing and cleaning it. These sprays may also serve to humidify or dehumidify the air to some extent.

In some large air-conditioning systems, air is cleaned by electricity. In this type of system, electrical precipitators remove the dust particles from the air. The air is first passed between plates where the dust particles are charged with electricity; then the air is passed through a second set of oppositely charged plates that attract and remove the dust particles (fig. 7-4). This method is by far the best method of air cleaning, but the most expensive.

CIRCULATION OF AIR

The velocity of the air is the primary factor that determines what temperature and humidity are required to produce comfort. (The chart in figure 7-3 is based on an air movement of 15 to 25 feet per minute.) We know from experience that a high velocity of air produces a cooling effect on human beings. However, air velocity does not produce a cooling effect on a surface that does not have exposed moisture. A fan does not cool the air, but merely increases its velocity. The increased velocity of air passing over the skin surfaces evaporates moisture at a greater rate; thereby, cooling the individual. For this reason, circulation of air has a decided influence on comfort conditions. Air can be circulated by gravity or mechanical means.

When air is circulated by gravity, the cold, and therefore heavier, air tends to settle to the floor, forcing the warm and lighter air to the ceiling. When the air at the ceiling is cooled by some sort of refrigeration, it will settle to the floor and cause the warm air to rise. The circulation of the air by this method will eventually stop when the temperature of the air at the ceiling is the same as the temperature on the floor.

Air may be circulated by mechanical means by axial or radial fans. When either the axial or radial fan is mounted in an enclosure, it is often called a blower.

Q1. What is the term given to the net effects of temperature, humidity, and air motion?

Q2. The comfort line is the specific effective temperature at which most people feel comfortable. True /False

Q3. What is the term for the amount of water vapor in a given volume of air?

Q4. What instrument is used to measure relative humidity?

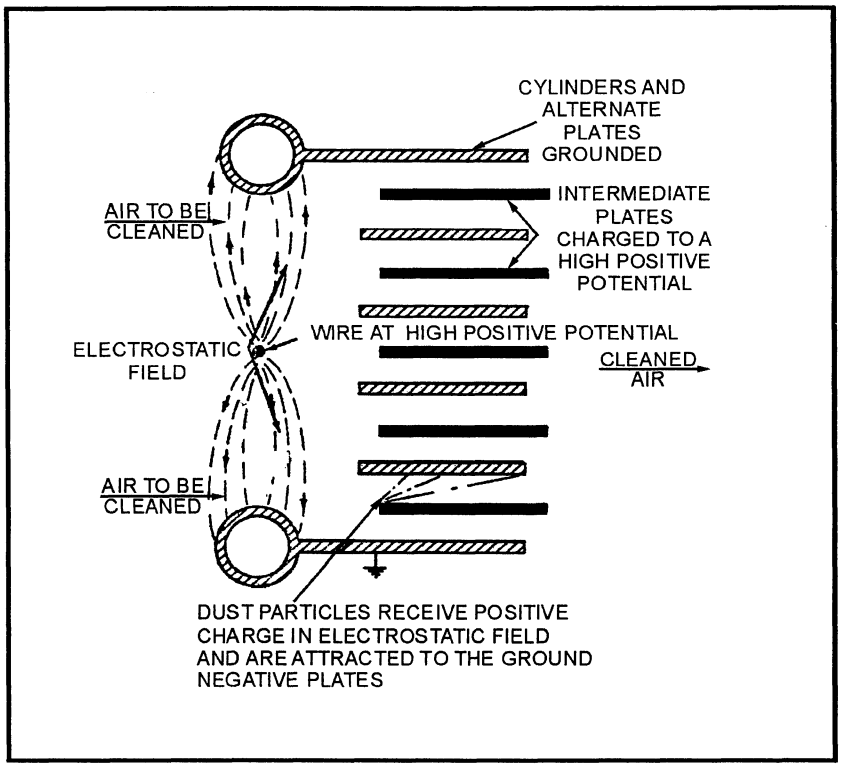


Figure 7-4.—Diagram of an electrostatic filter.

Q5. The point where water vapor condenses is called the dew point. True /False

Q6. What condition exists when the dry-bulb, wet-bulb, and dew-point temperatures are the same?

Q7. What are the two types of filter designs?

Q8. What is the primary factor that determines the temperature and humidity required for room comfort?

AIR-CONDITIONING SYSTEMS

Learning Objective: Recognize basic types of air-conditioning systems, and understand the operation, maintenance, and repair methods and procedures.

A complete air-conditioning system includes a means of refrigeration, one or more heat transfer units, air filters, a means of air distribution, an arrangement for piping the refrigerant and heating medium, and controls to regulate the proper capacity of these components. In addition, the application and design requirements that an air-conditioning system must meet make it necessary to arrange some of these components to condition the air in a certain sequence. For example, an installation that requires re-heating of the conditioned air must be arranged with the re-heating coil on the downstream side of the dehumidifying coil; otherwise, re-heating of the cooled and dehumidified air is impossible.

There has been a tendency by many designers to classify an air-conditioning system by referring to one of its components. For example, the air-conditioning system in a building may include a dual duct arrangement to distribute the conditioned air; therefore, it is then referred to as a dual duct system. This classification makes no reference to the type of refrigeration, the piping arrangement, or the type of controls.

For the purpose of classification, the following definitions are used:

- An air-conditioning unit is understood to consist of a heat transfer surface for heating and cooling, a fan for air circulation, and a means of cleaning the air, motor, drive, and casing.

- A self-contained air-conditioning unit is understood to be an air-conditioning unit that is complete with compressor, condenser, evaporator, controls, and casing.

- An air-handling unit consists of a fan, heat transfer surface, and casing.
- A remote air-handling unit or a remote air-conditioning unit is a unit located outside of the conditioned space that it serves.

SELF-CONTAINED AIR-CONDITIONING UNITS

Self-contained air-conditioning units may be divided into two types: window-mounted and floor-mounted units. Window-mounted air-conditioning units usually range from 4,000 to 36,000 Btu per hour in capacity (fig. 7-5). The use of windows to install these units is not a necessity. They may be installed in transoms or directly in the outside walls (commonly called a "through-the-wall" installation). A package type of room air conditioner, showing airflow patterns for cooling, ventilating, and exhausting services, is shown in figure 7-6.

In construction and operating principles, the window unit is a small and simplified version of much larger systems. As shown in figures 7-7 and 7-8, the basic refrigeration components are present in the window unit. The outside air cools the condenser coils. The room air is circulated by a fan that blows across the evaporator coils. Moisture, condensed from the humid air by these coils, is collected in a pan at the bottom of the unit; it is usually drained to the back of the unit and discharged. Most window units are equipped with thermostats that maintain a fixed dry-bulb temperature and moisture content in an area within reasonable limits. These units are installed so there is a slight tilt of the unit towards the outside, toward the condenser, to assist in drainage of the condensate. It is a good idea to mount the unit on the eastside of the building to take advantage of the afternoon shade. These units require very little mechanical attention before they are put into operation. Window units are normally operated by the user who should be properly instructed on their use.

Floor-mounted air-conditioning units range in size from 24,000 to 360,000 Btu per hour and are also

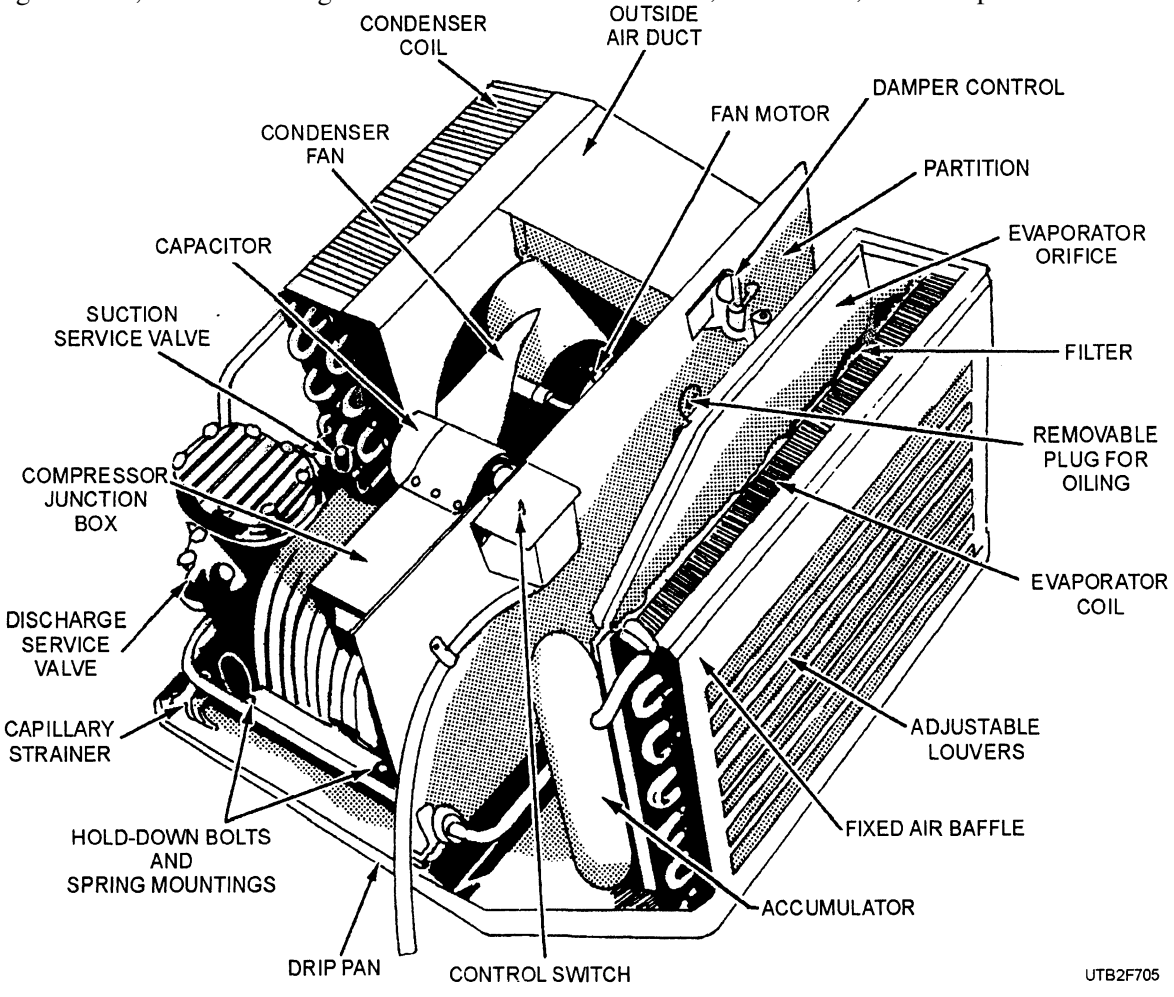


Figure 7-5.—Window air conditioner.

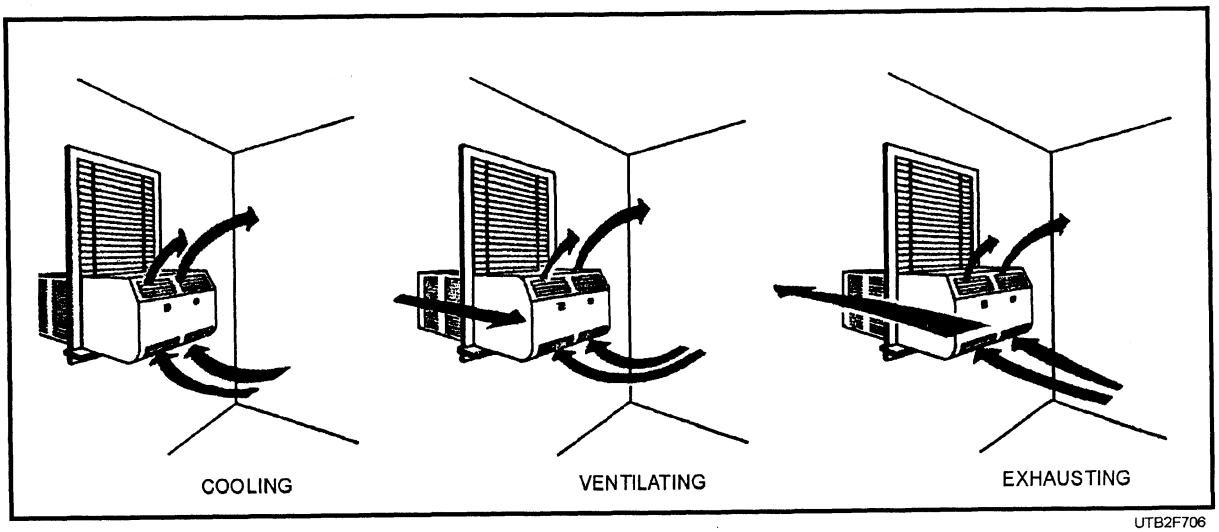


Figure 7-6.—Package type of air-conditioning unit showing airflow patterns.

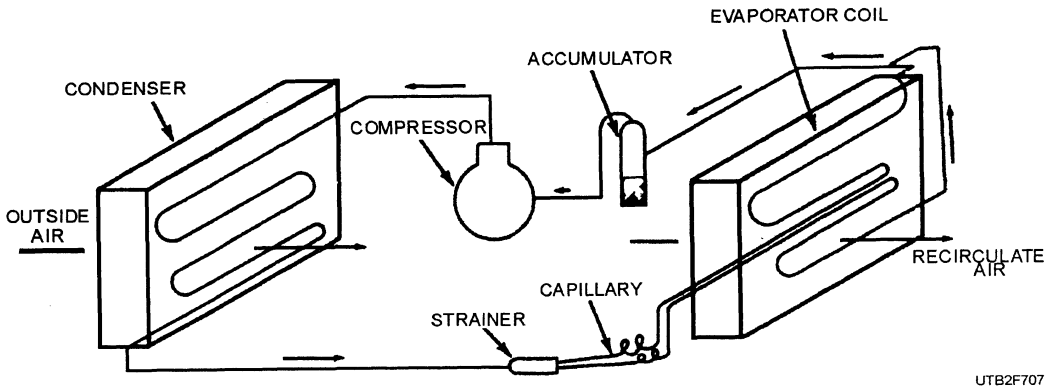


Figure 7-7.—A refrigerant cycle of a package air conditioner.

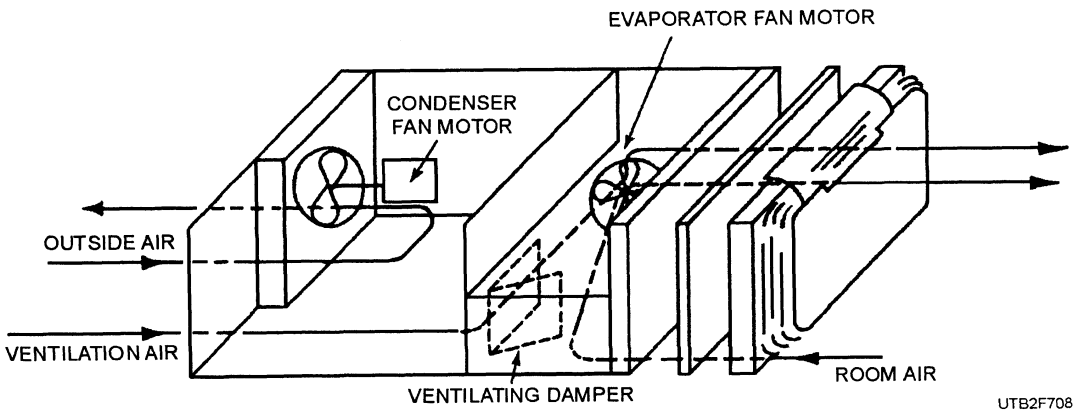


Figure 7-8.—Air-handling components of a package type of room air conditioner.

referred to as PACKAGE units, as the entire system is located in the conditioned space. These larger units, like window units, contain the complete system of refrigeration components. A self-contained unit with panels removed is shown in figure 7-9. These units normally use either a water-cooled or air-cooled condenser.

Self-contained units should be checked regularly to ensure they operate properly. Filters should be

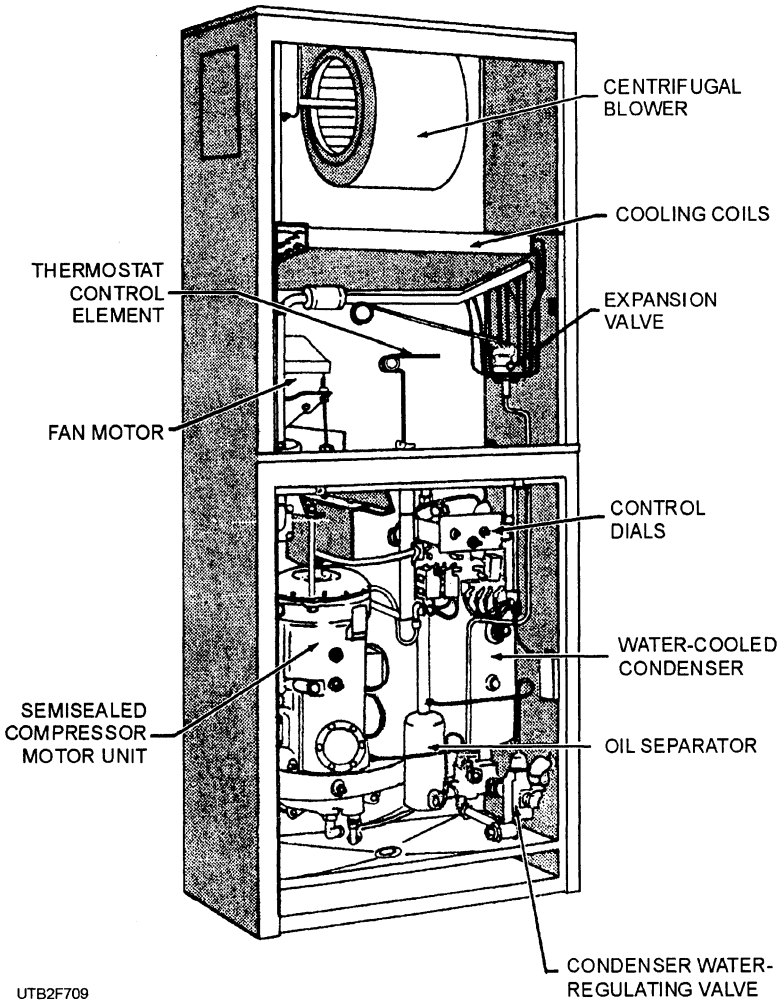


Figure 7-9.—A floor-mounted air-conditioning unit.

renewed or cleaned weekly or more often if necessary. Always stop the blower when changing filters to keep loose dust from circulating through the system. When the filters are permanent, they should be returned to the shop for cleaning. At least once a year, the unit should be serviced. When the unit is designed with spray humidifier, spray nozzle, water strainers, and cooling coils, each device should be cleaned each month to remove water solids and scale. Cooling coil casings, drain pans, fan scrolls, and fan wheels should be wire brushed and repainted when necessary. Oiling and greasing of the blower and motor bearings should be performed as required.

HEAT PUMPS

A heat pump removes heat from one place and puts it into another. A domestic refrigerator is a heat pump in that it removes heat from inside a box and releases it on the outside. The only difference between a refrigerator and a residential or commercial heat pump is that the latter can reverse its system. The heat pump is one of the most modern means of heating and cooling. Using no fuel, the electric heat pump automatically heats or cools as determined by outside temperature. The air type of unit works on the principle of removing heat from the atmosphere. No matter how cold the weather, some heat can always be extracted and pumped indoors to provide warmth. To cool during the hot months, this cycle is merely reversed with the unit removing heat from the area to be cooled and exhausting it to the outside air. The heat pump is designed to control the moisture in the air and to remove dust and pollen. Cool air, provided during hot weather, enters the area with uncomfortable moisture removed. In winter, when a natural atmosphere is desirable, air is not dried out when pumped indoors.

The heat pump is simple in operation (fig. 7-10). In summer, the evaporator is cooling and the condenser outside is giving off heat the evaporator picked up. In

winter, the condenser outside is picking up heat from the outside air because its temperature is lower than that of the outside air (until it reaches the balance point). This heat is then sent to the evaporator by the compressor and is given off into the conditioned space. A reversing valve is the key to this operation. The compressor always pumps in one direction, so the reversing valve changes the hot-gas direction from the condenser to the evaporator as indicated by the setting on the thermostat. The setting of the thermostat assures the operator of a constant temperature through an automatic change from heating to cooling anytime outside conditions warrant. Heat pumps are made not only for small homes but large homes and commercial buildings as well. The heat pump does not require an equipment room, and its minor noise is discharged into the atmosphere. The remote heat pump has only a blower and evaporator, which can be installed under the floor, in an attic, or other out-of-the-way location, depending on the application and its requirements. Supplemental heat can be added into the duct and be set to come on by a second stage of the thermostat, an outside thermosat, or both, depending on design of the system.

Heating Cycle

The initial heating demand of the thermostat starts the compressor. The reversing valve is de-energized during the heating mode. The compressor pumps the hot refrigerant gas through the indoor coil where heat is released into the indoor air stream. This supply of warmed air is distributed through the conditioned space. As the refrigerant releases its heat, it changes into a liquid, which is then transported to the outdoor coil. The outdoor coil absorbs heat from the air blown across the coil by the outdoor fan. The refrigerant changes from a liquid into a vapor, as it passes through the outdoor coil. The vapor returns to the compressor where it increases temperature and pressure. The hot refrigerant is then pumped back to the indoor coil to start another cycle. A graphic presentation of the nine steps of the cycle is shown in figure 7-11.

Cooling Cycle

Once the thermostat is put in the cooling mode, the reversing valve is energized. A cooling demand starts the compressor. The compressor pumps hot high-pressure gas to the outdoor coil where heat is released by the outdoor fan. The refrigerant changes into a liquid, which is transported to the indoor blower. The refrigerant absorbs heat from the indoor air of the

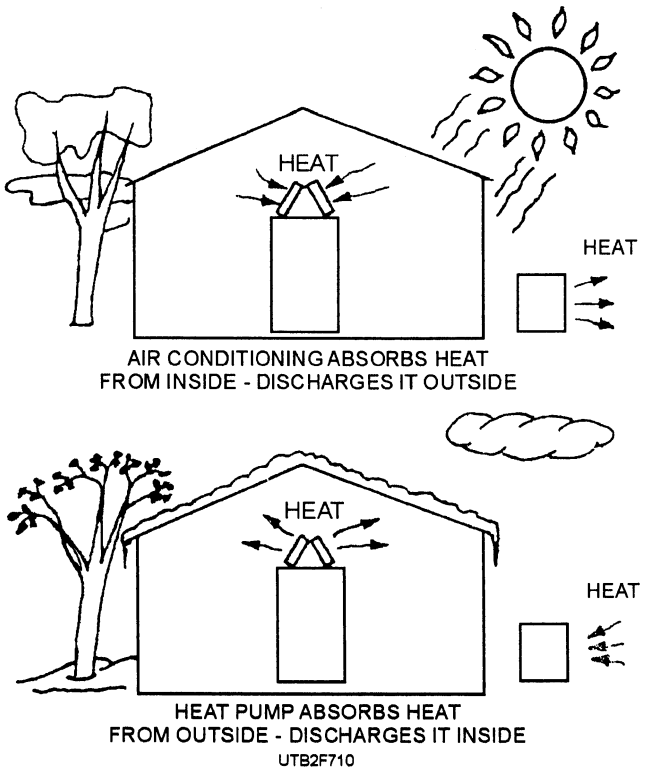


Figure 7-10. —Basic heat pump operation.

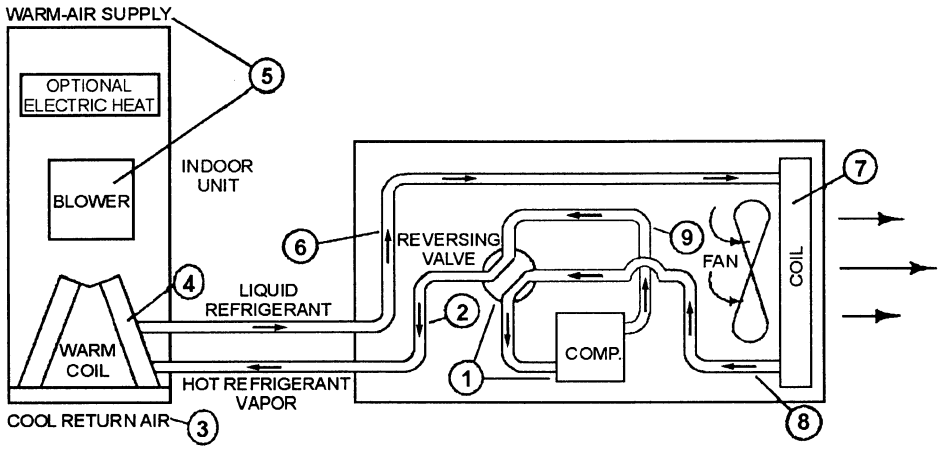


Figure 7-11.—Heating cycle.

supply air, which is distributed throughout the controlled space. This temperature change removes moisture from the air and forms condensate, which must be piped away. The compressor suction pressure draws the cool vapor back into the compressor where the temperature and pressure are greatly increased. This completes the cooling refrigerant cycle. A graphic presentation of the nine steps of the cycle is shown in figure 7-12.

Defrost Cycle

Heat pumps operating at temperatures below 45°F accumulate frost or ice on the outdoor coil. The relative humidity and ambient temperature affect the degree of accumulation. This ice buildup restricts the airflow through the outdoor coil, which consequently affects the system operating pressures. The defrost control detects this restriction and switches the unit into a defrost mode to melt the ice.

The reversing valve is energized and the machine temporarily goes into the cooling cycle where hot refrigerant flows to the outdoor coil. The outdoor fan stops at the same time, thus allowing the discharge temperature to increase rapidly to shorten the length of the defrost cycle. If there is supplemental heat, a defrost relay activates it to offset the cooling released by the indoor coil.

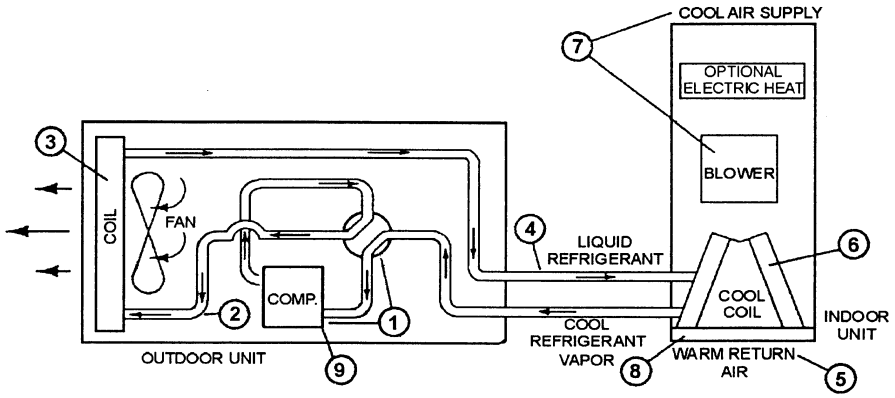
Supplemental Heat

As the outside temperature drops, the heat pump runs for longer periods until it eventually operates continually to satisfy the thermostat. The system "balance point" is when the heat pump capacity exactly matches the heating loss. The balance point varies between homes, depending on actual heat loss and the heat pump capacity. However, the balance point usually ranges between 15°F and 40°F. Either electric heat or fossil fuels provide the auxiliary heat.

Conventional heat pump applications use electric heaters downstream from the indoor coil. This design prevents damaging head pressures when the heat pump and auxiliary heat run simultaneously. The indoor coil can only be installed downstream from the auxiliary heat if a "fuelmaster" control system is used. This control package uses a two-stage heat thermostat with the first stage controlling heat pump operation and the second stage controlling furnace operation.

CHILLED-WATER SYSTEMS

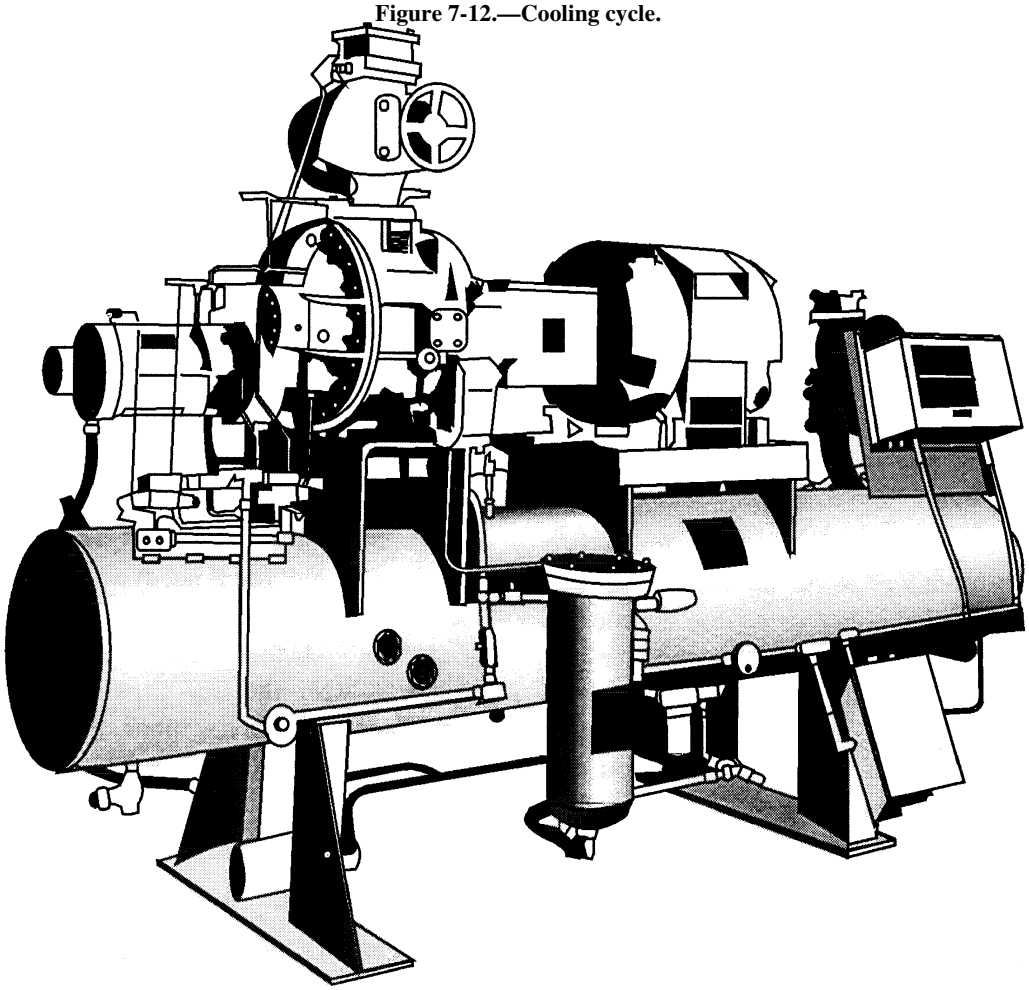
Water chillers (figs. 7-13 and 7-14) are used in air conditioning for large tonnage capacities and for central refrigeration plants serving a number of zones, each with its individual air-cooling and air-circulating



1. THE REVERSING VALVE AND COMPRESSOR ARE ENERGIZED.
2. THE COMPRESSOR PUMPS HOT REFRIGERANT GAS TO THE OUTDOOR COIL.
3. THE FAN DISSIPATES HEAT FROM THE REFRIGERANT AND CHANGES IT INTO A LIQUID.
4. THE LIQUID REFRIGERANT IS SENT ON TO THE INDOOR COIL.
5. WARM AIR IS DRAWN OVER THE INDOOR COIL BY THE BLOWER.
6. THE REFRIGERANT ABSORBS HEAT FROM THE INDOOR AIR AND CHANGES INTO A COOL VAPOR.
7. THIS LOWERS THE TEMPERATURE OF THE SUPPLY AIR WHICH IS DISTRIBUTED THROUGHOUT THE CONTROLLED SPACE.
8. THIS TEMPERATURE CHANGE WILL REMOVE MOISTURE FROM THE AIR AND FORM CONDENSATE WHICH MUST BE PIPED AWAY.
9. THE COMPRESSOR SUCTION PRESSURE DRAWS THE REFRIGERANT BACK INTO THE COMPRESSOR WHERE ITS PRESSURE IS GREATLY INCREASED. THIS COMPLETES ONE COOLING REFRIGERANT CYCLE.

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Figure 7-12.—Cooling cycle.



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Figure 7-13.—Rotary screw compressor unit.

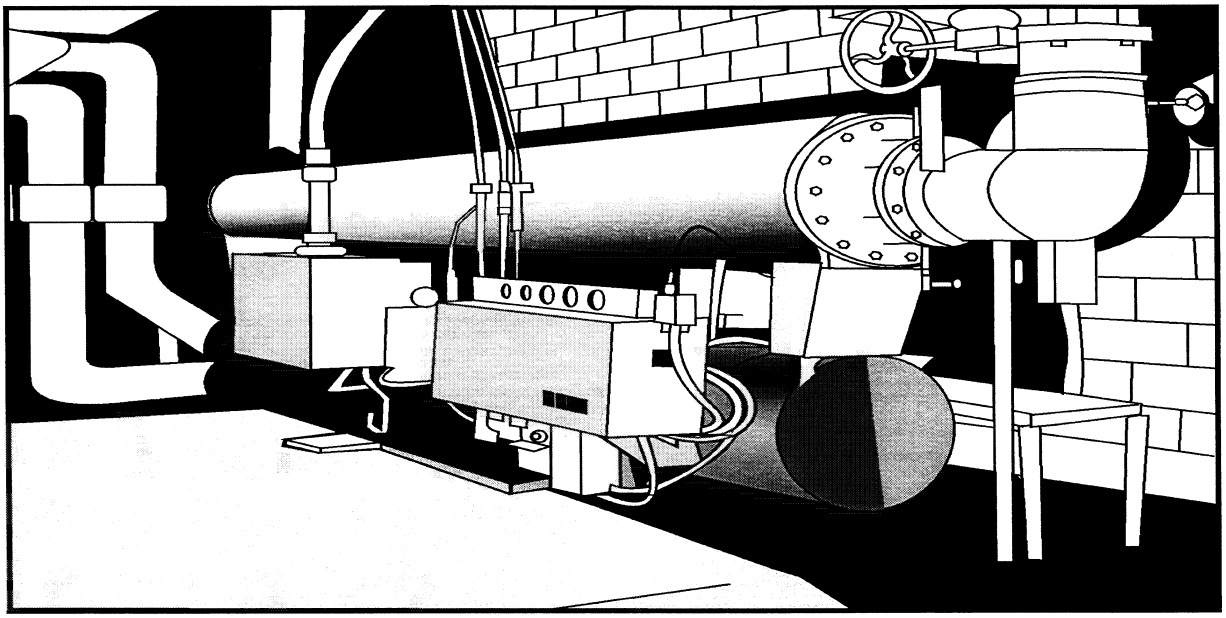


Figure 7-14.—Two-stage semihermetic centrifugal unit.

units. An example is a large hospital with wings off a corridor. Air conditioning may be necessary in operating rooms, treatment suites, and possibly some recovery wards. Chilled water-producing and water-circulating equipment is in a mechanical equipment room. Long mains with many joints between condensing equipment and conditioning units increase the chance of leaks. Expensive refrigerant has to be replaced. It may be better to provide water-cooling equipment close to the condensing units and to circulate chilled water to remote air-cooling coils. Chilled water is circulated to various room-located coils by a pump, and the temperature of the air leaving each coil may be controlled by a thermostat that controls a water valve or stops and starts each cooling coil fan motor.

Types of Coolers

The two most commonly used water coolers (evaporators) for chilled water air conditioning are flooded shell-and-tube and dry-expansion coolers. The disadvantage of the flooded shell-and-tube cooler is that it needs more refrigeration than other systems of equal size. Furthermore, water in tubes may freeze and split tubes when the load falls off.

Controls

Flooded coolers should be controlled with a low-pressure float control-a float valve placed so the float is about the same level as the predetermined refrigerant level. The float, as a pilot, moves a valve in the liquid line to control the flow of refrigerant to the evaporator. Automatic or thermostatic expansion valves control the dry-expansion coolers. The refrigerant is inside the tubes; therefore, freezing of water on the tubes is less likely to cause damage.

Condensers

The primary purpose of the condenser is to liquefy the refrigerant vapor. The heat added to the refrigerant in the evaporator and compressor must be transferred to some other medium from the condenser. This medium is the air or water used to cool the condenser.

WATER-COOLED CONDENSERS.—Condensing water must be noncorrosive, clean, inexpensive, below a certain maximum temperature, and available in sufficient quantity. The use of corrosive or dirty water results in high maintenance costs for condensers and piping. Dirty water, as from a river, can generally be economically filtered if it is noncorrosive; corrosive water can sometimes be economically treated to neutralize its corrosive properties if it is clean. An inexpensive source of water that must be filtered and chemically treated will probably not be economical to use without some means of conservation, such as an evaporative condenser or a cooling tower.

Water circulated in evaporative condensers and cooling towers must always be treated to reduce the formation of scale, algae, and chalky deposits. Overtreatment of water, however, can waste costly chemicals and result in just as much maintenance as undertreatment.

SHELL-AND-COIL CONDENSERS.—A shell-and-coil water-cooled condenser (fig. 7-15) is simply a continuous copper coil mounted inside a steel shell. Water flows through the coil, and the refrigerant vapor from the compressor is discharged inside the shell to condense on the outside of the cold tubes. In many designs, the shell also serves as a liquid receiver.

The shell-and-coil condenser has a low manufacturing cost, but this advantage is offset by the disadvantage that this type of condenser is difficult to service in the field. If a leak develops in the coil, the head from the shell must be removed and the entire coil pulled from the shell to find and repair the leak. A continuous coil is a nuisance to clean, whereas straight tubes are easy to clean with mechanical tube cleaners. In summary, with some types of cooling water, it may be difficult to maintain a high rate of heat transfer with a shell-and-coil condenser.

SHELL-AND-TUBE CONDENSERS.—The shell-and-tube water-cooled condenser shown in figure 7-16 permits a large amount of condensing surface to be installed in a comparatively small space. The condenser consists of a large number of 3/4- or 5/8-inch tubes installed inside a steel shell. The water flows inside the tubes while the vapor flows outside around the nest of tubes. The vapor condenses on the outside surface of the tubes and drips to the bottom of the condenser, which may be used as a receiver for the storage of liquid refrigerant. Shell-and-tube condensers are used for practically all water-cooled refrigeration systems.

To obtain a high rate of heat transfer through the surface of a condenser, it is necessary for the water to pass through the tubes at a fairly high velocity. For this reason, the tubes in shell-and-tube condensers are separated into several groups with the same water traveling in series through each of these various groups. A condenser having four groups of tubes is known as a four-pass condenser because the water flows back and forth along its length four times. Four-pass condensers are common although any reasonable number of passes may be used. The fewer the number of water passes in a condenser, the greater the number of tubes in each pass.

The friction of water flowing through a condenser with a few passes is lower than in one having a large number of passes. This means a lower power cost in pumping the water through a condenser with a smaller number of passes.

TUBE-WITHIN-A-TUBE CONDENSERS.—The use of tube-within-a-tube for condensing purposes is popular because it is easy to make. Water passing

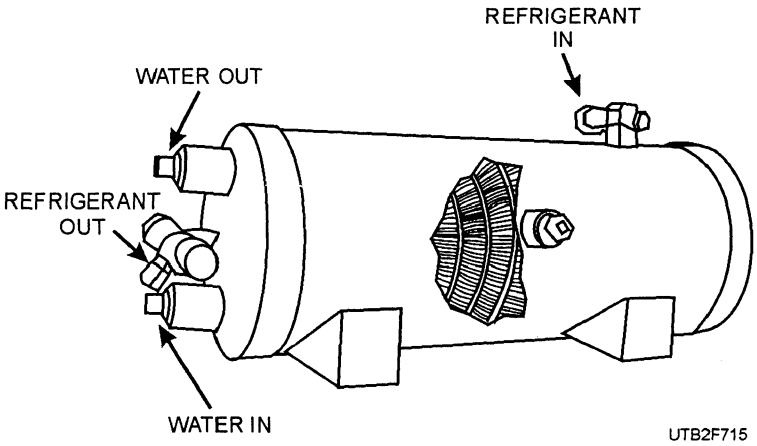


Figure 7-15.—A typical shell-and-coil water-cooled condenser.

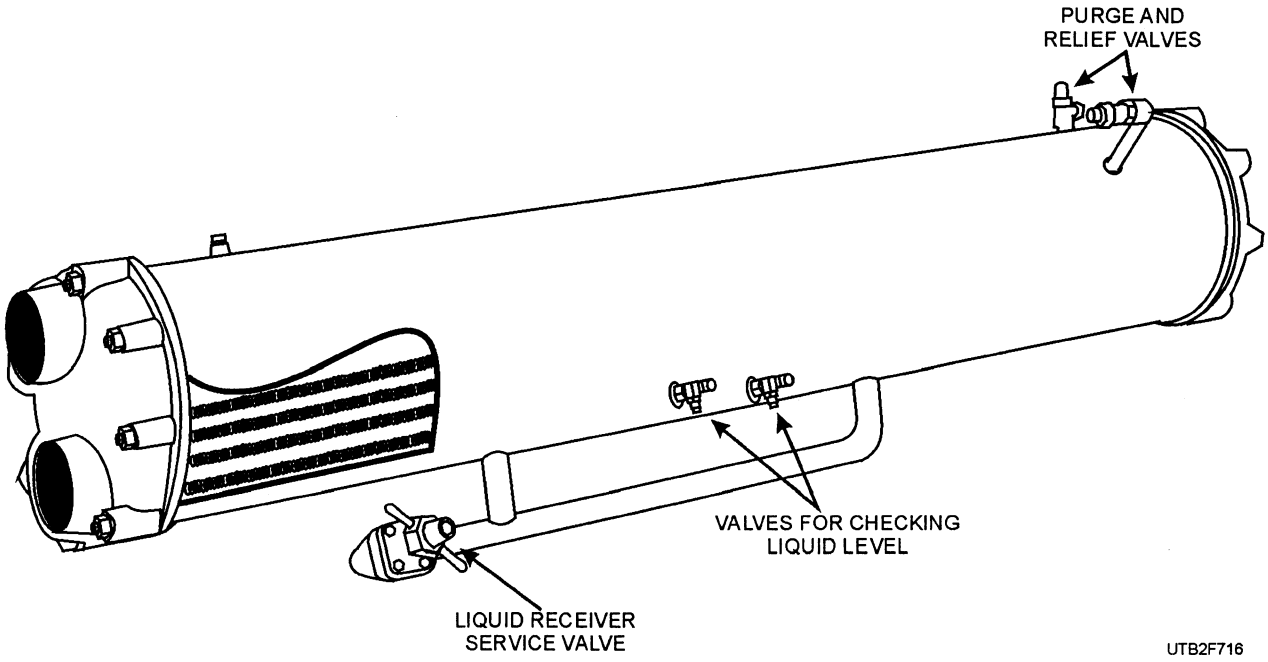


Figure 7-16.—A typical shell-and-tube condenser-liquid receiver.

through the inner tube along with the exterior air condenses (fig 7-17) the refrigerant in the outer tube. This "double cooling" improves efficiency of the condenser. Water enters the condenser at the point where the refrigerant leaves the condenser. It leaves the condenser at the point where the hot vapor from the compressor enters the condenser. This arrangement is called counterflow design.

The rectangular type of tube-within-a-tube condenser uses a straight, hard copper pipe with manifolds on the ends. When the manifolds are removed, the water pipes can be cleaned mechanically.

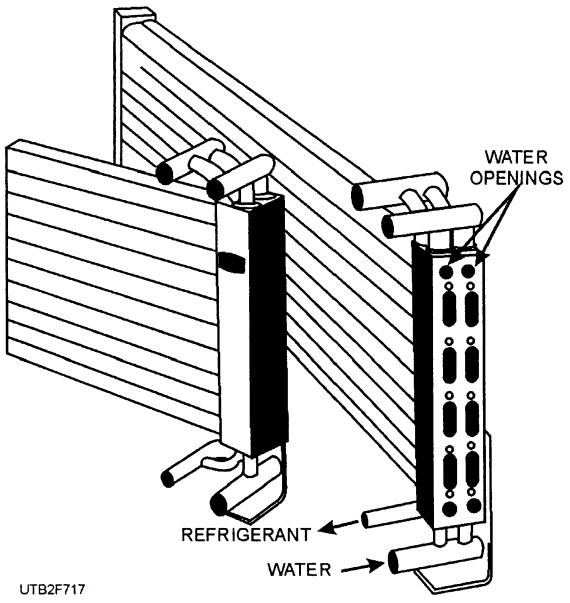


Figure 7-17.—Tube-within-a-tube condenser designed to permit cleaning of water tubes.

CLEANING WATER-COOLED CONDENSERS

You may be assigned to some activities where water-cooled condensers are used in the air-conditioning system. So, the Utilitiesman will probably have the job of cleaning the condensers. Information that assists you in cleaning water-cooled condensers is presented below.

Water contains many impurities—the content of which varies in different localities. Lime and iron are especially injurious; they form a hard scale on the walls of water tubes that reduces the efficiency of the condenser. Condensers can be cleaned mechanically or chemically.

Scale on tube walls of condensers with removable heads is removed by attaching a round steel brush to a rod and by working it in and out of the tubes. After the tubes have been cleaned with a brush, flush them by running water through them. Some scale deposits are harder to remove than others, and a steel brush may not do the job. Several types of tube cleaners for removing hard scale can usually be purchased from local sources. Be sure that the type selected does not injure water tubes.

The simplest method of removing scale and dirt from condenser tubes not accessible for mechanical

cleaning is by using inhibited acid to clean coils or tubes through chemical action. Figure 7-18 shows the connections and the equipment for cleaning the condenser with an inhibited acid, both when the acid flows by gravity (view 1) and when forced circulation is used (view 2). When scale deposit is not great, gravity flow of the acid provides enough cleaning. When the deposit almost clogs the tubes, forced circulation should be used.

WARNING

Prevent chemical solution from splashing in your eyes and on your skin or clothing.

Equipment and connections for circulating inhibited acid through the condenser using gravity flow, as shown in figure 7-18, view 1, are as follows:

1. A rubber or plastic bucket for mixing solution. Do not use galvanized materials because prolonged contact with acid deteriorates such surfaces.

2. A crock or wooden bucket for catching the drainage residue.

3. One-inch steel pipe that is long enough to make the connections shown.

4. Fittings for l-inch steel pipe. The vent pipe shown should be installed at the higher connection of the condenser.

Equipment and connections for circulating inhibited acid through the condenser using forced circulation, as shown in figure 7-18, are as follows:

1. A pump suitable for this application. A centrifugal pump and a 1/2-horsepower motor is recommended (30 gallons per minute at 35-foot head capacity).

2. A nongalvanized metal tank, stone or porcelain crock, or wooden barrel with a capacity of about 50 gallons with ordinary bronze or copper screening to keep large pieces of scale or dirt from getting into the pump intakes.

3. One-inch pipe that is long enough to make the piping connections shown.

4. Fittings for l-inch steel globe valves. The vent pipe, as shown, should be installed at the higher connection of the condenser.

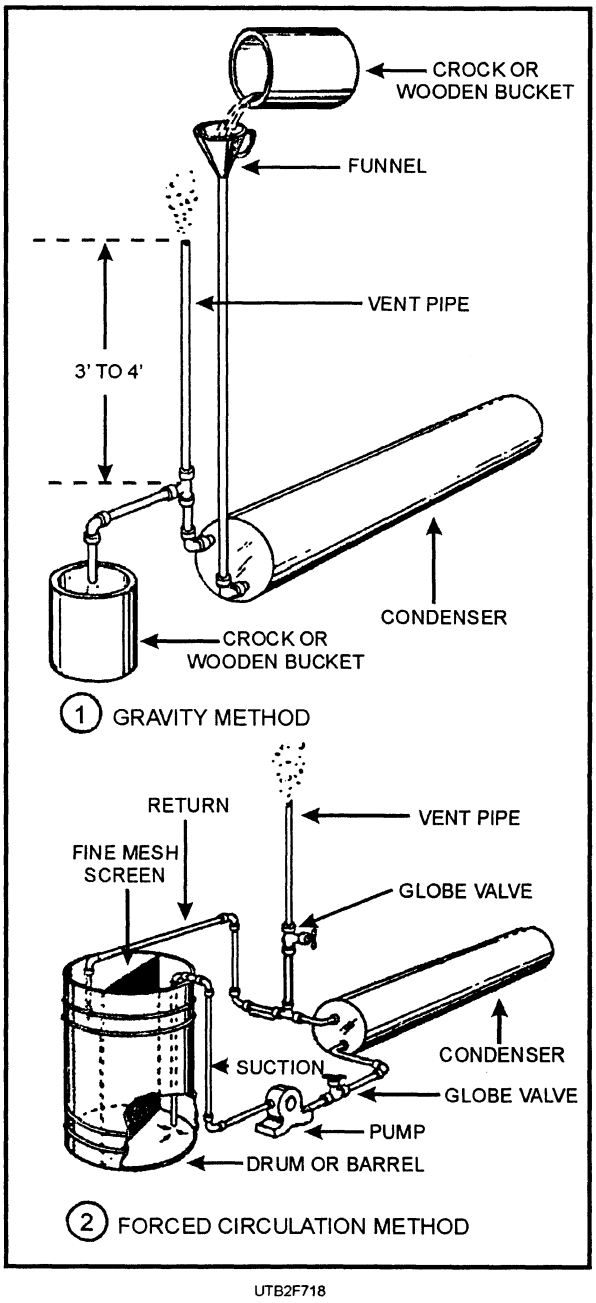


Figure 7-18.—Cleaning water-cooled condensers with acid solution.

Handle the inhibited acid for cleaning condensers with the usual precautions observed when handling acids. It stains hands and clothing and attacks concrete and if an inhibitor is not present, it reacts with steel. Therefore, use every precaution to prevent spilling or splashing. When splashing might occur, cover the surfaces with burlap or boards. Gas produced during cleaning that escapes through the vent pipe is not harmfu but prevents any liquid or spray from being carried hrough with the gas. The basic formula should

be maintained as closely as possible, but a variation of 5 percent is permissible. The inhibited acid solution is made up of the following:

1. Water.

2. Commercial hydrochloric (muriatic) acid with specific gravity of 1.19. Eleven quarts of acid should be used for each 10 gallons of water.

3. Three and two-fifths ounces of inhibitor powder for each 10 gallons of water used.

4. Place the required amount of water in a nongalvanized metal tank or wooden barrel, and add the necessary amount of inhibitor powder while stirring the water. Continue stirring the water until the powder is completely dissolved; then add the required quantity of acid.

WARNING

NEVER add water to acid; this mistake may cause an explosion.

In charging the system with an acid solution when GRAVITY FLOW is used, introduce the inhibited acid as shown in figure 7-18. Do not add the solution faster than the vent can exhaust the gases generated during cleaning. When the condenser has been filled, allow the solution to remain overnight.

When FORCED CIRCULATION is used, the valve in the vent pipe should be fully opened while the solution is introduced into the condenser but must be closed when the condenser is completely charged and the solution is circulated by the pump. When a centrifugal pump is used, the valve in the supply line may be fully closed while the pump is running.

The solution should be allowed to stand or be circulated in the system overnight for cleaning out average scale deposits. The cleaning time also depends on the size of the condenser to be cleaned. For extremely heavy deposits, forced circulation is recommended, and the time should be increased to 24 hours. The solution acts more rapidly if it is warm, but the cleaning action is just as thorough with a cold solution if adequate time is allowed.

After the solution has been allowed to stand or has been circulated for the required time through the condenser, it should be drained and the condenser thoroughly flushed with water. To clean condensers with removable heads by using inhibited acid, use the above procedure without removing the heads. However, extra precaution must be exercised in flushing out the condenser with clear water after the acid has been circulated through the condenser to ensure acid removal from all water passages.

MAINTENANCE

A well-planned maintenance program avoids unnecessary downtime, prolongs the life of the unit, and reduces the possibility of costly equipment failure. It is recommended that a maintenance log be maintained for recording the maintenance activities. This action provides a valuable guide and aids in obtaining extended length of service from the unit. This section describes specific maintenance procedures, which must be performed as a part of the maintenance program of the unit. Use and follow the manufacturer's manual for the unit you are to do maintenance on. When specific directions or requirements are furnished, follow them. Before performing any of these operations, however, ensure that power to the unit is disconnected unless otherwise instructed.

WARNING

When maintenance checks and procedures must be completed with the electrical power on, care must be taken to avoid contact with energized components or moving parts. Failure to exercise caution when working with electrically powered equipment may result in serious injury or death.

Coil Cleaning

Refrigerant coils must be cleaned at least once a year or more frequently if the unit is located in a dirty environment. This action helps maintain unit operating efficiency and reliability. The relationship between regular coil maintenance and efficient/ reliable unit operation is as follows:

- Clean condenser coils minimize compressor head pressure and amperage draw and promote system efficiency.
- Clean evaporator coils minimize water carry-over and helps eliminate frosting and/or compressor flood-back problems.

- Clean coils minimize required fan brake horsepower and maximize efficiency by keeping coil static pressure loss at a minimum.
- Clean coils keep the motor temperature and system pressure within safe operating limits for good reliability.

The following equipment is required to clean condenser coils: a soft brush and either a garden pump-up sprayer or a high-pressure sprayer. In addition, a high-quality detergent must be used. Follow the manufacturer's recommendations for mixing to make sure the detergent is alkaline with a pH value less than 8.5.

Specific steps required for cleaning the condenser coils are as follows:

1. Disconnect the power to the unit.

WARNING

Open the unit disconnect switch. Failure to disconnect the unit from the electrical power source may result in severe electrical shock and possible injury or death.

2. Remove enough panels from the unit to gain access to the coil.
3. Protect all electrical devices, such as motors and controllers, from dust and spray.
4. Straighten coil fins with a fin rake, if necessary.
5. Use a soft brush to remove loose dirt and debris from both sides of the coil.
6. Mix the detergent with water according to the manufacturer's instructions. The detergent and water solution may be heated to a maximum of 150°F to improve its cleaning ability.

WARNING

Do not heat the detergent and water solution to temperatures in excess of 150°F. High-temperature liquids sprayed on the coil exterior raise the pressure within the coil and may cause it to burst. Should this occur, the result could be both injury to personnel and equipment damage.

7. Place the detergent and water solution in the sprayer. If a high-pressure sprayer is used, be sure to follow these guidelines:
   - Minimmum nozzle spray angle is 15 degrees.
   - Spray the solution perp endicular (at a 90-degree angle) to the coil face.
   - Keep the sprayer nozzle at least 6 inches from the coil.
   - Sprayer pressure must not exceed 600 psi.

CAUTION

Do NOT spray motors or other electrical components. Moisture from the spray can cause component failure.

8. Spray the side of the coil where the air leaves first; then, spray the other side (where the air enters). Allow the detergent and water solution to stand on the coil for 5 minutes.
9. Rinse both sides of the coil with cool water.
10. Inspect the coil and if it still appears dirty, repeat Steps 8 and 9.
11. Remove the protective covers installed in Step 3.
2. Replace all unit panels and parts, and restore electrical power to the unit.

Fan Motors

Inspect periodically for excessive vibration or temperature. Operating conditions vary the frequency of inspection and lubrication. Motor lubrication instructions are found on the motor tag or nameplate. If not available, contact the motor manufacturer for instructions.

To re-lubricate the motor, complete the following:

WARNING

Disconnect the power source for motor lubrication. Failure to do so may result in injury or death from electrical shock or moving parts.

1. Turn the motor off. Make sure it cannot accidentally restart.

2. Remove the relief plug and clean out any hardened grease.

3. Add fresh grease through the fitting with a low-pressure grease gun.

4. Run the motor for a few minutes to expel any excess grease through the relief vent.

5. Stop the motor and replace the relief plug

Fan Bearing Lubrication

Fan bearings with grease fittings or with grease line extensions should be lubricated with a lithium-base grease that is free of chemical impurities. Improper lubrication can result in early bearing failure. To lubricate the fan bearings, complete the following:

1. Lubricate the bearings while the unit is not running; disconnect the main power switch.

2. Connect a manual grease gun to the grease line or fitting.

3. Add grease, preferably when the bearing is warm, while turning the fan wheel manually until a light bead of grease appears at the bearing grease seal.

Filters

To clean permanent filters, wash under a stream of hot water to remove dirt and lint. Follow with a wash of mild alkali solution to remove old filter oil. Rinse thoroughly and let dry. Recoat both sides of the filter with filter oil and let dry. Replace the filter element in the unit.

CAUTION

Always install filters with directional arrows pointing toward the fans.

PERIODIC MAINTENANCE

Perform all of the indicated maintenance procedures at the intervals scheduled. This prolongs the life of the unit and reduces the possibility of costly equipment failure and downtime. A checklist should be prepared which lists the required service operations and the times at which they are to be performed. The following is a sample of such a list.

Weekly

1. Check the compressor oil level. If low, allow the compressor to operate continually at full load for 3 to 4 hours; check the oil level at 30-minute intervals. If the level remains low, add oil.

2. Observe the oil pressure. The oil pressure gauge reading should be approximately 20 to 35 psi above the suction pressure gauge reading.

3. Stop the compressor and check the shaft seal for excessive oil leakage. If found, check the seal with a refrigerant leak detector (open compressor only).

4. Check the condition of the air filters and air-handling equipment. Clean or replace filters, as necessary.

5. Check the general operating conditions, system pressures, refrigerant sight glass, and so forth.

Monthly

(Repeat Items 1 through 5)

6. Lubricate the fan and motor bearings, as necessary. Obtain and follow the manufacturer's lubricant specifications and bearing care instructions.

7. Check the fan belt tension and alignment.

8. Tighten all fan sheaves and pulleys. If found to be loose, check alignment before tightening.

9. Check the condition of the condensing equipment. Observe the condition of the condenser coil in the air-cooled condenser. Clean, as necessary. Check the cooling tower water in the water-cooled condenser. If algae or scaling is evident, water treatment is needed. Clean the sump strainer screen of the cooling tower.

Annually

(Repeat Items 1 through 9)

10. Drain all circuits of the water-condensing system. Inspect the condenser piping and clean any scale or sludge from the tubes of the condenser.

11. If a cooling tower or evaporative condenser is used, flush the pumps and sump tank. Remove any rust or corrosion from the metal surfaces and repaint.

12. Inspect all motor and fan shaft bearings for signs of wear. Check the shafts for proper end-play adjustment.

13. Replace worn or frayed fan belts.

14. Clean all water strainers.

15. Check the condition of the ductwork.

16. Check the condition of the electrical contacts of all contactors, starters, and controls. Remove the condensing unit control box cover and inspect the panel wiring. All electrical connections should be secure. Inspect the compressor and condenser fan motor contactors. If the contacts appear severely burned or pitted, replace the contactor. Do not clean the contacts. Inspect the condenser fan capacitors for visible damage.

Seasonal Shutdown

In preparation for seasonal shutdown, it is advisable to pump down the system and valve off the bulk of the refrigerant charge in the condenser. This action minimizes the quantity of refrigerant that might be lost due to any minor leak on the low-pressure side of the system, and, in the case of the open compressor, refrigerant that might leak through the shaft seal.

The following steps should be followed for the hermetic compressor pump down.

1. Close the liquid line shutoff valve at the condenser and start the system. When the suction pressure drops to the cutout setting of the low-pressure control, the compressor stops.

2. Open the compressor electrical disconnect switch to prevent the compressor from restarting, and then front-seat the compressor discharge and suction valves.

The following steps should be followed for the open compressor pump down.

1. If the system is not equipped with gauges, install a pressure gauge in the back-seat port of the compressor suction valve. Crack the valve off the backseat.

2. Close the liquid line shutoff valve at the condenser.

3. Manually open the liquid line solenoid valve(s). If the valves do not have manual opening devices, lower the setting of the system temperature controller so the valves are held open during the pump down.

4. Install a jumper wire across the terminals of the low-pressure switch. Since the system suction pressure is to be pumped down below the cutout setting of the low-pressure switch, the jumper is necessary to keep the compressor running.

5. Start the compressor. Watching the suction pressure gauge, stop the compressor by opening its electrical disconnect switch when the gauge reading reaches 2 psig.

6. Front-seat the compressor discharge valve.

CAUTION

Do not allow the compressor to pump the suction pressure into a vacuum. A slight positive pressure is necessary to prevent air and moisture from being drawn into the system through minor leaks and through the now unmoving shaft seal.

7. Remove the jumper wire from the low-pressure control.

8. Remove the gauge from the port of the suction valve; replace the port plug and front-seat the valve.

The following steps are required for all systems:

1. Using a refrigerant leak detector, check the condenser and liquid receiver, if used, for refrigerant leaks.

2. Valve off the supply and return water connections of the water-cooled condenser. Allow the condenser to remain full of water during the off season. A drained condenser shell is more likely to rust and corrode than one full of water. If the condenser will be subjected to freezing temperatures, drain the water and refill it with an antifreeze solution.

3. Drain the cooling tower or evaporative condenser, if used; flush the sump and paint any rusted or corroded areas.

4. Open the system master disconnect switch and padlock it in the OPEN position.

Seasonal Start-up

The steps to follow for the seasonal start-up are as follows:

1 Perform all annual maintenance on the air-handling system and other related equipment.

2 Fill the water sump of the cooling tower or evaporative condenser, if used.

3. Open the shutoff valves of the water-cooled condenser.

4. Make certain the liquid line solenoid valve(s) is on automatic control.

5. Open the liquid line shutoff valve.

6. Back-seat the compressor suction and discharge valves.

7. Close the system master electrical disconnect switch.

8. Start the system.

9. After the system has operated for 15 to 20 minutes, check the compressor oil level sight glass, oil pressure, and the liquid line sight glass. If satisfactory, readjust the system temperature controller to the proper temperature setting.

SAFETY WARNINGS

Most units used for comfort air conditioning operate using R-12 or R-22 refrigerants that are not toxic except when decomposed by a flame. If the liquefied refrigerant contacts the eyes, the person suffering the injury must be taken to a doctor at once.

Should the skin come in contact with the liquefied refrigerant, the skin is to be treated as though it had been frostbitten or frozen. Refer to NAVEDTRA 13119, *Standard First Aid for Treatment of Frostbite.*

Do not adjust, clean, lubricate, or service any parts of equipment that are in motion. Ensure that moving parts, such as pulleys, belts, or flywheels, are fully enclosed with proper guards attached.

Before making repairs, open all electric switches controlling the equipment. Tag and lock the switches to prevent short circuits or accidental starting of equipment. When moisture and brine are on the floor, fatal grounding through the body is possible when exposed electrical connections can be reached or touched by personnel. De-energize electrical lines before repairing them, and ground all electrical tools.

Q9. What are the two types of self-contained air-conditioning units?

Q10. Who normally operates a window air-conditioning unit?

Q11. Floor units are often referred to as what type of unit?

Q12. What type of unit cools and heats by reversing its cycle?

Q13. The reversing valve changes the direction of hot gas from what component to what other component in the system?

Q14. Heat pumps operating below 45°F develop what problem on the outside coils?

Q15. When the capacity of a heat pump matches the heat loss, it has reached what point?

Q16. What are the two most common evaporators used for water chiller systems?

Q17. Dry-expansion evaporators are controlled by what type of expansion valve?

Q18. Why is a tube-within-a-tube condenser popular?

Q19. Condensers can be cleaned in what two ways?

Q20. Refrigerant coils should be cleaned at least how often?

MAJOR SYSTEM COMPONENTS AND CONTROLS

Learning Objectives: Recognize and understand different types of cooling towers, compressors, and controls. Understand basic maintenance requirements for cooling towers.

In this section, cooling towers and compressors which are the two major components of an air-conditioning system are discussed. In addition, the major control elements of an air-conditioned system are also covered.

COOLING TOWERS

Cooling towers are classified according to the method of moving air through the tower as natural draft, induced draft, or forced draft (figs. 7-19 and 7-20).

Natural Draft

The natural draft cooling tower is designed to cool water by means of air moving through the tower at the low velocities prevalent in open spaces during the summer. Natural draft towers are constructed of cypress or redwood and have numerous wooden decks of splash bars installed at regular intervals from the bottom to the top. Warm water from the condenser is

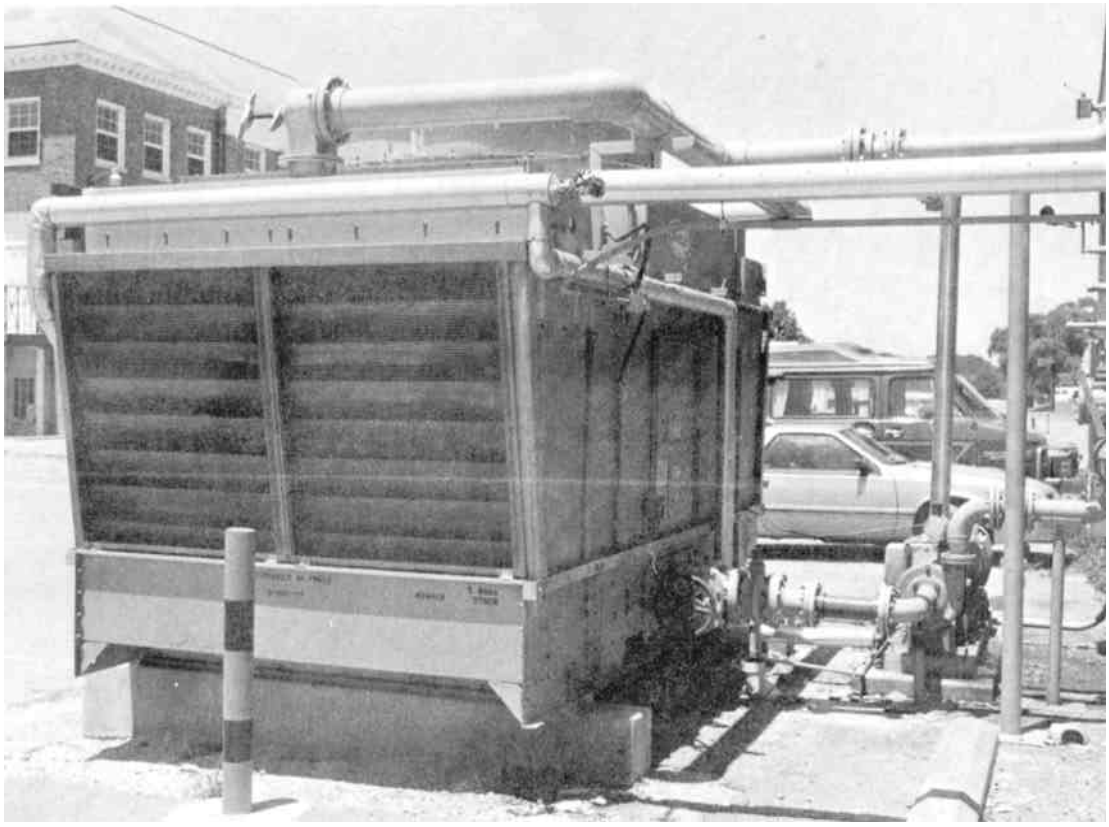


Figure 7-19.—A package tower with a remote, variable speed pump.

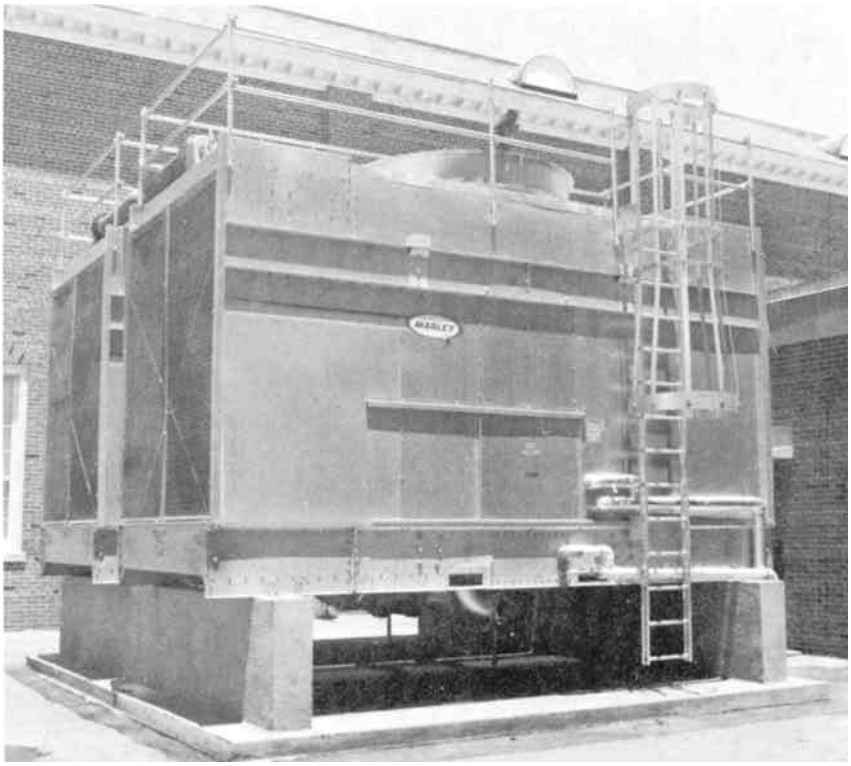


Figure 7-20.—Paralleled package towers.

flooded or sprayed over the distributing deck and flows by gravity to the water-collecting basin.

A completely open space is required for the natural draft tower since its performance depends on existing air currents. Ordinarily, a roof is an excellent location. Louvers must be placed on all sides of a natural draft tower to reduce drift loss.

Important design considerations are the wind velocity and the height of the tower. A wind velocity of 3-miles per hour is generally used for a design of natural draft cooling towers. The natural draft cooling tower was once the standard design for cooling condenser water in refrigeration systems up to about 75 tons. It is now rarely selected unless low initial cost and minimum power requirements are primary considerations. The drift loss and space requirements are much greater than for other cooling tower designs.

Induced Draft

An induced draft cooling tower is provided with a top-mounted fan that induces atmospheric air to flow up through the tower, as warm water falls downward. An induced draft tower may have only spray nozzles for water backup, or it may be filled with various slat and deck arrangements. There are several types of induced draft cooling towers.

In a counterflow induced draft tower (fig. 7-21, C), a top-mounted fan induces air to enter through the bottom of the tower and to flow vertically upward as the water cascades down through the tower. The counterflow tower is particularly well adapted to a restricted space as the discharge air is directed vertically upward, and if equipped with a inlet on each side, requires only minimum clearance for air intake area. The primary breakup of water may be either by pressure spray or by gravity from pressure-filled flumes.

A parallel-flow induced draft tower (fig. 7-21, A) operates the same way as a counter-flow tower, except the top-mounted fan pulls the air in through the top of the tower and pushes it out the bottom. The airflow goes in the same direction as the water.

Comparing counterflow and parallel-flow induced draft towers of equal capacity, the parallel-flow tower is somewhat wider but the height is much less. Cooling towers must be braced against the wind. From a structural standpoint, therefore, it is much easier to design a parallel-flow than a counterflow tower, as the low silhouette of the parallel-flow type offers much less resistance to the force of the winds.

Mechanical equipment for counterflow and parallel-flow towers is mounted on top of the tower and is readily accessible for inspection and maintenance. The water-distributing systems are completely open on top of the tower and can be inspected during operation. This makes it possible to adjust the float valves and clean stopped-up nozzles while the towers are operating.

The cross-flow induced draft tower (fig. 7-21, B) is a modified version of the parallel-flow induced draft tower. The fan in a cross-flow cooling tower draws air through a single horizontal opening at one end and discharges the air at the opposite end.

The cooling tower is a packaged tower that is inexpensive to manufacture and is extremely popular for small installations. As a packaged cooling tower

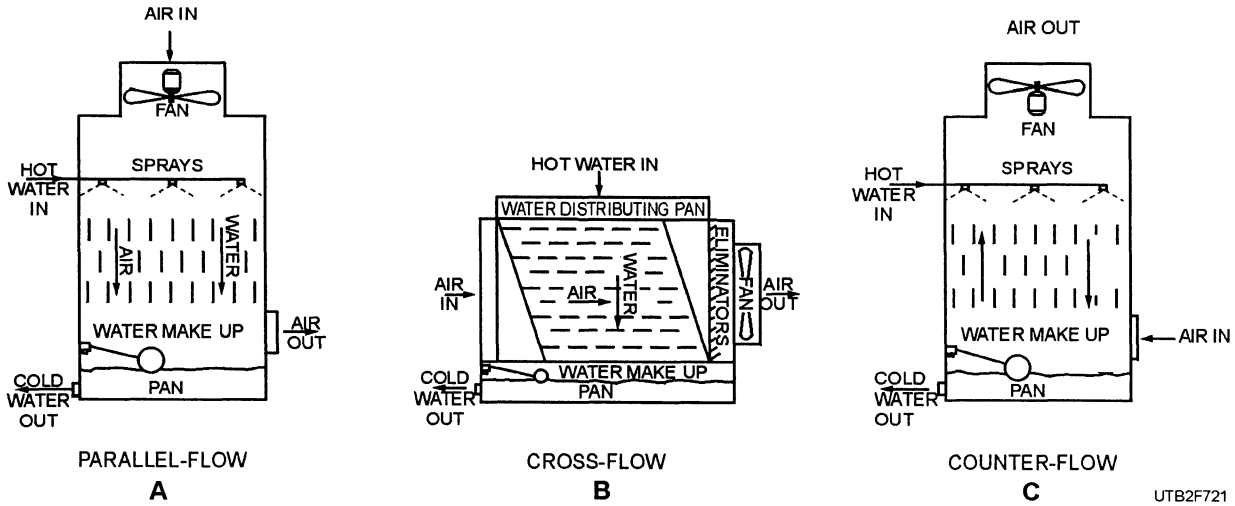


Figure 7-21.—Types of induced fan cooling towers.

with piping and wiring in place, it is simple to install and may be placed wherever there is a clearance of 2 feet for the intake end and a space of 10 feet or more in front of the fan. The discharge end must not face the prevailing wind and should not be directed into a traffic area because drift loss may be objectionable.

In some situations, an indoor location for the cooling tower may be desirable. An induced draft tower of the counterflow or cross-flow design is generally selected for indoor installation. Two connections to the outside are usually required—one for drawing outdoor air into the tower and the other for discharging it back to the outside. A centrifugal blower is often necessary for this application to overcome the static pressure of the ductwork. Many options are possible as to the point of air entrance and air discharge. This flexibility is often important in designing an indoor installation. Primary water breakup is by pressure spray and fill of various types.

The induced draft cooling tower for indoor installation is a completely assembled packaged unit but is so designed that it can be partially disassembled to permit passage through limited entrances. Indoor installations of cooling towers are becoming more popular. External space restrictions, architectural compatibility, convenience for observation and maintenance all combine to favor an indoor location. The installation cost is somewhat higher than an outdoor location. Packaged towers are available in capacities to serve the cooling requirements of refrigeration plants in the 5- to 75-ton range.

Forced Draft

A forced draft cooling tower uses a fan to force air into the tower. In the usual installation, the fan shaft is in a horizontal plane. The air is forced horizontally through the fill and upward to be discharged out of the top of the tower.

Underflow cooling towers are an improved design of the forced draft tower that retains all the advantages of the efficient parallel-flow design. Air is forced into the center of the tower at the bottom. The air is then turned horizontally (both right and left) through fill chambers and is discharged vertically at both ends. By forcing the air to flow upward and outward through the fill and leave at the ends, operating noise is baffled and a desirable reduction of sound level is achieved. All sides of the underflow tower are smoothly encased with no louver openings. This blends with modern architecture and eliminates the necessity of masonry walls or other screening devices oftentimes necessary to conceal cooling towers of other types.

Materials

Redwood has been the standard construction material for cooling towers for many years. Though cypress, as well as treated fir and pine, has been used occasionally, these materials have not enjoyed a wide application. Casings are constructed of laminated waterproof plywood. Such casings, as well as other noncorrosive materials at critical points, are essential in areas having a highly corrosive atmosphere. Nails, bolts, and nuts of copper or aluminum are almost standard practice for cooling tower construction.

Cooling towers of metal coated with plastic or bituminous materials that have air intake louvers and fill made of redwood have met with only limited success. The limited success is primarily because of the high maintenance cost as compared to wood towers.

Packaged towers with metal sides and wood fill are reasonably common. Some manufacturers have used sheet aluminum for siding for limited periods of time. Plastic slats have been used for fill material but have not proved satisfactory in all cases.

Fire ordinances of a large city may require that no wood be used in construction of cooling towers. With steel or some other fireproof casing and without fill, a cooling tower will comply with the most restrictive ordinances.

Maintenance

Recently, cooling towers have been linked to the spread of Legionnaire's disease. Several precautionary measures are recommended to help eliminate this problem. These include placing of cooling towers downwind and use of chloride compounds as disinfectants on a monthly maintenance schedule.

Water treatment is an important part of the operation of a cooling tower. The evaporation of water from a cooling tower leaves some solids behind. Recirculation of the water in the condenser cooling tower circuit, and the accompanying evaporation, causes the concentration of solids to increase. This concentration must be controlled or scale and corrosion will result.

Though draining the system from time to time and refilling with fresh water is one method of control, it is not recommended. Soon after refilling, the dissolved solids again build up to a dangerous concentration. A more common practice is to waste a certain amount of water continually from the system to the sewer. The water wasted is called blowdown. Blowdown is sometimes accomplished by wasting sump water through an overflow. A better practice, however, is to bleed the required quantity of blowdown from the warm water leaving the condenser on its way to the cooling tower. A mineral salt buildup (calcium bicarbonate concentration) of 10 grains per gallon is considered the maximum allowable concentration for untreated water in the sump if serious corrosion and scaling difficulties are to be avoided.

Cooling towers evaporate about 2 gallons of water every hour for each ton of refrigeration. A gallon of water weighs 8.3 pounds, and about 1,000 Btu is needed to evaporate 1 pound of water. Thus, to evaporate a gallon of water, 8.3 x 1,000 or 8,300 Btu is required.

In many instances, the makeup water contains dissolved salts in excess of 10 grains per gallon. It is obvious, then, that even 100 percent blowdown will not maintain a sump concentration of 10 grains. If the blowdown alone cannot maintain satisfactory control, then chemicals should be used.

Makeup water for a cooling tower is the sum of drift loss, evaporation, and blowdown. The drift loss for mechanical draft towers ranges from 0.1 percent of the total water being cooled for the better designed towers to as much as 0.3 percent. In estimating makeup water for a cooling tower, the higher value of 0.3 percent for drift loss is suggested. If the drift loss is actually less than this, the excess makeup water supplied is merely wasted down the overflow. This does, in effect, increase the amount of blowdown and is favorable from the viewpoint that the concentration of scale-forming compounds in the tower sump will be somewhat lower.

Redwood is a highly durable material; however, it is not immune to deterioration. The type of deterioration varies with the nature of the environmental conditions to which the wood is exposed. The principal types of deterioration are leaching, delignification, and microbiological attack.

Algae and slime are present in water and must be controlled chemically or the rate of heat transfer in the condenser will be materially reduced. Condenser tubing, cooling tower piping, and metal surfaces in the water-circulating system must be protected from scale and corrosion.

Using too much of a chemical or using the wrong chemical is known as overtreatment. It can materially reduce the performance or the life of a cooling tower condenser circuit.

COMPRESSORS

A compressor is the machine used to withdraw the heat-laden refrigerant vapor from the evaporator, compress it from the evaporator pressure to the condensing pressure, and push it to the condenser. A compressor is merely a simple pump that compresses the refrigerant gas. Compressors may be divided into the following three types—reciprocating, rotary, and centrifugal. The function of compressing a refrigerant is the same in all three general types, but the mechanical means differ considerably. Rotary compressors are used in small sizes only, and their use is limited almost exclusively to domestic refrigerators and small water coolers. Centrifugal compressors are used in large refrigerating and air-conditioning systems (fig. 7-22).

Reciprocating Compressors

Reciprocating compressors are usually powered by electric motors, although gasoline, diesel, and turbine drivers are sometimes used. In terms of capacity, reciprocating compressors are made in fractional horsepower for small, self-contained air conditioners and refrigeration equipment, increasing in size to about 250 tons or more capacity in larger installations. Reciprocating compressors are furnished in open, semisealed, and sealed (hermetic) types.

OPEN.—An open type of compressor shaft is driven by an external motor. The shaft passes through the crankcase housing and is equipped with a shaft seal to prevent refrigerant and oil from leaking or moisture and air from entering the compressor. Pistons are actuated by crankshafts or eccentric drive mechanisms mounted on the shaft. Discharge valves are usually mounted in a plate over the pistons. Suction valves are usually mounted either in the pistons, if suction vapors enter the cylinder through the side of the cylinder or through the crankcase, or in the valve plate over the pistons, if suction vapors enter the cylinder through the head and valve plate.



1. Centrifugal compressor with 5-inch impeller.
2. Refrigerant colled motor.
3. Control center.
4. Chiller section.
5. Condenser section.

Figure 7-22.—High-speed (36,000 rpm) single-stage centrifugal chiller.

Figure 7-23 shows a cross section of a typical open type of eccentric shaft compressor with suction valves in the valve plate of the head. Most belt-driven open type of compressors under 3 horsepower use a splash feed lubrication, but in larger size compressors, forced feed systems having positive displacement oil pumps are more common. The oil pump is usually driven from the rear end of the main shaft. Oil from the crankcase is forced under pressure through a hole in the main shaft to the seal, main bearing, and rod bearing, and through a hole in the rod up to the piston pins. Hermetically sealed compressor units used in window air conditioners are quite common in commercial sizes (under 5 horsepower) and are even made by some manufacturers in large tonnage sizes.

SEMISEALED.—Semisealed compressors are sometimes made in small sizes, but large tonnage units are always of the semisealed type. The primary difference between a fully sealed and a semisealed motor compressor is that in semisealed types the valve plates, and in some units the oil pump, can be removed for repair or replacement. This type of construction is helpful in larger sizes that are so bulky they would cause considerable trouble and expense in shipping, removing, and replacing the unit as a whole. Figure 7-24 shows a small semisealed compressor.

Sealed or semisealed units eliminate the belt drive and crankshaft seal, both of which are among the chief causes of service calls. Sealed and semisealed compressors are made either vertical or horizontal. The vertical type (fig. 7-25) usually has a positive displacement oil pump that forces oil under pressure of 10 to 30 psi to the main bearings, rod, or eccentric and pins, although they are sometimes splash oiled.

Although oil pumps for forced feed lubrication are also used on horizontal hermetic compressors, oil

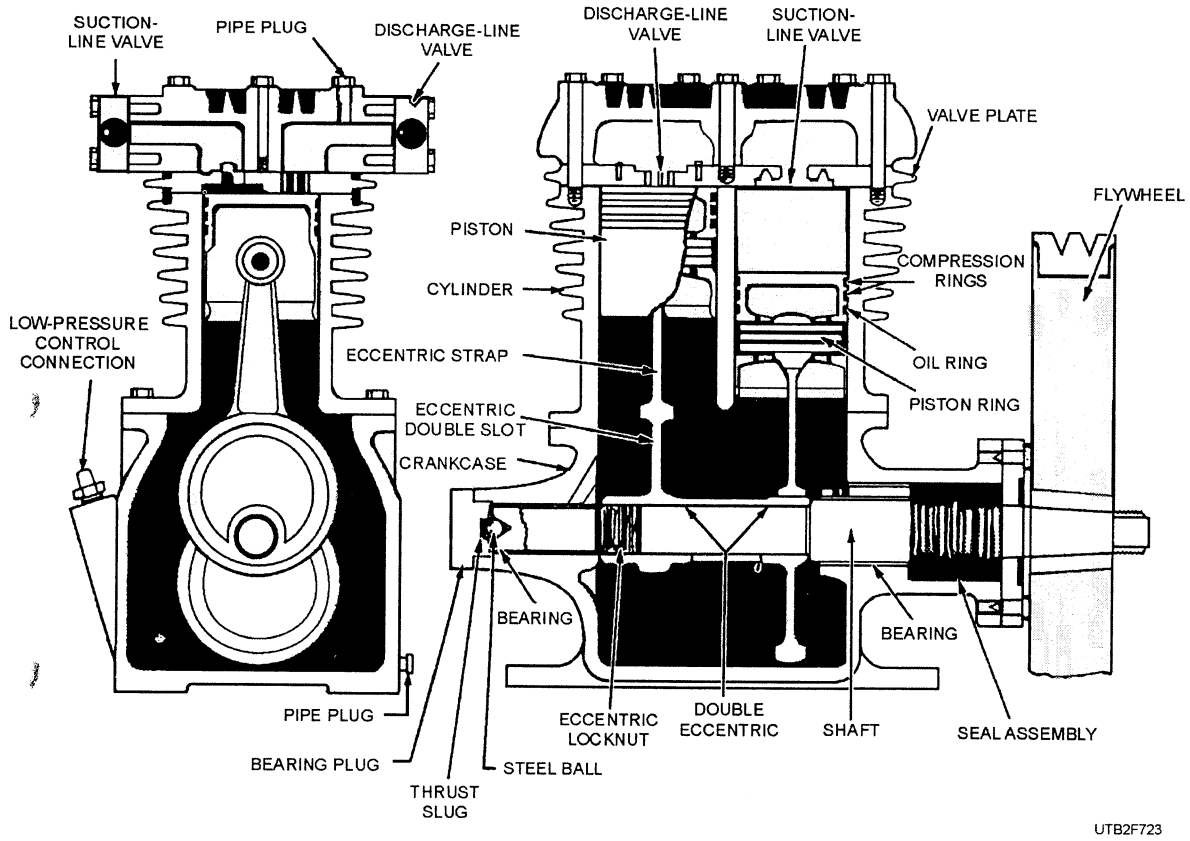


Figure 7-23.—Cross section of an open type of reciprocating compressor.

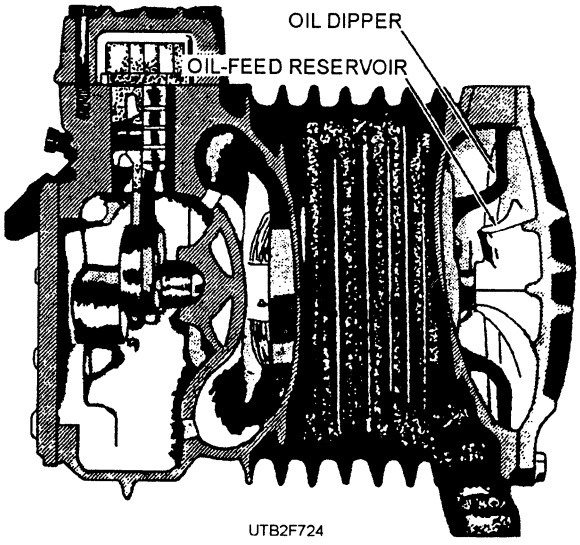


Figure 7-24.—Small semisealed compressor.

circulation at low oil pressure may be provided by slingers, screw type of devices, and the like. Splash and other types of oil feed must hot be considered inferior forced feed. With good design, they lubricate well. It is most important to maintain the proper oil level, use a correct grade of oil, and keep the system clean and free of dirt and moisture. This is true for all compression refrigeration systems, especially those equipped with

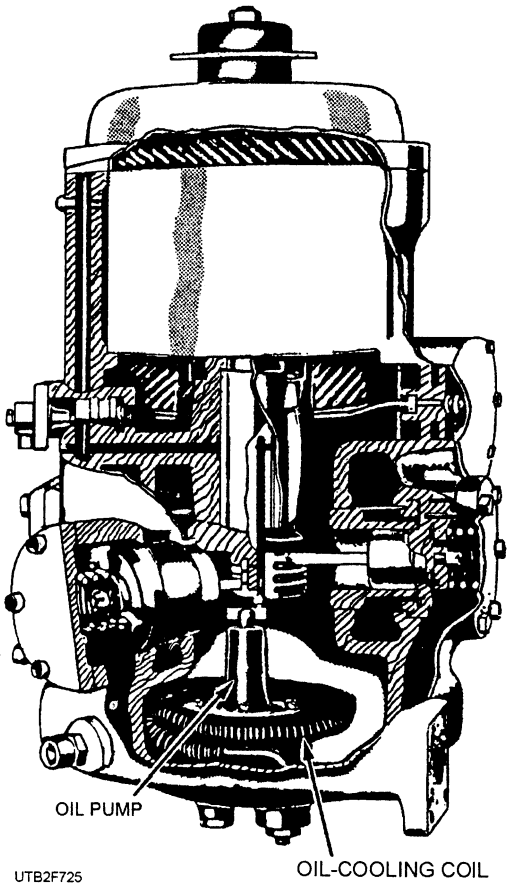


Figure 7-25.—Vertical semisealed compressor.

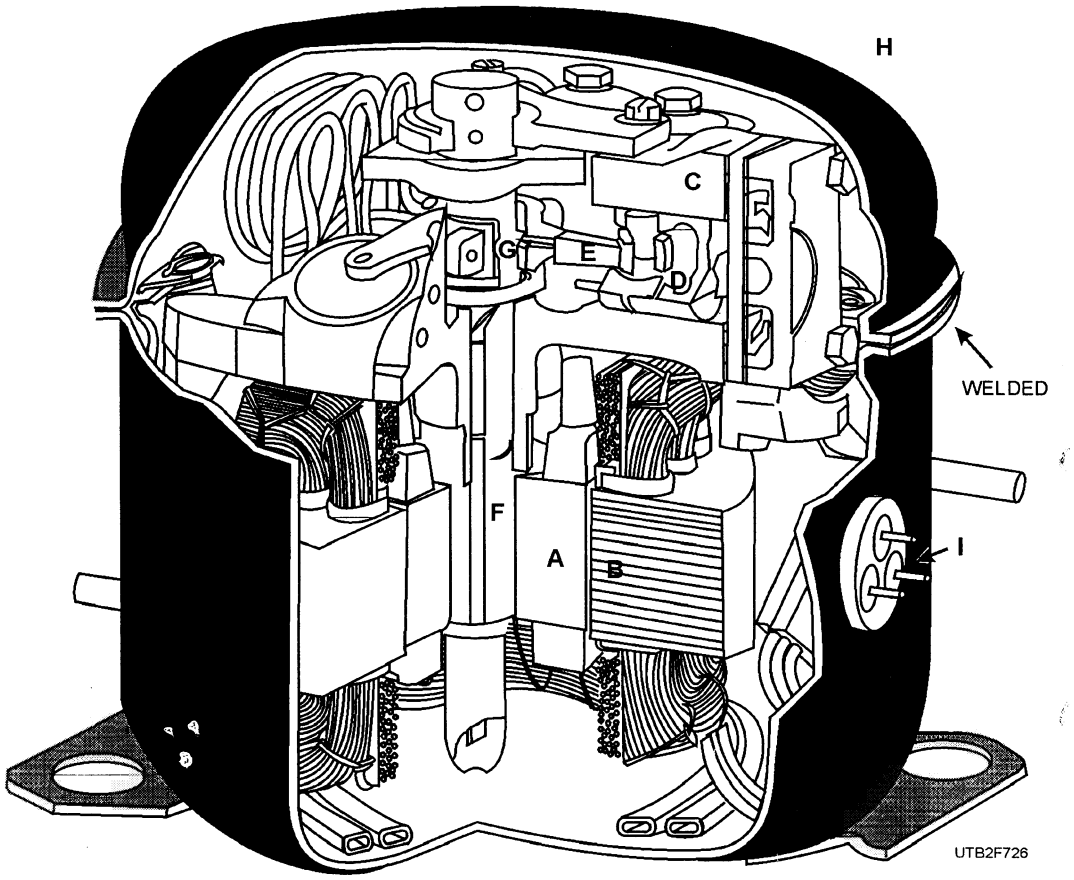


Figure 7-26.—Reciprocating hermetic compressor. (A) Motor rotor; (B) Motor stator; (C) Compressor cylinder; (D) Compressor piston; (E) Connecting rod; (F) crankshaft; (G) Crank throw; (H) Compressor shell (I) Glass sealed electrical connection.

hermetically sealed units whose motor windings may be attacked by acids or other corrosive substances introduced into the system or formed by the chemical reaction of moisture, air, or other foreign substances.

HERMETIC.—The term *sealed* or *hermetic* unit merely means that the motor rotor and compressor crankshaft of the refrigeration system are made in one piece, and the entire motor and compressor assembly is put into a gastight housing that is welded shut (fig. 7-26). This method of assembly eliminates the need for certain parts found in the open unit. These parts are as follows: motor pulley, belt, compressor flywheel, and compressor seal. The elimination of the preceding parts in the sealed unit similarly does away with the following service operations: replacing motor pulleys, replacing flywheels, replacing belts, aligning belts, and repairing or replacing seals. When it is realized there are major and minor operations that maintenance personnel must perform and the sealed unit dispenses with only five of these, it can be readily seen that servicing is still necessary.

Rotary Compressors

Rotary compressors are generally associated with refrigerators, water coolers, and similar small capacity equipment. However, they are available in larger sizes. A typical application of a large compressor is found in compound compressor systems where high capacity must be provided with a minimum of floor space.

In a rotary compressor (fig. 7-27), an eccentric rotor revolves within a housing in which the suction and discharge passages are separated by means of a sealing blade. When the rotating eccentric first passes this blade, the suction area is at a minimum. Further rotation enlarges the space and draws in the charge of refrigerant. As the eccentric again passes the blade, the gas charge is shut off at the inlet, compressed, and discharged from the compressor. There are variations

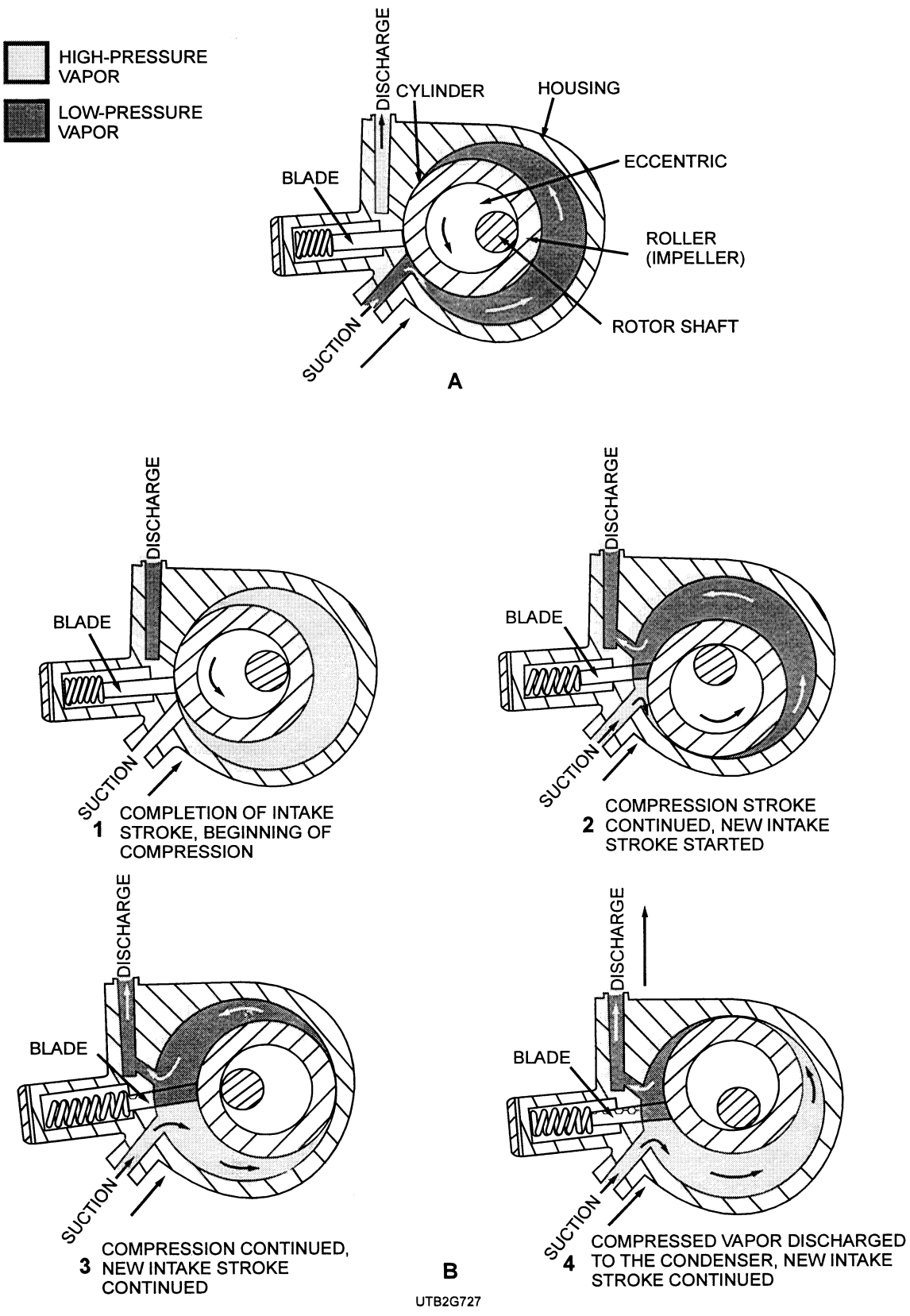


Figure 7-27.—Rotary compressor: A. Part identification; B. Operation.

of this basic design, some of which provide the rotor with blades to trap and compress the vapor.

Centrifugal Compressors

Centrifugal compressors are used in large refrigeration and air-conditioning systems, handling large volumes of refrigerants at low-pressure differentials. Their operating principles are based on the use of centrifugal force as a means of compressing and discharging the vaporized refrigerant. Figure 7-28 is a cutaway view of one type of centrifugal compressor. In this application, one or two compression stages are used, and the condenser and evaporator are integral parts of the unit. The heart of this type of compressor is the impeller wheel.

Scroll Compressors

A scroll compressor has two different offset spiral disks to compress the refrigerant vapor. The upper scroll is stationary, while the lower scroll is the driven scroll. Intake of refrigerant is at the outer edge of the driven scroll, and the discharge of the refrigerant is at the center of the stationary scroll. The driven scroll is rotated around the stationary or "fixed" scroll in an orbiting motion. During this movement, the refrigerant vapor is trapped between the two scrolls. As the driven scroll rotates, it compresses the refrigerant vapor through the discharge port. Scroll compressors have few moving parts and have a very smooth and quiet operation.

CONTROLS

Controls used in air conditioning are generally the same as for refrigeration systems—thermostats, humidistats, pressure and flow controllers, and motor overload protectors (fig. 7-29).

Thermostats

The thermostat is an adjustable temperature-sensitive device, which through the opening and closing of its contacts controls the operation of the

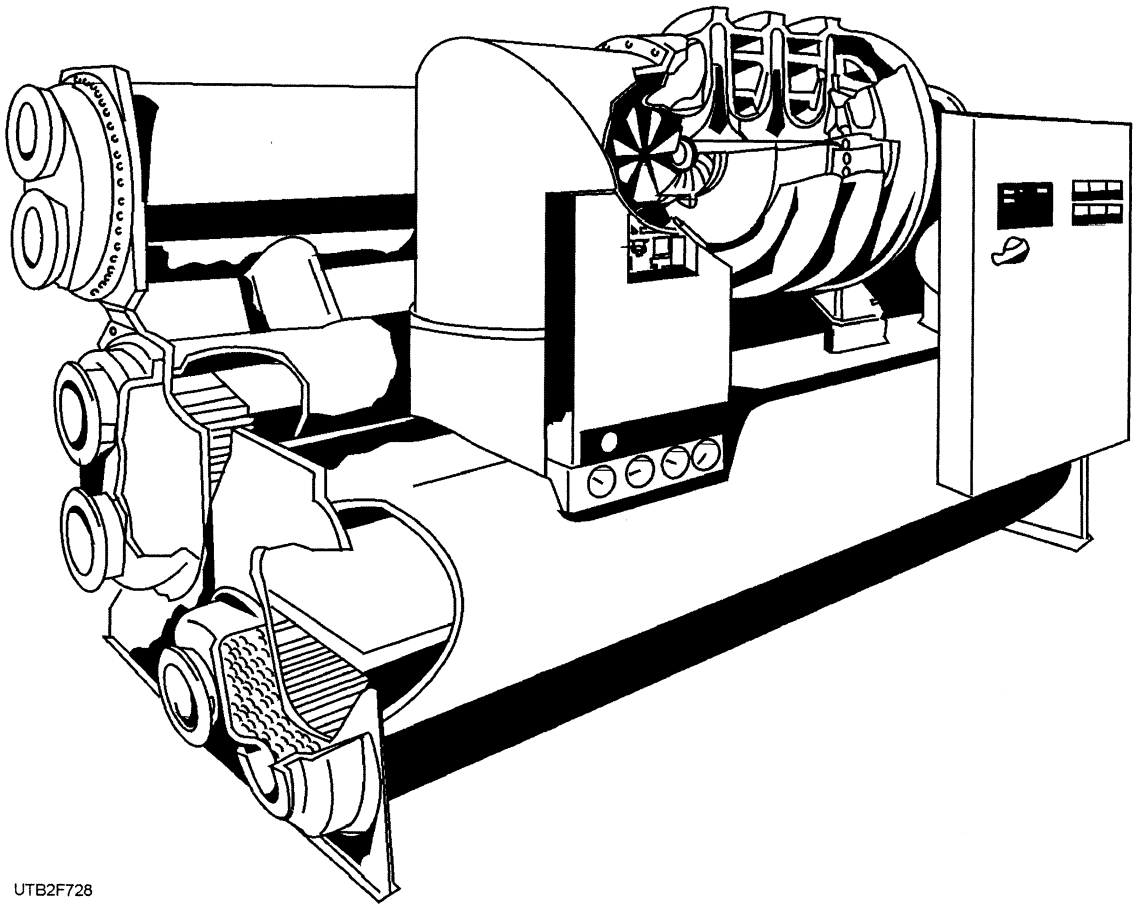
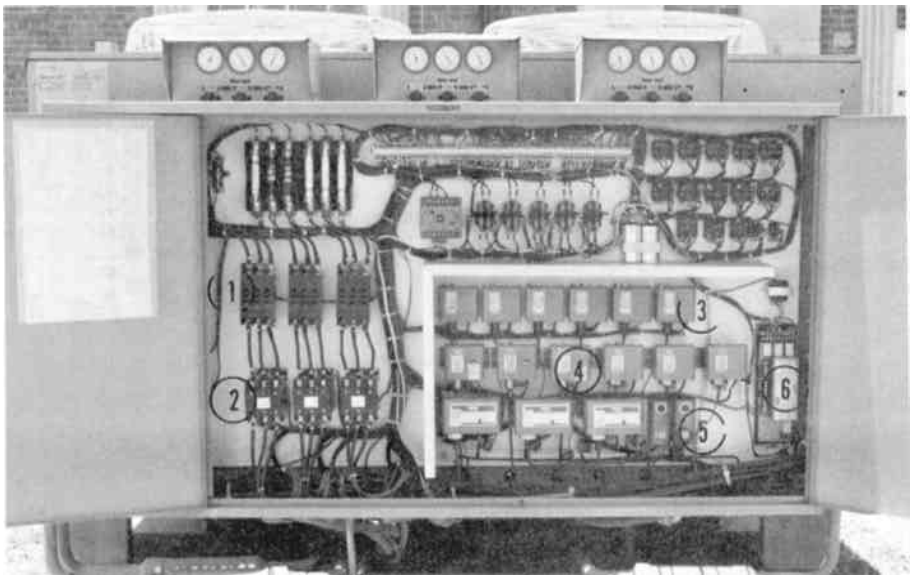


Figure 7-28.—Cutaway view of one type of centrifugal compressor.



1. Commpressor breakers.
2. Compressor starters.
3. Fan cycle controls.
4. High-pressure controls.
5. Oil failure controls.
6. Solid-state staging thermostat.

Figure 7-29.—Packaged air-cooled chiller controls.

cooling unit. The temperature-sensitive element may be a bimetallic strip or a confined, vaporized liquid.

The thermostats used with refrigerative air conditioners are similar to those used with heating equipment, except their action is reversed. The operating circuit is closed when the room temperature rises to the thermostat control point and remains closed until the cooling unit decreases the temperature enough. Also, cooling thermostats are not equipped with heat-anticipating coils.

Wall type of thermostats most common for heating and air conditioning in the home and on some commercial units use a bimetallic strip and a set of contacts, as shown in figure 7-30. This type of thermostat operates on the principle that when two dissimilar metals, such as brass and steel, are bonded together, one tends to expand faster than the other does when heat is applied. This causes the strip to bend and close the controls.

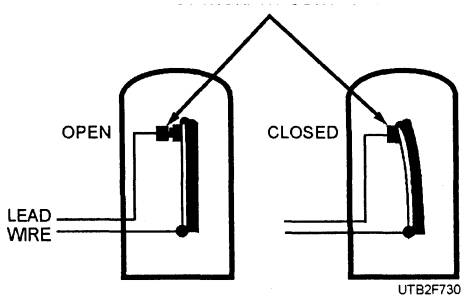


Figure 7-30.—Bimetallic thermostat.

As a Utilitiesman, you may be required to make an adjustment that sets the temperature difference between the cut-in and cutout temperatures. For example, if the system is set to cut in at 76°F and cut out at 84°F, then the differential is 8°F. This condition prevents the unit from cycling continually as it would if there were no differential.

Humidistats

A room "humidistat" may be defined as a humidity-sensitive device controlling the equipment that maintains a predetermined humidity of the space where it is installed. The contact of the humidistat is opened and closed by the expansion or contraction of natural blonde hairs from human beings, which is one of the major elements of this control. It has been found that these types of hairs are most sensitive to the moisture content of the air surrounding them.

Pressure-Flow Controllers

Pressure-flow controllers are discussed in chapter 6. The purpose of these controllers in air conditioning is to act as safety switches for the system, so if either the head pressure is too high or suction pressure too low, the system will be secured regardless of the position of the operating switches.

Refrigerant-Flow Controllers

The refrigerant-flow controllers used with air conditioners are also similar to the ones discussed in chapter 6. These controllers are either of the capillary type or externally equalized expansion valve type and

are usually of larger tonnage than those used for refrigerators.

Motor Overload Protectors

When the compressor is powered by an electric motor, either belt driven or as an integral part of the compressor assembly, the motor is usually protected by a heat-actuated overload device. This is in addition to the line power fuses. The heat to actuate the overload device is supplied by the electrical energy to the motor, as well as the heat generated by the motor itself. Either source of heat or a combination of the two, if too much, causes the overload device to open and remove the motor from the line.

Figure 7-31 shows a thermal-element type of overload cutout relay. It is housed in the magnetic starter box. On current overload, the relay contacts open, allowing the holding coil to release the starting mechanism, thereby stopping the motor.

An oil failure cutout switch is provided on many systems to protect the compressor against oil failure. The switch is connected to register pressure differential between the oil pump and the suction line. Figure 7-32 shows a typical oil failure cutout switch. The switch contains two bellows, which work against each other, and springs for adjusting. Tubing from the oil pump is connected to the bottom bellows of the switch. Tubing from the suction line is connected to the upper bellows. When a predetermined pressure differential is not maintained, a pair of contacts in the switch is opened and breaks the circuit to the compressor motor. A heating element with a built-in delay is in the switch to provide for starting the compressor when oil pressure is low.

The water-regulating valve used with a water-cooled condenser responds to a predetermined condensing pressure. A connection from the discharge side of the compressor to the valve transmits condensing pressure directly to a bellows inside the

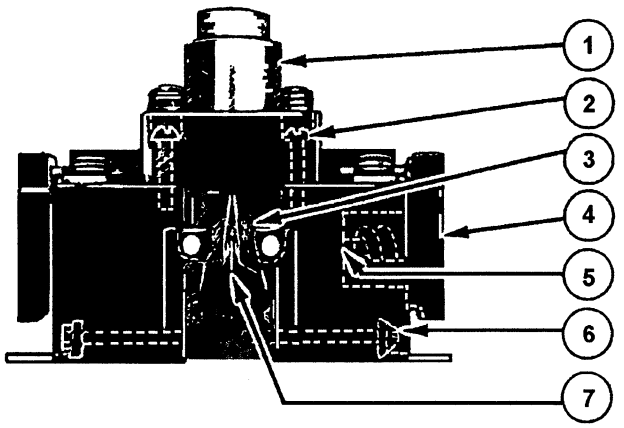


Figure 7-31.—Thermal overload relay.

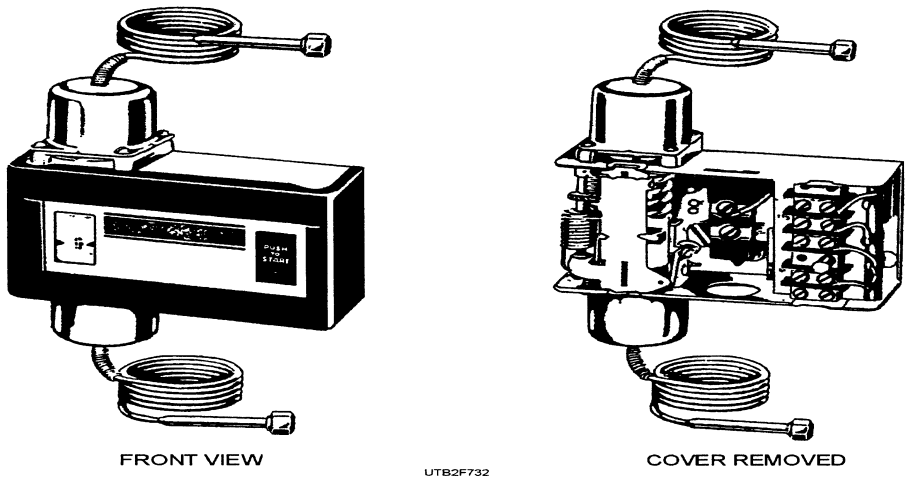


Figure 7-32.—Oil failure cutout switch.

valve. High pressure opens the valve, allowing a greater flow of water; low pressure throttles the flow. Use of such a valve provides for a more economical use of water for condensing. Figure 7-33 shows a typical water-regulating valve. When condenser water is supplied by a cooling tower, water-regulating valves are not customarily used because the cooling tower fan and circulating pump are wired into the compressor motor control circuit.

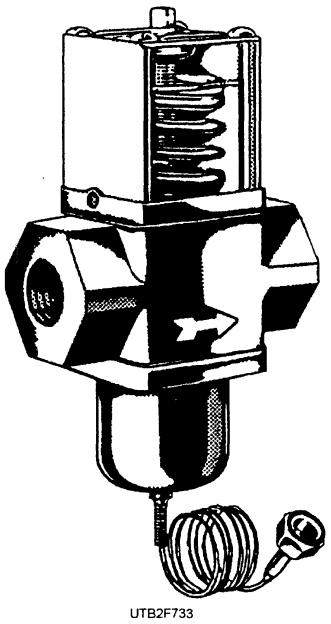


Figure 7-33.—Water-regulating valve.

Step Controller

The step controller contains a shaft upon which is mounted a series of cams. Rotation of the cams, in turn, operates electrical switches. Through adjustment of the cams on the shaft, the temperature at which each switch is to close and open (differential) is established. In addition, the switches may be adjusted to operate in almost any sequence (fig. 7-34).

TROUBLESHOOTING

Table Z of appendix II is a troubleshooting chart generally applicable to all types of air conditioners. Most manufacturers include more detailed and specific information in publications pertaining to their units. If you find that there is no manual with the unit when it is unpacked, write to the manufacturer and request one as soon as possible.

Q21. How are cooling towers classified?

Q22. A wind velocity of 8 mph is generally used to design natural draft cooling towers. True /False

Q23. Counter flow, parallel flow, and cross flow are types of what class of cooling tower?

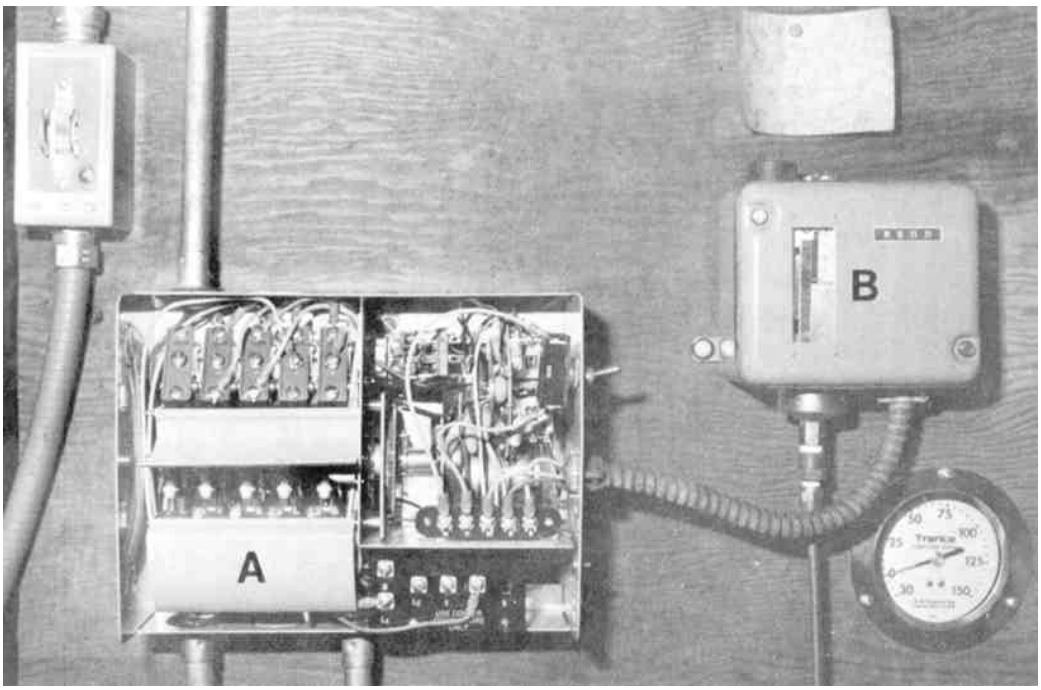


Figure 7-34.—Step controller and pressure-sensor configuration. (A) Step controller with modulating motor, single-pole double-throw mini switches, and mouse trap relay assembly; (B) Pressure sensor that controls the step controller.

Q24. What type of cooling tower is installed indoors?

Q25. Forced draft underflow towers retain the advantages of what other type of cooling tower?

Q26. Air intake louvers and fill are made of what material?

Q27. Cooling towers evaporate approximately how much water every hour for each ton of refrigeration?

Q28. Rotary compressors are used in what type of units?

Q29. Semisealed and sealed compressors have reduced service requirements because of the elimination of what part?

Q30. What control is temperature sensitive and controls the operation of the cooling unit?

Q31. What device maintains humidity at a predetermined point?

Q32. What causes a motor to shut down when a motor is too hot?

AUTOMOTIVE AIR CONDITIONING

Learning Objective: Understand the basic principles of operation, maintenance, and repair of automotive air conditioning.

Vehicle air conditioning is the cooling (refrigeration) of air within a passenger compartment. Refrigeration is accomplished by making practical use of three laws of nature—heat transfer, latent heat of vaporization, and the effects of pressure on boiling or condensation. The first two laws are discussed in chapter 6 of this TRAMAN; the practical application of the third is outlined below.

EFFECT OF PRESSURE ON BOILING OR CONDENSATION

The saturation temperature (the temperature where boiling or condensation occurs) of a liquid or vapor increases or decreases according to the pressure exerted on it.

In the fixed orifice tube refrigerant system, liquid refrigerant is stored in the condenser under high pressure (fig. 7-35). When the liquid refrigerant is released into the evaporator by the fixed orifice tube,

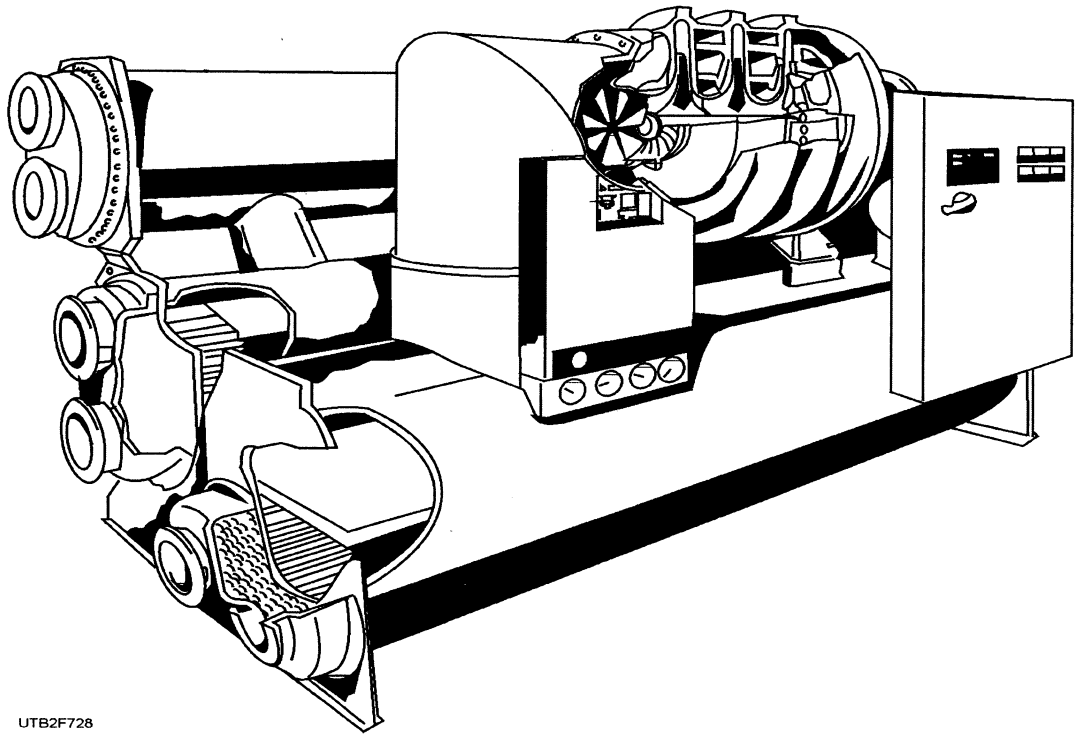


Figure 7-35.—Air-conditioning refrigeration system-fixed orifice.

the resulting decrease in pressure and partial boiling lowers its temperature to its new boiling point. As the refrigerant flows through the evaporator, passenger compartment air passes over the outside surface of the evaporator coils. As it boils, the refrigerant absorbs heat from the air and thus cools the passenger compartment. The heat from the passenger compartment is absorbed by the boiling refrigerant and hidden in the vapor. The refrigeration cycle is now under way. The following functions must be done to complete the refrigeration cycle:

1. Disposing of the heat in the vapor
2. Converting the vapor back to liquid for reuse
3. Returning of the liquid to the starting point in the refrigeration cycle

The compressor and condenser (fig. 7-35) perform these functions. The compressor pumps the refrigerant vapor (containing the hidden heat) out of the evaporator and suction accumulator drier, then forces it under high pressure into the condenser which is located in the outside air stream at the front of the vehicle. The increased pressure in the condenser raises the refrigerant condensation or saturation temperature to a point higher than that of the outside air. As the heat transfers from the hot vapor to the cooler air, the refrigerant condenses back to a liquid. The liquid under high pressure now returns through the liquid line to the fixed orifice tube for reuse.

It may seem difficult to understand how heat can be transferred from a comparatively cooler vehicle passenger compartment to the hot outside air. The answer lies in the difference between the refrigerant pressure that exists in the evaporator and the pressure that exists in the condenser. In the evaporator, the compressor suction reduces the pressure and the boiling point below the temperature of the passenger compartment. Thus heat transfers from the passenger compartment to the boiling refrigerant. In the condenser, the compressor raises the condensation point above the temperature of the outside air. Thus the heat transfers from the condensing refrigerant to the outside air. The fixed orifice tube and the compressor simply create pressure conditions that permit the laws of nature to function.

AUTOMOTIVE COMPRESSORS

There are three basic types of air-conditioning compressors in general use in automotive applications. Each of these uses a reciprocating (back-and-forth motion) piston arrangement—two-cylinder reciprocating, swash plate, and scotch yoke. Most automotive compressors are semihermetic.

Two-cylinder compressors (fig. 7-36) usually contain two pistons in a parallel V-type configuration. The pistons are attached to a connecting rod, which is driven by the crankshaft. The crankshaft is connected to the compressor clutch assembly, which is driven by an engine belt. Reed valves generally are used to control the intake and exhaust of the refrigerant gas during the pumping operation. These compressors are usually constructed of die cast aluminum.

In the swash plate or "wobble plate" compressor (fig. 7-37), the piston motion is parallel to the

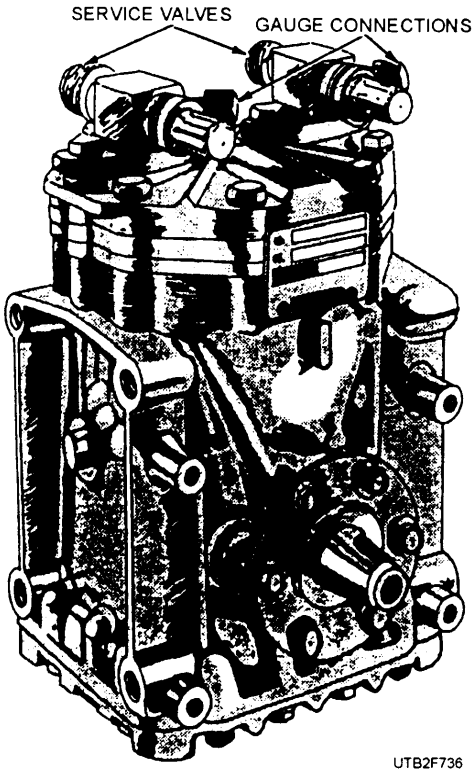


Figure 7-36.—Two-cylinder reciprocating compressor.

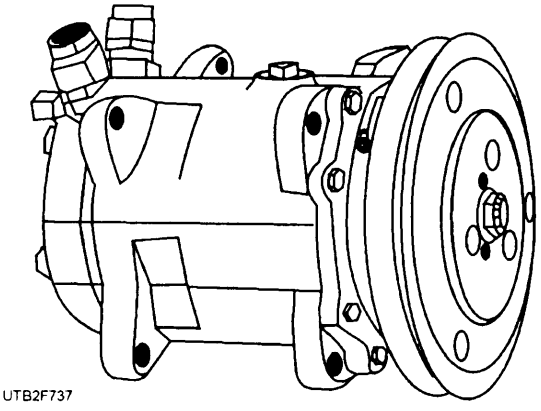


Figure 7-37.—Five-cylinder swash plate compressor.

crankshaft. The pistons are connected to an angled swash plate using ball joints. Swash plate compressors are of three types—five-cylinder, six-cylinder, and five-cylinder variable.

The five- and six-cylinder swash compressor has, in effect, three cylinders at each end of its inner assembly. A swash plate of diagonal design is mounted on the compressor shaft. It actuates the pistons, forcing them to move back and forth in the cylinders as the shaft is rotated. Reed valves control suction and discharge; crossover passages feed refrigerant to both high- and low-service fittings at the rear end of the compressor. A gear type of oil pump in the rear head provides for compressor lubrication.

The five-cylinder variable swash plate compressor is different from the other swash plate compressors. It uses a plate connected to a hinge pin that permits the swash plate to change its angle. The angle of the swash plate is controlled by a bellows valve that senses suction pressure. During high load conditions the swash plate angle is large, and during low load conditions, the swash plate is smaller. The displacement of the compressor is high at a large angle and low at a small angle.

A scotch-yoke compressor changes rotary motion into reciprocating motion. The basic mechanism of the scotch yoke contains four pistons mounted 90 degrees from each other. Opposed pistons are pressed into a yoke that rides on a slide block located on the shaft eccentric (fig. 7-38). Rotation of the shaft provides a reciprocating motion with no connecting rods. Refrigerant flows into the crankcase through the rear and is drained through the reeds attached to the piston tops during the suction stroke. Refrigerant is then discharged through the valve plate out the connector block at the rear. These compressors are shorter in length and larger in diameter than other compressors.

Compressor Service Valves

Compressor service valves are built into some systems. They serve as a point of attachment for test gauges or servicing hoses. The service valves have three position controls—front seated, back seated, and midposition (fig. 7-39).

The position of this double-faced valve is controlled by rotating the valve stem with a service valve wrench. Clockwise rotation seats the front face of the valve and shuts off all refrigerant flow in the system. This position isolates the compressor from the rest of the system.

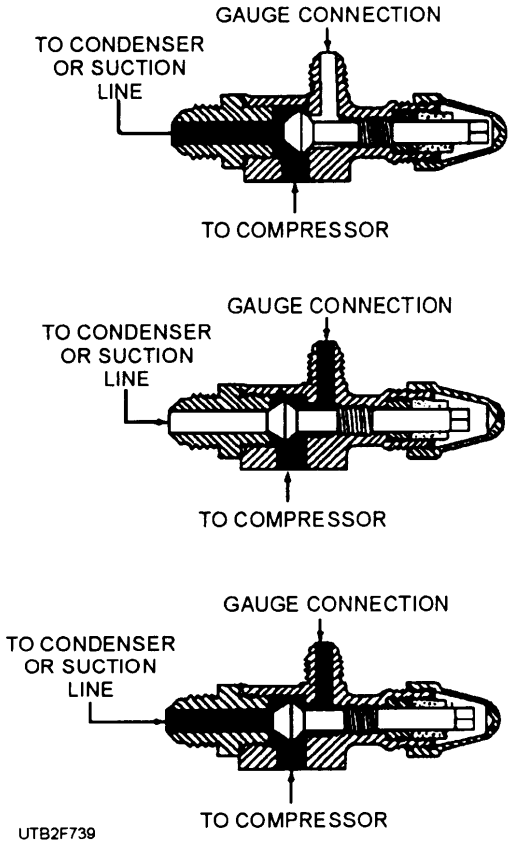


Figure 7-39.—Three-way service valve positions.

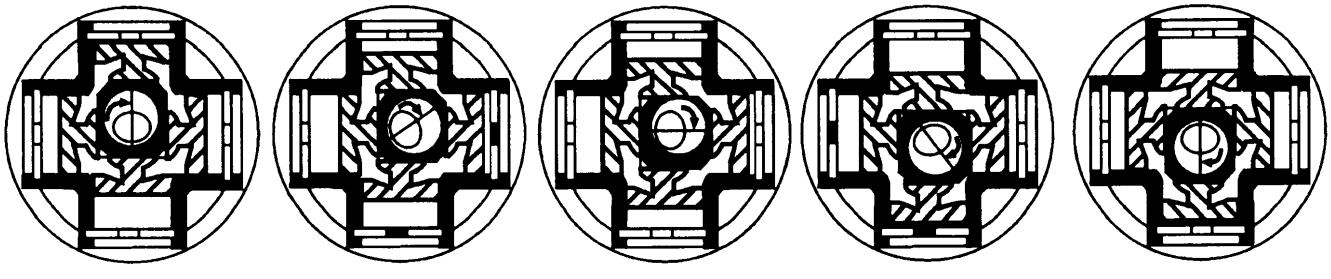


Figure 7-38.—Four-cylinder scotch-yoke mechanism.

Counterclockwise rotation unseats the valve and opens the system to refrigerant flow (midposition). Systematic checks are performed with a manifold gauge set with the service valve in midposition. Further counterclockwise rotation of the valve stem seats the rear face of the valve. This position opens the system to the flow of refrigerant but shuts off refrigerant to the test connector. The service valves are used for observing of operating pressures; isolating the compressor for repair or replacement; and discharging, evacuating, and charging the system.

Compressors used in automotive air-conditioning systems generally are equipped with an electromagnetic clutch that energizes and de-energizes to engage and disengage the compressor. Two types of clutches are in general use-the rotating coil and the stationary coil.

The rotating coil clutch has a magnetic coil mounted in the pulley that rotates with the pulley. It operates electrically through connections to a stationary brush assembly and rotating slip rings. The clutch permits the compressor to engage or disengage as required for adequate air conditioning. The stationary coil clutch has the magnetic coil mounted on the end of the compressor. Electrical connections are made directly to the coil leads.

The belt-driven pulley is always in rotation while the engine is running. The compressor is in rotation and operation only when the clutch engages it to the pulley.

Air-conditioning and refrigeration systems use various control devices, including those for the refrigerant, the capillary tube usually found on window units, the automatic expansion valves also found on window units and small package units, the thermal expansion valve, and various types of suction pressure-regulating valves and devices. A brief description of a suction pressure-regulating valve is given below. A suction pressure-regulating valve is used on automotive air conditioning because the varying rpm of the compressor unit must maintain a constant pressure in the evaporator.

Suction Pressure-Regulating Valves

Suction pressure-regulating valves may be installed in the suction line at the outlet of the evaporator when a minimum temperature must be maintained. Suction pressure-regulating valves decrease the temperature difference, which would otherwise exist between the compartment temperature and the surface of the cooling coils. The amount of heat that can be transferred into the evaporating refrigerant is directly proportional to the temperature difference. Figure 7-40 shows an exploded view of a typical suction pressure-regulating valve, sometimes called a suction throttling valve in automotive air conditioners.

Three types of suction pressure-regulating valves are used—suction throttling valve (STV), evaporator pressure regulators (EPR), or pilot-operated absolute valve (POA), developed by General Motors Corporation. These valves, in most cases, are adjustable.

The POA valve uses a sealed pressure element that maintains a constant pressure independent of the altitude of the vehicle. There are two basic types of metering devices built into a single container—the VIR (Valves-In-Receiver) and the EEVIR (Evaporator Equalized Valves-In-Receiver). These units combine the POA valve, receiver-drier, thermostatic expansion valve, and sight glass into a single unit.

The VIR assembly is mounted next to the evaporator, which eliminates the need for an external equalizer line between the thermostatic expansion valve and the outlet of the POA valve. The equalizer function is carried out by a drilled hole (equalizer port) between the two-valve cavities in the VIR housing.

The thermostatic expansion valve is also eliminated. The diaphragm of the VIR expansion valve is exposed to the refrigerant vapor entering the VIR unit from the outlet of the evaporator. The sight glass is in the valve housing at the inlet end of the thermostatic valve cavity where it gives a liquid indication of the refrigerant level.

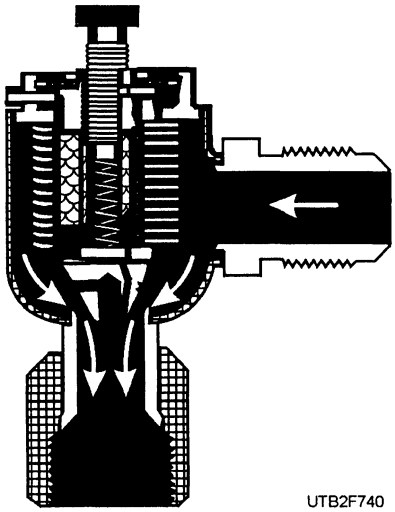


Figure 7-40.—A typical suction pressure-regulating valve.

The VIR thermostatic expansion valve controls the flow of refrigerant to the evaporator by sensing the temperature and pressure of the refrigerant gas, as it passes through the VIR unit on its way to the compressor. The POA valve controls the flow of refrigerant from the evaporator to maintain a constant evaporator pressure of 30 psi. The VIR and the POA valves are capsule type of valves. When found to be defective, you must replace the complete valve capsule.

The drier desiccant is in a bag in the receiver shell. It is replaceable by removing the shell and removing the old bag and installing a new bag of desiccant.

Service procedures for the VIR system differ in some respect from the service procedures performed on conventional automotive air-conditioning systems.

SERVICE PRECAUTIONS

Observe the following precautions whenever you are tasked to service air-conditioning equipment:

- Never open or loosen a connection before discharging the system.
- A system that has been opened to replace a component or one which has discharged through leakage must be evacuated before charging.
- Immediately after disconnecting a component from the system, seal the open fittings with a cap or plug.
- Before disconnecting a component from the system, clean the outside of the fittings thoroughly.
- Do not remove the sealing caps from a replacement component until you are ready to install it.
- Refrigerant oil absorbs moisture from the atmosphere if it is left uncapped. Do not open an oil container until it is ready to use, and install the cap immediately after using. Store the oil only in a clean, moisture-free container.
- Before connecting to an open fitting, always install a new seal ring. Coat the fitting and seal with the refrigerant oil before connecting.
- When installing a refrigerant line, avoid sharp bends. Position the line away from the exhaust or any sharp edges that may chafe the line.
- Tighten the fittings only to specified torque. The copper and aluminum fittings that are used in refrigerant systems will not tolerate over-tightening.
- When disconnecting a fitting, use a wrench on both halves of the fitting to prevent twisting of refrigerant lines or tubes.
- Do not open a refrigerant system or uncap a replacement component unless it is as close as possible to room temperature. This prevents condensation from forming inside a component that is cooler than the surrounding air.
- Keep the service tools and work area clean. Contamination of a refrigerant system through careless work habits must be avoided.

DIAGNOSIS, TESTING, AND SERVICING

Diagnosis is more than just following a series of interrelated steps to find the solution to a specific condition. It is a way of looking at systems that are not functioning the way they should and finding out why. Also, it is knowing how the system should work and whether it is working correctly. All good diagnosticians use the same basic procedures.

There are basic rules for diagnosis. If these rules are followed, the cause of the condition will usually be found the first time through the system.

1. Know the system; know how the parts go together. Also, know how the system operates and its limits, and what happens when something goes wrong. Sometimes this means comparing a system that is working properly with the one you are servicing.

2. Know the history of the system. How old or new is the system? What kind oftreatment has it had? Has it been serviced in the past in such a manner that might relate to the present condition? What is the service history? A clue in any of these areas might save a lot of diagnosis time.

3. Know the probability of certain conditions developing. It is true that most conditions are caused by simple things, rather than by complex ones, and they occur in a fairly predictable pattern. Electrical problem conditions, for instance, usually occur at connections, rather than in components. An engine "no-start" is more likely to be caused by a loose wire or some component out of adjustment than a sheared off camshaft. Know the difference between impossible and improbable. Many good technicians have spent hours diagnosing a system because they thought certain failures were "impossible," only to find out the failures

eventually were just "improbable" and actually had happened. Remember, new parts are just that—new. It does not mean they are good functioning parts.

4. Don't cure the symptom and leave the cause. Recharging a refrigerant system may correct the condition of insufficient cooling, but it does not correct the original problem unless a cause is found. A properly working system does not lose refrigerant over time.

5. Be sure the cause is found; do not be fooled into thinking the cause of the problem has been found. Perform the proper tests; then double-check the results. The system should have been checked for refrigerant leaks. If no leaks were found, perform a leak test with the system under extremely high pressure. If the system performed properly when new, it had to have a leak to be low in charge.

6. No matter what form charts may take, they are simply a way of expressing the relationship between the basic logic and a physical system of components. It is a way of determining the cause of a condition in the shortest possible amount of time. Diagnosis charts combine many areas of diagnosis into one visual display that allows you to determine the following:

- The probability of certain things occurring in a system
- The speed of checking certain components, or functions, before others
- The simplicity of performing certain tests before others
- The elimination of checking huge sections of a system by performing simple tests
- The certainties of narrowing down the search to a small area before performing in-depth testing

The fastest way to find a condition is to work with the tools that are available, which means working with proven diagnosis charts and the proper special tools for the system being worked on.

Servicing procedures for automotive air-conditioning units are similar to those used to service conventional air-conditioning systems. Discharging, evacuating, charging procedures, connections, and positions of valves on the gauge manifold set are shown in figure 7-41.

Servicing procedures for the VIR system are also similar to those used when servicing conventional air-conditioning systems. However, the hookup of the manifold gauge set is to the VIR unit. The high-pressure fitting is located in the VIR inlet line. The low-pressure fitting is located in the VIR unit.

SYSTEM VISUAL INSPECTION

It is often possible to detect a problem caused by a careful visual inspection of the air-conditioning refrigerant system. This includes broken belts, obstructed condenser air passages, a loose clutch, loose or broken mounting brackets, disconnected or broken wires, and refrigerant leaks.

A refrigerant leak usually appears as an oily residue at the leakage point in the system. The oily residue soon picks up dust or dirt particles from the surrounding air and appears greasy. Through time, this builds up and appears to be heavy, dirt-impregnated grease.

Most common leaks are caused by damaged or missing O-ring seals at various hose and component connections. When these O rings are replaced, the new O rings should be lubricated with refrigerant oil. Care should be taken to keep lint from shop towels or cloths from contaminating the internal surfaces of the connection. Leakage may occur at a spring lock coupling if the wrong O rings are used at the coupling.

Another type of leak may appear at the internal Schrader type of air-conditioning charging valve core in the service gauge port valve fittings. If tightening the valve core does not stop the leak, it should be replaced with a new air-conditioning charging valve core.

Missing service gauge port valve caps can also cause a refrigerant leak. If this important primary seal (the valve cap) is missing, dirt enters the area of the air-conditioning charging valve core. When the service hose is attached, the valve depressor in the end of the service hose forces the dirt into the valve seat area, and it destroys the sealing surface of the air-conditioning charging valve core. When a service gauge port valve cap is missing, the protected area of the air-conditioning charging valve core should be cleaned and a new service gauge port valve cap should be installed.

CAUTION

The service gauge port valve cap must be installed finger tight. If tightened with pliers, the sealing surface of the service gauge port valve may be damaged.

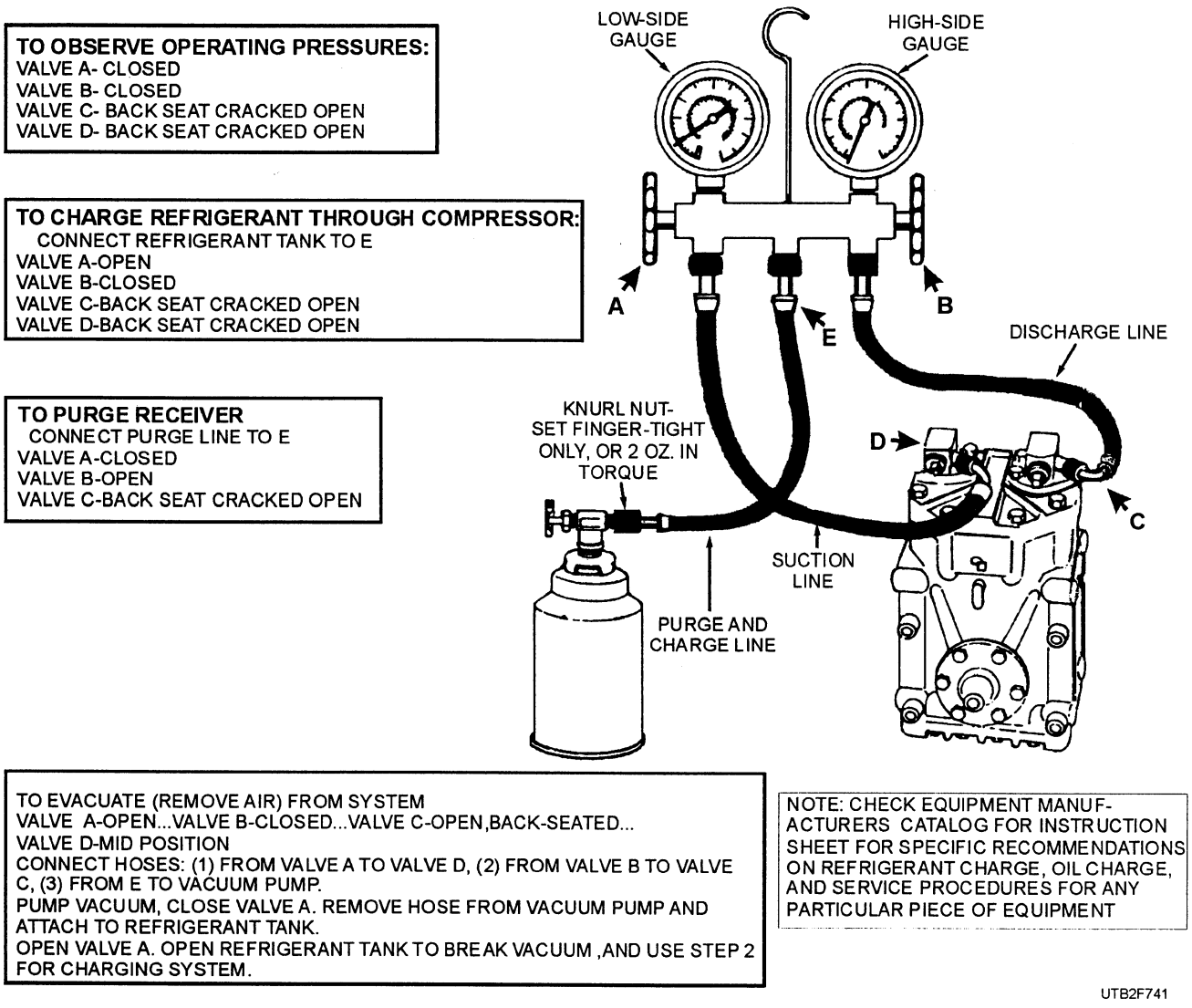


Figure 7-41.—Procedures for observing operating pressures, charging, purging, and evacuating a unit.

CLEANING A BADLY CONTAMINATED REFRIGERANT SYSTEM

A refrigerant system can become badly contaminated for a number of reasons.

- The compressor may have failed due to damage or wear.
- The compressor may have been run for some time with a severe leak or an opening in the system.
- The system may have been damaged by a collision and left open for some time.
- The system may not have been cleaned properly after a previous failure.
- The system may have been operated for a time with water or moisture in it.

A badly contaminated system contains water, carbon, and other decomposition products. When such a condition exists, the system must be flushed with a special flushing agent, using equipment designed especially for this purpose. Follow the suggestions and procedures outlined for proper cleaning.

Flushing Agents

A refrigerant to be suitable as a flushing agent must remain in the liquid state during the flushing operation to wash the inside surfaces of the system components. Refrigerant vapor will not remove

contaminant particles. They must be flushed with a liquid. Some refrigerants are better suited for this purpose than others.

R-11 and R-113 are suited for use with special flushing equipment. Both have rather high vaporization points—74.7°F for R-11 and 117.6°F for R-l 13. Both refrigerants also have low closed container pressures. This reduces the danger of an accidental system discharge to a ruptured hose or fitting. R-113 will do the best job and is recommended as a flushing refrigerant. Both R-11 and R-113 require a propellant or a pump type of flushing equipment due to their low closed container pressures. R-11 is available in pressurized containers. Although not recommended for regular use, it may become necessary to use R-11 if special flushing equipment is not available. It is more toxic than other refrigerants, and it should be handled with extra care. Currently new refrigerants are being developed to replace R-11 and R-113 because these refrigerants will be phased out by the year 2000.

CAUTION

Use extreme care and adhere to all safety precautions related to the use of refrigerants when flushing a system.

System Cleaning and Flushing

When it is necessary to flush a refrigerant system, the suction accumulator/drier must be removed and replaced, as it is impossible to clean. Remove the fixed orifice tube. If a new tube is available, replace the contaminated one; otherwise, wash it carefully in flushing refrigerant or mineral spirits and blow it dry. If it does not show signs of damage or deterioration, it may be reused. Install new O rings.

Any moisture in the evaporator will be removed during leak testing and system evacuation following the cleaning job. Perform each step of the cleaning procedure carefully as outlined below.

1. Check the hose connections at the flushing cylinder outlet and flushing nozzle to ensure they are secure.

2. Ensure the flushing cylinder is filled with approximately 1 pint of R-113 and that the valve assembly on top of the cylinder is tightened securely.

3. Connect a can of R-12 or R-134a to the Schrader valve at the top of the charging cylinder. A refrigerant hose and a special, safety type of refrigerant dispensing valve are required for connecting the small can to the cylinder. Ensure all connections are secure.

4. Connect a gauge manifold and a discharge system. Disconnect the gauge manifold.

5. Remove and discard the suction accumulator/drier. Install a new accumulator/drier and connect it to the evaporator. Do not connect it to the suction line from the compressor. Ensure a protective cap is in place on the suction line connection.

6. Replace the fixed orifice tube. Install a protective cap on the evaporator inlet tube as soon as the new orifice tube is in place. The liquid line will be connected later.

7. Remove the compressor from the vehicle for cleaning and servicing or replacement, whichever is required. If the compressor is cleaned and serviced, add the specified amount of refrigerant oil before installing it on the mounting brackets in the vehicle. Install the shipping caps on the compressor connections. Install a new compressor on the mounting brackets in the vehicle.

8. Back flush the condenser and the liquid line as follows:

a. Remove two O rings from the condenser inlet tube spring lock coupling.

b. Remove the discharge hose from the condenser and clamp a piece of (1/2-inch ID) heater hose to the condenser inlet line. Ensure the hose is long enough to insert the free end into a suitable waste container to catch the flushing refrigerant.

c. Move the flushing equipment into position and open the valve on the can of R-12 or R-134a (fully counterclockwise).

d. Back flush the condenser and the liquid line by introducing flushing refrigerant into the supported end of the liquid line with the flushing nozzle. Hold the nozzle firmly against the open end of the liquid line.

e. After the liquid line and condenser have been flushed, lay the charging cylinder on its side so R-12 or R-134a will not force more of the flushing refrigerant into the liquid line. Press the nozzle firmly to the liquid line and admit the R-12 or R-134a to force all of the flushing refrigerant from the liquid line and condenser.

f. Remove the 1/2-inch hose and clamp from the condenser inlet connection.

g. Stand the flushing cylinder upright and flush the compressor discharge hose. Secure it so the flushing refrigerant goes into the waste container.

h. Close the dispensing valve of the R-12 or R-134a can (fully clockwise). If there is any flushing refrigerant in the cylinder, it may be left there until the next flushing job. Put the flushing kit and R-12 or R-134a can in a suitable storage location.

i. Install the new lubricated O rings on the spring lock coupling male fittings on both the condenser inlet and the liquid lines. Assemble the couplings.

9. Connect all refrigerant lines. All connections should be cleaned and new O rings should be used. Lubricate new O rings with clean refrigerant oil.

10. Connect a charging station or manifold gauge set and charge the system with 1 pound of R-12 or R-134a. (Do not evacuate the system until after it has been leak tested.)

11. Leak test all connections and components with a flame type of leak detector or an electronic leak detector. If no leaks are found, go to Step 12. If leaks are found, service as necessary; check the system and then go to Step 12.

12. Evacuate and charge the system with a specified amount of R-12 or R-134a. Operate the system to ensure it is cooling properly.

SAFETY PRECAUTIONS

The use of safety when handling or using refrigerants can never be stressed enough. As discussed in chapter 6 of this TRAMAN, routinely think of safety for yourself and coworkers.

Extreme care must be taken to prevent any liquid refrigerant from coming in contact with the skin and especially the eyes. A bottle of sterile mineral oil and a quantity of weak boric acid solution must always be kept nearby when servicing the air-conditioning system. Should any liquid refrigerant get into your eyes, immediately use a few drops of mineral oil to wash them out; then wash the eyes clean with the weak boric acid solution. Seek a doctor's aid immediately even though irritation may have ceased. Always wear safety goggles when servicing any part of the refrigerant system.

To avoid a dangerous explosion, never weld, solder, steam clean, bake body finishes, or use any excessive amount of heat on or in the immediate area of any part of the refrigerant system or refrigerant supply tank, while they are closed to the atmosphere whether filled with refrigerant or not.

The liquid refrigerant evaporates so rapidly that the resulting refrigerant gas displaces the air surrounding the area where the refrigerant is released. To prevent possible suffocation in enclosed areas, always discharge the refrigerant into recycling/ reclaiming equipment. Always maintain good ventilation surrounding the work area.

Although R-12 gas, under normal conditions, is nonpoisonous, the discharge of refrigerant gas near an open flame can produce a very poisonous gas. This gas also attacks all bright metal surfaces. This poisonous gas is generated when the flame type of leak detector is used. Avoid inhaling the fumes from the leak detector. Ensure that R-12 is both stored and installed according to all federal, state and local ordinances.

When admitting R-12 or R-134a gas into the cooling unit, always keep the tank in an upright position. lf the tank is on its side or upside down, liquid R-12 or R-134 enters the system and may damage the compressor.

TRUCK AND BUS AIR CONDITIONING

The cabs of many truck-tractors and long distance hauling trucks and earthmover cabs are air-conditioned. Most of this equipment is of the "hang on" type and is installed after the cab has been made.

Some truck air-conditioning units have two evaporators—one for the cab and one for the relief driver's quarters in back of the driver. Some systems use a remote condenser, mounted on the roof of the cab. This type of installation removes the condenser from in front of the radiator, so the radiator can operate at full efficiency. This is especially important during long pulls in low gear.

The system is similar to the automobile air conditioner and is installed and serviced in the same general way.

The air conditioning of buses has progressed rapidly. Because of the large size of the unit, most bus air-conditioning systems use a separate gasoline engine with an automatic starting device to drive the compressor. The system is standard in construction except for the condensing unit. It is made as compact as possible and generally is installed in the bus, so it can be easily reached for servicing.

Condensing units are often mounted on rails with flexible suction and liquid lines to permit sliding the condensing unit out of the bus body to aid in servicing.

Air-cooled condensers are used. Thermostatic expansion valve refrigerant controls are standard. Finned blower evaporators are also used.

The duct system usually runs between a false ceiling and the roof of the bus. The ducts, usually one on each side of the bus, have grilles at the passenger seats. The passengers may control the grille by opening and closing.

CERTIFICATION

The Environmental Protection Agency (EPA) has established as per the Clean Air Act (CAA) that all technicians who maintain or repair air-conditioning or refrigeration equipment or technicians who operate recycling, reclaiming, and recovery equipment must be certified. Certification is administered by organizations with certification programs that are approved by the EPA. It is important to understand, that as a Utilitiesman, if you are not certified, you cannot do any HVAC/R service that requires use or removal of refrigerants. Certification requirements are divided into two different areas—automotive air-conditioning and HVAC/R.

Automotive Air-Conditioning Certification

Automotive air conditioning is serviced or repaired more often than other types of air-conditioning systems. In today's world, automotive air-conditioning systems are heavily used as our society spends more and more time in their vehicles. Industry experts say that 25 percent of the R-12 purchased in the United States is used in automotive air conditioning. The fittings and hoses used in automotive air conditioning allow leakage to occur. Automotive air-conditioning service facilities or technicians are now changing (retrofitting) systems in vehicles to use refrigerant R-134a and removing CFC R-12 to meet new standards. From the EPA's standpoint, technicians must be meet the following requirements to be certified:

- Be aware that venting refrigerant is illegal.
- Understand why all the regulations are being created. Understand what is happening to the environment.
- Have a working knowledge of SAE standards J-1989, J-1990, and J-1991.
- Perform service in a safe manner without injuring personnel or damaging equipment. Areas that must be understood include venting, handling, transporting, and disposing of refrigerant.

Once these requirements are met through testing of the individual applicant, a certification card is issued.

Heating, Ventilating, Air Conditioning, and Refrigeration Certification

Certification requirements to service standard types of air-conditioning systems are the same as for automotive air-conditioning certification. Unlike the automotive certification program, standard air-conditioning certification is divided into levels corresponding to the type of service the technician performs. There are four types of certification:

- Type I – Servicing small appliances
- Type II – Servicing high or very high-pressure appliances
- Type III – Servicing or disposing of low-pressure appliances
- Type IV (Universal) – Servicing all types of equipment

Individuals will be required to take a proctored, closed book test. These tests are offered by organizations approved by the EPA for the specific type of certification that the individual technician requires. Technicians can only work on air-conditioning systems that they have been certified for service.

Q33. The saturation temperature increases or decreases depending upon what factor?

Q34. What are the three basic types of automotive compressors?

Q35. A scotch-yoke compressor changes rotary motion into what type of motion?

Q36. Refrigerant can be put into a system when the service valve is back-seated. True /False

Q37. The POA valve, receiver-drier, expansion valve, and sight glass are combined in what type of device?

Q38. Service procedures for VIR systems are different than conventional automotive air-conditioning systems. True/False

Q39. What is the most important thing you should know before you perform a diagnosis on a system problem?

Q40. A refrigerant leak appears in what way at the point of the leak?

Q41. What is the most common cause of leaks on automotive air-conditioning systems?

Q42. For a refrigerant to be a suitable flushing agent, it must remain in what state during flushing operations?

Q43. Which part of an automotive air-conditioning system is replaced because it is impossible to clean?

Q44. A type IV certification is also known as what type of certification?

Q45. Who approves organizations to certify technicians?

DUCTWORK

Learning Objective: Understand the basic types of ductwork systems and the components of those systems for distribution of conditioned air.

Distributed air must be clean, provide the proper amount of ventilation, and absorb enough heat to cool the conditioned spaces. To deliver air to the conditioned space, air carriers are required, which are called ducts. Ducts work on the principle of air pressure difference. If a pressure difference exists, air will flow from an area of high pressure to an area of low pressure. The larger this difference, the faster the air will flow to the low-pressure area.

CLASSIFICATION OF DUCTS

There are three common classifications of ducts—conditioned air ducts, recirculating-air ducts, and fresh-air ducts. Conditioned air ducts carry conditioned air from the air conditioner and distribute it to the conditioned area. Recirculating air ducts take air from the conditioned space and distribute it back into the air conditioner system. Fresh air ducts bring fresh air into the air-conditioning system from outside the conditioned space.

Ducts commonly used for carrying air are of a round, square, or rectangular shape. The most efficient duct is a round duct, based on the volume of air handled per perimeter distance. In other words, less material is needed for the same capacity as a square or rectangular duct.

Square or rectangular duct fits better to building construction. It fits above ceilings and into walls and is much easier to install between joists and studs.

TYPES OF DUCT SYSTEMS

There are several types of supply duct systems (fig. 7-42) that deliver air to room(s) and then return the air from the room(s) to the cooling (evaporator) system. These supply systems can be grouped into four types:

1. Individual round pipe system
2. Extended plenum system
3. Reducing trunk system
4. Combination (of two or more systems)

Return air systems are normally of three types—single return, multiple return (fig. 7-42), or combination of the two systems.

CONSTRUCTION

Ducts may be made of metal, wood, ceramic, and plastic. Most commonly used is sheet steel coated with zinc (galvanized steel). Sheet metal brakes and forming machines are used in fabricating ducts. Elbows and other connections, such as branches, are designed using geometric principles. Some types of duct connections used in constructing duct systems are shown in figure 7-43.

Sheet metal ducts expand and contract as they heat and cool. Fabric joints are often used to absorb this movement. Fabric joints should also be used where the duct connects to the air conditioner. Many ducts are insulated to lower noise and reduce heat transfer. The insulation can be on the inside or the outside of the duct. Adhesives or metal clips are commonly used to fasten the insulation to the duct. As we are only briefly discussing construction here, you can find construction and fabrication methods in the *Steelworker,* volume 2. It details design and fabrication of steel ductwork.

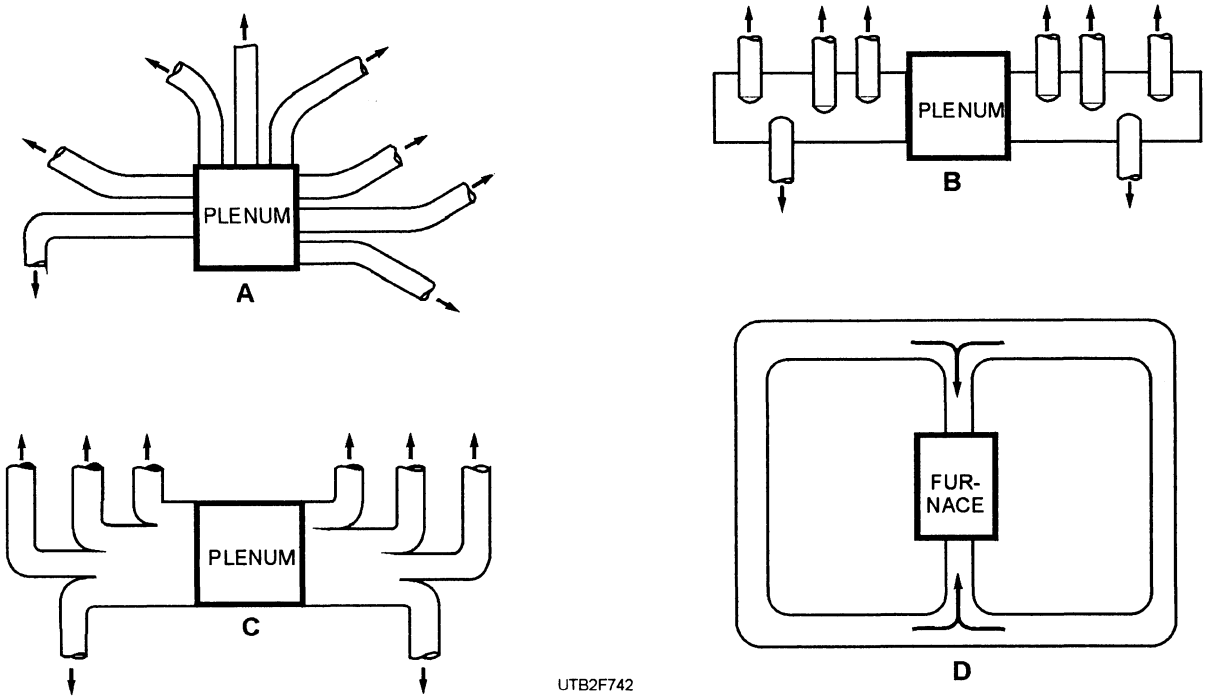


Figure 7-42.—Supply duct systems: A. Individual round pipe; B. Extended plenum; C. Reducing trunk; D. Multiple return air system.

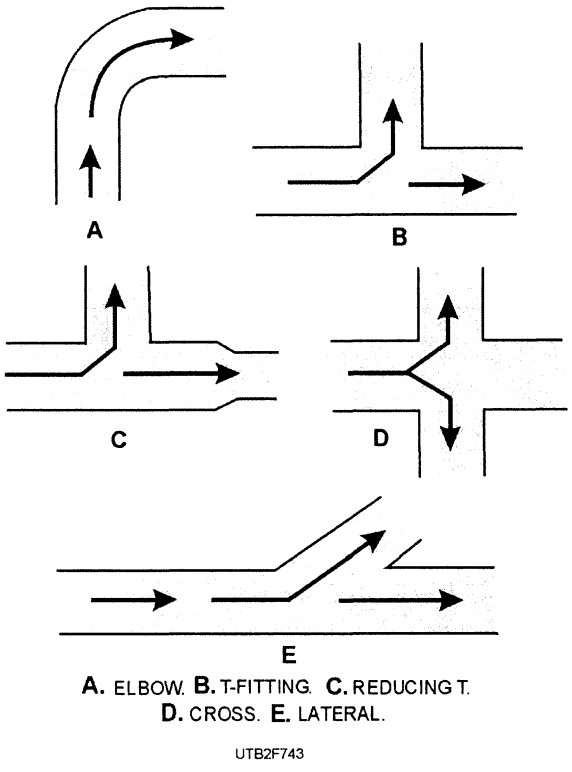


Figure 7-43.—Typical duct connections: A. Elbow; B. Tee: C. Reducing tee; D. Cross: E. Lateral.

COMPONENTS

To enable a duct system to circulate air at the proper velocity and volume to the proper conditioned areas, you can use different components within the duct system, such as diffusers, grilles, and dampers.

Diffusers, Grilles, and Registers

Room openings to ducts have several devices that control the airflow and keep large objects out of the duct. These devices are called diffusers, grilles, and registers. Diffusers deliver fan-shaped airflow into a room. Duct air mixes with some room air in certain types of diffusers.

Grilles control the distance, height, spread of air-throw, and amount of air. Grilles cause some resistance to airflow. Grille cross-section pieces block about 30 percent of the air. Because of this reason and to reduce noise, cross sections are usually enlarged at the grille. Grilles have many different designs, such as fixed vanes which force air in one direction, or adjustable to force air in different directions.

Registers are used to deliver a concentrated air stream into a room, and many have one-way or two-way adjustable air stream deflectors.

Dampers

One way of getting even air distribution is through the use of duct dampers. Dampers balance airflow or can shut off or open certain ducts for zone control. Some are located in the grille, and some are in the duct itself. There are three types of dampers used in air-conditioning ductwork—butterfly, multiple blade, and split damper (fig. 7-44). When installing a damper, always draw a line on temperature control.

Fire Dampers

Automatic fire dampers should be installed in all vertical ducts. Ducts, especially vertical ducts, will carry fumes and flames from fires. Fire dampers must be inspected and tested at least once a year to be sure they are in proper working order. There are two types of fire dampers, which are fail-safe units—spring-loaded to close and weight-loaded to close. Fire dampers are usually held open by a fusible link. Heat will melt the link and the damper will close by either gravity, weights, or springs (fig. 7-45).

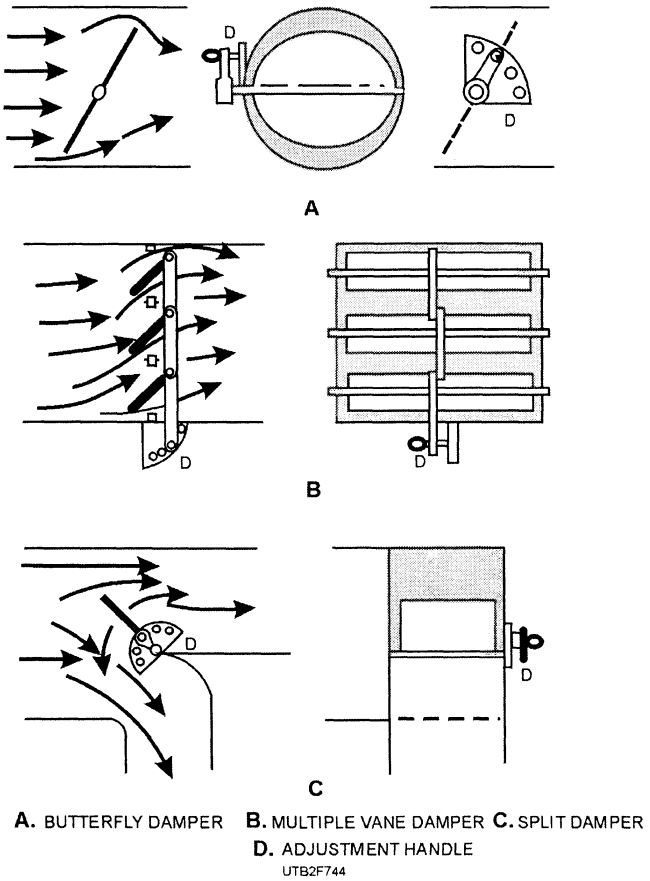


Figure 7-44.—Three types of duct dampers.

Fans

Air movement is usually produced by some type of forced airflow. Fans are normally located in the inlet of the air conditioner. Air is moved by creating either a positive pressure or negative pressure in the ductwork. The two most popular types of fans are the axial flow (propeller) or radial flow (squirrel cage) (fig. 7-46).

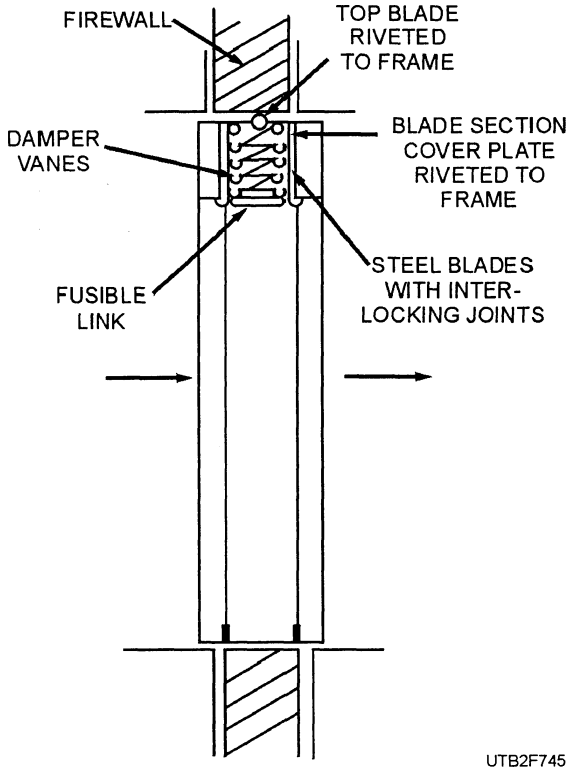


Figure 7-45.—Fire damper in OPEN position.

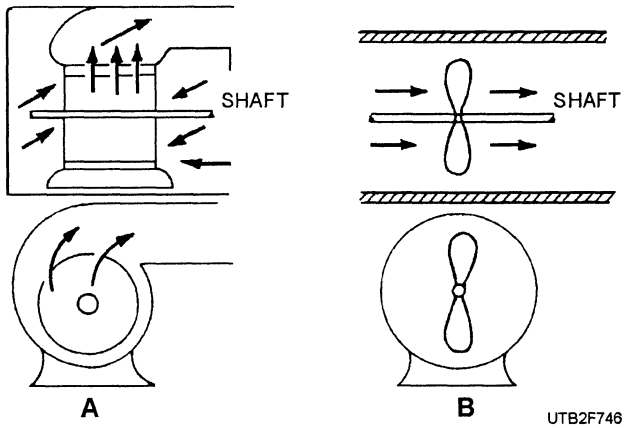


Figure 7-46.—Principal types of fans: A. Radial flow; B. Axial flow.

The axial-flow fan is usually direct-driven by mounting the fan blades on the motor shaft. The radial-flow fan is normally belt-driven but can also be direct-driven.

BALANCING THE SYSTEM

Balancing a system basically means sizing the ducts and adjusting the dampers to ensure each room receives the correct amount of air. To balance a system, follow these steps:

1. Inspect the complete system; locate all ducts, openings, and dampers.

2. Open all dampers in the ducts and at the grilles.

3. Check the velocities at each outlet.

4. Measure the "free" grille area.

5. Calculate the volume at each outlet. Velocity x Area = Volume

6. Area in square inches divided by 144 multiplied by feet per minute equals cubic feet/minute.

7. Total the cubic feet/minute.

8. Determine the floor areas of each room. Add to determine total area.

9. Determine the cfm for each room. The area of the room divided by the total floor area multiplied by the total cfm equals cfm for the room.

10. Adjust duct dampers and grille dampers to obtain these values.

11. Recheck all outlet grilles.

In some cases, it may be necessary to overcome excess duct resistance by installing an air duct booster. These are fans used to increase airflow when a duct is too small, too long, or has too many elbows.

Q46. What are the three common types of ducts?

Q47. What are the three types of return air systems?

Q48. Sheet metal ducts expand and contract as they heat and cool. True /False

Q49. What are the three types of dampers?

Q50. Once you have checked the velocities at each outlet, what is the next step when balancing the duct system?

APPENDIX I

GLOSSARY

ABSOLUTE ZERO —The point where all molecular motion ceases, -460°F.

AC — Alternating current.

AEROBIC DECOMPOSITION — Bacterial decomposition that occurs in the presence of oxygen.

AFTERCOOLER — Device which cools the final discharge from a compressor.

ANGLE VALVE — A stop valve that is actually a combination valve and elbow since its outlet branch is at right angles to its inlet branch.

ASME — American Society of Mechanical Engineers.

BILL OF MATERIAL — A list of all materials required to complete an installation based on takeoffs and estimates.

BOILER — An enclosed vessel that converts water to steam of proper temperature and pressure for an intended purpose.

BOILER SETTING — The structure that encloses a boiler and forms a furnace.

BREECHING — Connects a boiler to the stack.

BUSHING — A plumbing fitting used to reduce the pipe from one size to another size.

BUTTERFLY VALVE — A two-position valve with a vertical or horizontal disk.

CAP — A plumbing fitting used to close off a length of pipe.

CATHODIC PROTECTION — The use of material and liquid to cause electricity to flow to avoid corrosion.

CBMU — Construction Battalion Maintenance Unit.

CBR — Chemical, Biological, and Radiological.

CBU — Construction Battalion Unit.

CEC — Civil Engineer Corps.

CENTRIFUGAL FORCE — The force that impels a substance to move outward from the center of rotation.

CENTIGRADE — A thermometric scale in which 0 degrees represents the freezing point and 100 degrees represents the boiling point of water at a pressure of 1 atmosphere. Generally used with metric units of measure. Equal to the international thermometric scale of Celsius.

CHECK VALVE — An automatic non-return valve or a valve which permits a fluid to pass in one direction but automatically closes if the fluid begins to pass in the opposite direction.

CLARIFICATION OF WATER — The removal of suspended materials to produce a clear, clean liquid.

COLIFORM — The coliform groups of organisms are a bacterial indicator of contamination. This group has as one of its primary habitats, the intestinal tract of human beings. Coliforms also may be found in the intestinal tract of warm-blooded animals and in plants, soil, air, and the aquatic environment.

COMSECONDNCB — Commander, Second Naval Construction Brigade.

COMTHIRDNCB — Commander, Third Naval Construction Brigade.

COMPRESSOR — Pump of a refrigerating mechanism which draws a low pressure on the cooling side of the refrigerant cycle and squeezes or compresses the gas into the high pressure or condensing side of the cycle.

CONDENSATION — The process of changing a vapor to a liquid.

CONDENSER — Component in a refrigeration system that removes and dissipates heat from a compressed refrigerant.

CONDUCTION — The transmitting of heat from one substance or part to another substance or part that are in direct contact with each other.

CONVECTION — The transfer of heat by means of a medium, such as water, air, and steam.

COUPLING — A plumbing fitting used to join two lengths of pipe in a straight run.

DEGREE OF TEMPERATURE — Measurement of heat intensity.

DEHYDRATOR — Device used to remove moisture from a refrigerant system.

DEW POINT — Temperature at which vapor (at 100 percent humidity) begins to condense and deposit as a liquid.

DIATOMACEOUS EARTH — A porous mineral powder, used as a filtering medium for the removal of suspended materials.

ELBOW — A plumbing fitting used to change the direction of a length of pipe at 90° and 45° angles.

EVAPORATOR — Component of a refrigeration system that permits the absorption of heat from a desired medium or space.

EVAPORATION — A process of converting a liquid, by heat, into a vapor or gas.

FILTER-DRIER — Device for removing small foreign particles and moisture from refrigerant fluid.

FITTINGS — Devices which when placed in a pipe system make branch connections or changes in a direction of a line.

GATE VALVE — A sluice with two inclined seats between which the valve wedges down in closing. The passage through the valve is in an uninterrupted line, and when the valve is opened, the sluice is drawn up into a dome or recess, leaving an unobstructed passage the full diameter of the pipe.

GLOBE VALVE — A valve with a round, ball-like shell that is used for regulating or controlling the flow of gases or steam.

GPD — Gallons per day.

GPH — Gallons per hour.

GPM — Gallons per minute.

HEAT — The energy that is measured in British thermal units.

HERMETICALLY SEALED — Caused to be airtight.

HUMIDITY — The amount of water vapor in a given volume of air.

HYDROLOGIC CYCLE — Process by which water is circulated from ocean to atmosphere to earth's surface.

ID — Inside diameter.

INFLUENT — Water flow into a sewage or water treatment plant or equipment.

JOINING — All the procedures used to connect pipes together.

LATENT HEAT — Amount of heat required to change the state of a substance without a measurable change in temperature.

MATERIAL TAKEOFF — The estimate of materials required for a job based on plans and specifications.

METERING DEVICE — Valve or device used to regulate amount and state of refrigerant as it passes through the system.

NAVFAC — Naval Facilities Engineering Command.

NCR — Naval Construction Regiment.

NCTC — Naval Construction Training Center.

NMCB — Naval Mobile Construction Battalion.

OD — Outside diameter.

PACKING — Materials used to seal moving machinery joints against leakage.

P H — A value used to measure the acidity or alkalinity (basic) of a substance. A pH scale is from 0 to 14, with 7.0 as neutral. Below 7.0 on the scale is acid, and above 7.0 on the scale is alkaline or basic. Used in water treatment and purification.

PLUG — A plumbing fitting used to close off a fitting or a length of pipe by screwing into the fitting or pipe.

PPM — Parts per million.

PSI — Pounds per square inch.

PSIG — Pounds per square inch gauge.

PUMP — A mechanical device which applies a force to move any substance that flows or can be made to flow.

RADIATION — The transfer of heat through space by heat waves.

RECEIVER — Device in a refrigeration system to store refrigerant used by the system.

REDUCING VALVE — A spring-loaded or lever-loaded valve similar to a safety valve, designed to maintain a lower end constant pressure beyond the valve.

RELATIVE HUMIDITY — The percentage of water vapor in the air when compared to the amount it does hold as to the amount it could hold.

REVERSE OSMOSIS — A process whereby a solution flows through a semipermeable membrane into an area of lower solute concentration.

ROICC — Resident Officer- in-Charge of Construction.

ROUGHING IN — The installation of all parts of a plumbing system; completed before installation of fixtures.

SENSIBLE HEAT — Heat that can be measured in degrees of temperature with a thermometer.

SPECIFIC HEAT — The quantity of heat expressed in Btu required to raise 1 pound of any substance 1°F in temperature.

SUPERHEAT — The amount of heat expressed in Btu added to a substance above its boiling temperature.

TOTAL HEAT — Sensible heat plus latent heat expressed in Btu.

TRAMAN — Training manual.

VALVE — A device for regulating, stopping, or starting flow in a system and for controlling direction of flow.

VACUUM — Pressure lower than atmospheric pressure.

VAPORAZATION — The process of changing a liquid to a vapor.

VELOCIMETER — Instrument that measures air speeds using a direct-reading air speed indicating scales.

GLOSSARY OF

CHEMICALS USED IN WATER TREATMENT

ALUMINUM HYDROXIDE — AIOH, Reagent, used to decolorize water samples when preforming chloride tests on water.

ALUMINUM SULFATE — (Alum), $A1_3(SO_4)_3$, a white salt, a coagulant, used to flocculate dissolved solids in a weak acid water environment.

AMMONIA — NH_3, an alkaline colorless gas, used in solution to detect leaks in chlorine equipment and systems.

BARIUM CHLORIDE — $BaC1_2$, Reagent, used to test for sulfates in water.

CALCIUM HYPOCHLORITE — $CaC1_2O_2$, a granular white powder used to disinfect water.

CARBON DIOXIDE — CO_2, a liquid, is used to lower pH of softened and settled potable water.

CHLORINE — $C1_2$, a natural chemical element (Cl). A powerful disinfectant, used extensively in water treatment. As a gas, it's color is greenish yellow, and it is 2 1/2 times heavier than air. As a liquid, it's color is amber, and it is about 1 1/2 times heavier than water. It is an oxidizer, and is toxic to all organisms and corrosive (in the presence of water) to most metals.

DIAMINETETRACETATE — (EDTA), Reagent, used in solution with Sodium Ethylene to detect minerals which cause hardness in water.

FERRIC CHLORIDE — $FeC1_3$, a dark salt that hydrates to a yellow-orange form. A coagulant, used to flocculate dissolved solids in a strong acid water environment.

FERRIC SULFATE — FeS_3, a coagulant, used to flocculate dissolved solids in a strong acid water environment.

FERROUS SULFATE — $FeSO_4$, a coagulant, used to flocculate dissolved solids in a strong base (alkaline), water environment.

HYDRATED LIME — (Caustic Lime) $CaOH_2$, a dry white powder, a strong base (alkaline), consists of calcium hydroxide made by treating caustic lime with water. Used to balance water pH and absorb chlorine.

METHYL ORANGE — Reagent, used in solution to determine the alkalinity of water.

METHYL PURPLE — Reagent, used in solution to determine the alkalinity of water

PHENOLPHTHALEIN — $C_{20}H_{14}O_4$, Reagent, used as an pH indicator for water testing. Red color in bases (alkalines) or decolorized in an acid.

POTASSIUM CHROMATE — KC1, Reagent, used in testing for chlorine levels in water.

POTASSIUM HYDROXIDE-(Caustic Potash) K_2CrO_7, a white powder, strongly basic (alkaline), when dissolved in water produces heat. Used to balance water pH and absorb chlorine. Also used as a reagent to test water salinity.

SILVER NITRATE — $AgNO_3$, Reagent, used to determine amount of salinity and chloride in water.

SODIUM CARBONATE — (Soda ash), Na_2CO_3, salt of carbonic acid, strongly basic (alkaline). Used in

water softening, and balancing water pH to aid coagulation.

SODIUM ETHYLENE — (EDTA), $Na_2CH_3CH_2$, Reagent, used in solution with Diaminetetracetate, to detect minerals which cause hardness in water.

SODIUM HYDROXIDE — (Caustic Soda) NaOH, a strong base (alkaline), white powder used to balance pH in water to aid coagulation, and absorb chlorine.

SODIUM HYPOCHLORITE — NaOC1, a salt usually furnished in solution, used for disinfection of water.

SULFURIC ACID — (Standard), H_2SO_4, strong acid, used to balance water pH and aid in coagulation.

THIOSULFATE — A salt, used to neutralize chlorine water. Used to sterilize water sample containers.

APPENDIX II

TABLES FOR MAINTENANCE PROCEDURES

Table A.—Permissible Enlargement and Ellipticity of Holes in Tube Sheets

Table B.—Preoperation Checks for Boilers

Table C.—Additional Preoperating Checks for Gas-Fired Boilers

Table D.—Additional Preoperating Checks for Oil-Fired Boilers

Table E.—Operational Checks for Boilers

Table F.—Boiler Emergencies

Table G.—Fuel Gases

Table H.—A Comparison of Fuel Oils

Table I.—Troubleshooting Chart for Pot and Sleeve Oil Burners

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Table K.—Oil Burner Troubleshooting

Table L.—Common Operation Difficulties for Oil Burners

Table M.—Oil Pump Troubleshooting

Table N.—Troubleshooting Chart for Thermostats

Table O.—Troubleshooting Hot-Water System Boilers

Table P.—Inspection and Maintenance of Coppers and other Steam-Heated Equipment

Table Q.—Troubleshooting for Dishwashing Machines

Table R.—Troubleshooting Chart for Ovens, Ranges, & Boilers

Table S.—Troubleshooting Chart for Clayton Steam Generator

Table T.—Troubleshooting Chart for Residential Washers

Table U.—Troubleshooting Chart for Residential Dryers

Table V.—Troubleshooting Refrigeration Systems

Table W.—Troubleshooting Industrial Refrigeration

Table X.—Troubleshooting Laundry Equipment

Table Y.—Troubleshooting Checklist Domestic Refrigerators and Freezers

Table Z.—Troubleshooting Chart for Air Conditioners

Table A

Permissible Enlargement and Ellipticity of Holes in Tube Sheets

Outside diameter of tube (inches)	Maximum tube hole diameter (Inches)	Maximum ellipticity (inches)
1	1 1/16	1/32
1 1/4	1 5/16	1/32
1 1/2	1 37/64	3/64
1 3/4	1 53/64	3/64
2	2 3/32	1/16
2 1/4	2 11/32	1/16
2 1/2	2 5/8	5/64
3	3 1/8	5/64
3 1/4	3 13/32	3/32
3 1/2	3 21/32	3/32
4	4 3/16	1/8
4 1/2	4 11/16	1/8

Table B

Preoperating Checks for Boilers

Equipment	Check/Action
Boiler room	Remove rags, paint cans, oil spots from deck Stow tools and equipment
Furnace/gas passages	Must be clean and clear and all doors must fit tight Must be in good repair No oil/tools in combustion chamber Must be purged
Valves	Good operating condition Bent stems Missing/broken handwheels
Piping	Inspect piping for leaks Check for proper support
Electrical systems	Oil-soaked or frayed wiring Damaged or loose conduit Improperly secured control boxes
Guards	Tight and in proper position
Water-gauge glass	Well lighted Not stained

Table C

Additional Preoperating Checks for Gas-fired Boilers

Equipment	Checks
Pilot & main gas cock	Operate smoothly
Copper tubing	No restrictions, such as kinks or flat spots
Air shutters	Operate freely Linkage must not have too much lost motion
Burner & main gas valve	Must be firmly supported
Boiler Room	No free gas. Ventilate if present and test all piping with soap solution

Table D

Additional Preoperating Checks for Oil-fired Boilers

Equipment	Checks
Strainers	Inspect & clean
Burners	Must be clean Nozzle must be clean Inspect and set electrodes Check all fittings for leaks Check operation of burner safety switch
Oil system	Inspect for leaks, and repair

Table E

Operational Checks for Boilers

EQUIPMENT	ACTION/CHECK
Water Level	–Check frequently as water expands during the heating up period.
Main steam stop bypass (if installed)	–Open if the boiler is to be cut in on a cold line; –Main steam stop can be opened when there is no other boiler on the same steam line.
Air cock	–Close after steam has formed and has blown all air from boiler.
Steam pressure	–Raise slowly, usually 1/2 to 2 1/2 hours, depending upon type, size and condition of boiler. –Temperature of water should be raised at a rate of 100°F per hour.
Safety valve	– Manually lifts when pressure is at least 75% of the valve setting –Make sure valves reseat properly; if valves fail to reseat, lift them a second time.
Boiler feedwater	–Commence feeding boiler, it probably will be automatically controlled.
Firing	–Gas; Maintain ignition; maintain air-fuel ratio; there should be no soot formation. –Oil; Maintain ignition, observe flame and adjust dampers; check accuracy by flue-gas analysis.
Water level	–Blow down gauge glass and water column (observe promptness of return of water in glass). –Keep at proper level. –Frequently, determine true level of water with different methods.
Boiler blowdown	–Watch and monitor gauge glass. –Frequency depends on water tests.
Cutting in boiler	–If closed, open main steam stop valve slowly.

Table F

Boiler Emergencies

EMERGENCY	TASK	KEY POINTS
EMERGENCY ONE: Low water condition indicated by no water level in the gauge glass.	Secure the boiler, secure electrical switches, steam stop, and feedwater stop. Prove water level by opening try cocks. Cool the boiler slowly until the water temperature is 200°F. Secure all sources of draft. Check controls. Find out the cause for low water level. Correct the trouble. After correction has been made, add water to obtain the correct water level.	DO NOT ADD WATER TO THE BOILER to raise the water level in the gauge glass column. STAY AWAY from the discharge. DON'T FORCE COOL.
EMERGENCY TWO: High water condition indicated by gauge glass full of water.	Prove water level by opening the try cocks. Blowdown the boiler by opening the blowdown valves. Find out the cause of high water condition. Check feedwater pump controls. Correct the trouble. Secure the boiler if pump controls operate improperly.	STAY AWAY from discharge. Check blowdown pit. Watch the gauge glass until normal level is reached. If control operates properly, continue to operate the boiler.
EMERGENCY THREE: Serious tube failure making it impossible to maintain water level.	Secure the boiler by securing the electrical steam and fired systems. Add water to the boiler until the ruptured tube level is reached and the boiler is cooled to a temperature of 200°F. Open the boiler to replace the tube.	For large boilers: Water should be fed to the boiler until properly cooled. Mark the gauge glass if within its range. Observe level by whatever means available.
EMERGENCY FOUR: Flareback caused by an explosion within the combustion chamber.	Secure the boiler. Find the cause of flareback and correct the trouble. Check for sufficient fuel and type of fuel contamination. Check the burner.	Ensure that a slug of water did not interrupt flame with a refire before prepurge.
EMERGENCY FIVE: Minor tube failure indicated by trouble maintaining water level under normal steam demand.	Secure the boiler if it is possible to remove it from the line for sufficient time to make necessary repairs. Secure electrical switches. Open the steam stop and feed stop if additional water is not needed to protect remaining tubes.	If unable to secure boiler because of steaming requirements and you can maintain the water level, continue to operate. If unable to maintain the water level and/or supply, secure the boiler.
EMERGENCY SIX: Broken gauge glass on water column.	Securetop and bottomvalves. Replace gauge glass Use chains or whatever method available to prevent injury to personnel.	Boiler may be kept on line, if necessary. Check the boiler water level by using the try cocks.

Table G

Fuel Gases

Fuel	Source	Heating value Maximum (Btu per cuft)	Remarks
Natural gas	Gas wells	700–1,300 average 1,000	Ideal fuel. It is pumped to point of use
Manufactured Gas			
Carbureted Water Gas	Manufactured from coal enriched with oil vapors	520–540	A costly good fuel that is part of most city gas
Oil Gas	Manufactured from petroleum	520–540	Used on U.S. west coast; is often mixed with coke oven gas
Producer Gas	Manufactured from coal, coke, wood, etc.	135–165	Requires cleaning
Liquefied Petroleum Gas			
Propane	By-product of gasoline	2,500	Boiling point: -44°F. Liquefies under slight pressure
Butane	By-product of gasoline	3,200–3,260	Boiling point 32°F. Liquefies under slight pressure

Table H

A Comparison of Fuel Oils

Grade Number	Approximate weight/gallon	Heating value (Btu per gallon)	Type Fuel
1	6.92	136,000	A volatile distillate oil for use in burners that prepare fuel for burning solely by vaporization.
2	7.08	138,500	A moderately volatile distillate oil for use in burners which prepare fuel for burning by a combination of vaporization and atomization
4	7.58	145,000	A residual oil for burner installations not equipped with preheaters
5 (Light)	7.83	148,500	A residual oil of intermediate viscosity for use in burners equipped with preheaters; however, preheating may or may not be required depending on climate and equipment
5 (Heavy)	Greater than 5 light	Greater than 5 light	A residual oil of greater viscosity than 5 light. Preheating may be required before burning this oil; and in cold climates, preheating may be required before handling as well
6	8.16	152,000	A residual oil of high viscosity for which preheating is always required

Table I

Troubleshooting Chart for Pot and Sleeve Oil Burners

Problem	Probable Cause	Possible Remedy
Burner Smokes	Improper fuel	Use recommended fuel
	Insufficient oil flow Excessive chimney draft Pilot casing is poorly fitted Dirty burner	Troubleshoot for low flow Check draft regulator Remove and install correctly Clean the burner
Burner goes out	Low oil supply Plugged vent on the out supply line Insufficient oil flow Improper fuel Fuel inlet plugged with carbon Dirt in the oil control valve Oil valve is not level Filter cartridge plugged Excessive chimney draft Excessive flue downdraft	Add oil if necessary Clean the vent Troubleshoot for low oil flow Use recommended fuel Clean Clean the valve Level the valve Clean the filter Check draft regulator Install downdraft hood
Burner Flooded	Dirty float valve Improper operation Needle valve stuck	Remove and clean the float valve Instruct operating personnel on proper procedures Clean or replace the valve
	Dirty burner	Clean the burner
	Excessive flue downdraft	Install downdraft hood
Low oil flow	Air trapped in oil supply line	Eliminate high points in the piping and bleed air out
	Oil control valve not level	Level the valve
	Oil may be too heavy	Only use manufacturer's recommended grade of oil
	Dirt in the supply line or in the metering mechanism	Clean the line and components
	C logged oil strainer	Clean the strainer
	Flue inlet clogged with carbon	Remove the carbon
High fuel consumption	Improper fuel	Use manufacturer's recommended grade of oil
	Heat loss	Reduce air supply to the burner
	Excessive chimney draft	Check the draft regulator
	Heat exchanger caked with slag	Clean the affected areas

Table J

Troubleshooting Chart for Gas-fired Space Heaters

Problem	Probable Cause	Possible Remedy
Motor does not run	Incorrect current	Check and correct
	Faulty wiring	Rewire properly
	Defective wiring	Replace and lubricate
Motor runs intermittently	Thermal overload protectors cutting out	If no external cause, such as improper current, can be found, replace the motor
Excessive fan and motor noise	Bent fan blade	Straighten by hand or replace if serious
	Excessive end play in shaft	If end play exceeds 1/32 inch, repair or replace
Solenoid valve hums or flutters	Installed backwards	Check arrow on valve body and correct if required
	Poor electrical connection or faulty solenoid	Check, correct, or replace
Burner does not ignite	Faulty pilot burner, thermo-couple, or thermal bulb	Check, correct, or replace
	Inoperable solenoid valve	Impart current across the leads of the valve. A click indicates satisfactory operation. Replace solenoid if necessary
Delay in main burner operations (2 to 3 min) after fan starts	Malfunctioning limit switch	Replace limit switch
Improper burning of main burner	Primary air incorrectly set	Adjust primary air after the unit has been burning for 10 to 15 minutes. Adjust the shutter down until a yellow tip appears on the flame, and then open the shutter until the yellow tip disappears.
	Incorrect orifice size	Check manufacturer's specifications for the correct size and replace.
	Incorrect gas pressure	Check manufacturer's specifications regarding correct pressure for the gas being used. Measure pressure and adjust pressure regulator to correct condition.
Pilot fails to light or will not stay lit	Stopped pilot line	Clean line or replace, if required
	Excessive draft	Eliminate draft
	Low gas pressure	Check pressure regulator or tank level, if LPG

Table K

Oil Burner Troubleshooting

Burner fails to start

Source	Procedure	Causes	Correction
Thermostat control	Check thermostat settings	Thermostat is in OFF or COOL position	Switch to HEAT
		Thermostat is set too low	Turn to higher
Safety overloads	Check burner motor, primary safety control, and auxiliary limit switch	Burner motor overload tripped	Push motor overload reset button
		Primary control tripped on safety	Reset safety switch lever
		Auxiliary limit switch tripped on safety	Push auxiliary limit switch reset button
Power	Check furnace disconnect switch and main disconnect switch	Switch open Blown fuse or tripped breaker	Close switch Replace fuse or reset breaker
Thermostat unit	Touch jumper wire across thermostat terminals on primary control. If burner starts, then fault is in thermostat circuit	Loose thermostat screw connections Dirty contacts Thermostat not level Faulty thermostat	Tighten connection Clean contacts Level thermostat Replace thermostat
Cad Cell	Disconnect flame detector wires at primary control. If burner starts, fault is in the detector circuit	Flame detector leads shorted	Separate leads
		Flame detector exposed to light	Seal off false source of light
		Short circuit in flame detector	Replace detector

Table K

Oil Burner Troubleshooting (Continued)

Burner fails to start

Source	Procedure	Causes	Correction
Primary Control (1)	Place trouble light between the black and white leads. No light indicates there is no power to the control.	Primary or auxiliary control switch open	Check dial adjustment. Set to maximum stop setting Jumper terminals; if burner start switch is faulty, replace control.
		Open circuit between disconnect switch and limit control	Trace wiring and repair or replace
		Low line voltage or power failure	Call power company
Primary Control (2)	Place trouble light between the orange and black leads. No light indicates the control is faulty.	Defective internal control circuit	Replace control
Burner (1)	Place trouble light between the black and white leads to burner motor. No light indicates no power to the burner motor.	Blown fuse	Replace fuse
Burner (2)	Place trouble light between the black and white leads to burner motor. Light indicates power to the motor and a burner fault.	Binding burner blower wheel	Turn off power and rotate blower wheel by hand.
		Seized fuel pump	If seized, free wheel from binding or replace fuel pump.
		Defective burner motor	Replace motor

Table K

Oil Burner Troubleshooting (Continued)

Burner starts but no flame is established

Source	Procedure	Causes	Correction
Oil supply	Check tank gauge or use dip stick Coat dipstick with litmus paper and insert to bottom of the tank. Listen for pump whine	No oil in tank Water in oil tank Tank shutoff valve closed	Fill tank Pump or drain the water out if greater than 1 inch in depth Open valve
Oil filters and oil line	Listen for pump whine Open bleed valve or gauge port. Start burner. No oil or milky oil indicates loss of prime	Oil line filter plugged Kinks or restriction in oil line Plugged fuel pump strainer Air leak in oil supply line	Replace filter cartridge Repair or replace oil line Clean strainer or replace pump Locate and correct leak and tighten all connections
Oil Pump	Install pressure gauge on pump and read pressure. Pressure should not be less than 100 psig	Pump partially or corn- pletely frozen – No pressure and motor locks out on overload Coupling disengaged or broken – no pressure. Fuel pressure too low.	Replace pump Reengage or replace coupling Adjust pressure to 100 psig
Nozzle	Disconnect ignition leads. Observe oil spray (gun assembly must be removed form the unit) Inspect nozzle for plugged orifice or carbon buildup around orifice	Nozzle orifice plugged Nozzle strainer plugged Poor or off center spray	Replace nozzle with same size, spray angle, and spray type
Ignition electrodes	Remove gun assembly and inspect electrodes and leads.	Fouled or shorted electrodes and leads; Eroded electrode tips Improper position of electrode tips Bad buss bar connection Cracked or chipped insulators Cracked or burned lead insulators	Clean electrodes and leads Dress up electrode tips and reset gap to 1/8 inch and correctly position the tips Retension and align Replace electrode Replace electrode leads
Ignition Trans- former	Connect ignition leads to transformer. Start burner and observe spark. Check line voltage to transformer primary	Low line voltage Burned out transformer windings No spark or weak spark	Check voltage at power source. Correct cause of voltage drop or call power company. Replace transformer Properly ground transformer case
Burner Motor	Motor does not come up to speed and trips out on overload. Turn off power and rotate blower wheel by hand to check for binding or excessive drag	Low line voltage Pump or blower overloading motor Faulty motor	Check voltage at power source. Correct cause of voltage drop or call power company Correct cause of overloading or replace motor Replace motor

Table K

Oil Burner Troubleshooting (Continued)

Burner starts and fires but locks out on safety

Source	Procedure (1)	Procedure (2)	Cause	Correction
Poor fire	After burner fires, immediately place jumper across flame detector terminals at primary control	If burner continues to run, fault may be due to poor fire. Inspect fire.	Unbalanced fire	Replace nozzle
			Too much air – lean short fire	Reduce combustion air – check combustion
			Too little fire – long dirty fire	Increase combustion air – check combustion
			Excessive draft	Adjust barometric damper for correct draft
			Too little draft or Restriction	Correct draft or remove restriction
Flame detector		If fire is good, fault is in flame detector. Check detector circuit.	Dirty cad cell face	Clean cad cell face
			Faulty cad cell – exceeds 1,500 ohms	Replacecadcell
			Loose or defective cad cell wires	Secure connections Or replace cad cell holder and wire leads
Primary control		If burner locks out on safety, fault is in primary control.	Primary control circuit defective	Replace primary control

Table K

Oil Burner Troubleshooting (Continued)

Burner starts and fires but locks out on safety

Source	Procedure (1)	Procedure (2)	Cause	Correction
Poor fire	After burner fires, immediately place jumper across flame detector terminals at primary control	If burner continues to run (does not lock out on safety), fault may be due to poor fire. Inspect fire.	Unbalanced fire Too much air – lean short fire	Replace nozzle Reduce combustion air – check combustion
			Too little fire – long dirty fire	Increase combustion air – check combustion
			Excessive draft	Adjust barometric damper for correct draft
			Too little draft or restriction	Correct draft or remove restriction
Flame detector		If fire is good, fault is in flame detector. Check detector circuit.	Dirty cad cell face	Clean cad cell face
			Faulty cad cell –exceeds 1,500 ohms	Replace cad cell
			Loose or defective cad cell wires	Secure connections Or replace cad cell holder and wire leads
Oil supply (Listen for pump whine)		If burner looses flame (does not lock out on safety), fault is in fuel system.	Air slug or leak in supply line	Check supply line and oil tank
			Restriction or plugged strainers	Remove restriction or replace pump

Table K

Oil Burner Troubleshooting (Continued)

Burner runs continuously (too little heat)

Source	Procedure (1)	Procedure (1)	Cause	Correction
Combustion	Check burner combustion for CO2 stack temperature and smoke	If burner continues to run (does not lock out on safety), fault may be due to poor fire Inspect fire.	Unbalanced fire Too much air – lean short fire	Replace nozzle Reduce combustion air – check combustion
			Too little fire – long dirty fire	Increase combustion air – check combustion
			Excessive draft	Adjust barometric damper for correct draft
			Too little draft or restriction	Correct draft or remove restriction
Flame detector		If fire is good, fault is in flame detector. Check detector circuit.	Dirty cad cell face	Clean cad cell face
			Faulty cad cell – exceeds 1,500 ohms	Replacecadcell
			Loose or defective cad cell wires	Secure connections Or replace cad cell holder and wire leads
Oil supply (Listen for pump whine)		If burner looses flame (does not lock out on safety), fault is in fuel system.	Air slug or leak in supply line	Check supply line and oil tank
			Restriction or plugged strainers	Remove restriction or replace pump

Table K

Oil Burner Troubleshooting (Continued)

Burner starts and fires but short cycles (too little heat)

Source	Procedure	Causes	Correction
Thermostat	Check thermosta	Heat anticipator set too low	Correct heat anticipator setting
		Vibration in thermostat	Correct source of vibration
		Thermostat in warm-air draft	Shield thermostat from draft or relocate thermostat
Limit Control	Connect voltmeter between line voltage connections to primary control (black and White leads). If burner cycles due to power interruption, it is cycling off limit.	Dirty air filters (furnace)	Clean or replace filter
		Blower running too slow	Speed up blower for 85 to 95 temperature rise
		Blower motor seized or burned out	Replace motor
		Blower bearings seized	Replace bearings and shaft
		Blower wheel dirty	Clean blower wheel
		Blower wheel in back-wards	Reverse blower wheel
Power	If voltage fluctuates, then fault is in power source. Recheck voltage at power source	Wrong motor rotation	Replace with motor of correct rotation
	Disconnect thermostat wires at primary control.	Restrictions in return air or supply air system	Correct cause of restric-tion
	1. If burner turns off, fault is in thermostat circuit	Adjustable limit control set too low	Reset limit to maximum stop setting
	2. If burner does not turn off, fault is in the primary control..	Loose wiring connection	Locate and secure connec- tion
		Low or fluctuating line voltage	Call power company

Table K

Oil Burner Troubleshooting (Continued)

Burner starts and fires but locks out on safety

Source	Procedure (1)	Procedure (2)	Cause	Correction
Poor fire	After burner fires, immediately place jumper across flame detector terminals at primary control	If burner continues to run, fault may be due to poor fire. Inspect fire.	Unbalanced fire Too much air – lean short fire	Replace nozzle Reduce combustion air – check combustion
			Too little fire – long dirty fire	Increase combustion air – check combustion
			Excessive draft	Adjust barometric damper for correct draft
			Too little draft or Restriction	Correct draft or remove restriction
Flame detector		If fire is good, fault is in flame detector. Check detector circuit.	Dirty cad cell face Faulty cad cell –exceeds 1,500 ohms Loose or defective cad cell wires	Clean cad cell face Replace cad cell Secure connections Or replace cad cell holder and wire leads
			Primary control circuit defective	Replace primary control
Primary control		If burner locks out on safety, fault is in primary control.		

Table K

Oil Burner Troubleshooting (Continued)

Burner runs continuously (too much heat)

Source	Procedure	Cause	Correction
Thermostat	Disconnect thermostat wires at primary control	Shorted or welded thermostat contacts	Repair or replace thermostat
	1. If burner turns off, fault is in the thermostat circuit.	Stuck thermostat bimetal	Clear obstruction or replace thermostat
		Thermostat not level	Level thermostat
		Shorted thermostat wires	Repair short or replace wires
		Thermostat out of calibration	Replace thermostat
		Thermostat in cold draft	Correct cause of draft or relocate thermostat
	2. If burner does not turn off, the fault is in the primary control.	Defective primary control	Replace primary control

Table L

Common Operating Difficulties for Oil Burners

Condition	Check for
Furnace pulsates on starting, stopping, or during operation.	Proper adjustment of the nozzle electrode assembly land blast tube in relation to each other and firebox. Improper draft. Ensure no downdraft. Leaks in chimney. Defective nozzle. Air in the line, between fuel unit and nozzle.
Flame is raw and stingy.	Too large an opening in the air adjustment. Partly plugged nozzle. Air in the pump.
Ignition points collect carbon.	Ignition points too close to nozzle. Nozzle loose in holder. Improper oil cutoff when burner is shutdown.
Oil pump is noisy.	Air in oil line. Leaks in suction line. Plugged strainer.
Burner starts and stops too frequently.	Thermostat is improperly wired. Thermostat is improperly adjusted. Drive arm adjustment is incorrect. Limit control is set too low. Plugged air filters. Nozzle is too large for unit.
Burner failsafe is activated.	Low voltage occurring at night. Incorrect polarity of wiring. Primary control or stack switch improperly adjusted.
No oil at the nozzle	Fuel too low in the supply tank. Plugged nozzle. Leak in the suction line. Leak in the vacuum-gauge port. Pump failing to turn. Leaking strainer gasket. Leaking pump-shaft seal. Fuel unit not operating.

Table M

Oil Pump Troubleshooting

CONDITION	CAUSE	REMEDY
NO OIL FLOW AT NOZZLE	Oil level below intake line in supply tank	Fill tank with oil.
	Clogged strainer or filter	Remove and clean strainer. Replace filter element.
	Clogged nozzle	Replace nozzle.
	Air leak in intake line	Tighten all fittings in intake line. Tighten unused intake port plug. Check filter cover and gasket.
	Restricted intake line (High-vacuum reading)	Replace any kinked tubing and check any valves in intake line
	A two-pipe system that becomes air bound	Check for and insert bypass plug. Make sure return line is below oil level in tank.
	A single-pipe system that becomes air bound	Loosen gauge port plug or easy flow valve and bleed oil for 15 seconds after foam is gone in bleed hose. Check intake line fitting for tightness. Check all pump plugs for tightness.
	Slipping or broken coupling	Tighten or replace coupling.
	Frozen pump shaft	Replace pump.
OIL LEAK	Loose plugs or fittings	Dope with good quality thread sealer. Retighten.
	Leak at pressure adj. Screw or nozzle plug	Washer may be damaged. Replace the washer or O-ring.
	Blown seal (single-pipe system)	Check to see if bypass plug has been left in unit. Replace oil pump.
	Blown seal (two-pipe system)	Check for kinked tubing or other obstructions in return line. Replace oil pump.
	Seal leaking	Replace oil pump.
	Cover	Tighten cover screws or replace damaged gasket.
NOISY OPERATION	Bad coupling alignment	Loosen fuel unit mounting screws slightly and shift fuel unit in different positions until noise is eliminated. Retighten mounting screws.
	Air in inlet line	Check all connections. Use only good flare fittings.
	Tank hum on two-pipe system and inside tank	Install return line hum eliminator in return line.
PULSATING PRESSURE	Partially clogged strainer or filter	Remove and clean strainer. Replace filter element.
	Air leak in intake line	Tighten all fittings.
	Air leaking around cover	Be sue strainer cover screws are tightened securely. Check for damaged cover gasket.
IMPROPER NOZZLE CUT-OFF	To determine the cause of improper cutoff, insert a pressure gauge in the nozzle port of the fuel unit. After a minute of operation, shut burner down. If the pressure drops from normal operating pressure and stabilizes, the fuel unit is operating properly and air is the cause of improper cutoff. If, however, the pressure drops below 80 psig, oil pump should be replaced.	
	Filter leaks	Check face of cover and gasket for damage.
	Strainer cover loose	Tighten four screws on cover.
	Air pocket between cutoff valve and nozzle	Run burner, stopping and starting unit, until smoke and after-fire disappears
	Air leak in intake line	Tighten intake fittings. Tighten unused intake port and return plug.
	Partially clogged nozzle strainer	Clean strainer or change nozzle.
	Leak at nozzle adapter	Change nozzle and adapter.

Table N

Troubleshooting Chart for Thermostats

PROBLEM	PROBABLE CAUSE	POSSIBLE REMEDY
Thermostat fails to energize heating system	Setting too low	Check and increase setting.
	Wired incorrectly	Correct wiring.
	Loose or broken wiring	Replace or repair wiring
	Loose unit or mounting plate	Level and tighten mounting screws
	Dirty contacts	Clean contacts
	Affected by warm draft	Relocate.
	Mercury tube broken	Replace thermostat.
	Improper type for job	Replace with proper type.
Thermostat fails to de-energize heating system	Setting too high	Check and decrease setting
	Affected by cool draft	Relocate.
	Improper type for job	Replace with proper type
	Wired incorrectly	Correct wiring.
	Contacts fused together	Replace unit.
	Not level (mercury switch type)	Level and tighten mounting screws.
	Wiring shorted	Locate short and repair.
Room temperature does not reach thermostat setting or else exceeds the setting	Defective dial	Calibrate or replace unit.
	Improper type for job	Replace with proper type
	Thermometer reading incorrect	Replace unit.
	Defective components	Replace unit
	Heating components too small or too large for area	Check and correct if feasible.
System short-cycles	Improper type for job	Replace with proper type.
	Dirty contacts	Clean contacts.
	Incorrectly set thermostat heater	Adjust or replace.
	Heating components too large for area	Decrease output.

Table O

Troubleshooting Hot-Water Heating Systems

SYSPTOMS	REMEDY
Boiler smokes through the feed doors	Clean the boiler flues and the flue pipes. Repair any chimney leaks.
Boiler heats slowly	Increase the draft. Check on the type of fuel. Clean the boiler of scale. Blowdown the boiler.
Radiator produces insufficient heat	Clean the boiler of scale. Change to a larger boiler. Blowdown the boiler. Increase the draft, and check on the type of fuel.
Radiators do not heat	Insufficient water in the system. Bleed the air from the system. Open the radiator valves, and check the operation of the circulation.
Distribution piping does not transfer hot water to the radiators	Insufficient water in the system. Bleed the air from the high points in the distribution piping. Check the operation of the circulation pump. Check for corrosion stoppage in the distribution piping.

Table P

Inspection and Maintenance of Coppers and Other Steam-Related Equipment

INSPECTION POINT	SYMPTOMS	TIME	POSSIBLE TROUBLE/CAUSES	POSSIBLE CORRECTIONS
Steam jacket	Not heating	When noted	No steam; valve stuck closed; trap malfunctioning	Check steam supply; free stuck valve
Steam jacket	Stays hot	When noted	Valve partly open or scored seat	Repair or replace valve
Steam jacket	Leaks	Monthly	Rapid changes in temperature causing cracks; faulty weld	Raise heat slower; re-weld bust or crack
Pipe joints	Leaks	Monthly	Joint made incorrectly; not tight	Unscrew; clean and repair joint
Pipe joints	Corrosion	Monthly	Leaks or condensation	Repair and/or clean
Control valves	Stuck open or closed	When noted	No steam or too much steam; packing too tight or valve frozen	Loosen packing gland or free frozen valve steam
Control valves	Leaks at stem	Weekly	Packing not tight enough	Tighten packing
Condensate strainer	No flow	When noted	Restricted strainer	Clean strainer
Steam trap	Malfunctioning	Every 6 months	Parts worn or dirty	Disassemble, clean, and repair
Lagging	Broken or crushed	Quarterly	Water soaked; stepped on	Replace defective sections
Reducing valve	Incorrect pressure	When noted	Parts worn or dirty	Disassemble, clean, and repair; clean and adjust pressure every 6 months
Safety valve	Stuck open or lifting under pressure	When noted	Leaks or corrosion	Replace or repair valve
Covers	Tight operation	When noted	Hinges dirty	Clean and lubricate hinges
Drawoff valve	Leaks	When noted	Scored	Resurface or replace. DO NOT REPLACE WITH REGULAR GATE VALVE

Table Q

Troubleshooting for Dishwashing Machine

TROUBLE	PROBABLE CAUSE	POSSIBLE REMEDY
Dish racks slide off chain conveyor	Change of tension of either chain	Reset idler sprockets to proper tension on each chain.
Water pressure too low	Spray nozzles or slot plugged. Strainer baskets plugged. Slipped belts on pumps.	Dismantle spray assembly. Wash out all piping and clean parts. Disassemble and clean strainer. If belts are frayed or torn, replace them. Adjust tension by resetting idler pulley or by moving motor on sliding base
Water splashing on floor or into wrong compartment	Leaks around doors; torn curtains or curtains not in proper position	Realign door. Repair or replace gasket. Repair or realign curtain. Readjust spray to keep it within limits of tank.
Rinse water temperature is less than 180°F	Insufficient heat from booster heater	Remove scale from steam coil. Correct leaking fittings. Adjust gas burners. Calibrate or replace thermostat.
Spot or film on eating utensils after final rinse	Wash water saturated with grease. Dirty tank. Weak sprays in wrong direction. Improper detergent mixture	Stop operation and clean all equipment. Adjust speed of conveyor. Examine spray equipment. Clean nozzles, spray pipes, scrap trays, and strainers. Check piping for leaks. Check to see if valves are operating properly. Examine pump. Clean impellor if necessary

Table R

Troubleshooting Chart for Ovens, Ranges, and Boilers

Trouble	Check	Cause
OIL-FIRED OVENS		
MOTOR: Will not start -	– Fuse. – Thermostat. – Solenoid valve. – Fuel tank.	Blown. Set below baking chamber temperature. Reset. Activated. Or foreign particles in valve. Empty.
Runs, but fails to light oven -	– Ignition. – Transformer. – Fuel nozzle.	Carbon on electrodes. Damaged, bad. Replace. Clogged. Clean.
COMBUSTION FLAME: Disorganized & smoky -	– Damper. – Flue pipes.	Closed. Heavy soot deposits.
UNEVEN COOKING:	– Secondary air damper door.	Too far open or too near shut. Adjust.
IGNITION: Difficult -	– Oil supply.	Too low. Open valve. Shut off by solenoid valve.
BURNER: Starts, functions properly, but fails after short intervals -	– Burner openings. – Suction line. – Strainers. – Oil tank vent. – Controls.	Dirty. Clean. Air leak. Repair. Clogged. Clean. Obstructed. Clean. Out of order or improperly adjusted. Poor or delayed. Clean nozzle.
Puffs when started -		Insufficient.
Runs, but flame pulsates -	– Ignition. – Draft. – Draft. – Chimney.	Insufficient. A downdraft.
COMBUSTION CHAMBER: Smoke in chamber or in chimney-	– Air. – Nozzle.	– Insufficient – Clogged or defective Replace
Carbon forms in chamber -	– Oil burning rate. – Nozzle (oil spray on walls)	– Excessive. Reduce. – Dirty or incorrect model. – Clean/Replace.

Table R

Troubleshooting Chart for Ovens, Ranges, and Boilers (Continued)

Trouble	Check	Cause
OIL-FIRED OVENS–Continued		
FIRE: On one side -	– Nozzle.	Dirty or damaged. Clean/replace.
OIL CONSUMPTION: High -	– Air – Heat-absorbing surfaces. – Oil storage tank.	Too little. Increase. Dirty. Clean ducts. Leaks. Repair.
SOLENOID VALVE: Fails to function -	– Valve itself. – Thermostat. – Connections. – Emergency bypass valve.	Dirty or defective. Replace Damaged. Replace. Defective. Replace. Open.
PILOT FLAME: Inoperative or too low -	– Fuel passage. – Solenoid valve.	Clogged. Clean. Adjust setscrew to increase fuel to pilot flame.
OVEN: Overheats - Underheats -	– Thermostat. – Solenoid valve. – Fuel line. – Fuel shutoff valve. – Vaporizing parts.	Damaged. Replace. Stuck plunger, Dirty. Clean. Clogged. Clean/replace. – Not fully open. – Full of carbon. Clean.
OVEN OR RANGE: Fails to ignite – Does not heat fast enough – Cooks unevenly – No gas –	– Pilot flame. – Main gas or shutoff valve. – Air shutter. – – Gas input. – Cooling damper. – – Flue. – Doors. – Bypass Flame. – Main service valve. – Solenoid valve.	– Insufficient or none. – Closed. (adjacent to unit) – Completely closed. – Too Low or out of adjustment. – Open. – Too much draft. (pulls heat through flue). – Don't close tightly. Clean, – Adjust. – Closed. – Clogged, dirty or defective. Clean/replace.

Table R

Troubleshooting Chart for Ovens, Ranges, and Boilers (Continued)

OVEN OR RANGE: Constant "burning"–	– Draft. – Thermostat.	– Too much. Remove Draft. – Faulty. Replace.
Temperature rises, when not in use –	– Low flame setting.	– Is too high. (Cut low flame to a minimum.)
Fumes in room –	– Chimney	– Faulty, backdraft or improper gas adjustment.
	– Fans in room.	– Running with doors and windows closed.
Flare back on turndown –	– Bypass flame.	– Too low, adjust.
FIELD RANGES		
FUEL SYSTEM; Fails to maintain pressure –	– Fuel filter. – Air valve. – Fuel tank.	– Leaks. Replace gasket. – Defective. Replace. – Defective. Replace.
PREHEATER: Fails to ignite –	– Safety valve. – Fuel feed tube assembly. – Preheater generator.	– Does not reseat. Replace. – Damaged or missing. Replace. – Defective. Replace.
BURNER: Fails to ignite –	– Preheater generator. – Generator. – Feed tube assembly.	– Defective. Replace. – Defective. Replace. – Missing, clogged or dented. Clean/Replace.
Flame too low –	– Generator.	– Defective.
BURNER FLAME: Yellow –	– Generator flame valve.	– Defective. Repack/replace.
GENERATOR OR PREHEATER VALVE: Fuel leaks –	– Generator flame valve. – Generator.	– Defective. Repack/replace. – Defective. Replace
AIR PRESSURE GAUGE: Pressure rises above safe limit -	– Valves.	– Defective. Repack or replace.
	– Fuel tank. – Gauge.	– Too full. Only 8 quarts. – Defective. Replace

Table S

Troubleshooting Chart for Clayton Steam Generator

Trouble	Possible Cause	Remedy
Feedwater pump failing to maintain proper water level in accumulator gauge glass.	Accumulator blowdown valve open or leaking.	Inspect accumulator blowdown valve.
	Feedwater pump not primed.	Prime pump.
	Insufficient water to feedwater pump.	Check water supply to pump. Ensure intake valve is open.
	.Feedwater strainer clogged.	Clean strainer.
	Feedwater pump check valves not operating properly	Clean and inspect check valves.
	Water pump solenoid not releasing.	Remove water level electrodes and clean off rust and dirt. Check water pump solenoid armature and linkage for binding.
Circulating pump failing to maintain proper feed volume to heating coil, causing thermostat interruption.	Low oil level in water pump causing reduced pump capacity.	Ensure oil is maintained at proper level.
	Priming valve not operating properly.	Clean and inspect priming valve.
	Circulating pump check valves not operating properly.	Clean and inspect check valves.
	Vapor lock of circulating pump due to abrupt steam demand causing low pressure in accumulator.	On installations where there are sudden heavy steam demands, a back pressure valve should be installed to retain a normal steam pressure in the accumulator during these periods.
	Circulating pump not primed.	Prime circulating pump.

Table S

Troubleshooting Chart for Clayton Steam Generator (Continued)

Water System		
Too much water (unit operating with high water level in gauge glass).	Water pump solenoid not operating.	1. Check for burned out solenoid coil or open circuit to solenoid. 2. Remove and clean water level electrodes. Corrosion on electrodes may cause insulating effect and prevent operation of solenoid. 3. Check for defective water level relay.
	Stream trap plugged.	Remove and clean steam trap.
Noisy water pump operation.	Flexible coupling loose between motor and pump.	Tighten setscrews in flexible coupling.
	Pump intake surge chamber fouled.	Check and clean intake surge chamber.
	Restricting heating coil causing excessive feed pressure.	Check feed pressure for coil restriction.
Water pump cycles rapidly.	Leads to water level electrodes reversed.	Check wiring to electrodes (see wiring diagram).

Table S

Troubleshooting Chart for Clayton Steam Generator (Continued)

Fuel System		
Trouble	**Possible Cause**	**Remedy**
Low or no fuel pressure. CAUTION: Stop plant immediately to avoid damage to the fuel pump.	Fuel supply exhausted or supply lines restricted.	Check fuel supply. Ensure all valves in the supply line are open.
	Fuel bypassing through burner control valve.	Burner control valve must be airtight and all air pockets eliminated.
	Fuel pressure not adjusted properly.	Adjust fuel pressure.
	Air leak in supply line causing loss of prime.	Suction line must be airtight and all air pockets eliminated.
	Fuel pump failure.	Replace fuel pump
Burner fails to ignite.	Faulty ignition.	Check and adjust ignition electrodes. Check ignition transformer and cable. Check for low voltage condition which may a weak spark from the transformer.
	Safety switch in combustion control locked out.	Actuate reset on control. Also check for continuity of circuit between combustion control and flame detector (under burner manifold).
	Fuel pressure switch failure.	Check and adjust fuel pressure switch.
	Burner nozzles not replaced in burner.	Ensure nozzles are replaced after cleaning burner manifold.
	Insufficient fuel pressure.	Check causes and remedies under "Low or No Fuel Pressure."
	Oil valve failing to open.	Check for burned out solenoid.

Table S

Troubleshooting Chart for Clayton Steam Generator (Continued)

Fuel System		
Trouble	**Possible Cause**	**Remedy**
Partial or improper burner operation causing low steam pressure at normal load.	Low fuel pressure.	Check causes and remedies under "Low or No Fuel Pressure."
Burner shuts off before maximum steam pressure is reached.	Thermostat control interruption due to low water condition.	Correct cause of low water condition immediately. Test thermostat for proper control.
Smoke from flue outlet. To prevent sooting of the heating coil and burner, correct this condition immediately.	Improper air supply to burner.	Check air adjustment/
	Fuel pressure not adjusted properly.	Adjust fuel pressure.
	Carboned, loose, or worn burner nozzles.	Clean and tighten burner nozzles. Replace if worn.
	Heating coil sooted.	Remove soot from heating coil.
	Dirt or sludge in fuel oil or incorrect grade of fuel used.	Ensure fuel is clean and is the proper grade.
Fluttering burner shuts off during automatic operation.	Oil valve not seating properly.	Check and clean solenoid valve.
Oil drip from burner.	Oil valve not seating properly.	Check and clean solenoid valve.
Dead or fluttering fire.	Heating coil sooted.	Remove soot.
	Improper air adjustment.	Check air adjustment.
Motor fails to start, or stops during operation	Power failure or tripped circuit breaker.	Check power lines. Reset circuit breaker.
	Safety shutdown caused by overload relays	Wait 2 or 3 minutes for overloads to cool; then press reset on magnetic controller and restart unit. Check for cause of overload
Motor noisy or running hot.	Motor running single phase	Check for blown fuse or tripped circuit breaker in feeder lines.
Magnetic controller fails to contact.	Operating coil failure.	Replace coil.

Table T

Troubleshooting Chart for Washers

Problem	Check	Cause
Motor will not run.	Power to machine. Door switch Water level control Motor Timer	None, check outlet Defective, check all controls Faulty, replace Faulty, repair or replace Faulty, replace
Machine will not shut off.	Timer Wiring	Defective, replace Break, repair Faulty, replace
Timer will not advance to next cycle. NOTE: Timer does not advance during water fill period until the water level switch has been satisfied.	Timer motor Timer Water level control	Defective, replace Bound shaft or knob, clear Faulty, replace
Incorrect fill or temperature	Water level control Thermal element Hot-water supply Hoses	Faulty water level control. Faulty, repair or replace Inadequate, adjust temperature Reversed, correct
No water	Water valves Hoses Fill hose screen Fill solenoid Water level control Machine	Closed, Turn on valves. Unkink hoses. Clean dut screen. Replace solenoid. Replace control. Check controls and power at outlet.
Water will not shut off.	Timer Water level control Mix and fill valve Valve	Defective, replace Defective, replace Foreign particles, clean Defective, replace

Table T

Troubleshooting Chart for Washers (Continued)

Problem	Check	Cause
Water will not drain from washer	Drain hose Pump Suds Transfer valve Timer Belt	Kinked/clogged, unkink/clear Does not run, readjust and tighten Lock, remove suds, add cold water Faulty, replace Defective, replace Loose, adjust
No spray rinse	Water supply Timer	None, same as no water Defective, replace
Slow spin	Belt/clutch	Slips, adjust
Excessive vibration	Washer Flooring Load Washer feet Snubber or suspension bolts	Not level, adjust legs Weak, reinforce floor Unbalanced, redistribute No rubber cups, install them Damaged, replace
No agitation	Motor Timer contacts. Faulty transmission. Defective control solenoid. Linkage Water level switch	Failure, repair or replace. Faulty, replace timer. Faulty, repair or replace Defective, replace solenoids. Broken, repair or replace. Faulty, replace switch
Water leakage.	Inlet hose Drain hoses Hose Gasket Housing	Loosely connected, tighten Loosely connected, tighten Broken, repair or replace Leaky, replace Cracked, replace parts
No recirculation of water during agitation	Pump Pump drive Hose Distribution valve	Jammed, clean Defective, replace coupling or tighten Clogged, clean Defective, clean out, replace valve or solenoid
Torn clothing	Bleach Agitator Basket	Improper usage Broken, replace Defective, replace

Table U

Troubleshooting Chart for Residential Dryers

Problem	What to check for
Motor does not start	Service cord disconnected Circuit breaker tripped or a blown fuse Wiring loose or broken Loading door open Door switch defective Motor defective
Dryer does not shut off	Timer motor jammed Clock spring broken Stop pin in improper positioning Timer contact points are closed Motor grounded or windings shorted out
Dryer dries slowly	Clothes are too wet Lint box is clogged Thermostat is set too low Voltage is low Dryer is overloaded
Dryer is noisy	Suction fan alignment is incorrect Loose fan or loose fan pulley Loose or dry fan belt There are loose items between the drum and the cylinder Loose screws

Table V

Troubleshooting Checklist for Refrigeration Systems

TROUBLE	POSSIBLE CAUSE	CORRECTIVE MEASURE
High condensing pressure.	Air or non-condensable gas in system.	Purge air from condenser.
	Inlet water warm.	Increase quantity of condensing water.
	Insufficient water flowing through condenser	Increase quantity of water.
	Condenser tubes clogged or scaled	Clean condenser water tubes.
	Too much liquid in receiver, condenser tubes submerged in liquid refrigerant.	Draw off liquid into service cylinder.
	Insufficient cooling of air-cooled condenser	Check fan operation, cleanliness of condenser, and for adequate source of air flow
Low condensing pressure.	Too much water flowing through condenser	Reduce quantity of water
	Water too cold.	Reduce quantity of water
	Liquid refrigerant flooding back from evaporator.	Change expansion valve adjustment, examine fastening of thermal bulb.
	Leaky discharge valve	Remove head, examine valves. Replace anv found defective.
High auction pressure.	Overfeeding of expansion valve.	Regulate expansion valve, .check bulb attachment.
	Leaky suction valve.	Remove head, examine valve and replace if worn.
Low suction pressure.	Restricted liquid line and expansion valve or suction screens.	Pump down, remove, examineand clean screens.
	Insufficient refrigerant in system.	Check for refrigerant storage.
	Too much oil circulating in system.	Check for too much oil in circulation. Remove oil.
	Improper adjustment of expansion valves.	Adjust valve to give more flow.
	Expansion valve power element dead or weak.	Replace expansion valve power element
	Low refrigerant charge.	Locate and repair leaks. Charge refrigerant.

Table V

Troubleshooting Checklist for Refrigeration Systems (Continued)

TROUBLE	POSSIBLE CAUSE	CORRECTIVE MEASURE
Compressor short cycles on low-pressure control.	Thermal expansion valve not feeding properly. 1. Dirty strainers. 2. Moisture frozen in orifice or orifice plugged with dirt. 3. Power element dead or weak.	Adjust, repair, or replace thermal expansion valve. 1. Clean strainers. 2. Remove moisture or dirt (Use system dehydrator). 3. Replace power element.
Compressor short cycles on low-pressure control (continued)..	Water flow through evaporators restricted or stopped. Evaporator coils plugged, dirty, or clogged with frost	Remove restriction. Check water flow. Clean coils or tubes.
	Defective low-pressure control switch.	Repair or replace low-pressure control switch.
Compressor runs continuously.	Shortage of refrigerant.	Repair leak and recharge system.
	Leaking discharge valves.	Replace discharge valves.
Compressor short cycles on high-pressure control switch.	Insufficient water flowing through condenser, clogged condenser.	Determine if water has been turned off. Check for scaled or fouled condenser.
	Defective high-pressure control switch.	Repair or replace high-pressure control switch.

Table V

Troubleshooting Checklist for Refrigeration Systems (Continued)

TROUBLE	POSSIBLE CAUSE	CORRECTIVE MEASURE
Compressor will not run.	Seized compressor.	Repair or replace compressor.
	Cut-in point of low-pressure control switch too high. High-pressure control switch does not cut-in. 1. Defective switch. 2. Electric power cut off. 3. Service or disconnect switch open. 4. Fuses blown. 5. Overload relays tripped. 6. Low voltage. 7. Electrical motor in trouble. 8. Trouble in starting switch or control circuit. 9. Compressor motor stopped by oil-pressure differential switch.	Set L.P. control switch to cut-in at correct pressure. Check discharge pressure and reset H.P. control switch. 1. Repair or replace switch. 2. Check power supply. 3. Close switches. 4. Test fuses and renew if necessary. 5. Reset relays and find cause of overload. 6. Check voltage (should be within 10 percent of nameplate rating). 7. Repair or replace motor. 8. Close switch manually to test power supply. If OK check control circuit including temperature and pressure controls. 9. Check oil levels in crankcase. Check oil pressure.
Sudden loss of oil from crankcase.	Liquid refrigerant slugging back to compressor crankcase.	Adjust or replace expansion valve.

Table V

Troubleshooting Checklist for Refrigeration Systems (Continued)

TROUBLE	POSSIBLE CAUSE	CORRECTIVE MEASURE
Capacity reduction system fails	Hand-operating stem of capacity control valve not turned to automatic position.	Set hand-operating stem to automatic position.
Compressor continues to operate at full or partial load.	Pressure-regulating valve not opening.	Adjust or repair pressure-regulating valve.
Capacity reduction system fails to load cylinders.	Broken or leaking oil tube between pump and power element.	Repair leak.
Compressor continues to operate unloaded.	Pressure regulating valve not clossing.	Adjust or repair pressure regulating valve.

Table W

Troubleshooting Industrial Refrigeration

PROBLEM	POSSIBLE CAUSE	REMEDY
Compressor will not start	No power to motor	Check power to and from fuses; replace fuses if necessary Check starter contacts, connections, overloads, and timer (if part winding start). Reset or repair as necessary. Check power at motor terminals. Repair wiring, if damaged.
	Control circuit is open	Safety switches are holding circuit open. Check high pressure, oil failure, and low-pressure switches. Also check oil filter pressure differential switch is supplied. Thermostat is satisfied. Check control circuit fuses if blown; replace. Check wiring for open circuit.
Motor "hums" but does not start	Low voltage to motor	Check incoming power for correct voltage. Call power company or inspect/repair power wiring. Check at motor terminals. Repair or replace as necessary.
	Motor shorted	Check at motor terminals. Repair or replace as necessary
	Single-phase failure in the three-phase power supply	Check power wiring circuit for component or fuse failure.
	Compressor is seized due to damage or liquid	Remove belts or coupling. Manually turn crankshaft to check compressor.
	Compressor is not unloaded	Check unloader system.
Compressor starts but motor cycles off on overloads	Compressor has liquid or oil in cylinders	Check compressor crankcase temperature. Throttle suction stop valve on compressor to clear cylinders and act to prevent recurrence of liquid accumulation.
	Suction pressure is too high	Unload compressor when starting. Use internal unloaders if present. Install external bypass unloader.
	Motor control	Motor control located in hot ambient. Low voltage. Motor overloads may be defective or weak. Check motor control relay. Adjust circuit breaker setting to full load amps.
	Bearings are "tight"	Check motor and compressor bearings for temperature. Lubricate motor bearings.
	Motor is running on single-phase power	Check power lines, fuses, starter, motor, etc., to determine where open circuit has occurred.
Compressor starts but short cycles automatically	Low refrigerant charge	Check and add if necessary.
	Driers plugged or saturated with moisture	Replace cores.

Table W

Troubleshooting Industrial Refrigeration (Continued)

PROBLEM	POSSIBLE CAUSE	REMEDY OR COMMENT
Compressor starts but short cycles automatically (continued).	Refrigerant feed control is defective	Repair or replace
	No load	To prevent short cycling, if objectionable, install pump-down circuit, anti-recycle timer or false load system.
	Unit is too large for load	Reduce compressor speed. Install false load system.
	Suction strainer blocked or restricted	Check and clean or replace as necessary.
Motor is noisy or erratic	Motor bearing failure or winding failure	Check and repair as needed.
	If electric starter, check calibration on control elements	Adjust as necessary
Compressor runs continuously but does not keep up with the load	Load is too high	Speed up compressor or add compressor capacity. Reduce load.
	Refrigerant metering device is underfeeding, causing compressor to run at too low a suction pressure	Check and repair liquid feed problems. Check discharge pressure and increase if low.
	Faulty control circuit, may be low pressure control or capacity controls	Check and repair.
	Compressor may have broken valve plates.	Check compressor for condition of parts. This condition can usually be detected by checking compressor discharge temperature.
	Thermostat control is defective and keeps unit running	Check temperatures of product or space and compare with thermostat control. Replace or readjust thermostat.
	Defrost system on evaporator not working properly	Check and repair as needed.
	Suction bags in strainers are dirty and restrict gas flow	Clean or remove.
	Hot gas bypass or false load valve stuck	Check and repair or replace.
Compressor loses excessive amount of oil	High suction superheat causes oil to vaporize	Insulate suction lines. Adjust expansion valves to proper superheat. Install liquid injection (suction line desuperheating).
	Too low of an operating level in chiller will keep oil in vessel	Raise liquid level in flooded evaporator (R-12 systems only).
	Oil not returning from compressor	Make sure all valves are open Check float mechanism and clean orifice. Checka nd clean return line.

Table W

Troubleshooting Industrial Refrigeration (Continued)

PROBLEM	POSSIBLE CAUSE	REMEDY OR COMMENT
Compressor loses excessive amount of oil (continued).	Oil separator is too small	Check selection.
	Broken valves cause excessive heat in compressor and vaporization of oil.	Repair compressor.
	"Slugging" of compressor with liquid refrigerant that causes excessive foam in the crankcase	"Dry up" suction gas to compressor by repairing evaporator. Refrigerant feed controls are overfeeding. Check suction trap level controls. Install a refrigerant liquid transfer system to return liquid to high side.
Noisy compressor operation	Loose flywheel or coupling	Tighten.
	Coupling not properly aligned	Check and align if required.
	Loose belts	Align and tighten per specs. Check sheave grooves.
	Poor foundation or mounting	Tighten mounting bolts, grout base, or install heavier foundation.
	Check compressor with stethoscope if noise is internal	Open, inspect, and repair as necessary.
	Check for liquid or oil slugging	Eliminate liquid from suction mains. Check crankcase oil level.
Low evaporator capacity	Inadequate refrigerant feed to evaporators	Clean strainers and driers. Check expansion valve superheat setting. Check for excessive pressure drop due to change in elevation, too small of lines (suction and liquid lines). A heat exchanger may correct this. Check expansion valve size.
	Expansion valve bulb in a trap	Change piping or bulb location to correct.
	Oil in evaporator	Warm the evaporator, drain oil, and install an oil trap to collect oil.
	Evaporator surface fouled	Clean.
	Air or product velocity is too low	Increase to rated velocity. Coil not properly defrosting. Check defrost time. Check method of defrost.
	Brine flow through evaporator may be restricted	Chiller may be fouled or plugged. Check recirculating pumps. Check process piping for restriction.
Discharge pressure too high	Air in condenser	Purge noncondensibles.
	Condenser tubes fouled	Clean.
	Water flow is inadequate	Check water supply and pump.

Table W

Troubleshooting Industrial Refrigeration (Continued)

PROBLEM	POSSIBLE CAUSE	REMEDY OR COMMENT
Discharge pressure too high (continued).	Water flow is inadequate (continued).	Check control valve. Check water temperature.
	Airflow is restricted	Check and clean: Coils. Eliminators. Dampers.
	Liquid refrigerant backed up in condenser	Find source of restriction and clear. If system is overcharged, remove refrigerant as required. Check to make sure equalizer (vent) line is properly installed and sized.
	Spray nozzles on condensers plugged	Clean.
Discharge pressure too low	Ambient air is too cold	Install a fan cycling control system.
	Water quantity not being regulated properly through condenser	Install or repair water regulating valve.
	Refrigerant level low	Check for liquid seal, add refrigerant if necessary
	Evap condenser fan and water switches are improperly set	Reset condenser controls.
Suction pressure too low	Light load condition	Shut off some compressors. Unload compressors. Slow down RPM of compressor. Check process flows.
	Short of refrigerant	Add if necessary
	Evaporators not getting enough refrigerant	Discharge pressure too low. Increase to maintain adequate refrigerant flow. Check liquid feed lines for adequate refrigerant supply. Check liquid line driers.
	Refrigerant metering controls are too small	Check superheat or liquid level and correct as indicated.
Suction pressure too high	Low compressor capacity	Check compressors for possible internal damage Check system load. Add more compressor capacity.

Table X

Troubleshooting Laundry Equipment

WASHERS		
TROUBLE	**CHECK**	**PROBLEM**
DRAIN VALVE FAILURE:		
Drain fails to close -	– Master switch.	– Turned OFF.
	– Drain switch.	– At OPEN.
	– Drain finger.	– Not touching the timer cylinder or touching at a dirty spot.
	– Interior light not lit.	– Drain relay not working, or contacts are dirty.
	– Pilot solenoid valve not working.	– No voltage, or valve piston stuck.
	– Low air or water pressure.	– Adjust pressure regulator.
	– Piston cup.	– Needs replacement.
Drain fails to open -	– Exhaust line from pilot valve to soap chute.	– Clogged.
	– Drain valve.	– Rusted or broken spring.
	– Drain valve cylinder.	– Dented.
	– Pressure regulator.	– Faulty.
WATER VALVE FAILURE:		
Valve fails to open –		
	– Master switch.	– Turned OFF.
	– Appropriate water switch.	– Turned OFF.
	– Water finger.	– Not touching the timer cylinder or touching at a dirty spot.
	– Drain valve.	– Is OPEN.
	– Valve itself.	– Shorted coil or broken wire to inlet valves.
	– Pilot orifice in inlet of valve.	– Clogged.
	– Valve piston.	– Binding.
	– Water pressure.	– Too high.
	– Water level control.	– Not operating due to float binding.
Valve fails to close -	– Level control switches (inside).	– Not operating.
	– Water pressure.	– Extremely low.
	– Strainers, water inlet line.	– Dirty or clogged.
	– Water valve coil.	– Short or ground.
	– Water pressure.	– Extremely low.
	– Piston return spring (valve).	– Broken.
	– Piston or pilot orifice.	– Clogged.
	– Level control float chamber.	– Clogged.
	– Level control float.	– Cracked or faulty.
	– Float rod adjusting collars.	– Set too close together.

Table X

Troubleshooting Laundry Equipment (Continued)

WASHER		
TROUBLE	**CHECK**	**PROBLEM**
TIMER CYLINDER:		
Does not turn –	– Master switch.	– Not at formula.
	– Water level.	– Not attained.
	– Zero level starching.	– Improper switch position.
	– Clutch (joins the timer motor shaft to the time cylinder).	– Loose setscrew.
	– Timer motor.	– No voltage.
	– Timer cylinder motor.	– Bad. Replace motor and gear case.
AUTOMATIC CONTROLS:		
(washer cylinder running)		– Defective.
Do not operate –	– Transformer.	– Faulty drain relay or drain finger does not touch the drain cylinder screen.
	– Signals operate.	– At OPEN.
	– Drain switch.	
MILTROL:		– Faulty.
Operates but does not run, or runs in one direction –	– Reversing control timer motor.	– Burned out.
	– Reversing control contactor coil.	
	– Microswitch (on reversing control cam mechanism).	– Faulty.
	– Voltage.	– Low.
	– Wiring.	– Broken or shorted.
	– Signal relay or contacts.	– Faulty or dirty contacts.

Table X

Troubleshooting Laundry Equipment (Continued)

WASHER		
TROUBLE	**CHECK**	**PROBLEM**
MOTOR:		
Fails to start –	– Power.	– Failure.
(20, 26 inch models & 30 inch manual brake machines)	– Line fuses.	– Blown.
	– Overload relay.	– Tripped.
	– Wiring.	– Loose or broken connections.
	– Microswitch.	– Not actuating properly.
Fails to start –		
(26 & 30 inch automatic brake machines)	– Interlock switch.	– Faulty.
	– Brake air cylinder.	– Piston cup binding.
	– Brake "VN".	– Locked manually.
MOTOR RUNS:		–
Machine fails to come up to speed-		
	– Load.	– Not properly balanced.
	– Voltage.	– Low or frequency low.
	– Connections in switches or wiring.	– Loose or broken in switch or wiring.
	– Fuses.	– Blown.
	– Commutator brushes.	– Dirty or worn.
BRAKE NOT RELEASING:	– Interlock or brake shoes.	– Dragging.
Extractor turned on:	– Curb in basket.	– Jammed by foreign materials.
(20 inch)		
	– Brake mechanism.	– Solenoid plunger binding.
	– Voltage.	– Low or low frequency.
Extractor turned on –	– Brake pressure spring.	– Too much tension.
(26 & 30 inch)	– Solenoid wiring.	– Loose connection.
	– Exhaust port or pilot solenoid valve.	– Clogged.
	– Microswitch.	– Bad.
	– Pilot solenoid valve.	– Jammed open.
EXTRACTOR RUNNING:		
Makes knocking noise –	– Floor mounting.	– Not properly bolted.
	– Packing nut.	– Loose.
	– Spindle pulley.	– Loose on spindle.
	– Rubbers.	– Worn.
	– Basket.	– Loose on spindle.
EXTRACTOR NORMAL	– Bearings.	– Bad.
OUT-OF-BALANCE LOAD:	– Motor pulley.	– Loose on shaft.
Fails to carry –	– Rubbers.	– Too loose or too tight.
	– Motor.	– Not developing full power.
	– Brake.	– Not fully releasing when motor is turned on.
	– Floor mounting.	– Not fully bolted down.

Table Y

Troubleshooting Checklist for Domestic Refrigerators and Freezers

Trouble	Possible Causes	What to look for and what to do
1. Unit fails to start	Wiring	Loose connections, broken wires, grounded leads, open contacts, blown fuses, poor plug contacts, poorly soldered connections. Correct defects found.
	Low voltage	Rated voltage should be ± 10 percent. Overloaded circuits; read the voltage across the compressor-motor terminals; if it reads 100 volts or under, the circuit is overloaded. Check the voltage at the fuse panel; if this voltage is low, the power supply voltage needs correction. Provide a separate circuit for the unit.
	Compressor motor	Remove leads from the compressor motor. Apply 115 volts to the motor running winding terminals on the terminal plate from a separate two-conductor cable. Then, touch a jumper wire across both the starting and the running winding terminals. If the motor starts and runs, the trouble is isolated in the control or in the compressor motor thermostat. If the unit does not start, replace it.
	Motor thermostat	Connect a jumper to shunt the thermostat from the line-side terminal of the thermostat across to the common terminal of the compressor motor. If the compressor starts, the thermostat is open and should be replaced. Do not attempt to correct calibration of the thermostat. Replace the thermostat.
2. Unit runs normally but temperature is too high	Temperature selector control set too high	Reset the dial to its normal position.
	Temperature control out of adjustment	Readjust in accordance with the manufacturer's instructions.
	Poor air circulation in the cabinet	Paper on shelves; too much food in storage; other obstructions to proper air circulation. Maintain sufficient space in the cabinet for proper air' circulation.
	Damper control faulty	On models with this type of control it is best to replace the control or to follow the manufacturer's instructions.
3. Unit runs normally but temperature is too low	Temperature selector control out of adjustment	Reset the control to a higher position.
	Temperature control out of adjustment	Readjust the control in accordance with the manufacturer's instructions
4. Unit runs too long and temperature is too low	Temperature bulb improperly located or defective	Replace or relocate the bulb in accordance with the manufacturer's instructions. Be sure the bulb is securely attached to the evaporator. Replace defective bulbs.
	Compressor	Refer to item 7.

Table Y

Troubleshooting Checklist for Domestic Refrigerators and Freezers (Continued)

Trouble	Possible Causes	What to look for and what to do
5. Unit does not run and temperature is too high	No power at outlet	Check the fuses, and replace burned-out ones.
	Poor plug contact	Spread the plug contacts.
	Control in "Off" position	Turn to the "Coldest" position, then back to the “Normal” position
	Temperature control inoperative	Examine the control main contacts; clean them with a magneto file or with fine sandpaper; replace them if they are badly burned or pitted. Do not use emery cloth. Check and replace the relay assembly, if necessary. If the temperature control main contacts are found open, try warming the temperature control bulb by hand. If this does not close the control contacts, the control bellows has lost its charge, and the control should be replaced.
	Pressures in system not equalized	Wait for a period of about 5 minutes before trying to restart the unit. See item 3.
	Open circuit in wiring	Make voltmeter or test-lamp checks to determine whether any part of the electrical wiring system is open, or any controls are inoperative. Correct defective connections, and replace worn or damaged controls
	Compressor thermostat open	See item 1.
	Open motor windings	See item 1.
6. Unit runs for short periods; temperature too high	Defrosting heater	On a unit equipped with a defrosting heater, check the defrosting cycle in accordance with the manufacturer’s instructions. Ascertain whether the defrosting heater is turned off by making sure that no current flows through it during the refrigerating cycle.
	Unit operates on thermostat	See item 9.
7. Unit runs continuously; temperature too high	Moisture, obstruction, or restriction in liquid line	Before checking for moisture, be certain that the symptoms observed are not caused by improper operation of the defrosting heater, if so equipped. These heaters are wired into the cabinet wiring so that the control contacts short out the heaters when the contacts are closed. Thus the heaters are on only when the machine is off, when the control contacts open, and when the evaporator is on the defrost cycle. Check the control contacts to see that the defrosting heaters are off when the machine is running. At high ambient temperature, the unit will cycle on its thermostat. The evaporator will warm up over its entire surface is the liquid circulation is completely obstructed. If it is only partly obstructed, a part of the frost on the evaporator will melt. Under these conditions, the unit will probably operate noisily, and the motor will tend to draw a heavy current. If the liquid line is obstructed by ice, this ice will melt after the unit has warmed up. The unit will then refrigerate normally. If this obstruction occurs too frequently and spare units are available, replace the unit.
	Broken valves	Exceedingly high current to the motor. No cooling in the evaporator and no heating in the condenser. Excessive compressor noise. Replace the hermetic compressor or replace the valves in an open-type compressor.
	Clogged tubing	Check the tubing for damage, sharp bends, kinks, pinches, etc. Straighten the tubing, if possible, or replace the unit.

Table Y

Troubleshooting Checklist for Domestic Refrigerators and Freezers (Continued)

Trouble	Possible Causes	What to look for and what to do
7. Unit runs continuously; temperature too high (Continued)	Refrigerant leaks or undercharged	The unit may tend to run normally but more frequently. The evaporator becomes only partly covered with frost. The frost will tend to build up nearest to the capillary tube while the section nearest to the suction line will be free from frost. As leakage continues, the frostline will move back across the evaporator. When the refrigerant is entirely gone, no refrigeration will occur. Units with large evaporators will not frost up unless the evaporator is mounted inside of the box. Test for leaks with a halide leak detector. Recharge the unit, if necessary.
	Cabinet light	Check the operation of the light switch, see that the light goes out as the door is closed.
	Air circulation	See that sufficient space is allowed for air circulation. Relocate or reposition the unit, if possible.
	Evaporator needs defrosting	Advise the user on defrosting instructions.
	Gasket seals	Give them a thorough cleaning. If worn they should be replaced.
	Ambient temperature	Relocated the unit tin a location where the ambient temperature ranges from 55 degrees to 95 degrees
	Defroster heater	On units so equipped, check the defroster heater circuit. See item 6.
	Compressor suction valves sticks open or is obstructed by corrosion or dirt	Ascertain whether the condenser gets warm, and check the current drawn by the motor. If the condenser does not get warm and the current drawn is low, disassemble the compressor (open type) and check the action of the suction valve
	Compressor discharge valve sticks open or is obstructed	Connect the test gauge assembly, run the unit until the low-side pressure is normal. With an ear in close proximity to the compressor, listen for a hissing sound of escaping gas past the discharge valve. The low-side pressure gauge will rise, and the high side will drop equally until both are the same. Clean out obstructions.
8. Unit runs too long; temperature too high	Condenser	Check for any obstruction in the path of air circulation around the condenser. Clean any dust accumulation.
	Fan	On units so equipped, check to see that the fan blades are free to turn and that the fan motor operates.
	Door seal	Clean seals around the door. Check closure of the door with a strip of paper between the gasket and the cabinet at all points around the door. The gasket should grip the paper tightly at all points.
	Refrigerant	Check for leakage and undercharge of the refrigerant. See item 7.
	User	Warn the user against too frequent opening of the door, storage of hot foods, heavy freezing loads, and other improper usage.
9. Unit operates on thermostat; temperature too high	Voltage	Check voltage ± 10 percent of rating.
	Defrosting heater	See that the defrosting heater is turned off.
	Starting relay	Determine that the starting relay does not stick closed. Follow the manufacturer's instructions on methods of checking.

Table Y

Troubleshooting Checklist for Domestic Refrigerators and Freezers (Continued)

Trouble	Possible Causes	What to look for and what to do
9. Unit operates on thermostat; temperature too high (Continued)	Condenser	Check the air circulation around the condenser; also check the operation of the fan.
	Pressures not equalized	Wait 5 minutes after stopping, then restart; turn to the coldest position, then to the normal position
	Restrictions in liquid line	See item 7.
	Thermostat	Thermostat may be out of calibration. Replace the thermostat.
10. Noisy operation	Fan blades	If the blades are bent, realign them, and remove any obstructions. If the blades are so badly bent or warped that they cannot be realigned, they should be replaced.
	Fan motor	Check the motor mounting and tighten the connections.
	Tube rattling	Adjust the tubes so that they do not rub together.
	Food shelves	Adjust them to fit tightly.
	Compressor	Malfunctioning valves; loose bolted connections; improper alignment of open-type compressor. Replace the hermetic compressor tighten the connections; realign the open-type compressor
	Floor or walls	Check to see that the floor is rigid, and whether the walls vibrate. Locate and correct any such sources of noise. Make corrections by bolting or nailing loose portions to structural members.
	Belt	Check the condition of the motor belt. Replace it when it becomes worn or frayed.
11. Unit uses too much electricity	Door	Check the door seal. See item 7.
	Usage	Instruct the user on proper usage of the motor. See item 8. Check the overload.
	Ambient temperature too high	See item 7. The unit will operate more frequently and over longer periods of time in a high-temperature atmosphere. Correct, if possible, by changing the location of the unit.
	Defrost control	Check the defrost circuit according to the manufacturer's instructions
	Temperature control	Selector control dial set too low. Advise the user. Operate it as near to the "Normal" setting as possible.
12. Stained ice trays	Poor cleaning procedures	Use soap and warm water to wash trays. Rinse them thoroughly. Do not use metal sponges, steel wool, or course cleaning powders.

Table Z

Troubleshooting Chart for Air Conditioners

Type of Unit	Complaint	Cause	Possible Remedy
With open-type compressor	Electric motor will not start	Power failure	Check circuit for power source
		Compressor stuck	Locate cause and repair
		Belt too tight	Adjust belt tension
		Manual reset in starter open	Determine cause of overload and repair. Reset overload cutout
		Thermostat setting too high	Lower thermostat setting
		Low voltage	Check with voltmeter, then call power company
		Burned-out motor	Repair or replace
		Frozen compressor caused by locked or damaged mechanism	Remove and repair compressor
	Unit cycles on and off	Intermittent power interruption	Tighten connections or replace defective power supply parts
		High-pressure cutout defective	Replace high-pressure cutout
		High-pressure cutout set too low. Overload opens after having been reset	Raise cutout pressure. Check voltage and current drawn
		Leaky liquid-line solenoid valve	Repair or replace
		Dirty or iced evaporator	Clean or defrost evaporator. Check filters and fan drive
		Overcharge or refrigerant or non-condensable gas	Remove excess refrigerant or purge non-condensable gas
		Lack or refrigerant	Repair refrigerant leak and recharge
		Restricted liquid-line strainer	Clean strainer
		Faulty motor	Repair or replace faulty motor
	Coil frosts	Filters dirty	Clean filters
		Not enough air over coil	Clean or remove restriction from supply or return ducts or grilles
		Defective expansion valve	Replace valve

Table Z

Troubleshooting Chart for Air Conditioners (Continued)

Type of Unit	Complaint	Cause	Possible Remedy
With open-type compressor (continued)	Unit runs but will not cool	Unit not fully charged	Recharge slightly, then check for leaks in the refrigerant circuit, then fully charge
		Leaky suction valve	Remove compressor cylinder head and clean or replace valve plate
		Expansion valve not set correctly	Adjust expansion valve
		Strainer clogged	Remove, clean, and replace valve
		Air in refrigerant circuit. Moisture in expansion-valve orifice	Purge unit of air. Clean orifice and install silica gel dryer
		Flash gas in liquid line	Add refrigerant
	No air blows from supply grille	Ice or dirt on evaporator	Clean coil or defrost
		Blower belt broken or loose	Adjust belt tension, or replace belt
		Blower bearing frozen	Repair or replace bearing and lubricate as directed
	Discharge pressure too high	Improper operation of condenser	Correct airflow. Clean coil surface
		Air in system	Purge
		Overcharge of refrigerant	Remove excess or purge
	Discharge pressure too low	Lack of refrigerant	Repair leak and charge
		Broken or leaky compressor discharge valves	Remove head, examine valves and replace those found to be operating improperly
	Suction pressure too high	Overfeeding of expansion valve	Regulate superheat setting expansion valve and check to see that remove bulb is properly attached to suction line
		Expansion valve stuck in open position	Repair or replace valve
		Broken suction valves in compressor	Remove head, examine valves and replace those found to be inoperative
	Suction pressure too low	Lack of refrigerant	Repair leak and charge
		Clogged liquid line strainer	Clean strainer
		Expansion-valve power assembly has lost charge	Replace expansion-valve power assembly
		Obstructed expansion valve	Clean valve and replace if necessary
		Contacts on control thermostat stuck on closed position	Repair thermostat or replace if necessary

Table Z

Troubleshooting Chart for Air Conditioners (Continued)

Type of Unit	Complaint	Cause	Possible Remedy
With hermetic motor-compressor combination (continued)	Compressor runs continuously; good refrigeration effect	Air over condenser restricted	Remove restriction or provide for more air circulation over the condenser
	Compressor runs continuously; unit is too cold	Thermostatic switch contacts badly burned	Replace thermostatic switch
		Thermostatic switch bulb has become loose	Secure bulb in place
		Thermostatic switch improperly adjusted	Readjust thermostatic switch
	Compressor runs continuously; little refrigeration effect	Extremely dirty condenser	Clean condenser
		No air circulating over condenser	Provide air circulation
		Ambient temperature too high	Provide ventilation or move to a cooler location
		Load too great	Analyze load
	Compressor runs continuously; no refrigeration	A restriction that prevents the refrigerant from entering the evaporator. A restriction is usually indicated by a slight refrigeration effect at the point of restriction	Locate the possible points of restriction, and try jarring it with a plastic hammer, or heating to a temperature of about 110 degrees F. If the restriction does not open, replace the unit.
		Compressor not pumping. A cool discharge line and a hot compressor housing would indicate this. The wattage is generally low.	Replace the unit
		Short of refrigerant	See manufacturer's instructions
	Compressor short cycles, poor refrigeration effect	Loose electrical connections	Locate loose connections and make them secure
		Defective thermostatic switch	Replace thermostatic switch
		Defective motor starter	Replace defective motor starter or relay
		Air restriction at evaporator	Remove air restriction

Table Z

Troubleshooting Chart for Air Conditioners (Continued)

Type of Unit	Complaint	Cause	Possible Remedy
With hermetic motor-compressor combination (continued)	Compressor short cycles, no refrigeration	Dirty condenser	Clean the condenser
		Ambient temperature too high	Provide ventilation or move to a cooler location
		Defective wiring	Repair or replace defective wiring
		Thermostatic switch operating erratically	Replace thermostatic switch
		Relay erratic	Replace relay
	Compressor runs too frequently	Poor air circulation around the condenser or too high ambient temperature	Increase the air circulation around the condenser. In some localities the temperature is extremely high, and nothing can be done to correct this
		Load too great. Worn compressor. Generally accompanied by rattles and knocks	Analyze end use. Replace unit or bring it to the shop for repairs
	Compressor does not run	Motor is not operating	If the trouble is outside the sealed unit, it should be corrected; for example, wires should be repaired or replace and thermostatic switches or relays should be replaced. If the trouble is inside the sealed unit, the sealed unit should be replaced.
	Compressor will not run (Assume that the thermostatic switch and relay, and the electric wiring and current supply are in good condition and operating normally)	If the cabinet has been moved, some oil may be on top of the piston	Wait an hour or so, and then attempt to start the motor by turning the current on and off many times. On some compressors, it may be necessary to wait 6 or 8 hour
		Compressor may be stuck, or some parts may be broken	Replace the unit
		Connections may be broken on the inside of the unit, or the motor winding may be open	Replace the unit. Sometimes after sealed units have been standing idle for a long time, the piston may be stuck in the cylinder wall. It is sometimes possible to start the compressor by turning on the current and bumping the outer housing with a rubber mallet.
	Compressor is unusually hot	Condenser is dirty, or there is a lack of air circulation	Clean the condenser; increase the air circulation

Table Z

Troubleshooting Chart for Air Conditioners (Continued)

Type of Unit	Complaint	Cause	Possible Remedy
With hermetic motor-compressor combination (continued)		Unusually heavy service or load	If possible, decrease load. Perhaps another unit is required
		Low voltage	Too small feed wires could cause this. If the wires feeding the refrigerating unit becomes warm, it is an indication that they are too small and should be replaced with larger wires
		A shortage of oil	Add oil if possible; if this is not possible, the unit must be replaced. A shortage of refrigerant will cause a shortage of oil in the crankcase of the compressor
	No refrigeration after starting up after a long shutdown or on delivery	Generally, during a long shutdown, an amount of liquid refrigerant will get into the crankcase of the compressor. When this happens, the compressor operation will cause no noticeable refrigeration effect until the entire liquid refrigerant has evaporated from the crankcase.	Allow the compressor to operate until its internal heat drivers the liquid refrigerant from the crankcase. Under some conditions, this may take as long as 24 hours. This time can be shortened by turning an electric heater on the compressor and raising the compressor temperature, not exceeding 110 degrees F.
	Compressor is noisy	Mountings have become worn or deteriorated. The walls against which the unit is placed may be of an extremely hard surface and may resound and amplify the slight noise from the compressor into the room	Replace the rubber mountings. Place a piece of sound-absorbing material on the wall against which the unit is placed, or move the unit to a new location.
		Shortage of oil and/or refrigerant	Add oil and refrigerant if possible. If it is impossible, the unit must be replaced.
		The sealed unit mechanism has become worn	Replace the unit
	After each defrosting there is a long on cycle before refrigeration is again normal	Slight shortage of refrigerant	Add refrigerant if possible; if not, replace the unit
		Condenser is dirty	Clean the condenser
		Thermostatic switch bulb is loose	Secure the bulb in place
		There is a restriction between the receiver or condenser and/or the evaporator	Attempt to remove the restriction by jarring with a plastic hammer or by heating the possible points of restriction to about 110 degrees F. If this does not correct the trouble, the unit must be replaced or brought to the shop for repairs

APPENDIX III

MATH TABLES

CONVERSIONS, EQUIVALENTS AND USEFUL FORMULAS

TABLE A

EQUIVALENTS

1 inch = 25 millimeters	1 ounce = 30 grams
1 foot = 0.3 meter	16 ounces = 1 pound
1 yard = 0.9 meter	1 pound = 450 grams
	1 liter = 1 quart (lq)
	1 teaspoon = 5 ml
	1 tablespoon = 15 ml
1 square inch= 6.5 sq. centimeters	1 cup = 250 ml
1 square foot= 0.09 square meter	4 cups = 1 quart
1 square yard= 0.8 square meter	1 gram = 0.035 ounces (avdp)
	1 kilogram = 2.2 pounds (avdp)
	1 ounce (avdp)= 28 grams
	1 pound (avdp)= 0.45 kilogram
1 cubic inch= 16 cubic centimeters	
1 cubic foot= 0.03 cubic meter	
1 cubic yard= 0.8 cubic meter	1 pound per square inch =
	0.07 kilograms per square centimeter
1 mile = 1.6 kilometers	1 kilogram per square centimeter =
1 kilometer = 0.6 mile	14.2 pounds per square inch
1 inch = 2.5 cm	
1 millimeter = 0.04 inch	
1 cubic centimeter = 0.06 cubic inch	1 Kilowatt= 1.3 horsepower
	1 horsepower = 0.75 kilowatt
1 meter = 3.3 feet	
1 meter = 1.1 yards	
1 square meter = 11 square feet	
1 square meter = 1.2 square yards	
1 cubic meter = 35 cubic feet	
1 cubic meter = 1.3 cubic yards	
1 cubic meter = 250 gallons	
1 quart (lq.)= 1 liter	
1 gallon= 0.004 cubic meter	

TABLE B

CONVERSION OF ENGLISH MEASURE TO METRIC/ENGLISH MEASURE

MULTIPLY	BY	TO OBTAIN
Cubic feet	2.832×10^{6}	Cubic cms
Cubic feet	1728	cubic inches
Cubic feet	0.02832	cubic meters
Cubic feet	0.03704	cubic yards
Cubic feet	7.481	gallons
Cubic feet	28.32	liters
Cubic feet	59.84	pints (liq)
Cubic feet	29.92	quarts (liq)
Cubic inches	16.39	cubic centimeters
Cubic inches	5.787×10^{-4}	cubic feet
Cubic inches	1.639×10^{-5}	cubic meters
Cubic inches	2.143×10^{-5}	cubic yards
Cubic inches	4.329×10^{-2}	gallons
Cubic inches	1.639×10^{-2}	liters
Cubic inches	0.03463	pints (liq)
Cubic inches	0.01732	quarts (liq)
Cubic yards	7.636×10^{5}	cubic centimeters
Cubic yards	27	cubic feet
Cubic yards	46.656	cubic inches
Cubic yards	0.7646	cubic meters
Cubic yards	202.0	gallons
Cubic yards	764.6	liters
Cubic yards	1616	pints (liq)
Cubic yards	807.9	quarts (liq)
Feet	30.48	centimeters
Feet	0.3048	meters
Feet	.36	yards
Feet	1/3	yards
Feet of water	0.02950	atmosphere
Feet of water	0.8826	inches of mercury
Feet of water	304.8	kgs per sq meter
Feet of water	62.43	pounds per sq ft
Feet of water	0.4335	pounds per sq inch
Gallons	3785	cubic centimeters
Gallons	0.1337	cubic feet
Gallons	231	cubic inches
Gallons	3.785×10^{-3}	cubic meters
Gallons	4.951×10^{-3}	cubic yards
Gallons	3.785	liters

TABLE B (Continued)

CONVERSION OF ENGLISH MEASURE TO METRIC/ENGLISH MEASURE

MULTIPLY	BY	TO OBTAIN
Inches	2.540	centimeters
Inches	10^4	mils
Inches	.03	yards
Inches of mercury	0.03342	atmosphere
Inches of mercury	1.133	feet of water
Inches of mercury	345.3	kgs per sq meter
Inches of mercury	70.73	pounds per sq ft
Inches of mercury	0.4912	pounds per sq inch
Inches of water	0.002458	atmospheres
Inches of water	0.07355	inches of mercury
Inches of water	25.40	kgs per sq meter
Inches of water	0.5781	ounces per sq in
Inches of water	5.204	pounds per sq ft
Inches of water	0.03613	pounds per sq inch
Ounces	8	drams
Ounces	437.5	grains
Ounces	28.35	grams
Ounces	0.0625	pounds
Ounces (fluid)	1.805	cubic inches
Ounces (fluid)	0.02957	liters
Pounds	7000	grams
Pounds	453.6	grams
Pounds	16	ounces
Pounds	32.17	poundals
Pounds	0.8229	pounds (av)
Pounds of water	0.01602	cubic feet
Pounds of water	27.68	cubic inches
Pounds of water	0.1198	gallons

TABLE C

CONVERSION OF METRIC/ENGLISH TO ENGLISH MEASURE

MULTIPLY	BY	TO OBTAIN
Centiliters	0.01	Liters
Centimeters	0.3937	inches
Centimeters	0.01	meters
Centimeters	393.7	mils
Centimeters	10	millimeters
Cubic centimeters	3.531×10^{-3}	cubic feet
Cubic centimeters	6.102×10^{-2}	cubic inches
Cubic centimeters	10-6	cubic meters
Cubic centimeters	1.306×10^{-6}	cubic yards
Cubic centimeters	2.642×10^{-4}	gallons
Cubic	10-2	liters
centimeters Cubic	2.113×10^{-3}	pints (liq)
centimeters	1.057×10^{-3}	quarts (liq)
Cubic centimeters	10^{4}	cubic centimeters
Cubic meters	35.31	cubic feet
Cubic meters	81.023	cubic inches
Cubic meters	1.303	cubic yards
Cubic meters	264.2	gallons
Cubic meters	10^{2}	liters
Cubic meters	2113	pints (liq)
Cubic meters	1057	quarts (liq)
Cubic meters	10^{2}	grams
Kilograms	70.93	poundals
Kilograms	2.2046	pounds
Kilograms	1.102×10^{-2}	tons (short)
Kilograms	3281	feet
Kilometers	10^{7}	meters
Kilometers	1093.6	yards
Kilometers	10^{2}	cubic centimeters
Liters	0.03531	cubic feet
Liters	61.02	cubic inches
Liters	10^{3}	cubic meters
Liters	1.308×10^{-2}	cubic yards
Liters	0.2642	gallons
Liters	2.113	pints (liq)
Liters	1.057	quarts (liq)
Liters	100	centimeters
Meters	3.2808	feet
Meters	39.37	inches
Meters	10^{-3}	kilometers
Meters	10^{3}	millimeters
Meters	1.0936	yards
Meters	25	inches
Millimeters		

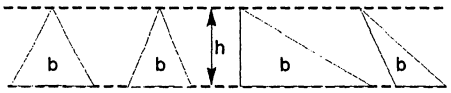
TABLE D

USEFUL FORMULAS

Triangle:

$$\text{Area} = \frac{b \times h}{2}$$

$$\text{Volume} = \frac{b \times h}{2} \times \text{length}$$



TRIANGLES UTB10246

Square/Rectangle:

$$\text{Area} = b \times b$$

$$\text{Volume} = b \times b \times b$$

$$\text{Perimeter} = 2b + 2b$$

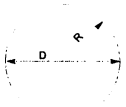


SQUARE RECTANGLE
UTB10247

Circle:

$$\text{Area} = \pi \times R^2$$

$$\text{Volume} = \pi \times R^2 \times \text{length}$$

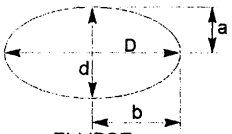


CIRCLE UTB10248

Ellipse:

$$\text{Area} = \frac{\pi \times D \times d}{4}$$

$$\text{Volume} = \frac{\pi \times D \times d}{4} \times \text{length}$$



ELLIPSE UTB10249

Circular cone:

$$\text{Lateral area} = s \times \pi \times R$$

$$\text{Volume} = \frac{\pi \times R^2 \times h}{3}$$



RIGHT CIRCULAR CONE
UTB10250

APPENDIX IV

ANSWER KEY

CHAPTER 1 — BOILERS

STEAM GENERATION THEORY

Q1. Temperature increases and the volume expands.

Q2. Heat intensity.

Q3. Temperature of steam and boiling water.

BOILER DESIGN REQUIREMENTS

Q4. 1) Safe to operate; 2) Able to generate steam at desired rate and pressure; and 3) Economical.

Q5. American Society of Mechanical Engineers (ASME).

TYPES OF BOILERS

Q6. Water-tube and fire-tube.

Q7. 1) Scotch Marine; 2) Vertical-tube; 3) Horizontal return; and 4) Firebox.

Q8. They require no setting.

BOILER FITTINGS AND ACCESSORIES

Q9. Lowest point of the boiler spaces.

Q10. Annually.

Q11. At the steam drum above the water level and 6 inches below the water level.

Q12. 1) Float operated; 2) Float and mercury switch; and 3) Electrode probe.

Q13. Three.

Q14. Safety valve.

Q15. Backup to main steam stop.

AUTOMATIC CONTROLS

Q16. Pressure regulating.

Q17. Combustion control.

Q18. The air damper.

Q19. Manual reset.

INSTRUMENTS AND METERS

Q20. Indicating rate and indicating the total.

Q21. Pressure difference producing the flow.

BOILER WATER TREATMENT AND CLEANING

Q22. Precipitates of hardness.

Q23. External and internal.

Q24. 30 ppm and 60 ppm.

Q25. Causticity exists.

Q26. 70°F.

CLEANING BOILERS FIRESIDES AND WATERSIDES

Q27. 1) Wire brush and scraper; 2) Hot-water washing; 3) Wet-steam lancing; and 4) Sweating.

Q28. 70 to 150 psig.

Q29. Pitting and general corrosion.

Q30. 1) Hydrochloric acid; 2) Phosphoric acid; 3) Sulfamic acid; 4) Citric acid; and *4)* Sulfuric acid.

Q31. Circulation and fill and soak.

CHAPTER 2 — BOILER MAINTENANCE

MAINTENANCE OF AUXILIARY EQUIPMENT

Q1. Low water.

Q2. Plug valve opening on gauge glass.

Q3. 1) Controlling high water; 2) Removing sludge and sediment; 3) Controlling chemical concentrations; and 4) Dumping a boiler for cleaning or inspection.

Q4. Tightness of all the parts and strength of the drum.

BOILER TUBES

Q5. 1) Name or trademark of manufacturer; 2) Heat number; 3) Class letter; 4) Specification number; and 5) Outside diameter, wall thickness, and length.

Q6. Arc welding equipment.

Q7. 3/16" to 5/16".

Q8. 1/8" to 3/16".

Q9. Drill a hole in the tube.

REPAIRING BOILER REFRACTORIES

Q10. Escape of steam created from moisture in the brick.

Q11. 2900° to 3000°F.

Q12. Improperly sealed doors.

BOILER OPERATIQNS

Q13. To ensure equipment and the boiler are in sound operating condition and functioning properly.

Q14. Line-up boiler systems.

Q15. Open all drain valves between the boiler, the header, and the two stop valves.

Q16. 1) Maintain proper water level and 2) present loss of ignition.

Q17. 150°F.

Q18. 25 psig.

Q19. Record continuous data of plant performance.

SAFETY

Q20. Hard hat, goggles, and safety toed shoes.

Q21. Green.

Q22. Safety valve.

Q23. Keys can be controlled easier than combination locks.

CHAPTER 3 — STEAM DISTRIBUTION SYSTEMS

EXTERIOR STEAM DISTRIBUTION SYSTEMS

Q1. Underground and aboveground.

Q2. Their high cost of installation.

Q3. High cost of maintenance.

INTERIOR STEAM DISTRIBUTION SYSTEMS

Q4. Hydrostatic head.

Q5. Inhibits emission of heat from the heating system.

Q6. A return trap system has a gravity return and a condensate pump system has a forced return.

Q7. Withdraws air and water from the system, separates them, expels the air, and pumps the water back to the boiler.

STEAM DISTRIBUTION SYSTEM COMPONENTS

Q8. Fin-tube and cast iron.

Q9. 10°F or lower than that of the water.

Q10. Upright or standard, and inverted.

Q11. The bellows develops holes.

Q12. Emvar and copper.

Q13. Pyrometric crayon test.

Q14. Storage and instantaneous.

Q15. Temperature regulator.

Q16. 1) Slip, 2) bellows, 3) swing, 4) expansion loop, and 5) ball.

Q17. Annually.

CHAPTER 4 — HEATING SYSTEMS

PRINCIPLES OF HEATING

Q1. Combustion, friction, and chemical action or resistance to flow of electricity.

Q2. Temperature and pressure.

Q3. Heat intensity in degrees Fahrenheit or Celsius.

Q4. 27.8°C.

Q5.. Conduction, convection, and radiation.

COMBUSTIBLE FUELS

Q6. Natural gas, manufactured gas, and liquefied petroleum gas.

Q7. Hydrogen and carbon (hydrocarbons).

WARM-AIR HEATING EQUIPMENT

Q8. Suspended vertical discharge, suspended horizontal discharge, and floor mounted.

Q9. In Kw.

Q10. Safety.

Q11. Condensation.

Q12. Atmospheric vaporizing burners.

Q13. Fuel level control valve.

Q14. Draft regulator.

WARM-AIR HEATING SYSTEMS

Q15. Rate of delivery and temperature of the air delivered.

Q16. Vertical counter-flow, up-flow, highboy, lowboy, and horizontal unit.

Q17. Thermocouple control relay.

Q18. The limit control.

Q19. Burner compartment combustion, radiating compartment, and blower compartment.

Q20. The thermostat.

Q21. Spiral-bimetallic and mercury bulb.

Q22. 75 to 150 psi.

Q23. Manufacturer's instruction manual.

Q24. Flue gas analyzer.

DOMESTIC HOT-WATER HEATING AND HOT-WATER BOILERS

Q25. Increase the pressure of the boiler to operate the valve monthly.

Q26. "Sailswitch."

HOT-WATER HEATING DISTRIBUTION SYSTEM

Q27. It is difficult to get enough circulation to avoid large temperature drops from one end of the system to the other.

Q28. Pneumatic compression tank.

Q29. Circulation of water, thus reducing heating capacity.

HIGH-TEMPERATURE HOT WATER SYSTEMS

Q30. 350°F to 450°F.

Q31. Hot-water boilers or generators and cascade or direct contact heaters.

Q32. 20 to 40 ppm.

Q33. True.

CHAPTER 5 — GALLEY AND LAUNDRY EQUIPMENT

GALLEY EQUIPMENT

Q1. Medical Department.

Q2. Self-contained.

Q3. True.

Q4. As needed.

Q5. 5°F

Q6. 138°F to 145°F.

Q7. Small particles could become embedded in food.

Q8. Blue.

Q9. Weekly.

Q10. Concrete or brick.

Q11. Quarterly.

LAUNDRY EQUIPMENT

Q12. 88 minutes.

Q13. Five.

Q14. 25 psi.

Q15. 30 psi.

Q16. Every 2 months.

Q17. True.

Q18. Ensure the proper power is being connected.

Q19. 4 square feet.

Q20. True.

Q21. 5 minutes.

Q22. Manufacturer's instructions.

Q23. Blower rotor blades.

Q24. Fill, agitate, drain, and spin.

Q25. Main drive motor.

Q26. Electric and gas.

CHAPTER 6 — REFRIGERATION

HEAT AND REFRIGERATION PRINCIPLES

Q1. False.

Q2. A quantity of heat required to change the temperature of 1 pound of any substance 1°F compared to water.

Q3. Sensible heat is the increase of temperature, and latent heat is the change of state.

Q4.. 12.7 psia.

Q5. Decreases its volume in proportion to the increase of pressure.

Q6. Condense into a liquid.

MECHANICAL REFRIGERATION SYSTEMS

Q7. Reciprocating, rotary, and centrifugal.

Q8. The external is positioned on the outside of the crankcase.

Q9. The inaccessibility or repair and low capacity.

Q10. Dry or flooded.

Q11. Refrigerators and window air conditioners.

Q12. To determine the presence and amount of vapor in the refrigerant.

REFRIGERANTS

Q13. Chloroflorocarbons and hydrochloroflorocarbons.

Q14. Reduced efficiency, mechanical problems, and dangerous conditions.

Q15. CFCs and HCFCs.

Q16. R-134a.

REFRIGERANT SAFETY

Q17. False.

Q18. Anytime a refrigerant is discharged.

Q19. To avoid confusion.

REFRIGERATION EQUIPMENT

Q20. Remote equipment has a condenser at a remote location from the main unit.

Q21. Between 30°F and 45°F.

Q22. A unit cooler type.

Q23. Ease of assembly and ease of relocation.

Q24. Single door and multi-door.

Q25. Hot gas and/or electric heater.

Q26. Heat exchanger.

Q27. The type of evaporator installed.

INSTALLATION OF REFRIGERATION EQUIPMENT

Q28. Hydrochloric acid.

Q29. To permit unrestricted airflow.

Q30. Vibration strain.

Q31. A neutral atmosphere within the tube or pipe.

Q32. Ten feet.

Q33. True.

MAINTENANCE, SERVICE, AND REPAIR OF REFRIGERATION EQUIPMENT

Q34. Manifold gauge set and vacuum pump.

Q35. To get its pressure lower than the storage cylinder.

Q36. To remove moisture and air from the system.

Q37. Until a deep vacuum has been obtained.

Q38. Low-side charging.

Q39. Halide, electronic, or soap and water.

Q40. Condenser/receiver.

Q41. Vapor and liquid.

Q42. Single or multiple pass method.

MAINTENANCE OF COMPRESSORS

Q43. Shaft bellows seals.

Q44. Weak refrigerant charge.

Q45. Leaks, high temperatures, or vibrations.

MAINTENANCE OF MOTORS

Q46. Mechanical and electrical.

Q47. After every repair or replacement.

Q48. A dehydrator.

Q49. 35°F or below.

Q50. Across the component.

Q51. Ohmmeter on lowest setting.

Q52. A short.

Q53. True.

LOGS

Q54. True.

Q55. False.

CHAPTER 7 — AIR CONDITIONING

PRINCIPLES OF AIR CONDITIONING

Q1. Effective temperature.

Q2. True.

Q3. Humidity.

Q4. Sling psychrometer.

Q5. True.

Q6. Air becomes saturated.

Q7. Permanent and throwaway types.

Q8. Velocity of the air.

AIR-CONDITIONING SYSTEMS

Q9. Window-mounted and floor-mounted units.

Q10. User.

Q11. Package units.

Q12. Heat pumps.

Q13. Condenser to the evaporator.

Q14. Accumulate frost or ice.

Q15. Balance point.

Q16. Flooded shell and tube and dry-expansion.

Q17. Thermostatic.

Q18. Easy to make.

Q19. Mechanically or chemically.

Q20. Annually.

MAJOR SYSTEM COMPONENTS AND CONTROLS

Q21. By the method of moving air through the tower.

Q22. False.

Q23. Induced draft.

Q24. Counter flow or cross-flow.

Q25. Parallel flow.

Q26. Redwood.

Q27. 2 gallons.

Q28. Domestic refrigerators and small water coolers.

Q29. Belt drive and crankshaft seal.

Q30. Thermostat.

Q31. Humidistat.

Q32. Motor overload protector.

AUTOMOTIVE AIR CONDITIONING

Q33. According to the pressure exerted on the liquid or vapor.

Q34. Two-cylinder reciprocating, swash plate, and scotch yoke.

Q35. Reciprocating motion.

Q36. True.

Q37. VIR (valves-in-receiver).

Q38. True.

Q39. Know the system.

Q40. As a oily residue at the point of leakage.

Q41. Damaged or missing O-rings.

Q42. Liquid.

Q43. The suction accumulator/drier.

Q44. Universal type.

Q45. Environmental Protection Agency.

DUCTWORK

Q46. Conditioned air ducts, recirculating air ducts, and fresh air ducts.

Q47. Single return, multiple return, and a combination of the systems.

Q48. True.

Q49. Butterfly, multiple blade, and split damper.

Q50. Measure the "free" grille area.

APPENDIX V

REFERENCES USED TO DEVELOP THE TRAMAN

NOTE: Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. Therefore, you need to be sure that you are studying the latest revision.

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Assignment Questions

Information: The text pages that you are to study are provided at the beginning of the assignment questions.

ASSIGNMENT 1

Textbook Assignment: "Boilers," chapter 1, pages 1-1 through 1-42.

1-1. A boiler may be defined as a closed vessel in which steam is produced as a result of the burning of fuel.

1. True
2. False

1-2. You are boiling water in an open container at sea level. What is the highest temperature the boiling water can reach when the burner is set for 400°F?

1. 612°F
2. 400°F
3. 212°F
4. 200°F

1-3. What value must increase when you want to increase the boiling point of water?

1. Pressure
2. Heat
3. Volume
4. Evaporation rate

1-4. You are boiling water in a closed container while maintaining a constant pressure on the steam and water within it. What is the temperature relationship between the steam and the boiling water?

1. The steam temperature is higher than the boiling water temperature
2. The temperature of the steam is inversely proportional to the temperature of the boiling water
3. The temperature of the boiling water is higher than the temperature of the steam
4. The temperatures of the steam and boiling water are the same

1-5. Superheated steam is steam at a temperature higher than the saturation temperature corresponding to pressure.

1. True
2. False

1-6. Which of the following is NOT a required criteria for a boiler to be considered satisfactory for operation?

1. It must be safe to operate
2. It must be able to generate steam at the desired rate and pressure
3. It must be economical to operate
4. It must have a steel floor

1-7. What authority establishes design rules for boilers?

1. Society of American Military Engineers (SAME)
2. American Welding Society (AWS)
3. American Society of Mechanical Engineers (ASME)
4. Department of Occupational Safety and Health (OSHA)

1-8. The headers in a sectional-header cross drum boiler are made of what type of material?

1. Forged steel
2. Polished brass
3. Aluminum
4. Cast iron

1-9. Gases are directed across the tubes of the sectional-header cross drum boiler a total of how many times before being discharged from the boiler?

1. One
2. Two
3. Three
4. Four

1-10. What number of plates go into the makeup of the box-header cross drum boiler?

1. Five
2. Two
3. Three
4. Four

1-11. What types of drums are used in the box-header longitudinal drum boiler?

1. Horizontal or inclined
2. Vertical or inclined
3. Vertical or horizontal
4. Longitudinal or vertical

1-12. What types of drums are used in the bent-tube boiler?

1. Steam, water, and tube
2. Tube, crosshead, and water
3. Crosshead, tube, and steam
4. Mud, steam, and water

1-13. Which of the following factors is a disadvantage of water-tube boilers?

1. Little flexibility in starting-up
2. Low productive capacity
3. Considerable danger of disastrous explosion
4. High construction costs

1-14. The Scotch marine boiler is classified as what type of boiler?

1. Water tube
2. Firebox
3. Fire tube
4. Bent tube

1-15. What advantage does the Scotch marine boiler have over other boilers for Seabee use?

1. Its shell does not require reinforcing
2. Its furnace is fired from the outside
3. It is portable
4. It is easy to clean the surfaces of the section below the combustion chamber

1-16. What condition is present when a fusible plug in a Scotch marine boiler blows?

1. The water level in the boiler is high
2. The water level in the boiler is low
3. The plug's tin is intact
4. The plug is covered with water

1-17. Which of the following factors is a disadvantage of the vertical fire-tube boiler?

1. It is not portable
2. It is not self-contained
3. It has a limited capacity
4. It requires too much floor space

1-18. A vertical fire-tube boiler is similar to a

1. Scotch marine boiler
2. horizontal fire-tube boiler
3. straight-tube boiler
4. bent-tube boiler

1-19. The blowdown pipe of a vertical fire-tube boiler is attached to the

1. top of the shell
2. bottom tube sheet
3. lowest part of the water leg
4. outside row of tubes

1-20. When a stationary fire-tube boiler is required, the horizontal-return-tube type is popular for which of the following reasons?

1. It has a relatively low initial cost
2. It is adaptable to a variety of fuels
3. Its replacement tubes are of uniform, size, length, and diameter
4. Each of the above

1-21. What amount of pitch must a horizontal return tubular boiler have to allow sediment to settle towards the rear near the bottom blowdown?

1. 1 to 2 inches
2. 2 to 3 inches
3. 3 to 4 inches
4. 4 to 5 inches

1-22. What means are used in boiler operation to ensure that enough air is available for proper combustion?

1. Chimneys
2. Vents
3. Breechings
4. Draft fans

1-23. What boiler part must have a cross-sectional area 20 percent greater than that of the stack?

1. Breeching
2. Settling
3. Damper
4. Combustion chamber

1-24. What are the two types of fusible plugs?

1. Steam-actuated and temperature-actuated
2. Fire-actuated and temperature-actuated
3. Steam-actuated and water-actuated
4. Fire-actuated and steam-actuated

1-25. What type of fusible plug can be replaced without taking the boiler out of service?

1. Temperature-actuated
2. Fire-actuated
3. Steam-actuated
4. Water-actuated

1-26. At what interval should fusible plugs be replaced?

1. Monthly
2. Quarterly
3. Semiannually
4. Annually

1-27. A water column is connected at least 6 inches below the lowest permissible water level and at the top of the steam drum for what purpose?

1. To bypass the gauge glass
2. To indicate steam generation
3. To control the high-water level
4. To steady the gauge glass water level

1-28. A boiler equipped with a float-operated feedwater control is protected against damage resulting from what condition?

1. Low-water level
2. High-water level
3. Closed fuel supply valve
4. Constantly operating feedwater pump

1-29. Other than the low-water cutoff, what operation(s) is/are controlled by the float-operated feedwater control?

1. Operation of the feedwater pump
2. Operation of the alarm bell
3. Securing the burners
4. All of the above

1-30. How many electrodes are contained in an electrode probe type of feedwater control?

1. Five
2. Two
3. Three
4. Four

1-31. What device allows the boiler operator to determine the water level in the boiler?

1. Gauge cocks
2. Gauge glass
3. Try cocks
4. Site glass

1-32. What boiler fitting is considered the most important?

1. Air cock
2. Feedwater regulator
3. Safety valve
4. Surface blow valve

1-33. What is the minimum number of safety valves required when a boiler has more than 500 square feet of heating surface?

1. Five
2. Two
3. Three
4. Four

1-34. What design feature is common in all boiler safety valves?

1. They must be suitable for any type of installation
2. They must open and close constantly for long periods of time
3. They must open at a specified pressure and then close when the pressure drops slightly
4. They must open completely at a specified pressure and close only after a specified pressure drop

1-35. When should the lifting lever on a safety valve be used to check the valve action and clear the seat?

1. As soon as steam pressure starts to build up within the boiler
2. When the pressure has reached 25 psi within the boiler
3. When the pressure is at least equal to the safety valve setting
4. When the pressure within the boiler is at least 75 percent of the safety valve setting

1-36. The injector feed system uses an injector that serves both as a boiler feeder and a

1. standby feed unit
2. cooler sprinkler
3. main steam stop valve
4. system flusher

1-37. When a steam injector is started, the water supply valve should be turned

1. a quarter of a turn
2. a half a turn
3. a full turn
4. all the way open

1-38. For a steam injector to operate properly, the water supply should not be hotter than

1. 120°
2. 140°
3. 160°
4. 180°

1-39. The root valve in the main steam line serves what function?

1. To blow down a boiler
2. To shut off steam in an emergency
3. To connect a boiler to the auxiliary steam line
4. To allow air to enter and escape the boiler

1-40. Floats are used in boiler instruments to control the

1. pressure between inlet and outlet points
2. incoming and outgoing flow of water
3. mixed flow of air and fuel
4. mixed flow of water and steam

1-41. Of the following functions, which one is NOT a function of a pressure control?

1. To control the pressure in the boiler
2. To secure the fuel-burning equipment when pressure reaches a predetermined cutout
3. To control the flow of mixed water and steam
4. To start the fuel-burning equipment when pressure drops to the cut-in point

1-42. A modulating motor controls the operation of the oil valve and the air shutters on a boiler to regulate the rate of firing. What factors causes the modulating motor to operate?

1. Fuel oil pressure
2. Feedwater regulator
3. Pressure-regulating valve
4. Electrical imbalance created by pressure change signals to the pressuretrol

1-43. The rate at which combustion air is delivered can be changed by throttling the intake to the blower by opening or closing the air damper.

1. True
2. False

1-44. Normal atomizing pressures are generally within what range?

1. 75 to 85 psi
2. 95 to 105 psi
3. 95 to 120 psi
4. 105t o120 psi

1-45. When the pilot flame is not established and confirmed, the flame failure control must create a safety shutdown within how many seconds after lighting?

1. 15 seconds
2. 10 seconds
3. 7 seconds
4. 4 seconds

1-46. What meter is used in controlling the relationship between air required and air actually supplied to bum the fuel in a boiler?

1. Draft meter
2. Steam and air flowmeter
3. Air analyzer
4. Air pressure meter

1-47. A draft gauge is essential to boiler operation safety.

1. True
2. False

1-48. What is the most widely used method for internally treating boiler water?

1. Alkaloid-chlorine-tannin
2. Benzene-hexcloride-tannin
3. Borax-sulfate-tannin
4. Alkaline-phosphate-tannin

1-49. Which of the following tests is NOT used to test boiler water?

1. Tannin
2. Caustic alkalinity
3. Sodium sulfide
4. Phosphate

1-50. When performing a phosphate test, you should not use concentrated stannous chloride that is more than

1. 1 month old
2. 2 months old
3. 3 months old
4. 6 months old

1-51. When a phosphate test is being performed, which of the following readings would indicate a high level of phosphate?

1. 70 ppm
2. 60 ppm
3. 50 ppm
4. 40 ppm

1-52. You are collecting a boiler water sample for a caustic alkalinity test without tannin. The water temperature should be

1. 160°F or above
2. 120°F or below
3. 80°F or above
4. 70°F or below

1-53. What test is run to determine the degree of acidity in a boiler water sample?

1. Caustic alkalinity test with tannin
2. Caustic alkalinity test without tannin
3. Sodium sulfite test
4. pH test

1-54. The condensate pH normal acceptable range is between

1. 6 and 6.5
2. 7 and 7.5
3. 8 and 8.5
4. 9 and 9.5

1-55. Of the following cleaning methods, which one is NOT a method of cleaning boiler firesides?

1. Wet-steam lancing
2. Sweating
3. Cold-water washing
4. Wire brush and scraper cleaning

1-56. The method used most often to clean superheaters and economizers is by hot-water washing.

1. True
2. False

1-57. When performing wet-steam lancing, you should ensure the steam pressure is maintained between

1. 50 to 100 psig
2. 60 to 120 psig
3. 80 to 170 psig
4. 70 to 150 psig

1-58. What cleaning method is used to remove fireside slag from the convection superheaters?

1. Wet-steam lancing
2. Sweating
3. Hot-water washing
4. Wire brush and scraper cleaning

1-59. What is the most common type of tube cleaner used to clean the watersides of the generating tubes?

1. Hydraulic turbine-driven
2. Pneumatic turbine-driven
3. Electric turbine-driven
4. Hydropneumatic turbine-driven

1-60. Before cleaning boiler tubes, you should ensure that there is

1. varying size brushes for varying size tubes
2. a checklist of all tubes requiring cleaning
3. adequate ventilation and lighting
4. no damage to the safety valves

1-61. Which of the following factors is NOT an advantage of using acid to clean a boiler?

1. Less outage time is required
2. Less dismantling of the unit
3. Performs a more through job
4. Less safety equipment required

1-62. Which of the following types of acid is frequently used for cleaning boilers?

1. Citric
2. Hydrochloric
3. Sulfuric
4. Phosphoric

1-63. What type of acid is used to remove boiler waterside deposits?

1. Citric
2. Hydrochloric
3. Phosphoric
4. Sulfamic

1-64. When inhibitors are not added, acid solutions attack boiler metal as readily as they attack the deposits.

1. True
2. False

1-65. Of the following chemical solutions, which one is NOT a neutralizing solution?

1. Soda ash
2. Trisodium phosphate
3. Sulfite phosphate
4. Sodium tripolyphosphate

ASSIGNMENT 2

Textbook Assignment: "Boiler Maintenance," chapter 2, pages 2-1 through 2-30.

2-1. On a steam boiler, the head mechanism of the low water cutoff devices should be removed from the bowl for cleaning at least once a

1. week
2. month
3. quarter
4. year

2-2. When replacing a broken glass gauge on a boiler, you should take what action first?

1. Close the upper and lower gauge glass valves
2. Remove the packing nuts and packing
3. Remove all pieces of the broken glass
4. Preheat the replacement glass

2-3. What action should you take when replacing the gauge glass while the boiler is in service?

1. Heat the gauge glass to the operating temperature of the boiler before installation
2. Close the blowdown valve and gauge valves to prevent any loss of steam from the boiler
3. Crack the gauge valves slightly and slowly bring the glass to operating temperature
4. Close the blowdown valve and open the gauge valves quickly to bring the glass to operating temperature

2-4. The steam and water connections of a feedwater regulator should be blown down separately at which of the following intervals?

1. Weekly
2. Monthly
3. Quarterly
4. Yearly

2-5. Which of the following types of valves is NOT serviced and maintained by a Utilitiesman?

1. Gate type of stop valve
2. Globe type of stop valve
3. Stop-and-check valve
4. Double-acting valve

2-6. In the care of valves, you should loosen and lift the packing at least

1. quarterly
2. monthly
3. weekly
4. daily

2-7. At what interval should you open the blowdown valves?

1. Daily
2. Weekly
3. Biweekly
4. Monthly

2-8. At what interval should you test safety valves by raising steam pressure to popping pressure?

1. Semiannually
2. Annually
3. Monthly
4. Quarterly

2-9. Lime deposits from a steam injector can be removed by placing the injector into a

1. tube of sulfuric acid for a minute
2. tube with a mixture of baking soda and water overnight
3. tube of hot, soapy water overnight
4. tube of muriatic acid for several hours

2-10. At what interval should steam traps be dismantled and cleaned?

1. Monthly
2. Quarterly
3. Semiannually
4. Annually

2-11. At what interval should you check the forced-draft fan to prevent dust from accumulating in or around the fan?

1. Monthly
2. Every 2 weeks
3. Weekly
4. Daily

2-12. A new gasket should be installed in a handhole fitting

1. each time the boiler is overhauled
2. each time the handhole is opened
3. when deposits on the seating surface cause leaks
4. once a month

2-13. Before installing a new gasket, you should water-soak the gasket for what period of time?

1. 24 hours
2. 12 hours
3. 6 hours
4. 4 hours

2-14. When correctly centered, the clearance between the shoulder of the manhole plate and the manhole must not exceed

1. one-sixteenth of an inch
2. one-eighth of an inch
3. three-sixteenth of an inch
4. one-quarter of an inch

2-15. What action should you take when the clearance between the manhole plate and the manhole exceeds the recommended clearance?

1. Use a different size gasket
2. Replace the manhole plate
3. Build up the manhole plate by welding at the inner edge of the shoulder
4. Grind the manhole until the recommended clearance is achieved

2-16. The tension on a manhole gasket is relieved by using

1. a wrench provided by the gasket manufacturer
2. water pressure from a fire hose
3. air pressure from a hose
4. a hammer

2-17. What precaution should you take before making a hydrostatic test of a boiler?

1. Close the air cocks
2. Close the water gauges
3. Gag the safety valves
4. Close the pressure valves

2-18. You have filled a boiler with water until the water discharges from the air cock. You then close the air cock and turn on the building water service valve. What minimum water temperature must you maintain?

1. 50°F
2. 60°F
3. 70°F
4. 80°F

2-19. You are hydrostatically testing a boiler with a maximum allowable working pressure of 80 psi. What amount of pressure should you apply at each of the ten increments?

1. 12 psi
2. 16 psi
3. 80 psi
4. 120 psi

2-20. What is the most pressure you should apply above the maximum working pressure on a low-pressure boiler?

1. 5 pounds
2. 2 pounds
3. 10 pounds
4. 15 pounds

2-21. What is the maximum allowable pressure drop during a hydrostatic test of a boiler over a 4-hour period?

1. 0.5%
2. 1.0%
3. 1.5%
4. 2.0%

2-22. Which of the following methods should you use to test the safety valves after completing a hydrostatic test on a boiler?

1. Air pressure
2. Steam pressure
3. Water pressure
4. Manual pressure

2-23. Of the following properties, which one is NOT a property of a metal?

1. Porous
2. Malleability
3. Hardness
4. Conductivity

2-24. Which of the following chemical compounds is an example of a metal?

1. Hydrogen sulfide
2. Any alloy of steel
3. Sodium chloride
4. Carbon tetrachloride

2-25. Of the following dimensions, which one is NOT a boiler tube identification marking?

1. Outside diameter
2. Inside diameter
3. Wall thickness
4. Length

2-26. When a safety-ripping chisel is not available, you should take what action to prepare the tube for removal?

1. Using a round nose chisel, split the tube through and beyond the sheet
2. Using a diamond nose chisel, split the end of the tube to the tube sheet
3. Using a square nose chisel, split the end tube and drive out the stub
4. Using a flat chisel, make two splits about three-fourths of an inch apart from the end of the tube to the header

2-27. Before installing a new boiler tube, how should you prepare the outside surface of the tube end that will be expanded in the tube sheet?

1. Polish the tube end with abrasive paper and then round off the tube ends with a file
2. Remove mill scale with a file and file marks with an emery cloth
3. Polish the tube end with abrasive paper and wipe with a kerosene-soaked rag
4. Square off the tube ends with a tuning cutter and polish the tube with a mild abrasive

2-28. Tubes that are 2 inches OD or larger should project into the drum or header what distance?

1. Between 3/32 to 3/16 inch
2. Between 5/16 to 7/16 inch
3. Between 3/8 to 7/16 inch
4. Between 7/16 to 15/32 inch

2-29. "Boilerman's feet" are used to expand tubes that measure

1. smaller than 1 inch
2. from 1 to 2 inches
3. from 2 to 3 inches
4. from 3 to 4 inches

2-30. In expanding tubes, you should select expanders for the tube size and

1. thickness of the tubes
2. type of tube sheet
3. thickness of the seat
4. the expansion factor

2-31. When belling tubes that are 2 inches OD or larger, you should ensure they are belled a minimum of 1/8 inch and a maximum of

1. 1/2 inch
2. 5/16 inch
3. 1/4 inch
4. 3/16 inch

2-32. When boiler tubes are leaking, you should use which of the following methods to accomplish an emergency repair?

1. Re-expand the tube
2. Remove the tube ends and weld the tube sheet closed
3. Weld the end closed
4. Plug the tube ends

2-33. When plugging sidewall tubes, you should never plug more than what total number of tubes next to each other?

1. 5
2. 2
3. 3
4. 4

2-34. What material should you use to plug up a case opening?

1. Asbestos packing
2. Plastic refractory
3. Firebrick mortar
4. Navy-approved sealing compound

2-35. When an economizer element develops a leak, you should insert a plug at what location?

1. At the superheater tube bank and the superheater screen
2. At the sidewall heater and the steam drum
3. At the tube sheet and the rear wall tubes
4. At the inlet header and the outlet header

2-36. You are replacing refractory brick in a furnace. To prevent air bubbles from forming, you should place the mortar on the wet brick in what manner?

1. By using an edgewise motion to dip one end and a side of the brick into the mortar
2. By using a trowel to place the mortar on the wet brick surface
3. By placing the mortar in the space to be occupied by the brick before the brick is set in
4. By dipping both ends and a side of the brick into the mortar

2-37. What is the maximum thickness allowed for joints between firebricks in a boiler?

1. 1/8 inch
2. 5/16 inch
3. 1/16 inch
4. 3/16 inch

2-38. The joints between firebricks are beaded with mortar for which of the following reasons?

1. To prevent turbulence in the burner flame
2. To compensate for shrinkage of the mortar as it dries
3. To protect the comers of the firebrick
4. To bond the mortar to the adjacent brickwork

2-39. What material should you use to make emergency repairs to the cracks in the furnace lining?

1. Plastic firebrick
2. Plastic chrome ore
3. Grade A firebrick
4. Fire clay

2-40. You are repairing a refractory brick wall and have rammed a piece of plastic into place so it fits tightly. What action do you take next?

1. Trowel the surface
2. Apply anchor bolts to hold the plastic in place
3. Vent the plastic section with 3/16-inch holes, 2 inches apart
4. Build a small fire to bake out the plastic

2-41. What temperature is required to bake out plastic refractory?

1. 1000°F to 1200°F
2. 1500°F to 1700°F
3. 2000°F to 2200°F
4. 2900°F to 3000°F

2-42. You should NOT use high-temperature bonding and an air-dry type of mortar, diluted with water to the consistency of light cream, for patching when bricks fall out.

1. True
2. False

2-43. After removing all the old refractory and foreign material, you should inspect the furnace metal for which of the following conditions?

1. Soundness
2. Tightness
3. Corrugation
4. Heat cracks

2-44. Before installing tiles, you should take what action?

1. Preheat the tiles
2. Wash the tiles
3. Dry fit and match mark the tiles
4. Coat the sealing area with an insulating pulp cement

2-45. It is normal for refractories exposed to hot gases to develop thin, hairline cracks. What size does a crack have to be before you clean and fill it with high-temperature bonding mortar?

1. Between 1/16 to 1/8 inch
2. Between 1/8 to 1/4 inch
3. Between 1/4 to 3/8 inch
4. Between 3/8 to 1/2 inch

2-46. After inspecting the door head gasket, you should coat the gasket with which of the following types of mixtures?

1. Gasket cement mix
2. Vee block mixture
3. Wash coat mixture
4. Oil and graphite mixture

2-47. When replacing the door gasket, you should use what size rope gasket?

1. 1 1/4 inches
2. 1 1/2 inches
3. 1 3/4 inches
4. 2 1/4 inches

2-48. There are seven major phases in the operation of a boiler.

1. True
2. False

2-49. Which of the following actions is NOT required by a oncoming watch stander?

1. Test the water columns and gauges
2. Inspect the fans, damper, and damper drives
3. Test fire the furnace
4. Visually inspect the setting and casting

2-50. Immediately after accepting the operational responsibility for a boiler, you should make a complete inspection of all auxiliary equipment.

1. True
2. False

2-51. Which of the following tasks should you complete before lining up a boiler?

1. Remove excess water from the gas tank
2. Check for fuel leaks
3. Measure the amount of fuel oil with a stick or gauge
4. Check the fuel oil pressure

2-52. Which of the following tasks is NOT performed when lining up a gas-fired unit?

1. Open the main gas cock
2. Check the draft devices
3. Purge air out of the gas lines by external vents
4. Close the control valves and safety shutouts

2-53. Before a boiler is lighted off, which of the following valves must be opened?

1. Feedwater drain
2. Feedwater stop and check
3. Burner fuel
4. Main steam stop

2-54. You are filling a newly repaired boiler with treated water and the temperature of the pressure parts is 40°F. What is the maximum allowable temperature for the fill water?

1. 50°F
2. 60°F
3. 75°F
4. 90°F

2-55. You have just fired off a newly repaired boiler. The temperature should be raised what number of degrees per hour until operating pressure is reached?

1 50°F
2. 100°F
3. 150°F
4. 200°F

2-56. Before cutting in the boiler, you should open all drain lines between the boiler and the header.

1. True
2. False

2-57. What are the major duties of a boiler operator during normal boiler operation?

1. To ensure the water level is not too high or too low
2. To maintain a safe and efficient combustion condition in the furnace and to correct fuel-air ratios
3. To keep the correct water level and prevent the loss of ignition
4. To see and interpret prevailing operating conditions and take action to control, modify, or correct them

2-58. When securing a boiler, you should relieve the boiler pressure at the

1. safety valves
2. superheater drain and nonreturn valves
3. bottom blowdown valves
4. main steam stop bypass valves

2-59. Before water can be drained, the water must be below what temperature?

1. 250°F
2. 225°F
3. 212°F
4. 200°F

2-60. Of the following situations, which one is NOT an emergency during boiler operations?

1. Broken gauge glass on the water column
2. Flarebacks caused by an explosion in the combustion chamber
3. Tube failure making it impossible to maintain water level
4. Flue-gas temperature above 150 degrees higher than the temperature of the steam produced

2-61. At what time intervals should entries be made in the boiler room operating log?

1. Hourly
2. Every 8 hours
3. Every 12 hours
4. Every 24 hours

2-62. While on boiler watch, you notice that the last-pass draft reading has increased with each log entry. This is an indication of the

1. amount of air being supplied is incorrect
2. gas passages becoming clogged
3. baffles leaking
4. draft fan not operating at the correct speed

2-63. Abnormally high flue gas temperature can be caused by dirty heating surfaces or by leaking baffles.

1. True
2. False

2-64. You should record the outside temperature in the boiler room operating log for a comparison with

1. steam generated and fuel used
2. water pressure and makeup water
3. fuel used and makeup water
4. steam generated and water pressure

2-65. The economy in a steam flowmeter is obtained by

1. dividing fuel burned by steam generated
2. dividing cost of steam by cost of fuel
3. dividing steam generated by fuel burned
4. dividing cost of fuel by steam generated

2-66. At what time intervals should you check the boiler settings for external air leaks?

1. Every 8 hours
2. Every 12 hours
3. Every 18 hours
4. Every 24 hours

2-67. Before entering a boiler to make repairs, you should attach a sign that reads

1. DANGER
2. KEEP OUT
3. CAUTION-MAN WORKING INSIDE
4. CLOSED DOOR

2-68. Fuel-oil suction and discharge strainers should be cleaned at what time interval?

1. Every 8 hours
2. Every 12 hours
3. Every 16 hours
4. Every 24 hours

2-69. When checking flame conditions on an operating boiler, you should use what shade of colored lens in your safety goggles?

1. 1.5 to 3.0
2. 3.5 to 9.5
3. 10.0 to 14.5
4. 15.5 to 30.0

2-70. If the water goes out of sight in the bottom of the gauge glass, you should NOT take which of the following actions?

1. Drain the boiler completely and open it for inspection
2. Close the steam stop valve immediately
3. Feed cold water to the boiler with low water until it has cooled
4. Kill the fire the quickest way possible

2-71. Handles on pull chains to boiler water-gauge cocks and water gate valves for the top gauge cock should be painted what color at shore installations?

1. Green
2. Blue
3. Yellow
4. White

2-72. A valve must be fitted with a new spring and restamped by the manufacturer for changes that exceeds what percentage?

1. 20%
2. 15%
3. 10%
4. 5%

2-73. A lockout device is a mechanism or arrangement that allows the use of a key or combination locks to hold a switch lever or valve handle in either the ON or OFF position.

1. True
2. False

2-74. The use of what lockout device enables more than one person to accomplish hazardous work on a piece of equipment at the same time?

1. Multiple lock adapter
2. Master combination lock
3. Multiple keyed padlock
4. Duplicate key

2-75. Locks should identify the user by

1. name, rank, and serial number
2. color code of rating, name, and serial number
3. name, rate, and shop
4. color code of rating, name, and shop

ASSIGNMENT 3

Textbook Assignment: "Steam Distribution Systems" and "Heating Systems," chapters 3 and 4, pages 3-1 through 4-4.

3-1. What are the two types of steam distribution systems?

1. Interior and exterior
2. Automatic and manual
3. Electric and hydraulic
4. Pneumatic and manual

3-2. What are the two types of major underground steam distribution systems?

1. Conduit and interior
2. Utilidor and conduit
3. Interior and utilidor
4. Network and conduit

3-3. The conduit of a conduit type of steam distribution system is constructed of what type of material?

1. Galvanized steel
2. Masonry cement
3. Brick
4. Cast iron

3-4. What factors determine the size and shape of a utilidor?

1. Number of manholes and the type of pipe hangers to be used
2. Type of insulation and the imposed loads
3. Number of distribution pipes and the depth into the ground
4. Materials to be used in construction and the provision for pipe expansion

3-5. What is the primary disadvantage of using an overhead steam distribution system?

1. It has a high maintenance cost
2. It requires an expansion joint
3. The type of material required for the steam return piping
4. Water collects and seeps through the sealer at the openings

3-6. Of the following factors, which one is NOT considered when classifying interior steam distribution systems?

1. Pipe arrangement
2. Accessories used
3. Type of controls used
4. Size and type of boiler

3-7. What is the function of the air valve in a gravity, one-pipe, air-vent system?

1. It vents air from the radiators
2. It shuts off the radiators
3. It turns on the radiators
4. It vents condensate from the radiators

3-8. Water hammer and slow heating are characteristics of a gravity, one-pipe, air-vent system when the pipe sizing, pitch, and general design are inadequate.

1. True
2. False

3-9. Water hammer in a gravity, one-pipe, air-vent system can be controlled by

1. venting air from the radiators
2. ensuring that condensate and steam flow in the same direction
3. providing enough hydrostatic head above the entrance to the boiler
4. ensuring condensate is properly drained from the lines

3-10. To obtain the necessary internal drainage when installing a gravity, one-pipe, air-vent system, you should slope the lines down at least

1. one-fourth of an inch for every 10 feet of pipe
2. one-fourth of an inch for every 20 feet of pipe
3. one-eighth of an inch for every 20 feet of pipe
4. one-eighth of an inch for every 10 feet of pipe

3-11. What is the purpose of the main steam stop valve in most steam systems?

1. To hold condensate in the boiler until it is released
2. To hold steam in the boiler until it is released
3. To ensure the proper water level is maintained
4. To drain water from the radiator

3-12. When opening the main steam stop valve, you should

1. crack the valve open
2. open the valve one-quarter of a turn
3. open the valve one-half of a turn
4. open the valve one full turn

3-13. When a radiator fails to heat or develops water hammer, which of the following malfunctions is NOT a probable cause?

1. Failure of the air vents to operate
2. Radiator valves not fully opened
3. Radiator and line incorrectly pitched
4. Excessive pressure drop in the supply lines

3-14. In a two-pipe vapor system, what trap permits the flow of condensate and air from the radiator?

1. Air
2. Condensate
3. Thermostatic
4. Boiler pressure return

3-15. In the two-pipe vapor system, the bottom of the trap should be installed how many inches above the boiler waterline?

1. 12
2. 18
3. 24
4. 36

3-16. In a two-pipe vapor system with a condensate pump and the whole system fails to heat, which of the following malfunctions may NOT be the cause of the trouble?

1. Clogged receiver vents
2. Flooded return line
3. Air binding the system
4. Inoperative steam trap

3-17. In the two-pipe vapor distribution system, what component returns the condensate to the boiler and maintains the vacuum or subatmospheric pressure in the return system?

1. Thermostatic trap
2. Float switch
3. Vacuum pump
4. Condensate pump unit

3-18. You should only use the float switch in which of the following situations?

1. To remove excess condensate from the thermostatic trap
2. When the vacuum switch is defective
3. To eliminate air leakage
4. When the system fails to heat

3-19. What are the two categories of steam radiators?

1. Wall and floor
2. Fin tube and cast iron
3. One tube and two tube
4. Sectional and integral

3-20. What are the two types of radiator air vents?

1. Wall and floor
2. Sectional and integral
3. Automatic and manual
4. Electrical and hydraulic

3-21. The hermetically sealed bellows of an air vent contains a volatile liquid that has a boiling point that is how much lower than that of water?

1. 20°F
2. 15°F
3. 10°F
4. 5°F

3-22. A steam trap is installed in a steam line for which of the following reasons?

1. To allow steam to escape from the line
2. To prevent the escape of steam from a using device
3. To keep foreign particles from passing through the line
4. To drain condensate from the drain line without allowing steam to pass through it

3-23. Of the following types of traps, which one is NOT a steam trap?

1. Float
2. Ball-float
3. Thermodynamic
4. Thermostatic impulse

3-24. The operation of a bucket trap depends on what condition?

1. Difference in temperature between the steam and the condensate
2. Difference in the density between the steam and the condensate
3. Buoyancy of the bucket
4. Mixture of air and condensate in the trap

3-25. What type of steam trap is often used on radiators and is commonly known as a "radiator trap"?

1. Bucket
2. Thermostatic
3. Float
4. Impulse

3-26. What component of the float thermostatic trap activates the discharge valve?

1. Thermostatic vent
2. Cooling leg
3. Ball float
4. Bellows

3-27. The design of what type of steam trap is based on the principle that a volume of hot water that is under pressure will flash into steam when the pressure is reduced?

1.Impulse
2.Thermodynamic
3.Throttling
4.Bimetallic-element

3-28. The pressure on the discharge side of the trap should NOT exceed what percentage of the inlet pressure to ensure that an impulse trap operates properly?

1. 5 percent
2. 10 percent
3. 20 percent
4. 25 percent

3-29. A thermodynamic trap is usually constructed from what type of material?

1. Cast iron
2. Stainless steel
3. Malleable steel
4. Aluminum

3-30. The bimetallic-element trap works basically the same as what other type of trap?

1. Float
2. Thermostatic
3. Impulse
4. Thermodynamic

3-31. When a test plug is not available on the top of the trap, you can prime an inverted bucket trap by

1. blowing down the trap
2. allowing the discharge from another trap to backup into the trap
3. closing the discharge valve and opening the steam supply valve slowly until the trap is filled with condensate
4. opening the discharge and steam supply valves until the trap is filled with condensate

3-32. When the test valve method for testing steam traps is used, a continuous steam blow indicates which of the following malfunctions?

1. Loss of prime
2. No condensate is passing
3. Considerable rattling
4. Slight temperature difference

3-33. You test a steam trap by listening with an engineer's stethoscope held in contact with the body of the trap. What should you hear if the trap is working properly?

1. Faint hissing sound
2. Regular opening and closing of the trap valve
3. Continuous flow of steam
4. Rattling sound

3-34. What type of tank helps to eliminate disturbances caused in piping systems by violent steam formation?

1. Flash
2. Storage
3. Surge
4. Supply

3-35. What are the two general types of water heaters?

1. Flash and surge
2. Floor and instantaneous
3. Surge and storage
4. Storage and instantaneous

3-36. According to safety regulations, the water inside a storage type of hot-water heater should not exceed

1. 212°F
2. 195°F
3. 180°F
4. 165°F

3-37. To ensure that steam is not leaking into the water, you inspect the coil

1. every 2 years
2. annually
3. semiannually
4. quarterly

3-38. The operation of the instantaneous type heater and the storage type of heater are basically the same.

1. True
2. False

3-39. Of the following types, which one is NOT a type of expansion joint?

1. Bellows joint
2. Slip joint
3. Ball loop
4. Expansion loop

3-40. What type of expansion joint is most often used to allow expansion to occur naturally in a system that has screwed joints?

1. Slip
2. Swing
3. Bellow
4. Ball

3-41. You should lubricate slip joints at what interval?

1. Monthly
2. Quarterly
3. Semiannually
4. Annually

3-42. You should inspect slip joints for signs of erosion, corrosion, wear, deposits, and binding at what interval?

1. Monthly
2. Quarterly
3. Semiannually
4. Annually

3-43. The measurement of heat intensity in degrees Fahrenheit (F) or Celsius (C) is know by what term?

1. Sensible heat
2. Temperature
3. Latent heat
4. Total heat

3-44. What type of heat does the thermometer measure?

1. Sensible
2. Latent
3. Specific
4. Total

3-45. On the Fahrenheit thermometer what is the range between freezing and boiling?

1. 100°
2. 128°
3. 150°
4. 180°

3-46. On the Celsius thermometer, what is the range from freezing to boiling?

1. 100°
2. 128°
3. 150°
4. 180°

3-47. When the temperature is 95°F, what is the Celsius equivalent?

1. 25°C
2. 30°C
3. 33°C
4. 35°C

3-48. When the temperature is 25°C what is the Fahrenheit equivalent?

1. 20°F
2. 32°F
3. 44°F
4. 77°F

3-49. A British thermal unit is the amount of heat required to change the temperature of 1 pound of pure water 1°F at sea level.

1. True
2. False

3-50. A block of ice at 32°F melts into water at the same temperature. What form of heat was required to produce this change of state?

1. Latent
2. Intense
3. Specific
4. Thermal

3-51. The amount of heat added to a substance above its boiling point is the definition of what term?

1. Superheat
2. Sensible heat
3. Specific heat
4. Latent heat

3-52. Sensible heat plus latent heat equals what type of heat?

1. Measurable
2. Intense
3. Total
4. Superheat

3-53. Absolute zero is what temperature on the Celsius scale?

1. -10°C
2. -32°C
3. -238°C
4. -320°C

3-54. In what direction does heat flow?

1. Clockwise
2. Counterclockwise
3. From a warmer to a cooler substance
4. From a cooler to a warmer substance

3-55. What condition must be present for heat to flow?

1. Space to heat
2. Substance to heat
3. Difference in pressure
4. Difference in temperature

3-56. When one end of a stove poker is held in a flame, the other end soon becomes too hot to handle. What method of heating has been used?

1. Convection
2. Conduction
3. Radiation
4. Diffusion

3-57. The transfer of heat by means of media, such as water, air, and steam, defines

1. convection
2. conduction
3. radiation
4. diffusion

3-58. A hand held in front of a stove is warmed by what means?

1. Convection
2. Conduction
3. Radiation
4. Diffusion

3-59. What type of material is the best known reflector?

1. Black clothing
2. White clothing
3. Dull metal
4. Polished metal

3-60. Gaseous fuels are usually classified according to what factor?

1. Abundance
2. Use
3. Source
4. Cost

3-61. Natural gas has which of the following characteristics?

1. It is odorless and colorless
2. It has a distinctive odor
3. It has a distinctive color
4. It is replete with ash

3-62. Of the following types of gas, which one is NOT a type of manufactured gas?

1. Methane
2. Carbureted water
3. Oil
4. Producer

3-63. What is the major element in manufactured gases?

1. Methane
2. Ethane
3. Hydrogen
4. Oxygen

3-64. Propane boils at what temperature?

1. -44°F
2. -54°F
3. -62°F
4. -70°F

3-65. Butane vaporizes at what temperature?

1. 60°F
2. 54°F
3. 32°F
4. 25°F

ASSIGNMENT 4

Textbook Assignment: "Heating Systems" (continued), chapter 4, pages 4-4 through 4-36.

4-1. An installed equipment item and a component of a system, consisting of an extended or finned heat transfer surface, and a propeller or blower fan to create an airflow through it is known as what type of heating unit?

1. Central heater
2. Central heating system
3. Unit heating system
4. Unit heater

4-2. What type of direct-fired unit generates heat directly by an electrical coil or by a combustible fuel?

1. Space heater
2. Central heater
3. Space distribution heater
4. Unit heating system

4-3. Of the following types of heaters, which one is NOT a type of unit heater?

1. Suspended horizontal discharge
2. Suspended vertical discharge
3. Vertical forced warm-air
4. Horizontal type of blower unit

4-4. Space heaters are desirable as a means of providing heat to a small space because of their simplicity of construction, low initial cost, and reasonable fuel consumption.

1. True
2. False

4-5. One kilowatt equals a total of how many Btu per hour?

1. 3,415
2. 2,775
3. 2,225
4. 1,775

4-6. Electric space heaters are operated manually with an ON-OFF switch or automatically with a

1. humidstat
2. thermostat
3. rheostat
4. flurostat

4-7. What are the two types of gas heaters?

1. Butane and propane
2. Manual and automatic
3. Direct fired and indirect fired
4. Vented and unvented

4-8. A vented gas heater is preferred over an unvented heater because

1. the flame burns in a open combustion chamber
2. the flame bums in the lower portion of the burner
3. there is less danger of carbon monoxide poisoning
4. there is less danger of explosion

4-9. Unvented gas heaters should be used in well-ventilated areas to

1. remove sulfur deposits
2. remove carbon monoxide produced by the gas flame
3. comply with the American Gas Association (AGA) requirements
4. comply with the NAVFAC DM3

4-10. Approximately how many gallons of water is produced when 1,000 cubic feet of natural gas is burned?

1. 4
2 8
3. 12
4. 16

4-11. Horizontal flue pipes for vented gas heaters should have an upward pitch of at least how many inches per foot?

1. 1
2. 2
3. 3
4. 4

4-12. Oil is fed to a natural draft pot distillate burner that is located at the

1. top of the burner, at the center
2. bottom of the burner, either at the center or on the sides
3. end of the perforated sleeves
4. middle of the left side of the burner

4-13. The flame in a perforated sleeve burner should be what color?

1. Blue
2. Yellow
3. Green
4. Red

4-14. What is the only safety device on an oil-fired space heater?

1. Atmospheric vaporizing type of burner
2. Safetronic diffuser
3. Fuel level control valve
4. Draft diverter

4-15. The draft produced by a chimney depends upon the height of the chimney and what other factor?

1. Width of the chimney
2. Temperature of the flue gas
3. Temperature of the outside air
4. Difference between the flue gas and the outside air

4-16. On what two factors does the operation of the draft regulator depend?

1. Balance and free action
2. Balance and counterbalance
3. Downdraft and updraft
4. Updraft and free action

4-17. Which of the following conditions may result in poorly working burners?

1. Chimney that is too high above the roof line
2. Chimney that is not high enough above the roof line
3. Face of the damper is not plumb
4. Counterweight placed on the damper

4-18. What is the major advantage of using copper tubing with heat installations?

1. It is not affected by heat
2. It is maintenance free
3. It requires fewer fittings
4. It eliminates the need for a tubing bender

4-19. The burner goes out on a perforated sleeve burner. Which of the following conditions is NOT a probable cause?

1. Insufficient oil flow
2. Struck needle valve
3. Oil valve not level
4. Improper fuel

4-20. A gas-fired space heater has a humming sound in the solenoid. What condition is the most probable cause?

1. Incorrect gas pressure
2. Malfunctioning limit switch
3. Incorrect current
4. Solenoid installed backwards

4-21. What are the two types of warm-air heating systems?

1. Gravity and forced-air
2. Positive and negative
3. Automatic and semiautomatic
4. Central and dispersed

4-22. What is the most common problem with a gravity type of warm-air system when installed at floor level?

1. Heat insulation needed above the furnace top
2. Return-air opening is too small at the floor
3. Lack of a positive-pressure fan
4. Undersized jacket at the floor

4-23. What component installed in the forced warm-air system allows for smaller ducts?

1. Return-air jacket
2. Humidifier
3. Positive pressure fan
4. Negative pressure fan

4-24. What component of a forced warm-air system joins the main truck duct?

1. Duct extension
2. Sloping duct
3. Blower
4. Plenum

4-25. An objectionable noise will result at supply diffusers when room air velocities exceed 25 to 35 feet per minute (fpm).

1. True
2. False

4-26. What type of distribution is provided by a diffuser that discharges through a wall?

1. Horizontal
2. Vertical
3. Lateral
4. Cross wind

4-27. What are the two types of duct layout?

1. Warm air and cold air
2. Plenum and full
3. Individual or trunk and branch
4. Vertical and horizontal

4-28. Warm-air pipes are called "leaders."

1. True
2. False

4-29. Forced warm-air svstems usuallv have what register temperature range?

1. 100°F to 125°F
2. 125°F to 150°F
3. 150°F to 180°F
4. 180°F to 210°F

4-30. Outlet velocities of forced warm-air systems at registers may be as high as

1. 350 fpm
2. 400 fpm
3. 450 fpm
4. 500 fpm

4-31. What are the three compartments in a gas-fired furnace?

1. Return air, combustion enclosure, and fuel compartments
2. Blower, filter, and warm-air compartments
3. Return air, warm-air, and the combustion and fuel compartments
4. Blower, heat exchanger radiator, and combustion air compartments

4-32. The compartments and assemblies of a gas-fired furnace may be broken down into a total of how many units?

1. Five
2. Six
3. Three
4. Four

4-33. What assembly includes the gas valves, pressure regulator, and those parts that automatically control the flow of gas to the pilot and main burner?

1. Blower
2. Furnace casing
3. Burner
4. Gas manifold

4-34. What type of burner is usually used with a gas-fired furnace?

1. Hillary
2. Thompson
3. Bunsen
4. Taylor

4-35. What gas burner control should be installed first?

1. Gas pressure regulator
2. Manual gas cock or valve
3. Pilot light
4. Thermocouple relay

4-36. What type of gas pressure regulator is generally used in a domestic gas-heating system?

1. Spring controlled
2. Diaphragm
3. Solenoid
4. Vacuum

4-37. What condition causes the pressure regulator to close?

1. Burner pressure falls below the desired amount
2. Supply pressure is set above the desired amount
3. Burner pressure is set above the desired amount
4. Supply pressure falls below the desired amount

4-38. The adjusting screw for setting the pressure regulator is at what location?

1. On the bottom of the regulator
2. On the side of the regulator
3. On the top of the regulator
4. On the lead-in to the regulator

4-39. What design feature distinguishes the recycling solenoid gas valve from a standard solenoid gas valve?

1. Manual recycling switch
2. Recycling diverter
3. Recycling valve
4. Automatic recycling device

4-40. The primary feature of the diaphragm valve is the extreme valve noise made when opening or closing.

1. True
2. False

4-41. What component of a gas-fired furnace produces an electric current when it is hot?

1. Thermocouple
2. Resistor
3. Rheostat
4. Conductor

4-42. In the automatic gas burner system, the thermocouple is installed next to the

1. diaphragm valve
2. pressure regulator
3. pilot light
4. conversion burner

4-43. What unit shuts off the gas when the temperature inside the heating unit becomes excessive?

1. Thermocouple control relay
2. Thermocouple
3. Diaphragm valve
4. Limit control

4-44. What unit reduces downdrafts and updrafts that interfere with pilot and burner operation?

1. Draft diverter
2. Draft subverter
3. Draft converter
4. Draft inverter

4-45. What are the three compartments of an oil-fired furnace?

1. Burner, combustion and radiating, and blower
2. Combustion, radiating and burner, and blower
3. Blower, combustion and burner, and radiating
4. Radiating, blower and burner, and combustion

4-46. What type of pressure is used to atomize the oil in a gun type of domestic oil-burner?

1. Electrical
2. Differential
3. Pneumatic
4. Fuel oil

4-47. What is the usual oil pressure for the domestic oil burner?

1. 75 psi
2. 100 psi
3. 125 psi
4. 150 psi

4-48. What is the most common type of fuel unit used for oil burners?

1. Y-type, two stage
2. W-type, two stage
3. T-type, two stage
4. L-type, two stage

4-49. An electric transformer is required to step up line voltage to approximately 10,000 volts to cause a spark to jump between the ignition electrodes.

1. True
2. False

4-50. What is the speed of the atomizing cup in the horizontal rotary type of burner?

1. 2,350 rpm
2. 3,450 rpm
3. 4,530 rpm
4. 5,430 rpm

4-51. What is the purpose of the oil burner control system?

1. To provide automatic, safe, and convenient operation
2. To maintain the desired room temperature
3. To start the burner as needed
4. To provide an electrical connection between the thermostat and the burner

4-52. Of the following controls, which one controls the operation of the fire so the temperature and pressure of the heating plant never exceed safe operating limits?

1. Primary
2. Limit
3. Fan
4. Thermostat

4-53. The human hairs in a humidity-responsive device reacts to differences in

1. pressure
2. heat
3. humidity
4. ambient temperature

4-54. What action in the snap-action switch prevents excessive arcing across the points?

1. Closing only
2. Opening only
3. Slow opening and closing
4. Fast opening and closing

4-55. Every electric switch is designed so it has a specific rated capacity in

1. ohms and coulombs
2. coulombs and amperes
3. amperes and volts
4. volts and coulombs

4-56. The standard controls furnished for automatic fuel-burning equipment come in sets designed for warm-air, hot-water, and steam-heating systems.

1. True
2. False

4-57. What is the nerve center of the heating control system?

1. Humidstat
2. Thermostat
3. Essostat
4. Ergostat

4-58. What types of thermostats are used most often in heating control systems?

1. Mercury bulb and electric clock
2. Electric clock and spiral bimetallic
3. Programmable and electric clock
4. Spiral bimetallic and mercury bulb

4-59. The best location for a thermostat is on an inside wall and approximately how many feet from floor level?

1. 1 1/2
2. 2 1/2
3. 3 1/2
4. 4 1/2

4-60. To check the calibration of a thermostat, you should allow what amount of time for the thermostat and a test thermometer to adjust themselves to room temperature?

1. 5 to 10 minutes
2. 10 to 15 minutes
3. 15 to 30 minutes
4. 30 to 45 minutes

4-61. You do not have to recalibrate a thermostat if its closing point does not exceed that of the test thermometer by 1°F.

1. True
2. False

4-62. When installing a furnace, you should use what tool to ensure that it is level?

1. Float level
2. Spirit level
3. Dumpy level
4. Locke level

4-63. Gas-fired and oil-fired forced air units with the blower below the heating element should be setting on masonry at least 3 inches thick and extending what minimum distance beyond the casing wall?

1. 6 inches
2 9 inches
3. 12 inches
4. 18 inches

4-64. When ventilating the furnace room to supply air for combustion, you should allow what size opening for each 1,000 Btu per hour of furnace input rating?

1. 1 square inch
2. 2 square inches
3. 3 square inches
4. 4 square inches

4-65. To ventilate a furnace room adequately, you should install what total number of louvered openings?

1. One
2. Two
3. Three
4. Four

4-66. You should use what size and type of tubing from the oil tank or valve to the burner?

1. 1/8-inch copper
2. 1/4-inch copper
3. 3/8-inch seamless steel
4. 1/2-inch seamless steel

4-67. The suction and return lines for an underground fuel tank should be constructed of

1. black iron
2. PVC
3. copper tubing
4. seamless steel

4-68. Which of the following physical conditions does NOT have to be attained to ensure complete and efficient combustion of fuel-oil systems?

1. The mist must be thoroughly mixed with sufficient combustion air
2. The liquid must be thoroughly vaporized
3. Flame propagation temperature must be maintained
4. Primary combustion air must be admitted to the furnace through the casing surrounding the burner

4-69. Atomization of fuel oil is not accomplished by

1. using steam to break the oil into droplets
2. forcing oil under pressure through a suitable nozzle
3. passing an oil film through an annular groove and into a nozzle spray tip
4. tearing an oil film into tiny drops through centrifugal force

4-70. Steam-atomizing and air-atomizing burner nozzles are both classified as what type of nozzle?

1. Internal or external mixing
2. Centrifugal or centripetal
3. Static or dynamic
4. Open or closed

4-71. What is the required pressure range for the steam in a steam-atomizing burner?

1. 75 to 150 psi
2. 65 to 90 psi
3. 55 to 80 psi
4. 45 to 70 psi

4-72. What amount of air pressure is required to carry light oil to the burner tip of an air-atomizing burner?

1. 10 psi
2. 15 psi
3. 20 psi
4. 25 psi

4-73. In a mechanical atomizing burner, good atomizing results at what pressure?

1. 100 psi
2. 200 psi
3. 300 psi
4. 400 psi

4-74. Which of the following types of burners atomizes fuel by tearing it into tiny droplets?

1. Steam atomizing
2. Air atomizing
3. Mechanical atomizing
4. Horizontal rotary-cup

4-75. What is the speed of a motor-driven conical or cylindrical cup in a horizontal rotary-cup burner?

1. 2,450 rpm
2. 3,450 rpm
3. 4,450 rpm
4. 4,850 rpm

ASSIGNMENT 5

Textbook Assignment: "Heating Systems," chapter 4, pages 4-36 through 4-51.

5-1. Before trying to start or service oil burners, you should take what action?

1. Obtain a pressure gauge
2. Locate a full set of Allen setscrew wrenches
3. Order a complete set of socket wrenches
4. Ensure the correct maintenance equipment is available

5-2. When performing oil burner maintenance, you should use what type of pipe dope?

1. Oil line
2. Graphite
3. Graphite cord
4. SAE 10

5-3. Which of the following materials should you use to clean the grease and gum out of an oil burner nozzle?

1. Diesel
2. Gasoline
3. Kerosene
4. Warm soapy water

5-4. When installing an oil burner nozzle after cleaning, you should set the electrodes

1. 5/8 inch apart, 1/8 inch ahead of the nozzle, and 1/2 inch above the nozzle center line
2. 1/2 inch apart, 1/4 inch ahead of the nozzle, and 5/8 inch above the nozzle center line
3. 1/8 inch apart, 5/8 inch ahead of the nozzle, and 3/8 inch above the nozzle center line
4. According to the specific settings in the manufacturer's manual

5-5. After reinstalling an oil burner pump, you should take what action when there is evidence of end pressure?

1. Loosen the coupling and move it away from the pump
2. Loosen the coupling and move it closer to the pump
3. Loosen the pump and move it closer to the coupling
4. Loosen the pump and move it away from the coupling

5-6. After visually adjusting the burner, you should allow it to run for what length of time?

1. 10 minutes
2. 20 minutes
3. 30 minutes
4. 40 minutes

5-7. Which of the following faults is NOT likely to be caused by too little draft in an oil burner?

1. Firebox pressure
2. Odors in the building
3. Smoke
4. Flame flare-up

5-8. When the burner and draft are adjusted correctly, a flue-gas analysis should indicate what percentage of CO^2?

1. 10 percent
2. 15 percent
3. 20 percent
4. 30 percent

5-9. When the furnace is large enough and the burner is set for correct oil flow with minimum amount of air, what should be the maximum stack temperature?

1. 500°F
2. 600°F
3. 700°F
4. 800°F

5-10. What type of gauge measures suction in the smoke pipe of an oil burner?

1. Suction
2. Draft
3. Vacuum
4. Barometric

5-11. Suction in the smoke pipe or combustion chamber of an oil burner is measured in

1. inches of mercury
2. centimeters of mercury
3. inches of water
4. cubic centimeters of water

5-12. What device should you use to determine the percentage of CO_2 produced by combustion?

1. Flue-gas analyzer
2. Draft analyzer
3. Stack analyzer
4. Gas-burner analyzer

5-13. To test fuel pump valve operation, remove the nozzle line at the pump connection, start and stop the pump, and observe whether the valve cuts off sharp and clean.

1. True
2. False

5-14. When the pressure regulator of the fuel pump requires adjustment, you should use which of the following tools?

1. Phillips head screwdriver
2. Allen wrench
3. Inch-pound torque wrench
4. Tack hammer

5-15. Refer to appendix II, table M. When you troubleshoot an oil pump, what is the most likely cause of noisy operation?

1. Restricted intake line
2. Broken coupling
3. Air in the inlet pipe
4. Loose plugs or fittings

5-16. A cast-iron hot-water boiler is capable of developing what maximum horsepower?

1. 30
2. 55
3. 80
4. 98

5-17. What term is used to identify a boiler that has water in its base?

1. Wet-bottom
2. Water-laden
3. Wet-boiler
4. Soaked-boiler

5-18. What is the primary disadvantage of cast-iron hot-water heating boilers?

1. They are subject to corrosion
2. They are constructed in two sections
3. They crack or break when handled improperly
4. They require special equipment to lift them

5-19. Most steel hot-water boilers are constructed in a total of how many sections?

1. One
2. Two
3. Three
4. Four

5-20. The major disadvantage of a one-piece steel hot-water boiler is that it is heavy and requires special lifting equipment.

1. True
2. False

5-21. A boiler foundation should extend what distance above the finished floor?

1. 5 inches
2. 2 inches
3. 3 inches
4. 4 inches

5-22. What design feature in a boiler holds the hot gases as long as possible so they give maximum heat before passing into the chimney?

1. Baffles
2. Accumulators
3. Retainers
4. Reservoirs

5-23. As a minimum, pressure-relief valves should be operated at what intervals to prevent corrosion or sticking?

1. Weekly
2. Biweekly
3. Monthly
4. Bimonthly

5-24. What action should you take when the relief pressure on the gauge exceeds the setting of the nressure-relief valve?

1. Check the valve pressure with a spring scale and adjust it to the required amount
2. Check the valve pressure with an accurate gauge and replace the defective pressure gauge
3. Check the valve pressure with an accurate gauge and adjust it to the required amount
4. Replace the valve

5-25. To calibrate a pressure gauge correctly, you should use a

1. spring scale
2. deadweight tester
3. screed unit
4. master stage gauge

5-26. What device shuts down the firing equipment in case of an induced or forced draft failure?

1. Pressure gauge
2. Pressure-relief valve
3. Water-level control valve
4. Airflow switch

5-27. The distribution systems and piping for hot-water heating systems are simpler in design than those for steam.

1. True
2. False

5-28. The use of a one-pipe, open-tank gravity system is NOT recommended for which of the following reasons?

1. It is too expensive
2. It is difficult
3. It is hard to get enough circulation by gravity
4. It requires too much maintenance

5-29. The water temperatures are lowest in the two-pipe, open-tank gravity system in what part of the circuit?

1. Top
2. Bottom
3. Beginning
4. End

5-30. When the water in a one-pipe, closed tank distribution system is heated, the water expands into the pneumatic expansion tank.

1. True
2. False

5-31. A gravity closed-tank system with an average boiler water temperature of 190°F has a radiator emission rate of

1. 180 Btu per square foot
2. 170 Btu per square foot
3. 160 Btu per square foot
4. 150 Btu per square foot

5-32. What factor allows the temperature in a closed hot-water system to exceed 212°F?

1. Increased pressure prevents the water from boiling
2. Decreased pressure prevents the water from boiling
3. Steam is required for maximum heating
4. Average radiator output exceeds 150 Btu psf

5-33. In a hot-water system, the water being distributed is within what temperature range?

1. 130°F to 220°F
2. 140°F to 212°F
3. 150°F to 250°F
4. 160°F to 270°F

5-34. Of the following advantages, which one does NOT apply to a forced-circulation, hot-water distribution svstem?

1. Smaller diameter pipe can be used
2. Radiators can be placed in the same level as the boiler
3. A positive flow of water is assured throughout the system
4. The friction and temperature losses for all radiators are nearly equal

5-35. What component is used on a one-pipe, closed-tank, forced-circulation system that is not required on a one-pipe, gravity system?

1. Pressure-relief valve
2. Circulating pump
3. Water-level control
4. Airflow switch

5-36. What is the minimum pitch per 10 feet for main and branches, so air in the system may be discharged through radiators and relief valves?

1. 1 inch
2. 1 1/2 inches
3. 2 inches
4. 2 1/2 inches

5-37. Which of the following components allows trapped air in the distribution lines of a hot-water distribution system to be released from the system?

1. Air shutoff vent
2. Air pressure release valve
3. Manually operated key type of air vent
4. Quick-release valve

5-38. You should take what action to prevent water from leaking around the valve stem of a radiator shutoff valve?

1. Replace the packing
2. Tighten the packing nut
3. Install a valve stem
4. Install a new shutoff valve

5-39. You should inspect unit heaters at what intervals?

1. Weekly
2. Monthly
3. Quarterly
4. Yearly

5-40. A circulating pump does not require which of the following devices?

1. Shaft packing glands and valves
2. Valves and float elements
3. Shaft packing glands and seals
4. Float control elements and traps

5-41. What is the purpose of the reducing valve?

1. To keep the closed system supplied with water at a predetermined pressure
2. To keep the open system supplied with water at a predetermined pressure
3. To reduce differences in water pressure to a safe system pressure
4. To maintain differences in water temperature and safe system pressure

5-42. You should check the flow control valve for correct down-free movement at what intervals?

1. Monthly
2. Biweekly
3. Weekly
4. Daily

5-43. Which of the following is not a maintenance action required on a hot-water heating system?

1. Ensure that all of the air is out of the system
2. Ensure that the radiators are full of water
3. Ensure that the circulating pumps are oiled regularly
4. Ensure that the pressure-reducing valves are checked periodically

5-44. Operator maintenance on an electrically driven feed pump consists mostly of

1. oiling the pump and motor
2. repacking the stuffing box
3. cleaning the pump and motor
4. tightening the packing gland nuts

5-45. Which of the following actions is not a maintenance requirement for feed-water heaters and economizers?

1. Removing solid matter from the units
2. Lubricating the pump motor
3. Repairing inoperative valve and pumps
4. Stopping steam and water leaks

5-46. Which of the following is not an advantage of a high-temperature hot-water (HTHW) system?

1. Minimum maintenance
2. High thermal efficiency
3. Easy operation
4. Light weight design

5-47. What happens to the heat in a high-temperature hot-water system that is NOT used by heat-consuming equipment or lost through pipe radiation?

1. It is vented to the atmosphere
2. It is returned to the boiler plant
3. It is stored in a reservoir
4. It is recirculated through the system

5-48. What is the high-temperature range for most military and federal heating plants?

1. 300°F to 400°F
2. 325°F to 425°F
3. 350°F to 450°F
4. 375°F to 475°F

5-49. What factor determines the maximum water temperature used in a high-temperature hot-water system?

1. Thermal efficiency
2. Cost
3. Method of circulating the water
4. Operating pressure

5-50. What type of pump is used in a one pump high-temperature hot-water circulation system?

1. Rotary
2. Diaphragm
3. Reciprocal
4. Centrifugal

5-51. The two common ways of heating water in an HTHW system are to use hot-water boilers and a/an

1. cascade or direct contact heater
2. matched set of generators
3. indirect contact heater
4. drum installation

5-52. What are the basic designs for pressurizing HTHW systems?

1. Mechanical gas cushion and automatic gas cushion
2. Saturated steam cushion and mechanical gas cushion
3. Automatic gas cushion and hydraulic gas cushion
4. Automatic gas cushion and saturated gas cushion

5-53. The water in a HTHW heating system is drawn from the lower part of the expansion tank, mixed with the system return water, and circulated through the system. Mixing is required for which of the following reasons?

1. To prevent cavitation at the pump suction
2. To prevent cavitation at the pump discharge
3. To decrease saturation temperature in the system flashing at the pump discharge
4. To maintain saturation temperature in the system

5-54. Load variations in a HTHW system will cause supply pressure changes, create flashing of saturated liquid in the system, and produce

1. cavitation
2. corrosion
3. water hammer
4. air locks

5-55. What type of gas is used as the source of pressure in a mechanical gas cushion?

1. Oxygen
2. Nitrogen
3. Methane
4. Carbon dioxide

5-56. What is the weakest link in a mechanical gas cushion?

1. Reservoir for stagnant water
2. Nitrogen space in the expansion tank
3. Generator tubes
4. Steam drum

5-57. To prevent oxygen corrosion in a HTHW system, you should add what chemical to the system?

1. Aluminum sulfite
2. Sodium phosphate
3. Soda ash
4. Sodium sulfite

5-58. To rid the system of oxygen, you should allow the expansion drum vent in a steam-pressurized system to blow for what length of time?

1. 1 hour
2. 2 hours
3. 3 hours
4. 4 hours

5-59. When operating an HTHW system, you should ensure the water is within what pH range?

1. 6.3 to 6.9
2. 7.3 to 7.9
3. 8.3 to 8.9
4. 9.3 to 9.9

5-60. After installing an HTHW system, you should test the system at 450 psi for what minimum amount of time?

1. 4 hours
2. 8 hours
3. 12 hours
4. 24 hours

5-61. The generator tubes of an HTHW system are subjected to an ASME test of 900 psi.

1. True
2. False

5-62. All valves and accessories in a HTHW system are rated at working pressures of 540 to 1,075 psi at

1. 475°F
2. 450°F
3. 425°F
4. 400°F

ASSIGNMENT 6

Textbook Assignment: "Galley and Laundry Equipment," chapter 5, pages 5-1 through 5-32.

6-1. When supervising personnel, you should perform what duties other than just paying attention to operating instructions?

1. Conduct periodic safety lectures
2. Conduct periodic preventive maintenance inspections
3. Adapt instructions to local requirements
4. File periodic maintenance inspection reports

6-2. What department is responsible for conducting sanitary inspections of the galley?

1. Public works
2. Camp maintenance
3. Supply
4. Medical

6-3. What are the two types of steam kettle "coppers"?

1. Direct-steam and indirect-steam
2. Indirect-steam and self-contained
3. Self-contained and direct-steam
4. Fixed-steam and field-steam

6-4. The maintenance schedules for coppers require inspections to be conducted at what time intervals?

1. Weekly and monthly
2. Weekly and quarterly
3. Monthly and biannually
4. Monthly and annually

6-5. What equipment is designed to cook food through a steaming process?

1. Steam table
2. Steam kettle
3. Steam chest
4. Steam pot

6-6. When replacing the gaskets on a full-floating door, you must remove the door from the unit. This action allows for easier removal of the gasket and cleaning of the gasket channel.

1.True
2.False

6-7. You should place paper along the edge of the door opening when replacing gaskets on a steam chest door for which of the following reasons?

1. To prevent excess cement from adhering to the mating surfaces
2. To detect any gasket leaks
3. To check for a binding door
4. To prevent steam from escaping

6-8. When the door of a steam chest is adjusted with hexagon-head bolts, the door should touch the steamer evenly without binding at the corners.

1. True
2. False

6-9. Which of the following checks is not included in the monthly inspection of a steam table?

1. Check for leaks and corrosion
2. Check the thermostat with a mercury thermometer
3. Check the temperature control
4. Check the steam pressure on the gauge

6-10. When the thermostat of a steam table is checked with a mercury thermometer, the thermostat must be accurate to within plus or minus

1. 6°F
2. 7°F
3. 5°F
4. 4°F

6-11. After filling a domestic dishwasher with hot water and an approved cleaning solution, you should then operate the machine at high temperature for what length of time?

1. 10 minutes
2. 20 minutes
3. 30 minutes
4. 40 minutes

6-12. After the first descaling and draining operation, you should rinse a domestic dishwasher several times for what length of time, in minutes?

1. 5
2. 6
3. 3
4. 4

6-13. When selecting the grade and viscosity of the lubrication for a dishwasher, you should use what reference?

1. Fundamentals of Petroleum (NAVEDTRA 10883)
2. Defense Standardization Manual (DOD 4120.3)
3. Annual Book of ASTM Standards
4. Manufacturer's instruction manual

6-14. Before lubricating a domestic dishwasher, you should take what precaution?

1. Obtain the correct lubricate
2. Turn off the power
3. Turn off the indicator dial
4. Clean each component that is to be lubricated

6-15. The correct temperature for the wash water of a domestic dishwasher falls within what temperature range?

1. 115°F to 118°F
2. 125°F to 128°F
3. 138°F to 145°F
4. 148°F to 155°F

6-16. You should use what type of solvent to remove rust from a domestic dishwasher?

1. Air-inhibited sulfuric acid
2. Air-inhibited sulfamic acid
3. Moisture-proof sulfuric acid
4. Moisture-proof sulfamic acid

6-17. When cleaning the interior surfaces of a dishwasher, you should NEVER use

1. air-inhibited sulfamic acids
2. steel wool
3. abrasive cleaners
4. a wire brush

6-18. Which of the following dishwasher inspections is NOT required monthly?

1. Checking the piping system for faults
2. Checking electrical components for proper operation
3. Checking the pumps and impellers for corrosion or extreme wear
4. Checking the drive V-belt tension and alignment

6-19. What is the last step in the annual inspection and maintenance of a dishwasher?

1. Disassemble, repair, and replace bad components
2. Operate the machine through all settings
3. Tag the machine with inspection data
4. Record the inspection data on a DD 1348

6-20. When the air-oil mixture of a range is correct, the flame should be what color?

1. Orange
2. Blue
3. Red
4. Yellow

6-21. You should perform what test to determine the proper fuel-air mixture?

1. Carbon dioxide test
2. Hydrostatic test
3. Air flow analysis
4. Flue-gas analysis

6-22. Range equipment should be entirely repainted when bare spots account for more than what percentage of the total surface area?

1. 10%
2. 12%
3. 15%
4. 20%

6-23. A range thermostat should be precise to within how many degrees Fahrenheit?

1. 1°F
2. 2°F
3. 3°F
4. 5°F

6-24. You should service or perform preventive maintenance on a field range quarterly or after what total number of operating hours?

1. 150
2. 200
3. 250
4. 300

6-25. You should perform which of the following tasks each week on bakery ovens?

1. Clean the pilot
2. Adjust loose chains
3. Lubricate gearboxes
4. Repair cracked walls

6-26. You should conduct electrical checks on bakery ovens at what time intervals?

1. Annually
2. Quarterly
3. Monthly
4. Weekly

6-27. Grease traps should be cleaned at what time intervals?

1. Daily
2. Weekly
3. Biweekly
4. Monthly

6-28. Accumulated odor-forming solids in grease traps soon cause what type of action?

1. Aseptic
2. Organic
3. Septic
4. Inorganic

6-29. Liquids should be removed from grease traps at what interval?

1. Monthly
2. Quarterly
3. Semiannually
4. Annually

6-30. A total of how many units make up a complete laundry unit?

1. One
2. Two
3. Three
4. Four

6-31. What is the washing and drying capacity, in pounds (dry weight) per hour, of a skid-mounted laundry unit?

1. 350
2. 225
3. 150
4. 100

6-32. The washer is controlled through a complete cycle by what means?

1. By a timer with a formula chart
2. By the operator selecting each segment of the cycle
3. By a cycling timer
4. By an electronic modem

6-33. Laundry supplies are added to a washer before and during the complete cycle in which of the following ways?

1. By injection into the water as it is supplied
2. By an automatic injector
3. By an operator manually, a the beginning of the cycle only
4. By an operator manually, as required

6-34. Washing machines equipped with automatic supply injection may be operated manually by making what adjustment?

1. By rewiring the timer
2. By changing the formula chart
3. By removing the formula chart
4. By turning the formula chart to an uncut position

6-35. When a Milnor washer is installed, the machine should be bolted down to prevent vibration.

1. True
2. False

6-36. On a Milnor washer equipped with "steam boil," you should connect the steam line to what valve?

1. Steam distribution
2. Steam solenoid
3. Steam control
4. Steam injection

6-37. To eliminate water hammer when the inlet valves are closed, you connect the inlet valves to the water main with a short piece of rubber hose. This connection is made between the upstream side of the strainers and the

1. downstream side of the strainers
2. outlet valves
3. water main
4. steam valve

6-38. The water inlet valve of the washer is rated to handle what maximum amount of pressure?

1. 80 psi
2. 90 psi
3. 100 psi
4. 110 psi

6-39. What type of switch is installed so any washer can be turned off for repairs without affecting the operation of the others?

1. Quick disconnect
2. Line disconnect
3. Power divider
4. Power line

6-40. What total number of solenoid valves are within the supply injector?

1. Five
2. Two
3. Three
4. Four

6-41. You should drain and refill the gearbox of the washer at what interval?

1. Every 2 months
2. Quarterly
3. Semiannually
4. Annually

6-42. Which of the following actions are performed during the annual inspection of the washer?

1. Adjusting chains and V-belts
2. Cleaning the motor clutch assembly
3. Examining the top and walls for cracks
4. Checking the frame for adequacy of support

6-43. By what method is water removed from the material in an extractor?

1. By compression at low speed
2. By use of a wringer only
3. By centrifugal force to propel the water to the outer surface of the material and then to the drain
4. By a combination of centrifugal force and wringer

6-44. Extractors will operate without excessive vibration if properly leveled and bolted down to a solid foundation.

1. True
2. False

6-45. When an extractor is installed, what percentage of the area of the hold-down pads and rear angle should contact the grout?

1. 50%
2. 75%
3. 90%
4. 100%

6-46. The extractor should be lubricated at what time intervals?

1. Daily
2. Weekly
3. Monthly
4. Quarterly

6-47. What is the hourly capacity of a 42-inch tumbler?

1. 100 pounds
2. 125 pounds
3. 150 pounds
4. 225 pounds

6-48. What size opening to the atmosphere must be provided for a 3,000-cfm tumbler?

1. 6 square feet
2. 2 square feet
3. 3 square feet
4. 4 square feet

6-49. On steam-heated tumblers, you should maintain what minimum pressure for efficient performance?

1. 100 psi
2. 110 psi
3. 125 psi
4. 150 psi

6-50. What is the recommended procedure for exhausting the air discharge from the tumbler to the atmosphere?

1. Individually ducted by any route
2. Individually ducted by the shortest route
3. Connect each tumbler to the exhaust manifold
4. Connect each tumbler to a central exhaust blower

6-51. You should check and tighten wire connections to the electrical control box of a laundry tumbler at what time intervals?

1. Daily
2. Weekly
3. Monthly
4. Annually

6-52. You should remove and clean the cylinder motor and fan motor of a laundry tumbler at what time intervals?

1. Annually
2. Semiannually
3. Quarterly
4. Monthly

6-53. What amount of time is required for a steam generator to develop its full-rated pressure from a cold start?

1. 5 minutes
2. 2 minutes
3. 3 minutes
4. 4 minutes

6-54. What feature on a steam generator ensures a wet tube in the generator-heating unit at all times?

1. Feedwater regulator
2. Low-water cutoff
3. Constant capacity pump
4. Hot-well feedwater tank

6-55. The pump diaphragms of a steam generator are operated in what manner?

1. Pneumatically
2. Electrically
3. Hydraulically
4. Electra-hydraulically

6-56. The boiler of a steam generator is equipped to bum

1. No. 1 diesel fuel
2. No. 2 diesel fuel
3. kerosene
4. blended fuel oil

6-57. You should install what device next to the boiler connection of a steam generator to allow easy removal of parts for inspection and cleaning?

1. Rubber hose
2. Flexible metal-clad hose
3. Flexible hose with quick disconnects
4. Pipe union

6-58. What is the minimum allowable size of flue pipe to be used on a steam generator?

1. 10 inches
2. 11 inches
3. 12 inches
4. 18 inches

6-59. What amount of gravity feed is required with temperatures above 200°F in the hot-well tank?

1. 72 inches
2. 76 inches
3. 80 inches
4. 84 inches

6-60. A thermostat control test should be conducted on a steam generator at what interval?

1. Every 140 hours
2. Every 130 hours
3. Every 110 hours
4. Every 100 hours

6-61. If a heating coil is restricted, the condition will be shown by which of the following readings?

1. 5 to 10 psi above normal
2. 10 to 15 psi above normal
3. 20 to 25 psi above normal
4. 30 psi or greater above normal

6-62. On a steam generator equipped with oil-wick lubrication, you should add oil to the reservoirs of the motors at what interval?

1. Every 180 days
2. Every 90 days
3. Every 45 days
4. Every 30 days

6-63. The water pump crankcase in a steam generator should be changed

1. annually
2. semiannually
3. quarterly
4. monthly

6-64. When the water pump relief valve on a steam generator is adjusted correctly, it should open at what pressure?

1. 400 psi
2. 450 psi
3. 500 psi
4. 550 psi

6-65. Before adjusting the thermostat on a steam generator, the generator must be

1. operated with steam at minimum pressure
2. thoroughly heated and shut down
3. thoroughly heated and operating
4. shut down and drained

6-66. What are the four basic operations that make up a washing cycle?

1. Spin, drain, agitate, and fill
2. Agitate, rinse, drain, and spin
3. Fill, agitate, rinse, and spin
4. Fill, agitate, drain, and rinse

6-67. The timer starts running immediately once the washer is started.

1. True
2. False

6-68. What basic component in the washer is known as the brain?

1. Main drive motor
2. Transmission
3. Water pump
4. Timer

6-69. The timer motor is geared down to run at a speed of how many revolutions per hour?

1. 7/8
2. 3/4
3. 1/2
4. 1/4

6-70. The average main drive motor in an automatic washer is what size, in horsepower?

1. 1/3
2. 1/2
3. 1 1/2
4. 1 1/3

6-71. The hot- and cold-water lines of the automatic washer operate by what means?

1. By a solenoid
2. By a pneumatic control
3. By a hydraulic control
4. By a hydro-pneumatic control

6-72. What component acts as a safety device on an automatic washer?

1. Timer
2. Water-level switch
3. Door interlock switch
4. Temperature selector switch

6-73. When the timer of an automatic dryer is set, the drum begins to rotate at approximately how many revolutions per minute?

1. 50
2. 60
3. 70
4. 80

6-74. A dryer should NOT be exhausted into a convenient chimney.

1. True
2. False

6-75. The dryer vent should not exceed what maximum length?

1. 6 feet
2. 5 feet
3. 3 feet
4. 4 feet

ASSIGNMENT 7

Textbook Assignment: "Refrigeration," chapter 6, pages 6-1 through 6-22.

7-1. Refrigeration is defined as the process of

1. removing heat from a substance or area
2. replacing heat drawn from an substance
3. replacing cold drawn from an area or substance
4. producing cold in substance or area

7-2. Heat is a product of molecular motion that is known as kinetic energy.

1. True
2. False

7-3. What happens to molecular motion and the state of substance when enough heat is added to a substance?

1. The motion stops and the substance becomes a solid
2. The motion decreases and, if the substance was originally liquid, it becomes solid
3. The motion decreases and, if the substance was originally a gas, it becomes a liquid
4. The motion increases and the substance may change state

7-4. Molecular action in a substance is least when the substance is in what state?

1. Vapor
2. Liquid
3. Solid
4. Gas

7-5. When a person says a substance is "cold," what meaning is inferred?

1. It contains no heat
2. It cannot transfer heat
3. It is at absolute zero
4. It has less heat than a comparable warmer body

7-6. What characteristic of heat is shown by the speed of molecules within a substance?

1. Quality
2. Quantity
3. Intensity
4. Conductivity

7-7. When you have a pint of water in a container and a gallon of water in another and both are at the same temperature, what is required to raise the temperature of each container the same amount?

1. Different intensities of heat
2. Different temperatures of heat
3. Different qualities of heat
4. Different quantities of heat

7-8. A British thermal unit (Btu) is the amount of heat required to raise the temperature of 1 pound of water in any state 1°F at sea level.

1. True
2. False

7-9. A total of how many Btu is required to raise 5 pounds of water from 40°F to 165°F?

1. 125
2. 250
3. 625
4. 650

7-10. Which of the following formulas can be used to convert Fahrenheit to Celsius?

1. $C = \frac{(F - 32)}{18}$
2. $C = \frac{(F \times 1.8)}{18} + 32$
3. $C = \frac{(F + 32)}{18}$
4. $C = \frac{(F \times 1.8) - 32}{18}$

7-11. Convert 90° Celsius to degrees in Fahrenheit.

1. 180°F
2. 194°F
3. 212°F
4. 232°F

7-12. When you place an ice cube in a glass of water, what reaction develops almost immediately?

1. The ice melts because it is a solid
2. The water gets colder because it is a liquid
3. Heat is transferred from the water to the ice
4. Heat is given up by the ice to the water

7-13. What type of heat is equal to the number of Btu required to raise the temperature of 1 pound of any substance 1°F?

1. Sensible
2. Latent
3. Specific
4. Total

7-14. A total of how many Btu is required to raise the temperature of 1 pound of water 1°?

1. 1
2. 2
3. 3
4. 4

7-15. A total of how many Btu is required to raise the temperature of 10 pounds of milk 1°?

1. 6.00
2. 7.92
3. 8.29
4. 9.20

7-16. Sensible heat is heat added to or subtracted from a substance that changes its temperature but not its physical state.

1. True
2. False

7-17. What type of heat is absorbed or given off when the physical state of a substance is changing?

1. Latent
2. Specific
3. Effective
4. Sensible

7-18. Latent heat of fusion is the amount of heat required to change the state of a substance without affecting its temperature.

1. True
2. False

7-19. Total heat equates to the sum of what two types of heat?

1. Sensible and specific
2. Latent and sensible
3. Effective and latent
4. Sensible and effective

7-20. A day-ton of refrigeration is the amount of refrigeration produced by melting 1 ton of ice at 32°F in 24 hours.

1. True
2. False

7-21. What total number of Btu equals a day-ton of refrigeration?

1. 288,000
2. 144,000
3. 24,000
4. 12,000

7-22. An air conditioner rated at 24,000 Btu equals a total of how many day-tons?

1. 1
2. 1 1/2
3. 2
4. 2 1/2

7-23. Atmospheric pressure at sea level is

1. 17.4 psia
2. 15.7 psia
3. 14.7 psia
4. 13.5 psia

7-24. In refrigeration work, pressures above atmospheric pressure are measured in pounds per square inch. In what manner are pressures below atmospheric pressure measured?

1. Inches of water
2. Inches of vacuum
3. Inches of mercury
4. Inches of vapor

7-25. Refrigeration is made possible by altering the environment to allow what condition to occur?

1. Increased pressure on the makeup of a substance
2. Reduced pressure on the volume of a substance
3. Increased pressure on the volume of a substance
4. Reduced pressure on the boiling temperature of a substance

7-26. Vaporization is the process of changing a

1. liquid into a gas by increasing its pressure
2. gas into a liquid
3. liquid into a gas by adding latent heat of fusion
4. liquid into a gas by evaporization or boiling

7-27. What is meant by the term condensation?

1. To change vapor into a liquid
2. To change a liquid into a vapor
3. To change a solid into a liquid
4. To change a liquid into a solid

7-28. A refrigeration compressor increases the pressure on the gas and the condenser cools the gas. These two factors are critical to what refrigeration process?

1. Adding latent heat of fusion
2. Adding of latent heat of vaporization
3. Accelerating evaporation
4. Producing condensation

7-29. A refrigeration compressor withdraws the heat-laden refrigerant vapor from the evaporator and compresses the gas to a pressure that will liquefy in the condenser.

1. True
2. False

7-30. The crankshaft seal on a refrigeration compressor must prevent refrigerant and oil from leaking out and prevent air and moisture from entering the compressor.

1. True
2. False

7-31. What are the two types of compressor crankshaft seals?

1. Quad-ring and U-cup
2. O-ring and V-ring
3. Stationary bellows and rotating bellows
4. T-seal and flange packing

7-32. The term "hermetic" means airtight and refers to the

1. seal between the crankshaft and the crankcase
2. type of tubing connections used at the input and output of the compressor
3. case in which the motor and compressor are located
4. leakproofing of the bellows seal

7-33. The electrical motor and compressor of a hermetically sealed unit are sealed in the same case. By which of the following means are the motor and compressor cooled?

1. By water circulation
2. By oil circulation only
3. By the refrigerant vapor moving through the case only
4. By oil circulation and moving refrigerant through the case

7-34. Which of the following factors is not an advantage of a hermetically sealed compressor?

1. Elimination of a source of oil leaks
2. Elimination of pulleys
3. Elimination of coupling methods
4. Increased working capacity

7-35. Which of the following is not a type of condenser?

1. Air-cooled
2. Water-cooled
3. Evaporative
4. Pressurized

7-36. What type of condenser is used where low-quality water and its disposal make the use of circulating water-cooled types impractical?

1. Air-cooled
2. Evaporative
3. Pressurized
4. Constant pressure

7-37. What type of condensers uses several layers of small tubing formed into flat coils?

1. Water-cooled
2. Evaporative
3. Air-cooled
4. Constant pressure

7-38. What device is installed in the water boxes of water-cooled condensers to reduce electrolytic corrosion?

1. Anodes
2. Cathodes
3. Zinc wasting bars
4. Anticorrosion screens

7-39. The capacity of the water-cooled condenser will NOT be affected by which of the following factors?

1. Temperature of the water
2. Temperature of the refrigerant
3. Quality of the water
4. Quantity of the water

7-40. What is the function of the receiver?

1. To provide a reserve of gaseous refrigerant that is fed to the condenser as needed
2. To store liquid refrigerant available from the condenser during off-peak operation
3. To trap liquid refrigerant as it leaves the evaporator to prevent slugs of liquid refrigerant from entering the compressor
4. To trap oil that leaves the compressor and prevents it from entering the condenser or evaporator

7-41. What factor causes the refrigerant in the evaporator to boil?

1. The suction action of the compressor
2. The absorption of heat
3. The high-saturation action of the condenser
4. The conversion from a liquid state to a gaseous state

7-42. What are the two types of evaporators?

1. Dry and flooded
2. Wet and flooded
3. Dry and saturated
4. Dry and unsaturated

7-43. What type of evaporator uses the refrigerant in the evaporator to cool a secondary medium other than air?

1. Direct expanding
2. Indirect expanding
3. Forced-air
4. Natural convection

7-44. What is superheat?

1. The heat absorbed in the evaporator required to change the liquid to a gas
2. The difference in degrees between the saturation temperature and the increased temperature of the gas
3. The heat left in the liquid refrigerant as it leaves the expansion valve
4. The latent heat of vaporization

7-45. What is the purpose of the low-side float valve used with a flooded evaporator?

1. To control the flow of liquid refrigerant
2. To maintain a constant evaporator pressure
3. To increase the level of liquid refrigerant in the receiver
4. To ensure that only gaseous refrigerant enters the evaporator

7-46. The float valve of a high-side float expansion valve is located in the

1. liquid receiver
2. evaporator
3. capillary tube
4. compressor

7-47. What happens to refrigerant flow when the compressor shuts off in a system with capillary tubes?

1. The flow stops immediately
2. The flow continues until the remote bulb shuts off
3. The flow continues until the pressures in the evaporator and condenser are equal
4. The flow stops immediately if the evaporator is cool

7-48. In what location of a refrigeration system is a spring-loaded relief valve installed?

1. Between the compressor discharge connection and the discharge line stop valve
2. In the suction side of the compressor
3. Just beyond the compressor strainer
4. Next to the compressor shutoff valve

7-49. Solenoid stop valves are often used to control liquid flow to which of the following components?

1. Condenser
2. Receiver
3. Strainer
4. Expansion valve

7-50. What is the function of the dehydrator?

1. To offer resistance to the flow of the refrigerant
2. To change the gaseous refrigerant to a liquid
3. To remove compressor oil from the refrigerant
4. To remove moisture from the refrigerant

7-51. Bubbles appearing in the sight-flow indicator of a refrigeration system normally indicates the existence of what condition?

1. The proper amount of refrigerant gas is flowing to the evaporator
2. The proper amount of liquid refrigerant is flowing to the evaporator
3. The system is low on refrigerant
4. The dehydrator is not removing moisture from the system

7-52. A pressure regulator is installed between the outlet of the evaporator and the compressor to prevent

1. the evaporator pressure from being too high
2. the evaporator pressure from being too low
3. a restriction in the refrigerant flow when pressure is too low
4. a restriction in the suction line when pressure is too high

7-53. What is the function of the suction line filter-drier?

1. To remove dirt, scale, and moisture from the refrigerant after it leaves the compressor
2. To remove dirt, scale, and moisture from the refrigerant after it leaves the evaporator
3. To remove dirt, scale, and moisture from the refrigerant before it enters the compressor
4. To remove dirt, scale, and moisture from the refrigerant before it enters the evaporator

7-54. What is the function of the accumulator?

1. To trap oil out of the system
2. To provide a reservoir of liquid refrigerant for the thermostatic expansion valve
3. To prevent liquid from reaching the compressor suction inlet
4. To provide a reservoir of liquid refrigerant for the capillary tube

7-55. To prevent the accumulation of oil in various sections of the refrigeration system, you should install an oil separator between what two components?

1. Evaporator and compressor
2. Compressor and condenser
3. Condenser and receiver
4. Receiver and thermostatic expansion valve

7-56. Which of the following refrigerants is NOT considered a primary refrigerant?

1. Diclorodifluorohethane
2. Hydrofluorcarbon
3. Monchlorodifluoromethane
4. Refrigerant 502

7-57. A secondary refrigerant is cooled by

1. releasing its latent heat of vaporization into the space to be cooled
2. releasing its heat load to the primary refrigerant
3. expanding in an evaporator and vaporizing
4. being compressed and condensed in a refrigeration system

7-58. Refrigerants are classified into groups. Which of the following groups is considered the safest?

1. I
2. II
3. III
4. IV

7-59. What is the primary risk of R-12 to personnel?

1. Freezing effect it has on both skin and eyes
2. Poisonous fumes from the liquid waste it produces
3. Strong smell it produces
4. Tendency it has to decompose into deadly phosgene gas

7-60. The cylinder color code for R-502 is

1. silver
2. green
3. white
4. orchid

7-61. R-717 is commonly used in what systems?

1. Residential
2. Commercial
3. Industrial
4. Medical

7-62. Which of the following refrigerants is a blend component used in low- and medium-temperature applications?

1. R-125
2. R-134a
3. R-502
4. R-717

7-63. R-12 refrigerant that was used in automotive air conditioning is being replaced by which of the following refrigerants?

1. R-502
2. R-125
3. R-134a
4. R-114

7-64. When refrigerant contacts the eyes, rather then flood the eyes with water, your first step for first aid should be to irrigate the eyes with drops of a

1. weak boric acid solution
2. 2 percent saltwater solution
3. sterile mineral oil
4. weak solution of baking soda

7-65. You should take what action, if any, when refrigerant has been discharged from a cylinder?

1. Weight the cylinder and record the weight of the refrigerant remaining on the cylinder
2. Write the letters "MT" on the cylinder to designate that the cylinder is empty
3. Separate the cylinder from the full cylinders, so it can be used first
4. No action is required

ASSIGNMENT 8

Textbook Assignment: "Refrigeration and Air Conditioning" chapter 6, pages 6-23 through 6-52 and chapter 7, pages 7-1 through 7-46.

8-1. The condenser in a self-contained refrigeration system is installed in what general location?

1. An uninsulated compartment
2. An insulated compartment
3. A hermetically sealed compressor unit
4. An outside area for increased cooling

8-2. Reach-in refrigerators have a storage capacity of

1. 10 cubic feet or greater
2. 15 cubic feet or greater
3. 20 cubic feet or less
4. 25 cubic feet or less

8-3. In a typical self-contained reach-in refrigerator, the evaporator is mounted at what location?

1. On the side of the upper portion of the food compartment
2. On the side of the lower portion of the food compartment
3. In the center of the upper portion of the food compartment
4. In the center of the lower portion of the food compartment

8-4. Which of the following types of refrigerants can be used in small capacity, reach-in refrigerators?

1. R-22
2. R-125
3. R-502
4. R-717

8-5. What factor distinguishes the two types of walk-in refrigerators?

1. Location of the compressor
2. Location of the condenser
3. Type of evaporator
4. Inside temperature

8-6. What type of refrigerant is used in most domestic refrigerators?

1. R-12
2. R-22
3. R-134a
4. R-717

8-7. What type of compressor is used on a single door domestic refrigerator?

1. External drive
2. Open
3. Rotary
4. Hermetic

8-8. What type of automatic defrosting system uses the heat in the vapor from the compressor discharge line and the condenser to defrost the evaporator?

1. Forced air
2. Hot gas
3. Direct evaporation
4. Instantaneous

8-9. In a frost-free refrigerator-freezer, the evaporator is at what location?

1. At the bottom, inside the refrigeration compartment
2. At the top, inside the refrigeration compartment
3. On the side, inside the freezer compartment
4. Outside the refrigeration compartment

8-10. What type of water cooler only cools water when it is being drawn?

1. Instantaneous
2. Storage
3. Dispenser
4. Bottle

8-11. What component of a water cooler precools the fresh water line to the evaporator?

1. The condenser
2. The storage tank
3. The heat exchanger
4. The cold water dispenser

8-12. Many manufacturers of ice machines have switched from using R-22 to

1. R-404a
2. R-134a
3. R-502
4. R-717

8-13. When installing a refrigeration system, you must not allow dirt, scale, or moisture to enter any part of the system.

1. True
2. False

8-14. You should take what action if there is a question about the cleanliness of the piping to be used in the installation of a refrigeration svstem?

1. Rod out each length of pipe with a cloth swab
2. Use a strong blast of air to blast out each length of pipe
3. Flush each length of pipe with fresh water
4. Discard the piping and replace with new pipe

8-15. The corrosion in a refrigeration system results from hydrochloric acid which is formed by

1. R-12 coming in contact with air
2. R- 12 coming in contact with compressor oil
3. R-12 coming in contact with scale
4. R-12 coming in contact with water

8-16. Water-cooled condensers requires a free area equal to the

1. length of the evaporator
2. width of the evaporator
3. length of the condenser
4. width of the condenser

8-17. Service openings and inspection panels on unitary equipment require what minimum distance?

1. 6 inches
2. 12 inches
3. 18 inches
4. 24 inches

8-18. What malfunction can occur if there is inadequate ventilation around an air-cooled condenser?

1. The condenser overheats
2. The motor overloads
3. Ice forms in the expansion valve
4. Sludge builds up in the condenser

8-19. On a closed-coupled installation, both the suction and liquid lines are to be ran overhead. This type of installation will assist in the elimination of

1. vibration strains
2. relief valves
3. cooling coil traps
4. siphoning of liquid from the receiver

8-20. When preparing a pipe fitting for making silver solder joints, you. should use what type of material to brighten up the ends?

1. Emery cloth
2. Steel wool
3. Crocus cloth
4. Sandpaper

8-21. Parallel operation of two or more reciprocating compressors should be avoided unless there is a strong and valid reason for not using a single compressor.

1. True
2. False

8-22. When installing two compressors of different sizes, you should take what action to ensure proper operation?

1. Change pulleys to two different sizes
2. Adjust the height of the bases so they are the same level
3. Change the drive belts so they run at the same speed
4. Install a check valve in the equalizer line so pressure remains constant in each compressor

8-23. You should NEVER use a single equalizer line on compressors having two equalizer tappings.

1. True
2. False

8-24. When using two compressors and the condensers are more than 10 feet above the compressors, you should install what additional component in the horizontal discharge line?

1. V-trap
2. Oil filter
3. Oil separator
4. Water separator

8-25. If an oil separator is used at the bottom of a discharge riser, what component is eliminated?

1. Double riser
2. Suction line
3. Liquid line
4. Hot gas discharge riser

8-26. When refrigerants are being transferred,. the amount of refrigerant that may be placed in a cylinder is

1. 65 percent of the tare weight
2. 75 percent of the tare weight
3. 85 percent of the tare weight
4. 95 percent of the tare weight

8-27. When transferring refrigerants, you should place what device in the charging line to the service cylinder?

1. One-way check valve
2. Pressure relief valve
3. Poppet valve
4. Shutoff valve

8-28. When a refrigeration system is excavated, which of the following valves is NOT required to be open to allow the vacuum pump to draw back through the receiver and condenser to the compressor?

1. Discharge service valve
2. Expansion valve
3. Receiver service valve
4. Condenser service valve

8-29. When evacuating a refrigeration system, you should allow the vacuum pump to draw a vacuum of at least

1. 10 inches
2. 15 inches
3. 20 inches
4. 25 inches

8-30. In most small refrigerating systems, high-side charging is recommended for adding refrigerant after repairs have been made.

1. True
2. False

8-31. A halide leak detector is NOT used to detect which of the following refrigerants?

1. R-12
2. R-22
3. R-170
4. R-502

8-32. When you are performing a halide leak test, what color does the flame turn when the halogen refrigerant contacts the reactor plate?

1. Yellow
2. Blue
3. Orange
4. Green

8-33. What term is used to describe the process of cleaning refrigerant for reuse by oil separation?

1. Recovery
2. Reclaiming
3. Recycling
4. Refresh

8-34. When you are reclaiming refrigerant, the liquid refrigerant is stored in a storage chamber where it is cooled. What component is responsible for cooling the refrigerant?

1. The evaporator assembly
2. The receiver and purge unit
3. The recycle solenoid
4. The oil separator accumulator

8-35. Which of the following actions is NOT to be performed when removing a compressor from a refrigeration system?

1. Remove the drive belt or disconnect the drive coupling
2. Plug all openings through which refrigerant flows
3. Pump down the system
4. Remove the suction and discharge lines from the compressor service valves

8-36. What component is installed in the liquid line to absorb moisture in the refrigeration system?

1. Separator
2. Water filter
3. Dehydrator
4. Evaporator

8-37. You should defrost plate-type evaporators in below-freezing refrigerators when ice has built up to what thickness?

1. 1/8 inch
2. 1/4 inch
3. 1/2 inch
4. 3/4 inch

8-38. Operation and maintenance logs assist you in spotting trouble in the equipment.

1. True
2. False

8-39. Which of the following is a type of maintenance log entry?

1. Ambient temperature
2. Operating hours
3. Material used
4. Condenser pressure and temperature

8-40. Maintenance logs can be used to determine future budget requirements.

1. True
2. False

8-41. Air conditioning is the process of conditioning the air in a space to maintain a predetermined temperature-humidity relationship to meet comfort or technical requirements.

1. True
2. False

8-42. What type of chart is used to calculate effective temperature?

1. Atmospheric
2. Temperature conversion
3. Hygrometric
4. Psychrometric

8-43. The specific effective temperature within the zone at which most people feel comfortable is identified as the

1. comfort line
2. optimum line
3. psychrometric line
4. hygrometric line

8-44. What instrument is used to determine relative humidity?

1. Modified wet-bulb thermometer
2. Hygrometer
3. Sling psychrometer
4. Humidistat gauge

8-45. When air becomes saturated with moisture, the wet-bulb, dry-bulb, and dew point temperatures are all the same and the relative humidity is what percent?

1. 70%
2. 80%
3. 90%
4. 100%

8-46. What control device in an air conditioner is sensitive to various degrees of humidity?

1. Hygromistat
2. Humidistat
3. Thermostat
4. Hydromostat

8-47. What method of air cleaning is by far the most effective; however, it is also the most expensive?

1. Magnetic
2. Electrical
3. Air washing
4. Fiber filter

8-48. Air is circulated by either an axial fan or radial fan mounted in an enclosure. These enclosed fans are known as

1. excavators
2. eliminators
3. blowers
4. movers

8-49. The velocity of air is the primary factor that determines what temperature and humidity are required to produce comfort.

1. True
2. False

8-50. Window mounted air-conditioning units range in size from 4,000 to 36,000 Btu and floor-mounted units range from 24,000 to 360,000 Btu per hour.

1. True
2. False

8-51. What type of air-conditioning system is used for central refrigeration plants?

1. Heat pump
2. Chilled-water
3. Floor mounted
4. Window mounted

8-52. The two types of water coolers most often used for chilled water air conditioning are the flooded-shell-and-tube cooler and the

1. pneumatic cooler
2. chilled-water cooler
3. dry-expansion cooler
4. air-cooled cooler

8-53. What two chemicals form a hard scale on the walls of water tubes that reduce their efficiency?

1. Mercury and oxides
2. Carbon and salt
3. Potassium and hydroxides
4. Lime and iron

8-54. Never add water to acid because it may result in an explosion that could severely injure you.

1. True
2. False

8-55. The oil level in the compressor of an air-conditioning system should be checked

1. daily
2. monthly
3. weekly
4. annually

8-56. If liquid refrigerant contacts a person's eyes, that person must be taken to a doctor immediately.

1. True
2. False

8-57. Cooling towers are classified as natural draft, induced draft, or

1. partial draft
2. closed draft
3. open draft
4. forced draft

8-58. What type of wood is the standard construction material for cooling towers?

1. Knotted pine
2. Oak
3. Redwood
4. Walnut

8-59. A compressor is a pump that compresses refrigerant gas.

1. True
2. False

8-60. Which of the following is NOT a type of compressor?

1. Rotary
2. Centrifugal
3. Cyclical
4. Reciprocating

8-61. The term "hermetic unit" means that the motor rotor and compressor crankshaft of a refrigeration system are in a gas-tight housing that has been welded shut.

1. True
2. False

8-62. The humidity-sensitive device that controls the equipment that maintains a predetermined humidity in the space in which it is installed is a

1. thermostat
2. hydrometer
3. humidifier
4. humidistat

8-63. For troubleshooting an air-conditioning system, your best reference is the manufacturer's manual.

1. True
2. False

8-64. The saturation temperature of a liquid or vapor increases according to the pressure exerted on it.

1. True
2. False

8-65. The three types of air-conditioning compressors in general use in automobiles are the two-cylinder reciprocating, swash plate, and

1. universal
2. ten-cylinder
3. scotch yoke
4. electromatic

8-66. The three types of suction pressure-regulating valves used are the suction throttling valve (STV), evaporator pressure regulator (EPR), and the

1. pressure control valve (PCV)
2. suction depression valve (SDV)
3. pilot-operated absolute valve (POA)
4. temperature equalizer valve (TEV)

8-67. The fastest way to find a condition is to work with the proven diagnostic charts and the proper special tools for the air-conditioning system you are working on.

1. True
2. False

8-68. You must always wear safety glasses when servicing any part of an air-conditioning system.

1. True
2. False

8-69. What federal agency has established that all technicians who maintain air-conditioning systems must be certified?

1. Department of the Navy
2. Defense Department
3. Environmental Protection Agency (EPA)
4. Department of Labor

8-70. Standard air-conditioning certification is divided into levels corresponding to the type of service a technician performs. How many types of technician certification are there?

1. One
2. Two
3. Three
4. Four

8-71. The function of what component of a duct system is designed to deliver a concentrated air stream into a room?

1. Diffuser
2. Grill
3. Register
4. Damper

8-72. A radial-flow fan is normally belt-driven.

1. True
2. False