NONRESIDENT
TRAINING
COURSE

April 1995

Utilitiesman (Advanced)

NAVEDTRA 14259

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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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ERRATA #3 21 May 99

Specific Instructions and Errata for
Nonresident Training Course

UTILITIESMAN ADVANCED

1. No attempt has been made to issue corrections for errors in typing, punctuation, etc., that do not affect your ability to answer the question or questions.

2. To receive credit for deleted questions, show this errata to your local course administrator (ESO/scorer). The local course administrator is directed to correct the course and the answer key by indicating the questions deleted.

3. <u>Assignment Booklet</u>

Delete the following questions, and leave the corresponding spaces blank on the answer sheets:

<u>Questions</u>

1-27
1-35
5-43
6-46
7-60
7-61
8-16
8-32
8-33
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8-35
8-41
8-46
8-66
8-68

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.

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.

1995 Edition Prepared by
UTCS(SCW) Paul W. Ross, Jr.

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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."

CONTENTS

REGULATIONS ON ENVIRONMENTAL POLLUTION AND HAZARDOUS MATERIALS

Environmental Pollution and Hazardous Waste Handling and Disposal programs have been Enacted and are United States Law. These programs are of immense importance and should be taken into consideration during the planning stages before beginning any new construction or rehabilitation project.

As a member of the Naval Construction Forces, United States law requires you to be constantly aware of potential environmental pollution hazards or hazardous material spills and to report them to your immediate supervisor or other senior personnel at the earliest possible time.

The following list of directives contains information on the cognizant government departments and the procedures for preventing, reporting, and correcting environmental pollution hazards and hazardous materials disposal worldwide:

- Naval Occupational Safety and Health Program Manual, OPNAVINST 5100.23B
- Environmental and Natural Resources Protection Manual, OPNAVINST 5090.1
- Domestic Wastewater Control, MIL-HDBK 1005/8

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 (CODE 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
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NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you will receive retirement points if you are authorized to receive them 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.)

COURSE OBJECTIVES

In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following: Blueprint Reading and Technical Drawings; Planning, Estimating and Scheduling; Planning Plumbing Projects; Fire Protection Systems; Water Treatment and Purification; Sewage Treatment and Disposal; Compressed Air Systems; Boilers; Duct and Ventilation Systems; Air Conditioning and Refrigeration; and Environmental Pollution Control.

Student Comments

Course Title: *Utilitiesman (Advanced)*

NAVEDTRA: 14259 **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

ADMINISTRATION

The information in this chapter has been removed because it is of a general nature and pertains to all seven Seabee ratings. The subject matter has been revised and placed in the Naval Construction Force Seabee/PO 1 & C, NAVEDTRA 12543.

CHAPTER 2

LEADERSHIP AND SUPERVISION

The information in this chapter has been removed because it is of a general nature and pertains to all seven Seabee ratings. The subject matter has been revised and placed in the Naval Construction Force Seabee/PO 1 & C, NAVEDTRA 12543.

CHAPTER 3

FACILITIES MAINTENANCE MANAGEMENT

The information in this chapter has been removed because it is of a general nature and pertains to all seven Seabee ratings. The subject matter has been revised and placed in the Naval Construction Force Seabee/PO 1 & C, NAVEDTRA 12543.

CHAPTER 4

BLUEPRINT READING AND TECHNICAL DRAWINGS

Blueprints, sometimes called prints, are reproduced copies of mechanical or technical drawings. Drawing or sketching is the universal language used by engineers, technicians, and skilled tradesmen.

The term *reading print* is defined as the ability to interpret the ideas of others expressed on drawings and sketches. This chapter has been developed to give you some insight into the preparation and use of blueprints.

DEVELOPMENT OF CONSTRUCTION DRAWINGS

Drawings are generally categorized according to their intended purposes as follows:

- Preliminary drawings
- Presentation drawings
- Shop drawings
- Working drawings

PRELIMINARY DRAWINGS

A building project may be broadly divided into two major phases: the design phase and the construction phase. Preliminary drawings are prepared by the A and E (architects' and engineers') firm during the design phase to promote building development. These drawings are used for exploring design concepts between the designer and the user (customer), making material selection, determining preliminary cost estimates, and as a basis for preparing the finished working drawings.

PRESENTATION DRAWINGS

Presentation drawings show the proposed building or facility in an attractive setting in its natural surroundings at the proposed site. Since presentation drawings are actually used to sell an idea or a design, your only contact with such drawings will be as a cover sheet for a set of construction drawings.

SHOP/WORKING DRAWINGS

After approval has been given for construction, the shop and working drawings are developed. Throughout your career, you will hear these drawings referred to as construction drawings, prints, or plans. Basically, these terms are all correct; they can be used interchangeably.

As mentioned earlier, the construction drawings are developed from the preliminary drawings. With the collaboration of the designer or the architect and the engineer, both the materials to be used and the construction methods to be followed are decided. The engineer determines the loads that the supporting (structural) members will be required to bear and then designs the mechanical systems for the structure; for example, heating, power, lighting, and plumbing.

You will find the construction drawings, the specifications, and the bill of material (BM) your chief source of information during the construction phase of the project.

BLUEPRINT READING

There are several reasons for having construction drawings and why you need

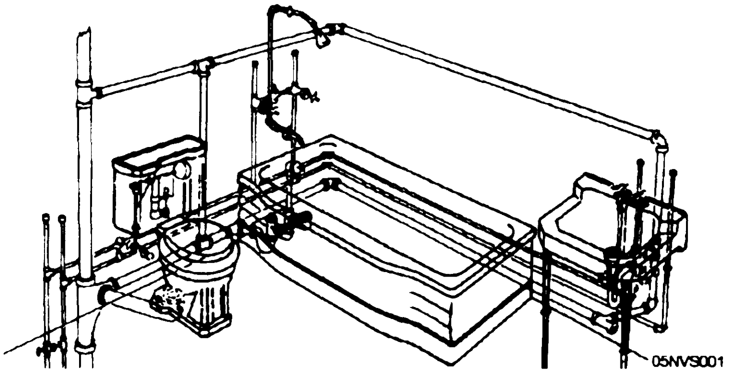


Figure 4-1(A).—Pictorial view of a typical bathroom.

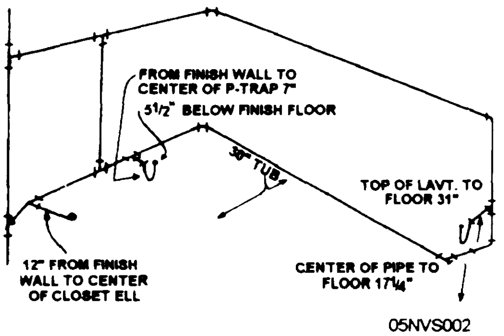


Figure 4-1(B).—Waste and vent.

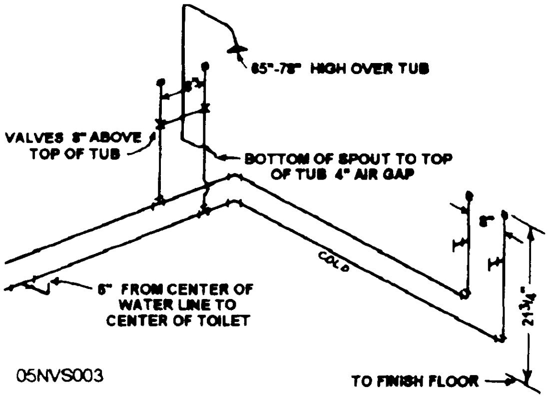


Figure 4-1(C).—Water service.

ability to read and interpret them. Imagine using only written instructions for the construction of a small building. It would take volumes of written material. Trying to understand and visualize all the details involved in a construction project would present a very difficult problem for anyone. For this reason, prints are used. They are also used by the supervisor to monitor the progress of construction.

You must be able to interpret the details, perform the work, and follow directions from these drawings. You must be capable of reading prints and passing along the information contained on the drawings. Figure 4-1(A) shows a typical bathroom. Compare the relationship between the views in figures 4-1(B) and 4-1(C) with 4-1(A)

BLUEPRINT LANGUAGE

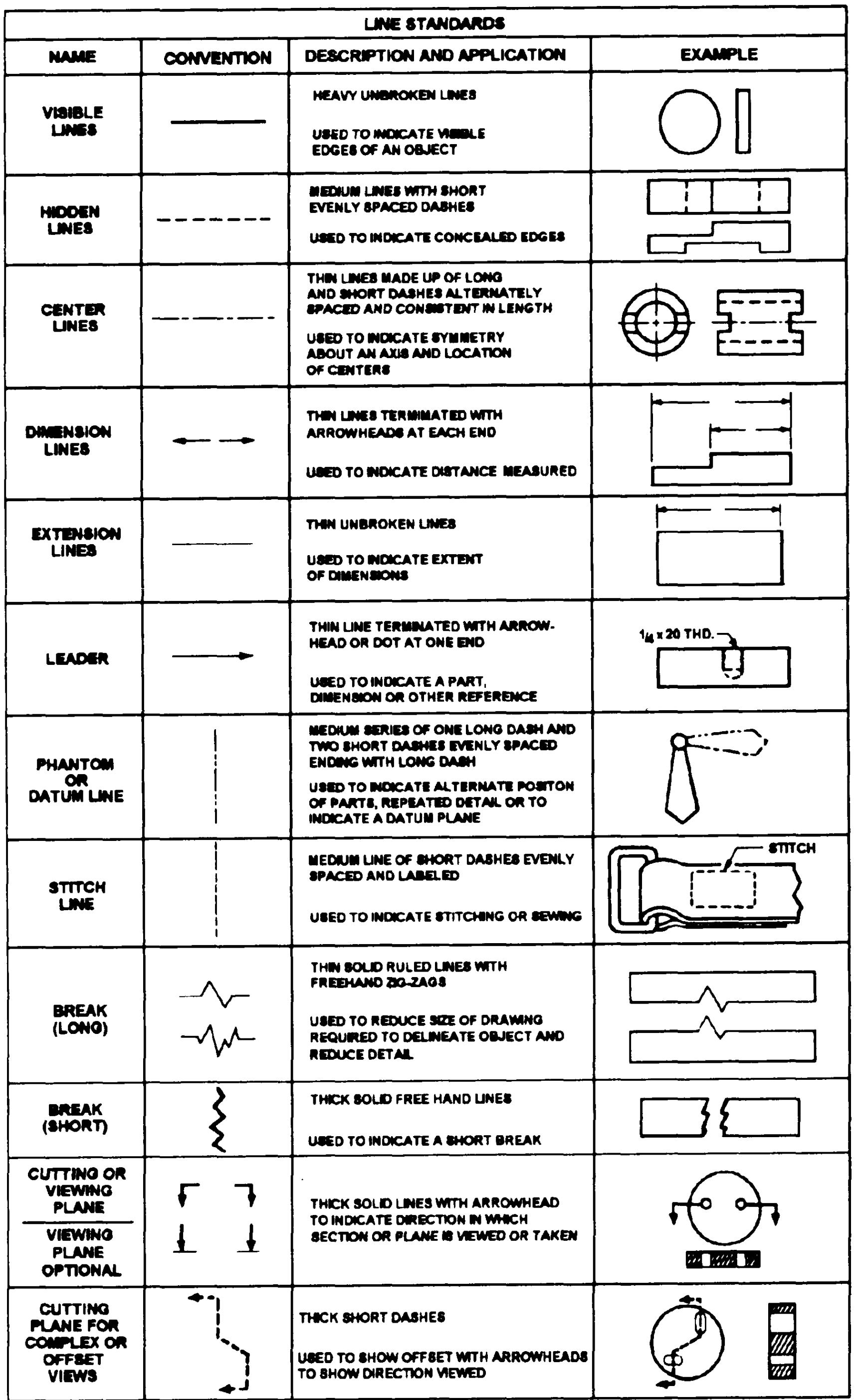
There are various ways that a blueprint shows work to be done. Since the written word can be confusing and take up valuable time and space, other means have been developed. These means include various types of lines, symbols, abbreviations, and other methods of providing dimensions and working directions.

TYPES OF LINES USED ON DRAWINGS

The main types of lines a Utilitiesman should be able to read and understand are depicted in figure 4-1(D).

ELECTRICAL SYMBOLS AND ABBREVIATIONS

In addition to using different types of lines, both the architect and the engineer's intentions are communicated through the use of symbols and abbreviations. In the preparation of electrical drawings, most engineers use symbols adopted by the American National Standards Institute (ANSI).



LINE STANDARDS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
VISIBLE LINES		HEAVY UNBROKEN LINES USED TO INDICATE VISIBLE EDGES OF AN OBJECT	
HIDDEN LINES		MEDIUM LINES WITH SHORT EVENLY SPACED DASHES USED TO INDICATE CONCEALED EDGES	
CENTER LINES		THIN LINES MADE UP OF LONG AND SHORT DASHES ALTERNATELY SPACED AND CONSISTENT IN LENGTH USED TO INDICATE SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS	
DIMENSION LINES		THIN LINES TERMINATED WITH ARROWHEADS AT EACH END USED TO INDICATE DISTANCE MEASURED	
EXTENSION LINES		THIN UNBROKEN LINES USED TO INDICATE EXTENT OF DIMENSIONS	
LEADER		THIN LINE TERMINATED WITH ARROW-HEAD OR DOT AT ONE END USED TO INDICATE A PART, DIMENSION OR OTHER REFERENCE	1/4 x 20 THD.
PHANTOM OR DATUM LINE		MEDIUM SERIES OF ONE LONG DASH AND TWO SHORT DASHES EVENLY SPACED ENDING WITH LONG DASH USED TO INDICATE ALTERNATE POSITON OF PARTS, REPEATED DETAIL OR TO INDICATE A DATUM PLANE	
STITCH LINE		MEDIUM LINE OF SHORT DASHES EVENLY SPACED AND LABELED USED TO INDICATE STITCHING OR SEWING	STITCH
BREAK (LONG)		THIN SOLID RULED LINES WITH FREEHAND ZIG-ZAGS USED TO REDUCE SIZE OF DRAWING REQUIRED TO DELINEATE OBJECT AND REDUCE DETAIL	
BREAK (SHORT)		THICK SOLID FREE HAND LINES USED TO INDICATE A SHORT BREAK	
CUTTING OR VIEWING PLANE / VIEWING PLANE OPTIONAL		THICK SOLID LINES WITH ARROWHEAD TO INDICATE DIRECTION IN WHICH SECTION OR PLANE IS VIEWED OR TAKEN	
CUTTING PLANE FOR COMPLEX OR OFFSET VIEWS		THICK SHORT DASHES USED TO SHOW OFFSET WITH ARROWHEADS TO SHOW DIRECTION VIEWED	

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Figure 4-1(D).—Construction drawing lines.

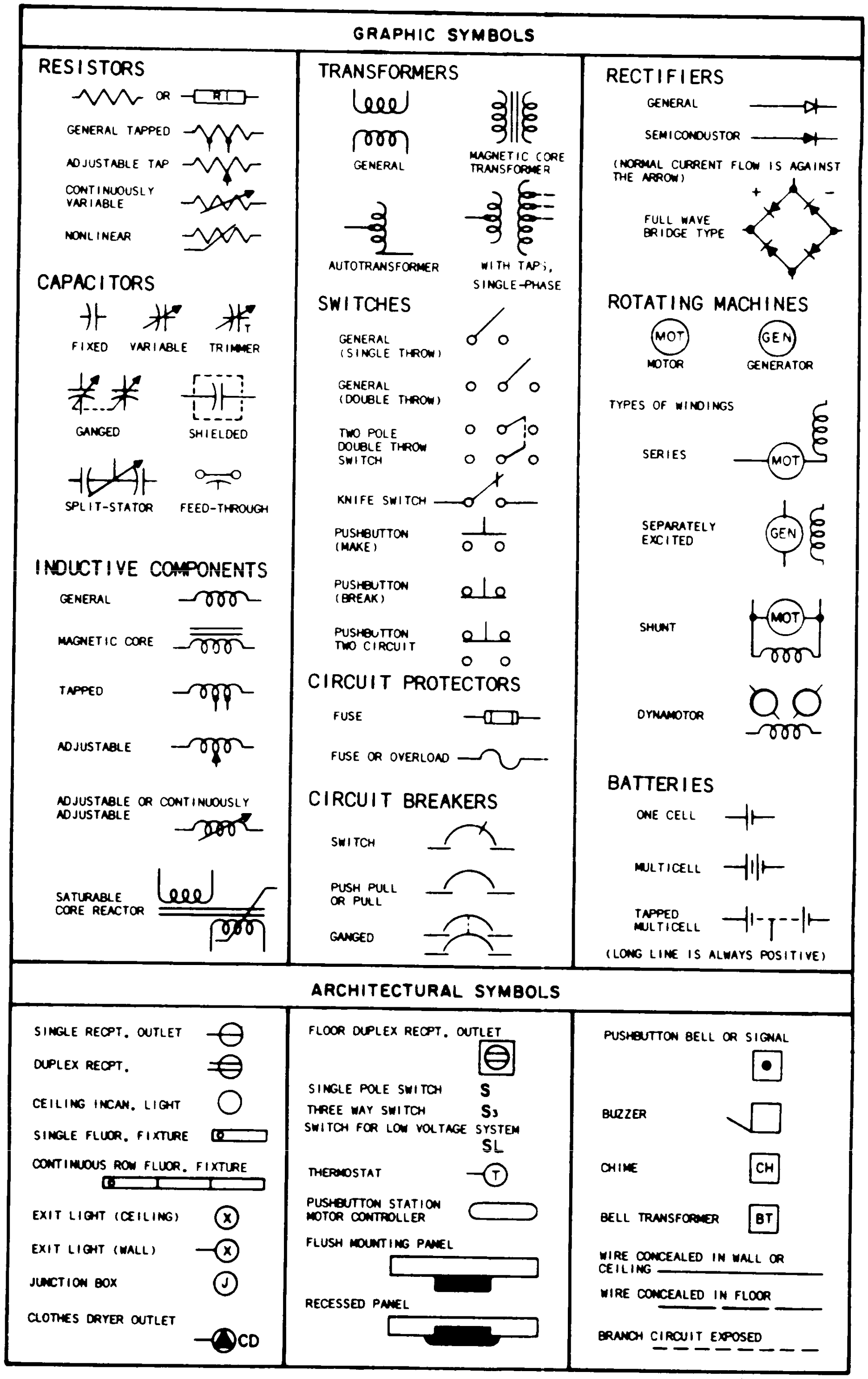

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Figure 4-2.—Electrical symbols.

(ANSI). However, many engineers will modify them to suit their needs. For this reason, most drawings have a symbol list or legend. The electrical symbols in figure 4-2 are taken from the ANSI Y32.9, 1972 publication.

CONSTRUCTION DRAWINGS

With a thorough knowledge of blueprint language (symbols, abbreviations, and lines), you will be able to extract the information that is provided on the different prints. Types of construction drawings you should be familiar with are discussed in the following sections.

Plot Plan

The plot plan is the starting point for any building that is to be constructed. It shows where the building is to be placed on the plot of land or property and shows the shapes and dimensions of the plot. When the plot plan is bounded by streets or drives, such information is also shown.

The plot plan aids the Utilitiesman by showing the point where the service taps from a main are to be connected or what route the pipe will need to be run for an underground service.

Exterior Elevation Drawings

The exterior elevation drawings show views of the finished exterior sides of the building. They show exterior trim, finish, window and door openings, roofing, and brickwork. Finished grade lines and floor lines are also shown. You may find this information helpful in locating outside wall hydrants or hose bibs.

Interior Elevation Drawings

The interior elevation drawings show views of inside wall space that contain counters, sinks, cupboards, and other special features. These drawings can be of great help in determining where to place rough-in piping for water or drainage systems in kitchens and bathrooms. The material that is to be used for walls also affects the distance from the finished wall that the through floor drainage or water supply will be roughed in to (water closets, floor drains, and so forth).

Sectional or Detail Drawings

Sectional or detail drawings are often inserted into drawings to show a specific detail. They may be a cross-sectional view of the building supports or foundation. They could be used to show story height and ceiling height. They may be used to show what floors are made of, whether they have wooden joists or some other type of construction. Any of these factors might influence the method of doing mechanical work and the kind of material that is to be used.

Floor Plan

A floor plan drawing is used to show exactly what the name implies, a plan of the floor. The drawing includes the layout of all interior and exterior walls, including windows and doors. It also shows all fixture requirements. A typical floor plan is shown in figure 4-3.

All the drawings mentioned thus far are proportional reductions of the final structure. The amount of reduction depends on the size drawing desired. Dimensions in feet are reduced to parts of an inch; for example, 1 foot may be reduced to 1/4 inch or 1/8 inch. The reduction is called the scale of the drawing. If the scale of a drawing is 1/4 inch = 1 foot, a 1-inch line would represent 4 feet on the actual structure.

BILL OF MATERIAL

A bill of material (BM) is a tabulated statement of the material required for a given project. It contains information such as stock numbers, unit of issue, quantity, line item-number, description, vendor, and cost. Sometimes the bill of material will be submitted on either material estimate sheets or material takeoff sheets; each contains similar information. Actually, a bill of material is a grouped compilation based on the takeoffs and the estimates of all the materials needed to complete a structure. Usually, the takeoff sheet is an actual tally and checkoff of the items shown, noted, or specified on the construction drawings and specifications.

Most NAVFAC drawings will contain a bill of material incorporated within the drawings. But, there are times when you are directed to tabulate materials needed for a new project that has been designed in-house for cost estimating and funding.

ELECTRICAL WIRING AND MECHANICAL DIAGRAMS

You will be working with mechanical equipment thta requires electrical connections. Therefore, you should maintain close liaison with the Construction Electrician who will involve you in working with electrical diagrams as well as mechanical mechanical drawings. This section discusses types of electrical diagrams and their usage, as they apply to a Utilitiesman.

An “electrical diagram” is defined as a line drawing that shows the arrangement and/or

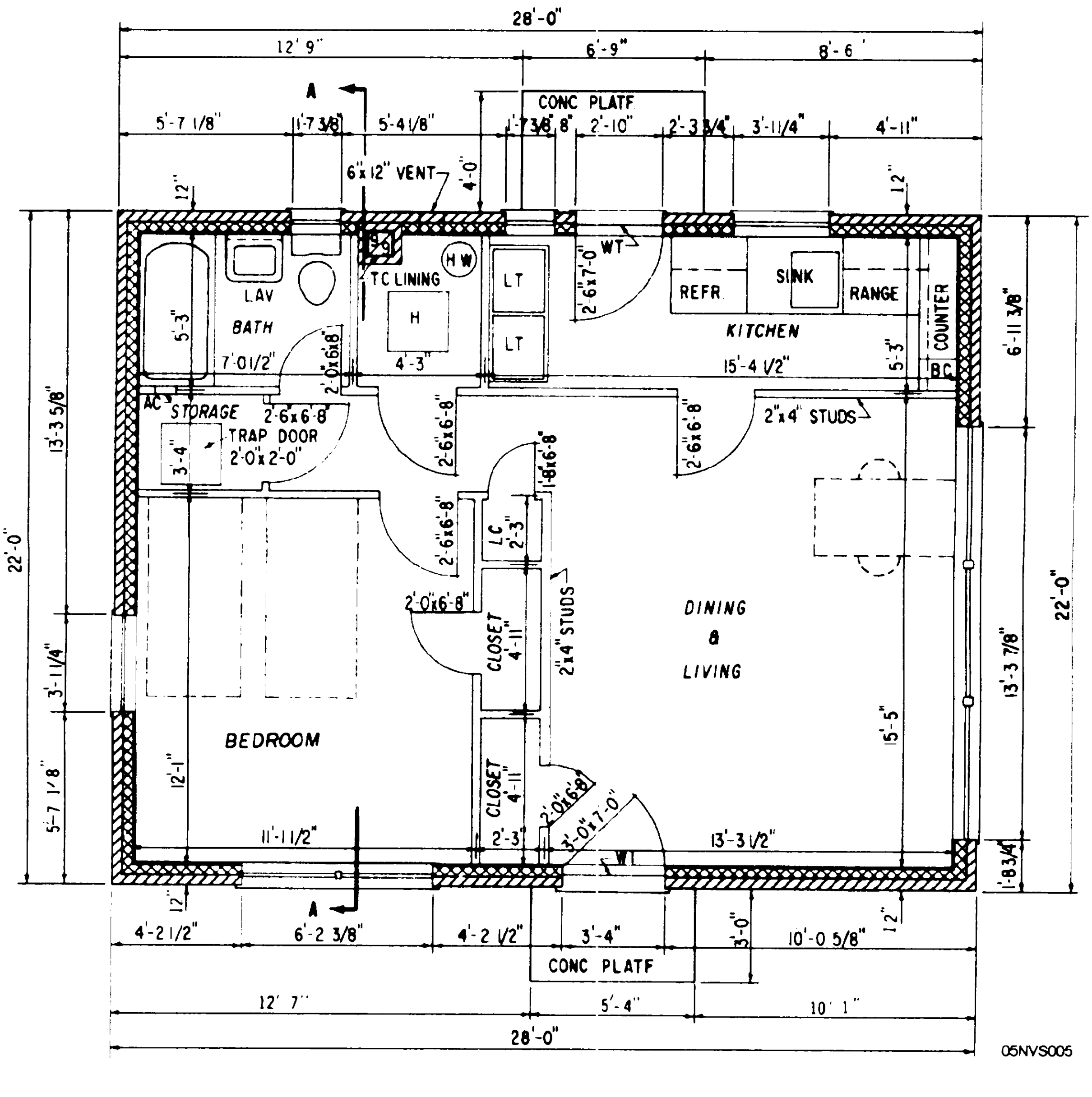

Figure 4-3.—Floor plan.

relationship of parts. Electrical diagrams are usually used to show how the parts of a piece of equipment or several pieces of equipment are wired together. These diagrams are similar to each other. Their names are sometimes used interchangeably, but they do have differences.

The types of diagrams with which you will be working are covered below. The short description of each should enable you to recognize the different diagrams.

ISOMETRIC WIRING DIAGRAMS

The isometric wiring diagram is not used very often in electrical work. When used, it shows the electrical relationship in multilevel buildings, between floors, or the total electrical system. In the isometric diagram, the cable and fixtures are shown only in their general location. Their exact locations are given in the electrical prints. (See fig. 4-4.)

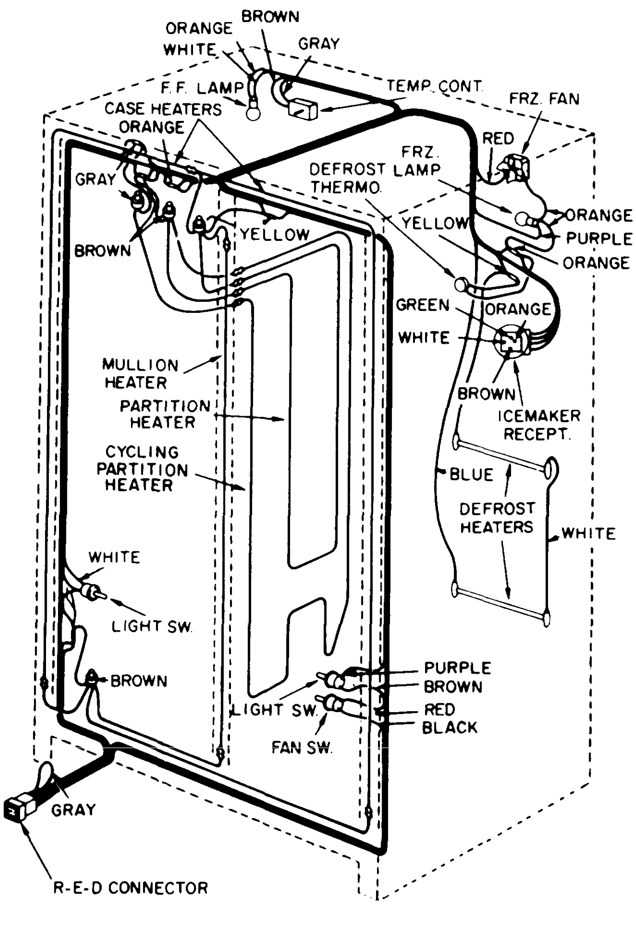

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Figure 4-4.—Schematic wiring diagram of side-by-side refrigerator with automatic ice maker.

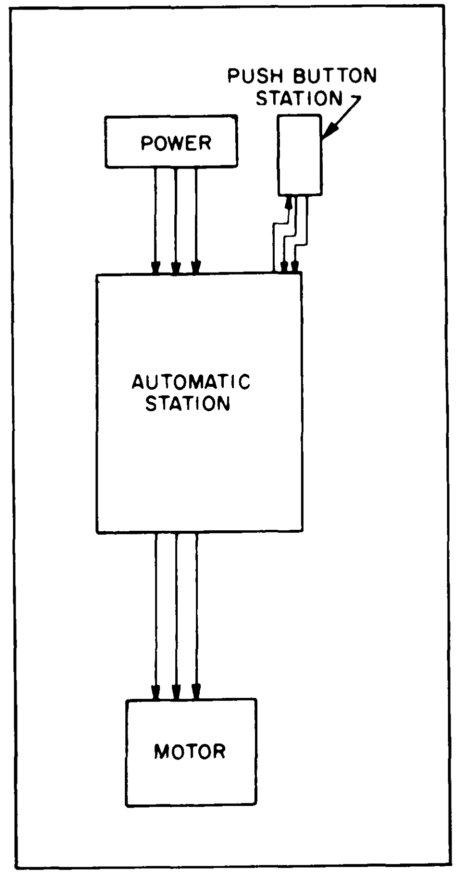

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Figure 4-5.—Block diagram.

A block diagram is a simple drawing showing the relationship of major parts of a system. Figure 4-5 shows a block diagram of a motor control system. You can easily see why it is called a block diagram. The parts or components in any block diagram will be shown just as they appear in this drawing, as blocks. They are then connected by a line or lines that show the relationship of the parts. The internal connections of the components are not shown in these drawings. The blocks are simply labeled to show what each represents. These drawings would be of little help for troubleshooting.

WIRING DIAGRAMS

The wiring diagram, which is like a picture drawing, shows the wiring between components and the relative position of the components.

Figure 4-6 is a wiring diagram of the same motor control system shown by the block diagram. You can see that instead of blocks being used to show components, a picture of the component is used. You can also see that the lines used to show the wiring are marked with numbers or letter-number combinations. Lines L1, L2, and L3 are incoming power leads, and the diagram shows the terminals in the starter to which they are connected, Wiring diagrams are often used along with a list of repair parts and are helpful in troubleshooting problems.

CONNECTION DIAGRAMS

Figure 4-7 is a connection diagram. It makes use of diagram symbols instead of pictures to show components. It also shows all the internal and external circuit connections. These connections can be read and traced more easily than on a wiring diagram. In the connection diagram, the components are still shown in their relative positions. This diagram may be used when you are connecting the wiring or tracing any part of the circuit. Remember that the connection diagram is a valuable troubleshooting tool. It is often found inside the cover of a piece of equipment. The dotted line indicates a single component.

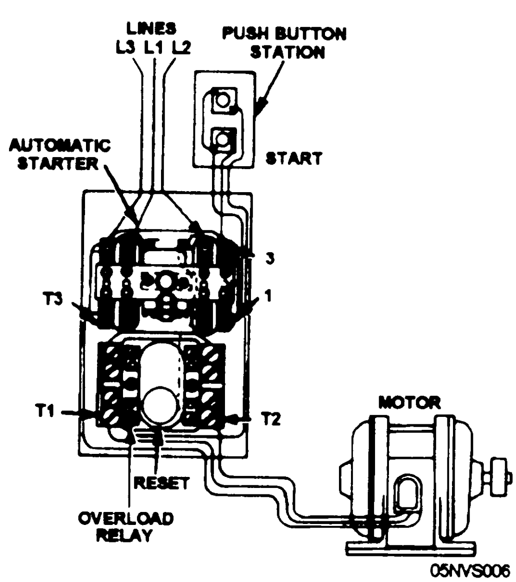


Figure 4-6.—Wiring diagram.

SCHEMATIC/SINGLE-LIINE DIAGRAMS

The schematic diagram is a drawing that shows the electrical plan of operations of a piece of equipment or component. The relative position of parts is not shown in this type of diagram. The schematic diagram, like the connection diagram, makes use of symbols instead of pictures. The schematic shown in figure 4-8 is a plan

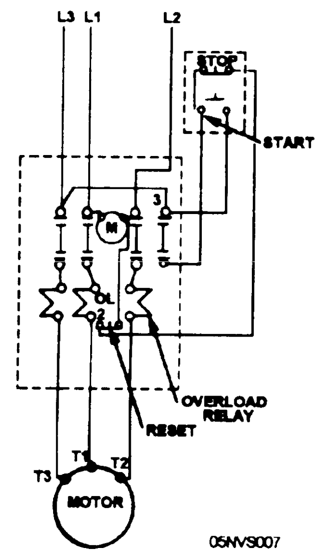


Figure 4-7.—Connection diagram.

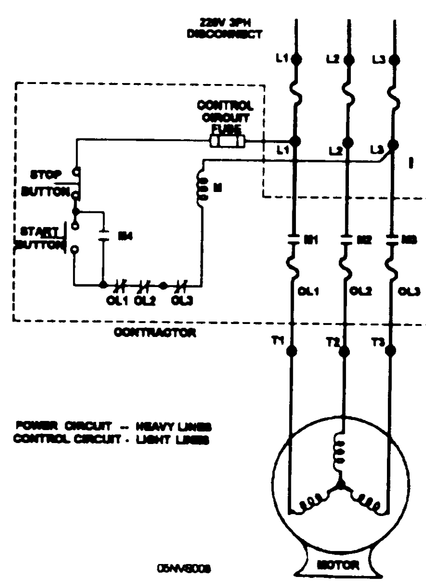


Figure 4-8.—Schematic diagram.

of the same motor control system shown in the other three diagrams. It is laid out so the process of operation is easy to trace. The schematic is sometimes called an elementary or a single-line diagram. It is also useful for troubleshooting purposes.

OPERATION PROCESS

To understand the electrical operation of figure 4-8, you must be able to identify all of the components in the figure. L1, L2, and L3 are the three phases of power. The control circuit fuse is placed in the path of the beginning of the control circuit. Therefore, when excessive current is drawn through the control circuit, the fuse will blow and open the path. The M coil is located in the control circuit, which, when energized, changes the position of contacts labeled with an M. OL1 and OL2 are in-line fuses in the load circuit which protect the motor. When OL1 or OL3 opens due to excessive current or too much heat, contacts OL1 or OL3 open, causing the M coil to be de-energized. Follow the logical sequence in table 4-1. It shows the electrical operation of this simple, but actual design, you will see in the field.

Table 4-1—Three Phase Motor Controller Circuit

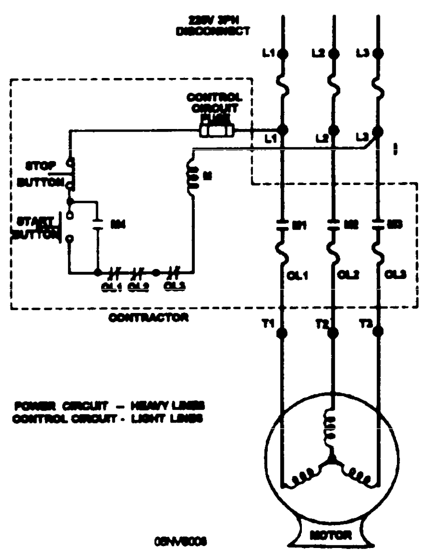
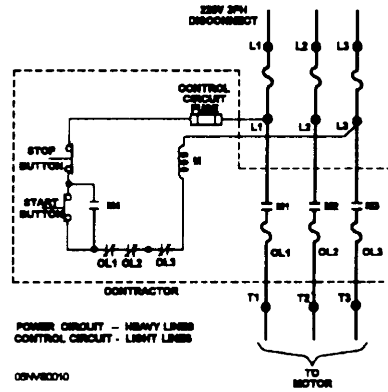
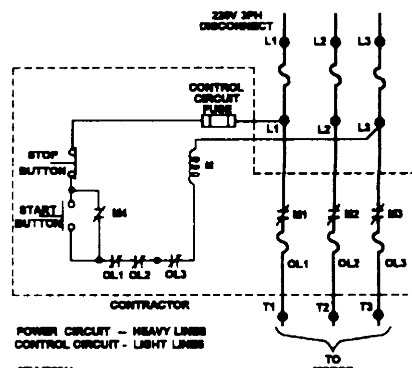
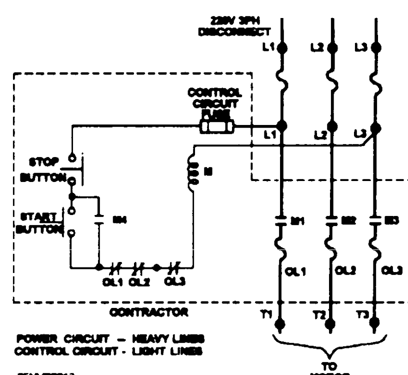
MANUAL ACTION	CONDITION	ILLUSTRATION
None	Voltage is present at L1, L2, and L3. The path extends to the top of contacts M1, M2, and M3. L1 is providing voltage through the control circuit fuse and the stop button. The load (motor) will not operate at this time.	

Table 4-1.—Three Phase Motor Controller Circuit—Continued

MANUAL ACTION	CONDITION	ILLUSTRATION
Start button is pushed	Current flows through the path from L1 through the control circuit fuse, the stop button, the start button, OL1, OL2, OL3, and to the bottom of the M coil. L3 is providing voltage to the top side of the M coil. The M coil is energized.	
None	When current energizes the M coil, contacts M1 through M4 close, providing current to the three-phase motor. (Notice that the start button no longer provides a path for current to flow.) The path through M4 is keeping the M coil energized.	
Stop button is pushed	Momentarily, the path leading to the M coil is open. This de-energizes the M coil, and opens contacts M1 through M4.	

WORKING SKETCH

The information provided in a floor plan is limited to what fixtures are to be installed and their locations. Diagrams that show the actual layout of plumbing systems are provided in the mechanical section of the prints. Before you send a crew to put in a system and its components, draw a working sketch translating the blueprint drawings in such a way that a crew leader can use it for the installation.

A working sketch is a drawing made to express a tasking clearly and to provide a quick reference for job requirements. It should be drawn to show actual conditions on the job, the size of piping to be installed, the locations where connections are to be made, and possibly the type of joints to be used. It should also show as much detail as possible to help the crew during installationor troubleshooting. A working sketch usually shows the work you want a crew to accomplish in a selected area. It also should provide ready reference to jobsite conditions. Figure 4-3 is the floor plan of a house; it shows a bath, heater room, and kitchen. The floor plan of a structure is located in the architectural section of a blueprint package. It shows the locations of plumbing fixtures, built-in cabinets, mechanical equipment, and so forth, that are to be installed as functional components of the completed facility.

Look at figure 4-9. This is an isometric drawing of the plumbing system that services the floor plan shown in figure 4-3. It shows every detail involved in the installation, but it is not representative of actual jobsite conditions. From the isometric drawing, you can determine planning and estimating information but not the actual locations or installation

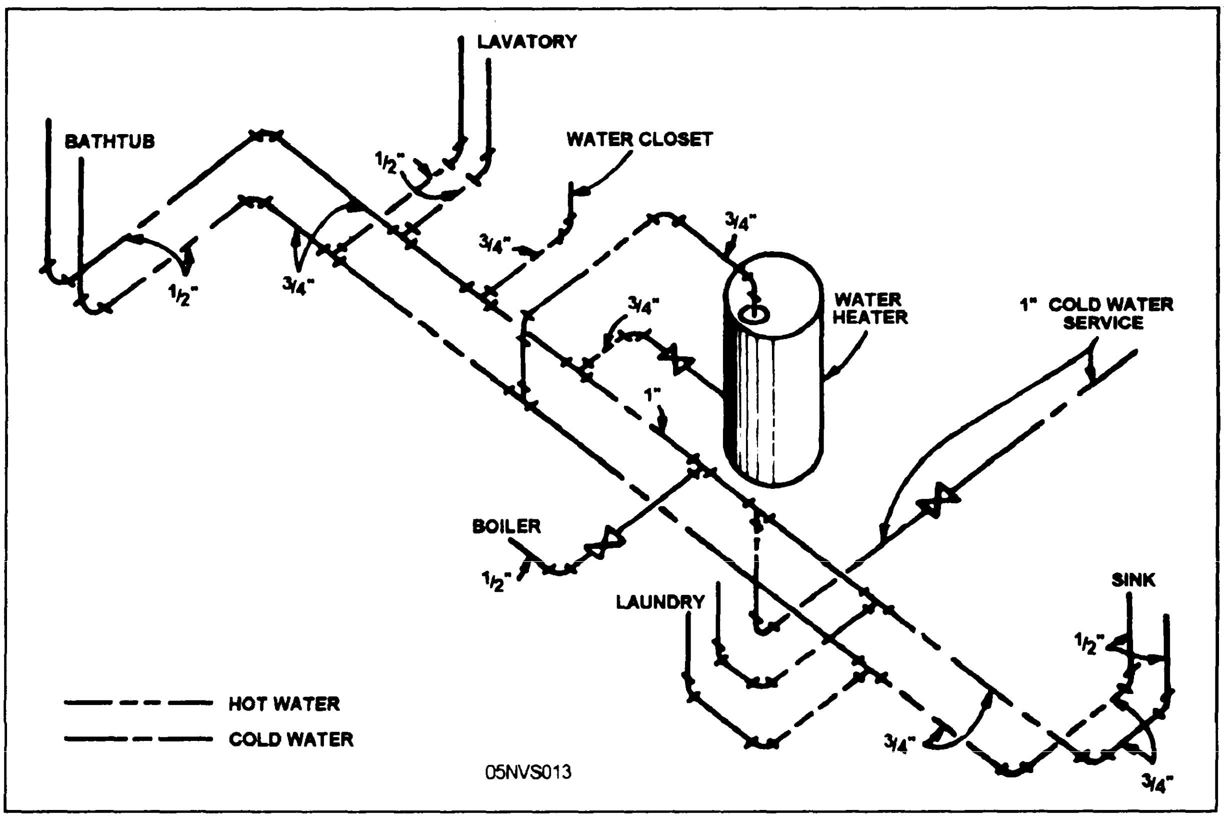


Figure 4-9.—Isometric hot-and cold-water piping system.

interfaces and problems your crew may encounter during the job.

The working sketch is something a crew should have with them while working. It can show them how, what, when, and where things happen in the sequence of a job. Your first step in making a working sketch is to draw the symbols that represent all the fixtures to be installed and locate them within the room. Try to draw them in the sequence of installation and include measurements. Now draw the piping for hot and cold water, show where it comes from and where it is going. Include pipe sizes, fittings, hanging requirements, and rough-in measurements. Do the same for the sanitary and vent systems.

The amount of detail you should use in a working sketch is determined by the crew's experience, the complexity of the system involved, and the need for interface with other trades working on the jobsite.

Working sketches are also useful to simplify complicated electrical schematics when you are installing or servicing mechanical equipment, such as air conditioners and boilers. Figure 4-10 shows electrical symbols commonly found on electrical schematics. By understanding what these electrical symbols represent, you will be able to translate the manufacturer's schematics.. By drawing a simplified working sketch of this information, you are aiding your crew in installing and troubleshooting the equipment.

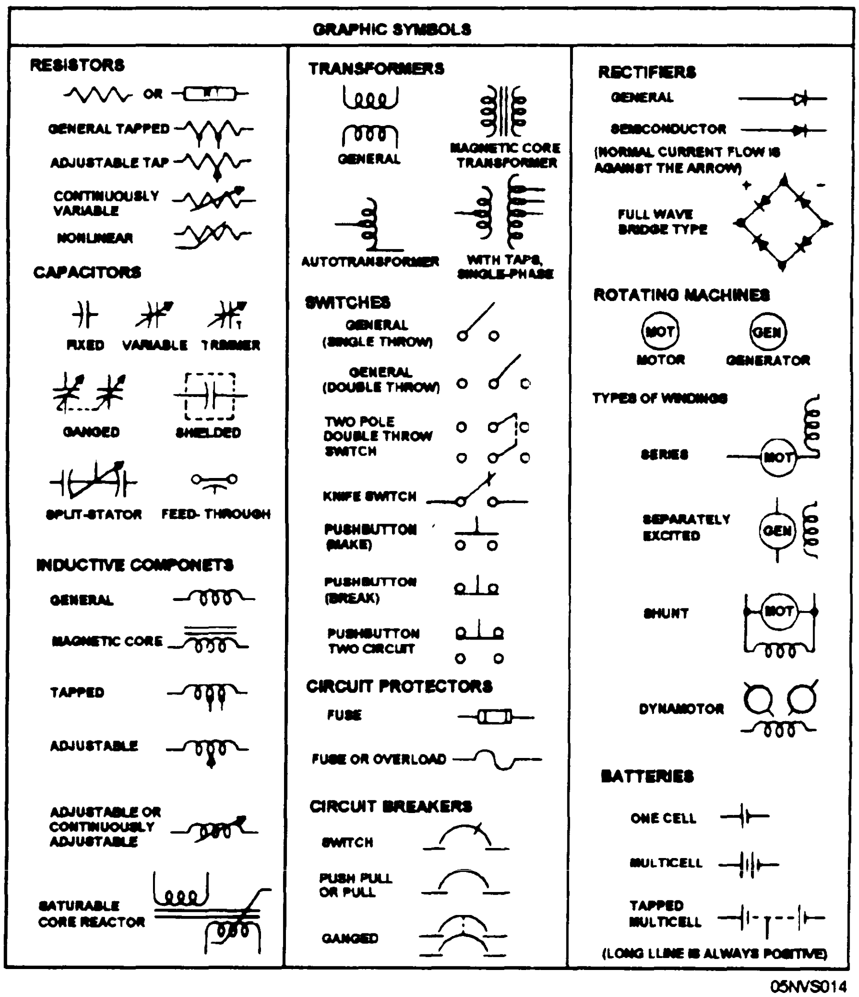


Figure 4-10.—Electrical symbols.

AS-BUILT DRAWINGS

Upon completion of a facility, the crew leader or project supervisor should provide operations with marked prints that indicate any construction deviations. The information required must show all features of the project as actually built. It is necessary for operations to review the as-built drawings after they are completed. This assures that all information appearing on the drawings shows the exact as-built conditions.

From the as-built drawings, record drawings are prepared. These drawings are the original construction drawings but are corrected according to the as-built marked print. They then provide a permanent record of as-built conditions. The original record drawings must be kept up-to-date at all times. If maintenance requires a change to the record drawing, this information should be passed back to operations or to the maintenance control division so the record print can be updated.

SCHEDULES

The schedule is a systematic method of presenting notes and information in tabular form. This makes the detailed information required easily accessible to the Utilitiesman and specifications writer. Schedules are used mostly on large projects.

A plumbing fixture schedule lists the type of fixture and identifies each one on the drawing by number. The manufacturer and catalog number of each type of plumbing fixture are provided along with the number, size, and type of fixture. A column is left for additional remarks. This Remarks column may provide such information as the mounting height above the finish floor (for wall mountings) or any other information required for proper installation. Sometimes this same information can be found in the specifications of the project, but combing through page after page of written material can be time consuming. You may not always have access to the specifications while working, but the drawings are there. Therefore, the schedule is an excellent way of providing essential information in a clear and accurate manner, allowing you to carry out your task in the least amount of time.

SPECIFICATIONS

When project specifications are prepared, they must be brief, clear, and complete. Specifications must convey the complete description of the work to be performed in a clear, concise, and coherent manner, stating the actual minimum needs of the government and the conditions known, such as site location or special construction techniques. The use of general statements should be avoided.

The specifications should be used with construction drawings to provide the Utilitiesman the needed details of a project. The drawings show the extent, size, shape, generic types of material, and the relationship between different materials. The specifications should describe the quality of materials, the installation requirements, and the method of construction. The writer of specifications should review the drawings during and after the writing of specifications. The ensures that the information appearing on the drawings has been covered in the specification and that all the requirements to accomplish the work have either been covered in detail on the drawings or described in the specifications. On the other hand, the designer or engineer should review the specifications to ensure complete coordination. Quite often, a simple detail, section, or note on the drawings makes it possible to eliminate lengthy, descriptive statements from the specification and at the same time clarify the designer's intent. Conflicts or duplications between drawings and specifications must be eliminated. The terminology used in specifications and drawings must be identical.

CHAPTER 5

PLANNING, ESTIMATING, AND SCHEDULING

The information in this chapter has been removed because it is of a general nature and pertains to all seven Seabee ratings. The subject matter has been revised and placed in the Naval Construction Force Seabee/PO 1&C, NAVEDTRA 12543.

CHAPTER 6

ADVANCED BASE PLANNING, EMBARKATION, AND PROJECT TURNOVER

The information in this chapter has been removed because it is of a general nature and pertains to all seven Seabee ratings. The subject matter has been revised and placed in the Naval Construction Force Seabee/PO 1 and C, NAVEDTRA 12543.

CHAPTER 7

PLANNING PLUMBING PROJECTS

The *NCF/Seabee PO 1 & C*, NAVEDTRA 12543, the *Battalion Crew Leader Handbook*, and *Seabee Planner's and Estimator's Handbook*, NAVFAC P-405, discuss general considerations of planning, estimating, and scheduling of projects. This chapter contains information you may need when planning plumbing projects.

RESPONSIBILITIES

You are the technical advisor during both the planning and execution phases of plumbing projects. You will be supervising crews in the field and following an approved project schedule. **Planning is not worth the paper it is written on unless it is executed properly on the job.**

TECHNICAL ADVISOR

As technical advisor, the battalion Operations Officer (S-3), your company, and crew expect you to have answers to their questions about plumbing jobs. You must have access to plans, specifications, plumbing codes, technical references, and manufacturers' manuals. You are not expected to know every detail of your rating. **You can be an effective technical advisor by knowing and using the resources available to you.**

Many problems will require you to make decisions based on personal experiences. Do not rely on rate training manuals or formal schools to provide you with everything you need to know to be a Utilitiesman. The extra effort of self-study, combined with on-the job training and field experience, will enable you to make recommendations with confidence.

PLANNER

Now that you are advising people on the technical aspects of installing and maintaining plumbing systems, you may become involved in the planning of these tasks.

Planning takes on many applications and phases. Home-port project planning results in a schedule that you should use to decide how and when your work is going to be done. The resulting precedence diagram, along with other available information about a project, can help you in managing and supervising your project.

SUPERVISOR

Your company should follow the construction schedule that was prepared during the home-port period. After arriving at the deployment site, you may need to make changes to the schedule to show actual conditions on the job, such as changes in personnel, equipment availability, or material delays. The schedule is designed to be a management tool to assist the supevisor. Used properly, the schedule will alert you to problems and job requirements in enough time to avoid project delays.

Coordinate your requirements with other companies and departments. For example, decide on material, equipment, and personnel requirements about 30 days in advance at the company level, 2 weeks in advance at the job supervisor level, and no less than 1 week in advance at the crew leader level. This should provide the time necessary for supporting elements of the organization to break out, deliver, and provide support to your job. The project you are working on should decide the amount of lead time planning you should allow. During home-port planning, you may not know the conditions on a particular jobsite. After being on the site, you may have to reevaluate the original schedule. Generally, you can make changes to the schedule within 45 days of crew arrival on the job. Good supevisors ensure equipment, material, tools, and other facilities are on the job when needed. Missing items require an extra trip back to camp; this affects both production and crew morale.

PLANNING, ESTIMATING, AND SIZING PLUMBING SYSTEMS

You will provide input on the planning, estimating, and sizing of plumbing systems. This input may concern installation techniques, types of material required, quantity and size of piping or fittings, and so forth. This section provides information you must consider for planning and estimating a plumbing project. The National Standard Plumbing Code, military specifications, and job specifications provide more concise information.

SANITARY SYSTEMS

Various types of pipe and fittings are used for sanitary waste and drainage. However, the location of the installation determines the type of material you must use. Threaded pipe that is underground requires coal tar protection. Install underground sanitary waste and drainage lines in a separate trench from the water-service line. The underground water service and the building drain or sewer should not be less than 6 feet apart horizontally and placed on undisturbed or compacted earth. When separate systems of sanitary drainage and storm building drains are placed in one trench, they should be placed side-by-side. A building sewer or building drain installed in fill dirt or unstable ground should be made of cast-iron soil pipe, except that nonmetallic drains may be used when laid on an approved continuous supporting system. Table 7-1 depicts code requirements for pipe usage.

Table 7-1.—Sanitary Waste and Drain Piping

PIPING MATERIAL	SEWERS OUTSIDE OF BUILDINGS	UNDERGROUND WITHIN BUILDINGS	ABOVEGROUND WITHIN BUILDINGS
ABS Pipe and Fittings, schedule 40 DWV (ASTM D2661)	✓	✓	✓
ABS Pipe - cellular core (ASTM F628) and DWV Fittings	✓	✓	✓
ABS Sewer Pipe and Fittings (ASTM D2751)	✓		
ABS and PVC Composite Sewer Pipe (ASTM D2680)	✓		
Brass Pipe 9ASTM B43)			✓
Cast-Iron Soil Pipe and Fittings - Bell and Spigot (ASTM A74)	✓	✓	✓
Cast-Iron Soil Pipe and Fittings - Hubless (CISPI 301, ASTM A888)	✓	✓	✓
Concrete Drain Pipe, Nonreinforced (ASTM C14)	✓		
Concrete Drain Pipe, Reinforced (ASTM C76)	✓		
Copper Pipe (ASTM B42)			✓
Copper Tube - DWV (ASTM B306) and Copper Drainage Fittings (ANSI B16,23)	✓	✓	✓
Copper Water Tube - K,L,M (B88) and Copper Drainage Fittings (ANSI B16,23)	✓	✓	✓
Galvanized Steel Pipe (A53) and Cast-Iron Drainage Fittings (ASME B16,12)		✓	
PVC Pipe and Fittings, DWV (ASTM D2665)	✓	✓	✓
PVC Sewer Pipe - Cellular Core (ASTM F891)	✓	✓	✓
PVC Sewer Pipe (PS-46) and Fittings (ASTM F789)	✓		
PVC Sewer Pipe (PSM) and Fittings (ASTM D3034)	✓		
Vitrified Clay Pipe - Standard Strength (ASTM C700)	✓		
Vitrified Clay Pipe - Extra Strength (ASTM C700)	✓	✓	
Lead Pipe and Fittings (FS WW-P-325B)			✓

(1) Plastic drain, waste, and vent piping classified by standard dimension ratio shall be SDR 26 or heavier (lower SDR number).

(2) Plastic sewer pipe classified by pipe stiffness shall be PS-46 or stiffer (higher PS number).

(3) Piping shall be applied within the limits of its listed standard and the manufacturer's recommendations.

Pay special attention to the joints so roots do not grow into the piping. The depth of the piping should be below the frost line. Also, you should encase the piping with concrete or sleeve it with a metallic material when laying piping under roadways.

It may be necessary to install the building sewer and the water-service pipe in the same trench (fig. 7-1). If so, use the following precautions:

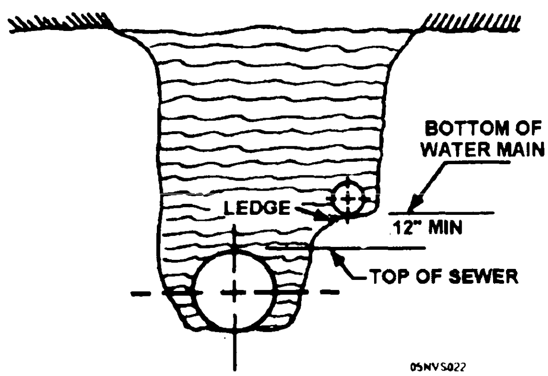


Figure 7-1.—Building sewer and the water-service pipe in the same trench.

- Ensure the bottom of the water pipe is at least 12 inches above the top of the building sewer.
- Place the water pipe on a solid shelf at the side of the trench.
- Use hot lead when joining cast-iron pipe for a building sewer; use a hot-poured compound in joining bell-and-spigot clay or concrete sewer pipe.
- After installation, test the building sewer with a 10-foot head of water, or equivalent test.

Grading

Install sanitary drainage piping on a uniform slope. This slope, pitch, grade, or drop per foot decides the flow velocity of liquid within the pipe. Piping with a diameter of 3 inches or less requires a slope of not less than 1/4 inch per foot. Pipe 4 inches or larger slopes no less than 1/8 inch per foot. This allows a velocity of not less than 2 feet per second, that provides the scouring action necessary to keep a pipe free from fouling. Sewer mains may have slopes of less than 1/8 inch per foot, as long as there is a cleaning velocity of 2 feet per second or greater. See table 7-1 (A) for code requirements.

Table 7-1 (A).—Discharge Rates and Velocities of Sloping Drains

Actual inside diameter of pipe in inches	1/16"/ft. slope Disch. gpm	vel fps	1/8"/ft. slope Disch. gpm	vel fps	1/4"/ft. slope Disch. gpm	vel fps	1/2"/ft. slope Disch. gpm	vel fps
1 1/4							3.40	1.78
1 3/8					3.13	1.34	4.44	1.90
1 1/2					3.91	1.42	5.53	2.01
1 5/8					4.81	1.50	6.80	2.12
2					8.42	1.72	11.9	2.43
2 1/2			10.8	1.141	15.3	1.99	21.6	2.82
3			17.6	1.59	24.8	2.25	35.1	3.19
4	26.70	1.36	37.8	1.93	53.4	2.73	75.5	3.86
5	48.3	1.58	68.3	2.23	96.6	3.16	137.	4.47
6	78.5	1.78	111.	2.52	157.	3.57	222.	5.04
8	170.	2.17	240.	3.07	340.	4.34	480.	6.13
10	308.	2.52	436.	3.56	616.	5.04	872.	7.12
12	500.	2.83	707.	4.01	999.	5.67	1413.	8.02

Chart shows gpm that will flow when pipe is half full. Half full means filled to half of the diameter of the pipe.
Computed from the manning formula for 1/2 full pipe, n = 0.015
For 1/4 full: multiply discharge by .274 and velocity .701
For 3/4 full: multiply discharge by 1.82 and velocity 1.13
For full: multiply discharge by 2.00 and velocity 1.00
For smoother pipe: multiply discharge and velocity by 0.015 and devide by "n" value of smoother pipe

Higher velocities, or greater drop per foot, will increase the carrying capacity of a drain. When designing fixture branches, keep in mind that a slope/drop of more than 1/4 inch per foot may cause siphonage of the trap seal.

Sizing Building Drains

The building drain in a sanitary system must be of sufficient size to carry off all the water and waste materials that may be discharged into it at any one time. The minimum allowable size is 3 inches for cast-iron pipe, but sound practice prescribes a 4-inch pipe, and most plumbing codes or ordinances require 4-inch pipe as a minimum. Increasing the size beyond that computed as required (the minimum of 3 inches still applies) does not increase the efficiency of the drain. The passage of liquid and solid waste through a horizontal pipe creates a natural scouring action, which is partially lost when the size of the drain is increased above the necessary size. The flow in too large a pipe is shallow and slow, and solids tend to settle to the bottom. The solids may accumulate to such an extent that they cause stoppages in the line. The optimum size of pipe should flow half full under normal use. This will create an efficient natural scouring action and still allow capacity for peak loads.

The standard method used in determining the size of a building drain is the Unit System. Drainage fixture unit system values for standard plumbing fixtures have been established and some of the most common are shown in table 7-2. Use the trap size listing at the bottom of table 7-2 for estimating drainage fixture unit (d. f u.) values for fixtures that are not listed.

To select the correct size of pipe for a horizontal sanitary drainage system, you must first calculate the total volume of liquid waste, expressed in drainage fixture units, that the system will be subjected to. Assume, for example, that a plumbing installation is to consist of 20 water closets, valve-operated; 22 lavatories with 1 1/4-inch traps; 15 shower heads in group showers; 20 wall urinals; 2 service sinks with standard traps; and 4 floor drains (2-inch). The total discharge,

Table 7-2.—Drainage Fixture Unit Values for Various Plumbing Fixtures

Type of Fixture or Group of Fixtures	Drainage Fixture Unit Values
Automatic clothes washer (2 "standpipe)	3
Bathroom group consisting of a water closet, lavatory and bathtub or shower stall:	
Flushometer valve closet	8
Tank-type closet	6
Bathtub (with or without overhead shower) 1 1/2 "trap	2
Bidet 1 1/2 "trap	3
Clinic sink	6
Combination sink-and-tray with food waste grinder 1 1/2 "trap	4
Combination sink-and-tray with one 1 1/2 " trap	2
Combination sink-and-tray with separate 1 1/2 "traps	3
Dental unit or cuspidor	1
Dental lavatory	1
Drinking fountain	1/2
Dishwasher, domestic	2
Floor drains with 2 "waste	3
Kitchen sink, domestic, with one 1 1/2 " trap	2
Kitchen sink, domestic, with food waste grinder	2
Lavatory with 1 1/4 "waste	1
Laundry tray (1 or 2 compartments)	2
Shower stall, domestic 2 "trap	2
Showers (group) per head	2
Sinks:	
Surgeon's	3
Flushing rim (with valve)	6
Service (trap standard)	3
Service (P trap)	2
Pot, scullery, etc.	4
Urinal, pedestal, siphon jet blowout	6
Urinal, stall lip	4
Urinal stall, washout	4
Urinal trough (each 6-foot section)	2
Wash sink (circular or multiple) each set of faucets	2
Water closet, tank-operated	4
Water closet, valve-operated	6
Fixtures not listed above:	
Trap Size 1 1/4 "or less	1
Trap Size 1 1/2"	2
Trap Size 2 "	3
Trap Size 2 1/2 "	4
Trap Size 3 "	5
Trap Size 4 "	6

expressed in drainage fixture units, would be calculated as follows from table 7-2.

Number and Type of Fixtures	Unit Values	Total Discharge
20 water closets (flush valve)	6	120
22 lavatories (1 1/4-inch traps)	1	22
15 shower heads	2	30
20 urinals (wall)	4	80
2 sinks (service)	3	6
4 floor drains (2-inch)	3	12
		270 d.f.u.

After calculating the total discharge and determining the slope of the piping and the velocity of flow, select the correct size of pipe by using table 7-3. Assume that the cast-iron house drain to be installed will have a slope of 1/4 inch per foot. From table 7-3, the minimum size pipe for the horizontal sanitary drainage system under discussion is 5 inches.

Table 7-3 is for cast-iron soil pipe or galvanized steel pipe house drains, house sewers, and waste and soil branches. When copper tubing is used, it may be one size smaller than shown in the table. Note that the size of building drainage lines must never decrease in the direction of flow.

When provision is made for the future installation of fixtures, those provided for must be considered in determining the required sizes of drainpipes. Construction to provide for such future installation should have a plugged fitting or fittings at the stack to eliminate any dead ends.

Sizing Stacks and Branches

The term *stack* is used for the vertical line of soil or waste piping into which the soil or waste branches carry the discharge from fixtures to the house drain. A *waste stack* carries liquid wastes that do not contain human excrement; a *soil stack* carries liquid wastes that do.

Most buildings do not have separate soil and waste stacks. A single stack known as the soil and waste stack, or simply the soil stack, serves to carry both soil and waste material. Soil stacks are usually made of cast-iron pipe with caulked joints. They may, however, be made of other materials

Table 7-3.—Maximum Loads for Horizontal Drains

Diameter of Drain	Horizontal Fixture Branch	Building Drain or Building Sewer Slope			
		1/16-in/ft	1/8-in/ft	1/4-in/ft	1/2-in/ft
(inches)	(d.f.u)[1]	(d.f.u.)	(d.f.u.)	(d.f.u.)	(d.f.u.)
1 1/4	1				
1 1/2	3				
2	6				26
2 1/2	12			24	31
3	32[2]		36[3]	42[2]	50[2]
4	160		180	216	250
5	360		390	480	575
6	620		700	840	1000
8	1400	1400	1600	1920	2300
10	2500	2500	2900	3500	4200
12	3900	3900	4600	5600	6700
15	7000	7000	8300	10000	12000

[1]Drainage fixture unit.

[2]Not more than two water closets or two bathroom groups.

[3]Less than 2 feet per second.

such as galvanized steel or copper tubing. Branches are usually either threaded galvanized steel pipe with drainage (recessed) fittings or copper tubing.

Sizing the Stack

The stack is sized in the same way as the building sewer. The maximum discharge of the plumbing installation is calculated in drainage fixture units. This figure is applied to table 7-4 or table 7-5 to obtain the proper stack size.

Continuing our example, the 270 drainage fixture units would require a 5-inch stack, if the stack had less than three branch intervals. (No soil or waste stack should be smaller than the largest horizontal branch connected, except that a 4 x 3 water closet connection should not be considered as a reduction in pipe size.)

Offsets on Drainage Piping

An offset above the highest horizontal branch is an offset in the stack vent and should be considered only as it affects the developed length of the vent.

An offset in a vertical stack with a change in direction of 45 degrees or less from the vertical piping may be sized as a straight vertical stack. In piping where a horizontal branch connects to the stack within 2 feet above or below the offset, a relief vent should be installed.

A stack with an offset of more than 45 degrees from the vertical should be sized as follows:

1. The portion of the stack above the offset should be sized for a regular stack, based on the total number of drainage fixture units above the offset.
2. The offset should be sized as for the building drain. See table 7-3.
3. The portion of the stack below the offset should be sized as for the offset, or based on the total number of drainage fixture units of the entire stack, whichever is larger. A relief vent should be installed for the offset. Never connect a horizontal branch or fixture to the stack within 2 feet above or below the offset.

Table 7-4.—Maximum Loads for Soil and Waste Stacks Having Not More Than Three Branch Intervals

Diameter of Stack	Maximum Load On Any One Branch Interval	Maximum Load On Stack
(inches)	(d.f.u)[1]	(d.f.u.)
1 1/4	1	2
1 1/2	2	4
2	4	9
2 1/2	8	18
3	20[2]	48[2]
4	100	240
5	225	540
6	385	930
8	875	2100

[1]Drainage fixture unit.

[2]Not more than two water closets or bathroom groups within each branch interval nor more than six water closets or bathroom groups on the stack.

Sizing Individual Waste Lines

The water closet, strictly speaking, has no waste. It is usually connected directly into the stack on a short as possible separate branch of its own by the use of a closet bend. The closet bend is 3 or 4 inches in diameter if made of cast iron or steel and 3 inches if made of copper.

Because lavatories are used for washing hair, loose hair is often carried down into the waste pipe, causing a stoppage. Lavatory drainage is improved by using a minimum number of fittings and by eliminating long horizontal runs. The minimum pipe size for lavatory wastes is 1 1/4 inches, but 1 1/2 inches is more satisfactory.

Urinals present a particular problem because cigarette butts, cigar stubs, chewing gum, matches, and so on are often discarded in them. These materials can easily cause a stoppage. For this reason, urinals should be equipped with an effective strainer. Size of waste pipe should be at least 1 1/2 inches for wall-mounted urinals and 3 inches for the pedestal siphon jet urinal.

Shower wastes seldom cause trouble since they have a relatively clear water waste flowing through them. The usual diameter of the waste pipe for a single shower is 2 inches if made of cast iron or steel and 1 1/2 inches if made of copper.

A domestic kitchen sink requires a 1 1/2-inch cast-iron or steel waste pipe. When a sink is equipped with a garbage disposal unit, a minimum of 2 inches is required for the cast-iron or steel drainage piping.

Table 7-5.—Maximum Loads for Soil and Waste Stacks Having Four or More Branch Intervals

Diameter of stack (inches)	Number of Branch Intervals: 4		5		6		7		8		9		10	
	on any one interval	on stack	on any one interval	on stack	on any one interval	on stack	on any one interval	on stack	on any one interval	on stack	on any one interval	on stack	on any one interval	on stack
in.	d.f.u.[1]	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.
2	3	13	3	16	3b	18c								
3a	18a	72a	17a	85a	16a	96a	15ab	102ac						
4	90	360	84	420	80	480	76b	530c						
5	205	820	190	950	180	1,080	175	1,215	170	1,360	155b	1,400c		
6	350	1,400	325	1,625	310	1,860	299	2,090	290	2,320	285	2,560	280	2,800
8	785	3,140	735	3,675	700	4,200	675	4,725	655	5,240	640	5,780	630	3,300
10	1,405	5,620	1,310	6,550	1,200	7,500	1,205	8,435	1,170	9,360	1,145	10,310	1,125	11,250
12	2,195	8,780	2,045	10,225	1,950	11,700	1,880	13,160	1,825	14,600	1,790	16,090	1,755	17,550
15	3,935	15,740	3,675	18,375	3,500	21,000	3,375	23,620	3,280	26,240	3,210	28,880	3,150	31,500

Diameter of stack (inches)	Number of Branch Intervals: 11		12		13		14		15		16	
	on any one interval	on stack	on any one interval	on stack	on any one interval	on stack	on any one interval	on stack	on any one interval	on stack	on any one interval	on stack
in.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.
2												
3a												
4												
5												
6	265b	2,900c										
8	620	6,830	610	7,350	585b	7,600c						
10	1,110	12,200	1,095	13,100	1,080	14,070	1,070b	15,000c				
12	1,730	19,020	1,705	20,500	1,690	21,960	1,670	23,410	1,655	24,800	1,620b	26,000c
15	3,100	34,160	3,060	36,700	3,030	39,390	3,000	42,015	2,975	44,600	2,955	47,280

[1]Drainage fixture units.

a. Not more than two water closets or bathroom groups within any one branch interval and not more than six water closets or bathroom groups on the stack.

b. Loads on any one branch interval for higher stacks shall not exceed these values; however, this shall not prevent the installation of higher stacks.

c. Stack loads for higher stacks shall not exceed these values; however, this shall not prevent the installation of higher stacks.

There are two styles of service sinks (slop sinks): the trap-to-wall and the trap-to-floor. They are used for disposal of wash water, filling swab buckets, and washing out swabs. The trap-to-wall type requires a 2-inch or 3-inch waste pipe; the trap-to-floor, a 3-inch waste pipe. For both types, if copper tubing is used, a one size reduction is allowed.

Scullery sinks are large sheet metal sinks used for washing large pots and pans and for general scouring purposes. The large amount of grease that usually passes through a scullery sink makes a 2-inch waste pipe necessary.

Drinking fountains carry only clear water wastes and a 1 1/4-inch waste pipe is suitable. An indirect drain (covered later in this chapter) should be used.

Sizing Sanitary Collecting Sewers

The design and sizing of collecting sewers, the subtrunks, and the main trunk lines are provided by engineers. However, the UT should understand the factors that contribute to the design and the requirements that must be met.

While the unit system is used to size the building sanitary piping and the building drain, the sewage quantities used in sewer design normally are computed on a contributing population basis. The population to be used in design depends upon the type of area that the sewer is to serve. If the area is strictly residential, the design population is based on full occupancy of all quarters served. If the area is industrial, the design population is the greatest number employed in the area at any time. There are exceptions to the general rule that sewers must be designed on a population basis. Among these exceptions are laundry sewers and industrial-waste sewers. The per capita contribution for sewer design varies. Typical values are 100 gallons per person per day for permanent residents and 30 gallons per person in the industrial area per 8-hour period.

The sizing of the sewer includes the average rate and the extreme (peak) rate of flow (which occurs occasionally). The ratio of the peak rate of flow to the average rate of flow may vary with the area served, because the larger the area or the greater the number of persons served, the greater the tendency for flow to average out. Typical peak flows might range from 6 for small areas down to 1.5 for larger areas.

An allowance for infiltration of subsurface water is added to the peak flow to obtain the design flow. A typical infiltration allowance is 500 gallons per inch of pipe diameter, per mile of sewer per day.

Additional capacity to provide for population increase is usually included for areas that are likely to continue to develop. Provision of approximately 25 percent additional capacity over the initial requirements is advisable.

Each length of pipe from one manhole to the next is sized to carry the design flow. However, to help prevent clogging and to facilitate maintenance, a minimum size is usually specified which may be larger than is necessary to carry the design flow at the upper ends of the system. Typical minimum sizes are 6-inch pipe for house and industrial-waste sewers and 8-inch pipe for all other sewers.

It is sometimes the practice to select a pipe size that will carry the design flow when the pipe is half full, thus allowing for expansion. More often, however, sufficient safety factors in the future population estimate and the peak flow factor are included so the pipe may be designed to carry the design flow when flowing full.

The formulas or tables used in sizing the pipe are based on experiments and experience. One of the factors taken into account is the roughness of the pipe. Asbestos-cement pipe, for example, is smoother than concrete pipe. Because there is less friction on the inside of the asbestos-cement pipe, it will carry a greater flow than concrete pipe of the same size.

Another factor is the slope at which the pipe will be laid. The slope will generally be determined by the fall available on the natural ground area through which the sewer runs. The plans for collecting sewer systems generally show slope (or grade) in terms of fall per hundred feet. Slope is sometimes expressed as a percent rather than in inches per foot. A 1 percent slope means 1 foot of frill in a 100-foot length of pipe, or about 1/8 inch per foot. A 0.5 percent slope (6 inches in 100 feet is about 1/16 inch per foot.

Table 7-6 gives the minimum slope for some of the most commonly used pipe sizes. The slope should remain constant in the section between each manhole. Each section between successive manholes should be analyzed and the slope for that particular section determined. If the fall is relatively steep, the velocity of the flow is faster and a smaller pipe size may be used. If the slope is relatively flat, the velocity is slower and a larger pipe size may be used. In the larger pipe, the depth of flow may decrease to such extent that the velocity might be no greater than a smaller pipe

Table 7-6.—Minimum Slope for Sewer Pipe

Inside pipe diameter (inches)	Minimum fall (ft per 100 ft)
6	0.6
8	0.4
10	0.3
12	0.24
18	0.14

on the same grade. Therefore, an increase in pipe size to obtain the desired flow velocity is limited by the rate of flow. Typical minimum flow velocities are 2 feet per second when the design flow fills the pipe and 1.6 feet per second at the average rate of flow. Maximum velocities must also be considered; too high a velocity will erode the pipe. A typical maximum velocity is 15 feet per second for concrete pipe. Because of the differences in available slopes, smaller pipe may be used in some sections than is required in an upper section of the same sewer. The pipe size should be reduced whenever better flow conditions would result.

Manholes provide access to sewers for inspection and cleaning. They are placed where there is a change in grade, a change in pipe size, a junction of two or more sewerlines, or a change in direction. Otherwise, they are placed at intervals of 300 or 500 feet of sewerline. The manholes should be built so there is no decrease in velocity and a minimum of water disturbance. The channel should be deep enough to prevent sewage from spreading over the manhole bottom. The covers should be of a weight strong enough to support the expected traffic. Perforated covers should not be used for sanitary sewer manholes, because openings in the sewer manhole would permit the entrance of sand, grit, and surface water. The sewers are ventilated by the stacks of the building plumbing systems.

STORM DRAINAGE SYSTEMS

Storm drainage systems are designed to drain all surface and sometimes subsurface water that may cause damage to Navy facilities, property, or adjoining land. They consist of pipe, inlets, catch basins, and other drainage structures to carry the surface runoff and subsurface water to a point of disposal.

Storm drainage systems should be separate from sanitary sewage systems wherever possible. Some Navy bases may have combination systems still in use. However, storm water should never be drained into sewers intended for sanitary sewage only.

EOs and BUs generally are responsible for building ditches, culverts, and other structures that are a part of storm sewers. Therefore, construction of these facilities is not covered in this chapter.

The UT is generally concerned with only the pipework itself. This involves laying storm drain lines both inside and outside buildings and other structures. This pipe material may be the same as that used for the sanitary system. Storm sewer systems, however, may include pipe of much larger sizes than are needed for sanitary sewers. Plain or reinforced concrete pipe (rather than clay, cast iron, or asbestos cement) is generally used for the larger lines. Also, it is not so important that the joints be watertight in storm sewer systems. In fact, the mortar is sometimes omitted from a portion of the joint and washed gravel is placed next to the opening; the storm drain thus serves also as an underdrain to pick up subsurface water.

Installation Considerations

Storm and sanitary systems may differ in the installation of the piping. Building storm drains should generally be graded at least 1/4 inch per foot whenever feasible. This amount of drop per foot provides an unobstructed and self-scouring flow. However, a greater drop per foot may be given as no fixture traps which might lose their seals are associated with it.

When a change of direction is necessary, long radius fittings are used and a cleanout need not be installed. This is especially true in and under buildings. But a manhole is used outside of buildings when a change of direction is necessary, or when two or more lines are connected together.

Sizing Building Storm Drains

To determine the size of building storm drains, a number of factors must be considered, such as rainfall intensity, roof size, and pitch of roof. Tables have been made for use in estimating the size of pipe to select. One example is table 7-7; it shows storm drain sizes. Remember that this table is to be used only as a guide when estimating for storm drainage, as different areas have different intensities of rainstorms.

Another method for sizing building storm drains is to provide 1 square inch of pipe cross-sectional area for each 100 square feet of roof area. This method is easy to remember: 1 square inch for 100 square feet. (However, it is not as accurate as using table 7-7.) Using this method, you can prepare a table similar to table 7-8. Show the diameter in the first column; then the radius (which is one-half the diameter); then the square of the radius; then the cross-sectional area, which is *pi* (3.14) times the radius squared. Since each square inch may take 100 square feet of roof, move the decimal of the square inches over two places to the left (which is multiplying by 100) to get the area of the roof that may be drained to the pipe. As you can see by comparing table 7-7 with table 7-8, the second method is much more conservative.

Sizing Site Storm Sewers

While rules of thumb such as those just described are used to size building storm drains, different procedures are used to size the storm sewers that carry the runoff from the building site and surrounding land areas. The design and sizing of storm drains are provided by engineers. It is not necessary that the UT understand the factors that contribute to the design. Therefore, the information is not included here.

WATER SUPPLY SYSTEMS

After the pipe runs and fittings are located on a print or drawing, the size, quantity, and joining requirements of the pipe must be determined. When a plumbing print is available for the job, it will contain this information. If there is no blueprint, you must determine these requirements yourself. The quantity of pipe required and the number and types of fittings you intend to use

Table 7-8.—Fixture Demand

Fixture	Units[a]	Gallons per minute
Water closet	6	45
Urinal	5	39 1/2
Slop sink	3	22 1/2
Shower	2	15
Laundry tray	2	15
Bathtub	2	15
Kitchen sink	2	15
Lavatory	1	7 1/2

[a]1 unit = 7 1/2 gallons per minute

Table 7-7.—Size of Horizontal Building Storm Drains and Building Storm Sewers

Diameter of Drain (inches)	Maximum Projected Area for Drains of Various Slopes					
	1/8-Inch Slope		1/4-Inch Slope		1/2-Inch Slope	
	Square Feet	gpm[2]	Square Feet	gpm	Square Feet	gpm
3	822	34	1,160	48	1,644	68
4	1,880	78	2,650	110	3,760	156
5	3,340	139	4,720	196	6,680	278
6	5,350	222	7,550	314	10,700	445
8	11,500	478	16,300	677	23,000	956
10	20,700	860	29,200	1,214	41,400	1,721
12	33,300	1,384	47,000	1,953	66,600	2,768
15	59,500	2,473	84,000	3,491	119,000	4,946

[1]Table 7-7 is based upon a maximum rate of rainfall of 4 inches per hour for a 5 minute duration and a 10 year return period. Where maximum rates are more or less than 4 inches per hour, the figures for drainage area shall be adjusted by multiplying by four and dividing by the local rate in inches per hour.

[2]Gallons per minute.

are easily determined by tracing the layout of the water supply system as drawn in a print or sketch. Determining the size pipe you will require to meet the fixture demand of a facility is more complicated and will be discussed in this section.

Sizing Cold-Water Supply Systems

Some factors that affect the size of the water service in a plumbing system are the types of flush device used on the fixtures, the pressure of the water supply in pounds per square inch (psi), the length of the pipe in the building, the number and kind of fixtures installed, and the number of fixtures used at any given time. The stream of water in a pipe is made up of a series of layers moving at different speeds with the center layer moving the fastest. The resistance to flow is called *pipe friction* and causes a drop in pressure of the water flowing through the pipe. Friction loss may be overcome by supplying water at greater pressure than would normally be required or by increasing the size of the pipe.

The two most important things to consider are the maximum fixture demand and the factor of simultaneous fixture use. The *maximum fixture demand* in gallons is the total amount of water that would be needed to supply all fixtures if they were being used at the same time for 1 minute. Since it is very unlikely that all fixtures would be turned on at the same time, a probable percentage of the fixtures in use at any given time must be found. This is the *factor of simultaneous use.* The more fixtures in a building, the smaller the possibility that all will be used at the same time. Therefore, simultaneous use factors decrease as the number of fixtures increase.

To estimate the maximum fixture demand in gallons, the number and type of all fixtures in the completed plumbing system must be known. Table 7-8 is used to obtain the maximum fixture demand. For example, assume a plumbing system consists of three urinals, two water closets, one slop sink, two shower stalls, one kitchen sink, one laundry tray, and four lavatories. From table 7-8 a maximum fixture demand of 321 gallons per minute (gpm) can be figured. Normally only a small percentage of fixtures would be used at the same time, so the maximum fixture demand is reduced by applying the factor of simultaneous use.

The factor of simultaneous use, also called the probable demand, is only an estimate. Table 7-9 gives data for making an estimate of probable demand. When using this table, take the actual number of fixtures installed, not the fixture unit value. For example, five fixtures would have a probable demand of about 50 percent, while 45 fixtures would have a probable demand of about 25 percent. When a table showing the factors of simultaneous use is not available, a practical way of figuring the probable demand is 30 percent of the maximum fixture demand in gallons.

Many factors affect the flow of water through pipes resulting in a loss of water pressure. Difficult calculations are required to consider all the factors involved that may cause a loss of water pressure. These calculations are beyond the range of this manual. For simple systems, approximate figures are acceptable for most plumbing installations.

Table 7-10 (for galvanized iron pipe) and table 7-11 (for copper tubing) may be used with the maximum fixture demand and the factor of simultaneous use to find the correct size of pipe for water-service lines. The minimum practical size for a water-service line is 3/4 inch. This size should be used even when calculations show that a smaller size could be used.

To continue the example above, the 14 fixtures would have a factor of simultaneous use of about 35 percent. Since the maximum fixture demand was 321 gpm, the water-service line must have a capacity of 35 percent of 321, or 112 gpm. Assuming a length of pipe 60 feet long and a pressure at the main of 40 psi, table 7-10 or 7-11 shows that either a 1 1/2-inch galvanized iron or a 1 1/2-inch copper tubing water-service line would be large enough for the example fixture demand.

Sizing Hot-Water Supply Systems

The hot-water system is that part of the plumbing installation that heats water and distributes it to various fixtures. There are many ways of heating the water, but whichever is used must be able to supply maximum demand. The materials used in hot-water systems are similar to those used in cold-water supply systems. The use

Table 7-9.—Factors of Simultaneous Use

No. of fixtures	Percent of simultaneous use
1-4	50-100
5-50	25-50
51 or more	10-25

Table 7-10.—Capacitiesof Pipe in Gallons Per Minute (Galvanized Iron)

a. 3/8 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	5	3	3	2	2	2	----	----	----	----
20	9	5	4	3	3	3	2	2	2	2
30	10	6	5	4	4	3	3	3	3	2
40	----	8	6	5	4	4	4	3	3	3
50	----	9	7	6	5	4	4	3	3	3
60	----	9	7	6	6	5	5	4	4	4
70	----	10	8	7	6	6	5	5	4	4
80	----	----	8	7	7	6	5	5	5	4

b. 1/2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	10	8	5	5	4	3	3	3	3	3
20	14	10	8	6	6	5	5	4	4	4
30	18	12	10	8	8	7	6	6	5	5
40	20	14	11	10	10	8	7	7	6	6
50	----	16	13	11	11	9	8	7	7	7
60	----	18	14	12	12	10	9	9	8	7
70	----	----	15	13	12	11	10	9	8	8
80	----	----	----	----	----	----	----	----	----	----

c. 3/4 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	22	14	12	10	8	8	7	6	6	6
20	30	22	18	14	12	12	11	10	10	8
30	38	26	22	18	16	14	13	12	12	10
40	----	30	24	21	19	17	16	16	15	13
50	----	34	28	24	21	19	18	17	16	15
60	----	38	31	26	23	21	20	19	18	17
70	----	----	34	29	25	23	22	21	19	18
80	----	----	36	30	27	24	23	22	21	20

d. 1 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	40	28	22	18	16	15	14	13	12	11
20	55	40	32	27	24	22	20	19	18	16
30	70	50	40	34	30	27	25	23	22	20
40	80	58	45	40	35	32	29	27	25	24
50	----	65	57	45	40	36	33	31	29	27
60	----	70	58	50	44	40	36	34	32	30
70	----	76	63	54	45	42	40	37	34	32
80	----	----	65	57	47	43	39	37	35	33

Table 7-10.—Capacities of Pipe in Gallons Per Minute (Galvanized Iron)—Continued

e. 1 1/4 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	80	55	45	37	35	30	27	25	26	24
20	110	80	65	55	50	45	41	38	36	34
30	----	100	80	70	60	56	51	47	45	42
40	----	----	95	80	72	65	60	56	52	50
50	----	----	107	92	82	74	68	63	60	55
60	----	----	----	102	90	81	75	70	65	62
70	----	----	----	----	97	88	82	74	69	67
80	----	----	----	----	105	95	87	79	74	72

f. 1 1/2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	120	90	70	60	55	50	45	40	40	35
20	170	130	100	90	75	70	65	60	55	55
30	----	160	130	110	100	90	80	75	70	65
40	----	170	150	130	110	100	90	90	80	80
50	----	----	170	140	130	120	110	100	90	90
60	----	----	----	160	140	130	120	110	100	100
70	----	----	----	170	150	140	130	120	110	100
80	----	----	----	----	160	150	140	130	120	110

g. 2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	240	160	130	110	100	90	90	80	80	70
20	300	240	200	160	150	140	130	120	110	100
30	----	300	240	200	180	160	150	140	140	130
40	----	----	280	240	220	200	180	160	160	150
50	----	----	----	280	240	220	200	200	180	160
60	----	----	----	----	280	240	220	200	200	180
70	----	----	----	----	300	260	240	220	220	200
80	----	----	----	----	----	280	260	240	220	220

Table 7-11.—Capacities of Pipe in Gallons Per Minute (Copper Tubing)

a. 1/2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	8	5	4	3	3	2	2	2	2	2
20	12	8	6	5	5	4	4	3	3	3
30	15	10	8	7	6	5	5	4	4	4
40	17	12	9	8	7	6	6	5	5	4
50	----	14	10	9	8	7	6	6	5	5
60	----	15	12	10	9	8	7	7	6	6
70	----	----	13	11	10	9	8	7	7	6
80	----	----	14	12	10	10	8	8	7	7

b. 5/8 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	12	8	7	6	5	5	4	4	3	3
20	18	12	10	9	7	6	6	5	5	5
30	22	16	12	10	9	9	8	7	6	6
40	26	18	14	12	10	10	9	8	8	7
50	----	22	16	14	12	11	10	9	9	8
60	----	24	18	16	14	13	12	11	10	9
70	----	----	20	18	15	14	13	12	11	10
80	----	----	22	19	16	15	14	13	12	11

c. 3/4 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	20	14	10	10	8	8	6	6	6	5
20	30	20	16	14	12	10	10	10	8	8
30	36	26	20	17	15	14	13	11	10	8
40	----	30	24	20	18	16	15	14	13	12
50	----	34	28	24	20	18	16	16	14	14
60	----	36	30	26	22	20	18	18	16	16
70	----	----	32	28	24	22	20	18	18	16
80	----	----	36	30	26	24	22	20	18	18

d. 1 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	50	30	24	20	18	16	14	14	12	12
20	70	45	36	30	26	24	22	20	18	18
30	80	55	45	38	34	30	28	26	24	22
40	----	65	55	45	40	36	32	30	28	26
50	----	75	60	50	45	40	36	34	32	30
60	----	80	65	55	50	45	40	38	36	34
70	----	----	70	60	55	50	45	40	38	36
80	----	----	80	65	60	50	50	45	40	40

Table 7-1l.—Capacities of Pipe in Gallons Per Minute (Copper Tubing)—Continued

e. 1 1/4 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	80	55	42	37	32	30	27	25	22	22
20	110	80	65	55	47	42	40	35	35	32
30	----	105	80	70	60	55	50	45	42	40
40	----	110	95	80	70	65	60	55	50	47
50	----	----	110	90	80	70	65	60	57	55
60	----	----	----	105	90	80	75	70	65	60
70	----	----	----	110	100	90	80	75	70	65
80	----	----	----	----	105	95	85	80	75	70

f. 1 1/2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	130	90	70	60	50	45	40	40	35	35
20	170	130	100	90	75	70	65	60	55	50
30	----	170	130	110	100	90	80	75	70	65
40	----	----	155	130	115	105	95	88	80	77
50	----	----	170	150	130	120	108	100	90	88
60	----	----	----	165	145	130	120	110	105	98
70	----	----	----	170	160	142	130	122	113	106
80	----	----	----	----	170	155	140	130	122	115

g. 2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	280	180	150	145	110	100	90	85	80	70
20	320	280	220	190	165	160	140	125	120	110
30	----	320	280	240	210	180	170	160	150	140
40	----	----	320	280	240	220	200	190	175	160
50	----	----	----	320	280	250	230	210	200	190
60	----	----	----	----	300	280	260	240	220	200
70	----	----	----	----	320	300	280	260	240	230
80	----	----	----	----	----	320	300	280	260	240

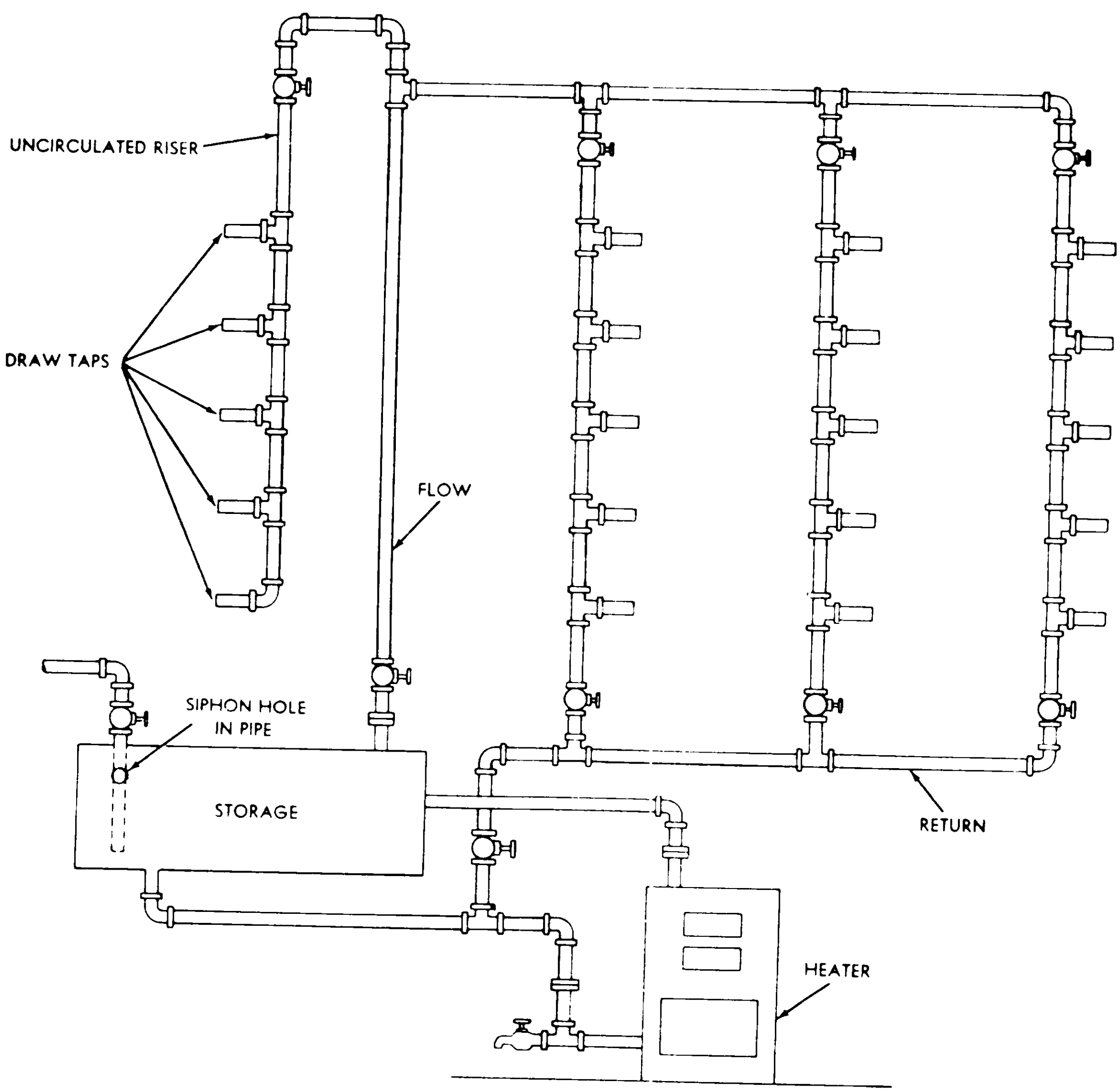
of copper has become the most popular because of copper's ability to resist corrosion that increases in proportion to the temperature of the water. Sizing of the piping for a hot-water system is done the same way as for a cold-water system.

The layout of a hot-water system is designed to carry heated water from a storage unit to plumbing fixtures. Installation planning begins with the water-heating device and a main supply line from that device. The system should be graded to a centrally located drip cock near the water heater to allow for draining the system when maintenance is required. Water for the individual fixtures located throughout the facility is taken off the main hot-water supply by risers as needed.

Each fixture riser should have a valve to make repair work easier.

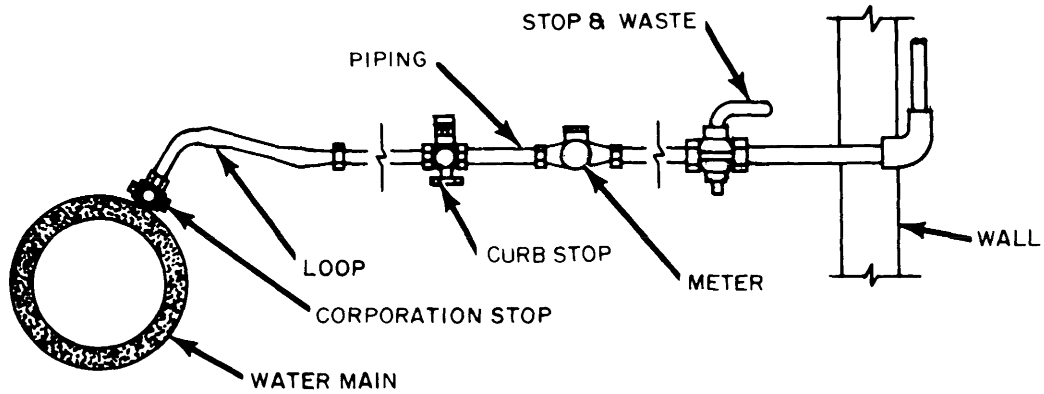
Buildings of considerable floor area or of multifloor construction have the added problem of supplying hot water to the fixture as soon as possible after the tap is opened. In a one-pipe system (such as that used for cold-water supply), a lag occurs from the time the hot-water tap is opened until the heated water travels from the the water-heating device to the fixture. To overcome this lag, a circulating water supply system is often used. (See fig. 7-2.)

The circulating supply system is a two-pipe system in which hot water flows from the heating device through the main fixture risers and returns to the heating device. This type of looped system



87.338

Figure 7-2.—Hot-water circulating supply system.



87.339

Figure 7-3.—Typical building water supply system.

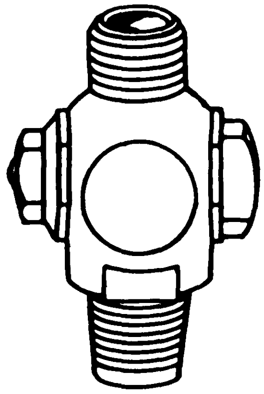


Figure 7-4.—Corporation stop.

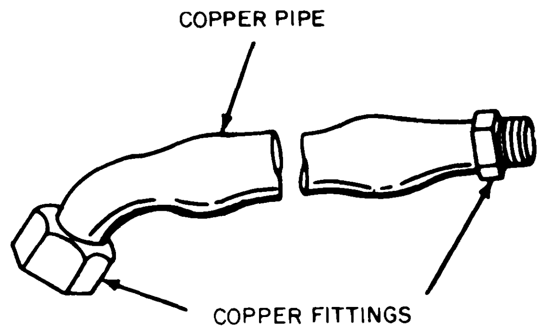


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Figure 7-5.—Flexible gooseneck connector.

provides for circulation of the hot water at all times. The circulation is created because warm water tends to rise and cold water tends to fall.

The circulating system shown in figure 7-2 is known as an overhead feed and gravity-return system because of its construction. This type of system tends to become airbound, preventing circulation of the hot water. Since air collects at the highest point of the distribution piping, the most practical way to relieve the air lock is to connect an uncirculated riser to the line at that point. Any air lock that develops is relieved when a fixture on the uncirculated riser is used.

Piping and Fitting General Requirements

A typical building water-service line is shown in figure 7-3. This line is composed of a corporation stop, a flexible connector, a curb stop, a stop and waste valve, and a meter stop or gate valve.

The corporation stop is installed at the location (fig. 7-4) on the water main where a tap is made. Its function is to make the removal of the taping machine and the installation of the remaining fittings easier by securing the water flow from the tap. A corporation stop may not be needed if you are installing building service lines from a newly installed, unpressurized water main.

When you install the line between the corporation stop and the curb stop, use some type of flexible connection for joining the pipe to the corporation stop. This flexible connection protects the corporation stop from strain or damage that can result from any movement of the water main or service pipe because of settling, earth movement, or expansion and contraction.

Several types of flexible connectors are used. The type you choose will depend on the type of material used for the supply line. A *gooseneck* (fig. 7-5) is used when galvanized iron or steel pipe is used as the supply line. It consists of a length of copper pipe with fittings wiped or soldered on each end. Another flexible connector is the *swing joint* type commonly used with galvanized iron or steel service lines. (See fig. 7-6.) This connection consists of two elbows separated by a short section of pipe or a nipple. Next is the *expansion loop* (fig. 7-7) used when copper tubing is used as the service line.

A curb stop must be provided in every service line to conform to the *National Standard Plumbing Code,* paragraph 10.12.1. (See fig. 7-8.) The curb stop provides an accessible shutoff of the water supply to the building.

Next, a stop and waste valve (fig. 7-9) will be installed to conform to the *National Standard Plumbing Code,* paragraph 10.12.2. This valve is used to drain the building water system. It must be installed at a point where drainage by gravity can be achieved. When the valve is turned off, drainage will occur through a drilled passage in the valve body.

Finally, a meter stop is installed when a water meter is to be included in the service line (fig. 7-10). It is installed on the pressure side of the meter and can be used for convenient securing of the water supply to the building. Where no meter is used, a simple gate valve may be provided for convenient use when repairing or maintaining the building water lines.

Each fixture to be installed requires a fixture stop valve and a certain size branch and riser piping. Branch lines are calculated in the same fashion as service supply lines. Risers for each

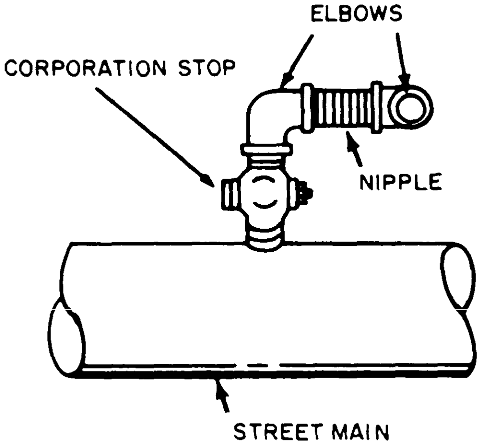

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Figure 7-6.—Typical swing joint.

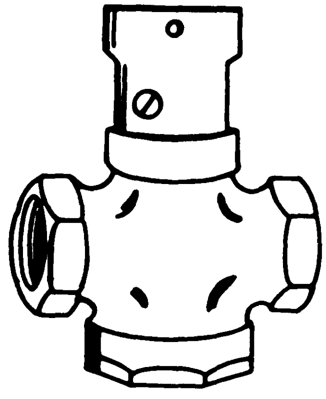

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Figure 7-8.—Curb stop.

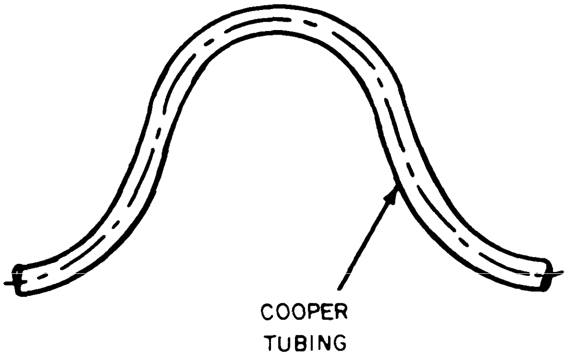

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Figure 7-7.—Expansion loop.

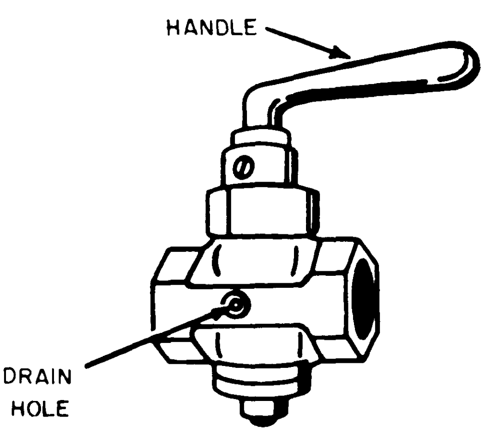

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Figure 7-9.—Stop and waste valve.

individual fixture are sized according to table 7-12 for both cold- and hot-water risers. A typical layout for branch lines and fixture risers is shown in figure 7-11.

For more complete information, refer to the latest edition of the *National Standard Plumbing Code.* The code will guide you in determining all required installation considerations of facility water supply system needs.

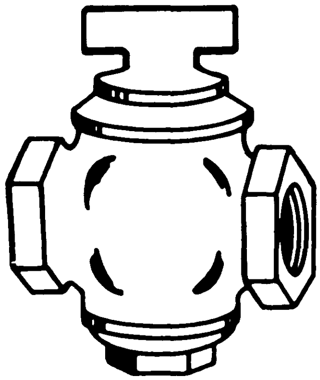

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Figure 7-10.—Meter stop.

CORROSION PREVENTION AND PROTECTION

As a Utilitiesman, you must consider the effects of corrosion on the equipment that you are installing. When planning a project, the

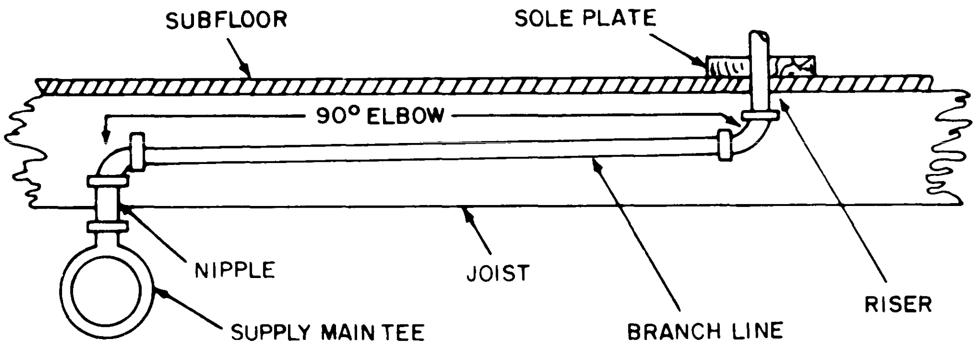

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Figure 7-11.—Water supply branch line.

Table 7-12.—Water Pipe Size Chart for Plumbing Fixtures

PLUMBING FIXTURE	PIPE DIAMETER (inches)
Dishwasher	1/2 or 3/4
Water closet tank	1/2
Water closet flushometer valve	1
Urinal with flushometer valve	1/2
Lavatory	1/2
Shower bath	1/2
Kitchen sink	1/2
Slop sink	1/2
Scullery sink	3/4
Laundry tray	1/2
Drinking fountain	1/2
Hot-water heater (domestic)	3/4
Bathtub	1/2

necessary materials and equipment required for galvanic cathodic protection of underground pipes and fittings must be considered. First you must understand what corrosion is and how it occurs.

TYPES OF CORROSION

Man has had corrosion problems to contend with ever since he started making articles out of metal. For thousands of years, the only fact known about corrosion was that it would affect some metals more than others. For example, iron, one of the most abundant and useful metals, corrodes very much; whereas metals such as gold, platinum, and silver corrode very little. Later, men began to study corrosion to find out what caused it. As might be expected, many theories were proposed to explain corrosion and its causes. Among the many theories, the electrochemical theory is most generally accepted as an explanation of corrosion.

The electrochemical theory of corrosion is best explained by the action that takes place in a galvanic cell. A galvanic cell can be produced by placing two dissimilar metals in a suitable electrolyte, as shown in figure 7-12. The resulting electrochemical reaction develops a potential difference between these metals. This causes one metal to be negative or anodic and the other metal to be positive or cathodic. In a dry cell battery, the zinc case is the anode and the carbon rod the cathode. Now, when an external electrical circuit is completed, current flows from the zinc case into the electrolyte, taking with it particles of zinc. This is an example of galvanic corrosion of the zinc case. It is this electrochemical action that illustrates the electrochemical theory.

Corrosion may be divided into several types, such as uniform corrosion, localized corrosion, and compositional corrosion. Each type will be explained in the following paragraphs.

Uniform Corrosion

Uniform corrosion is caused by direct chemical attack. An example of this type of corrosion is zinc exposed to hydrochloric acid. If you examine the surface of zinc in a solution of hydrochloric acid, you will find that the entire surface is corroding. Furthermore, if the zinc is left in the acid long enough, it will be dissolved by the acid.

Localized Corrosion

Localized corrosion is caused by the electrolytic action of a galvanic cell. A local galvanic action is set up when there is a difference of potential between the areas on a metallic surface that is an electrolyte. Localized corrosion may be in the form of pits, pockets, or cavities due to the deterioration or destruction of metal.

Localized corrosion may develop under a number of various conditions when different types

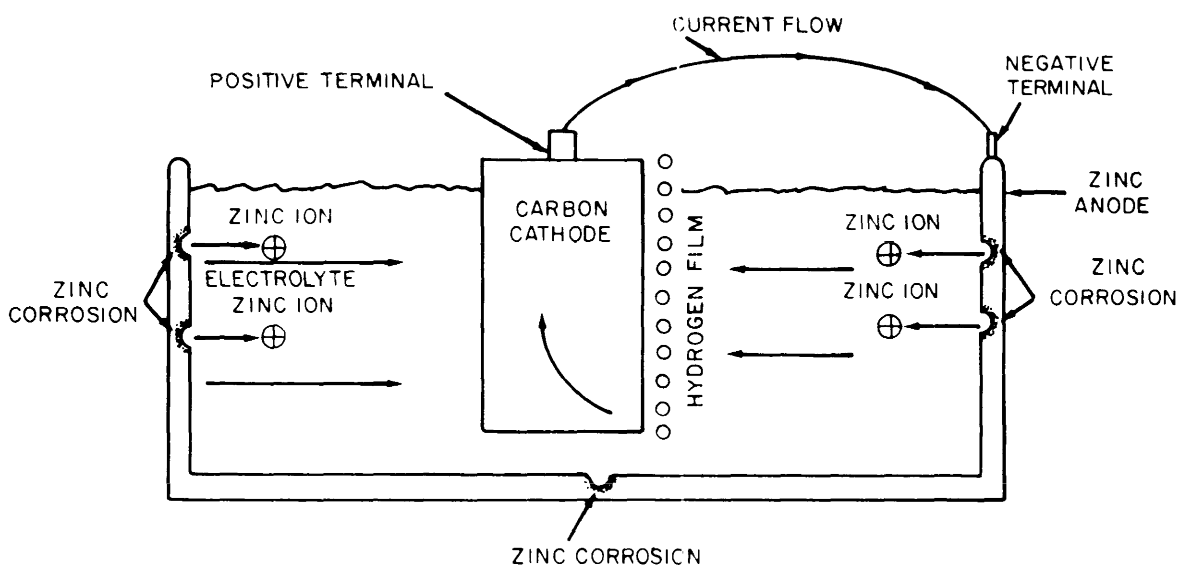

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Figure 7-12.—Galvanic cell showing internal galvanic action.

of equipment are buried in the ground. Some examples of localized corrosion are discussed in the following paragraphs.

● Corrosion due to mill scale. The mill scale embedded in the walls of iron pipe during its manufacture is one cause of pipe corrosion. It actually becomes the cathodic area, the iron pipe the anodic area, and the moist soil the electrolyte, as shown in figure 7-13. Current leaves the iron pipe wall and passes through the electrolytic soil to the mill scale. This electrochemical action causes severe pitting of the pipe metal at the anodic areas. Continued action of this type will eventually weaken the pipe to the extent of failure.

● Corrosion due to cinders. Another type of corrosion occurs when iron pipe is laid in a cinder-fill in direct contact with the cinders. The cinders and the iron pipe make up the dissimilar metals. The pipe forms the anodic area, the cinders form the cathodic area, and the highly ionized soil serves as the electrolyte. The current leaves the pipe through the soil to the cinders and returns to the pipe. Severe corrosion occurs at the points where the current leaves the pipe.

● Corrosion due to dissimilarity of pipe surface. This type of galvanic corrosion occurs when there are bright or polished surfaces on some areas of the pipe walls in contact with suitable electrolytic soil. These bright surfaces become anodic to the remaining pipe surfaces. In highly ionized soil, the polished surfaces corrode at an accelerated rate, thus weakening the pipe at that point.

● Corrosion due to different soil conditions. This is a general corrosion problem, especially prevalent in highly alkaline areas. Corrosion currents leave the pipe wall and pass into compact soils and enter the pipe wall from light sandy soils. The intensity of the corrosion currents and the resulting rate of corrosion at the anodic areas of the pipe are directly proportional to the conductivity of the soil.

● Corrosion due to stray currents. Direct current circuits that pass in and out of an electrolyte usually cause stray currents, many of which are a direct cause of corrosion. Corrosion does not occur at the point where the current enters the structure, because it is catholically protected. However, at the section where the current leaves the structure, severe stray current corrosion occurs. Over a period of a year, this type of corrosion has been known to displace as much as 20 pounds of pipe wall for every ampere of current.

● Corrosion due to bacteria. Biological corrosion is another distinct type of corrosion caused by electrolytic or galvanic cell action. It is the deterioration of metals by corrosion processes that occurs as either a direct or an indirect result of the metabolic activity of certain minute bacteria, particularly in water or soil envirnments. These organisms that cause bacterial corrosion are bacteria, slime, and fungi.

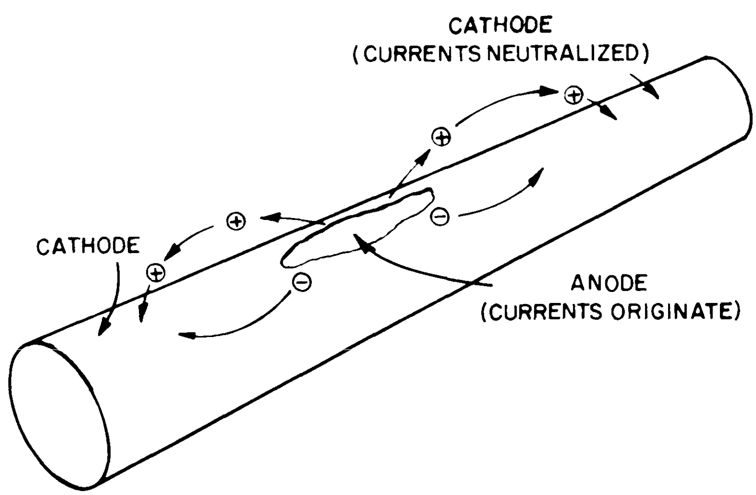

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Figure 7-13.—Pipe with corroding (anode) and noncorroding (cathode) areas.

Microbiological corrosive action in the soil is due to physical and chemical changes in the soil caused by the presence of these organisms. Some bacteria are responsible for the production of active galvanic cells. These bacteria are mostly found in highly waterlogged, sulfate-bearing, blue clay soils. The bacteria concentration, as well as the corrosion rate, varies considerably with the different seasons of the year. Cast-iron and steel pipes are corroded mostly by sulfide production.

Compositional Corrosion

Compositional corrosion alters the composition of metals. Some of the specific types of compositional corrosion are discussed in the following paragraphs.

● Dezincification. This is a selective type of corrosion that occurs in copper and zinc alloys. When alloys of this kind (brasses) are exposed to this type of corrosion, the zinc dissolves out of the alloy and leaves only the copper.

● Graphitization. Another type of compositional corrosion is graphitization or graphitic softening. It is a peculiar form of disintegration that attacks grey cast iron. Cast iron is an alloy made of iron and carbon, the carbon being in the form of graphite. When cast iron with such a composition is subjected to graphitization, the iron dissolves out and leaves only the graphite. This action leaves cast-iron pipes and other similar equipment weakened mechanically. However, after graphitization corrosion occurs, the graphite pipe may last for many years if it is not subjected to any mechanical forces or sudden pressures. The action of this type of corrosion is similar to dezincification.

● Hydrogen embrittlement. This is a term applied to metal that becomes brittle because of the action of some form of corrosion that causes the formation of hydrogen on its surface. When hydrogen forms on the surface of steel, the action of the hydrogen may form blisters or actually embrittle the metal. Hydrogen liberated near the surface of steel in an electrolyte will diffuse into the metal quite rapidly. The hydrogen picked up by the steel is in an atomic state and causes the steel to become brittle.

When the production of atomic hydrogen on the surface of the metal stops, the hydrogen leaves the metal in a few days and the metal again regains its original ductility.

Stress Fatigue of Metals

Corrosion affects metals that are under stress. The action caused by stresses on a pipeline or structure is due to the shifting of the various rocks and soils of the earth. Usually a complete pipeline is not under stress; certain sections are under stress while adjacent sections are not. Because of these pressures and strains, localized electrochemical action takes place. The section of the pipe or structure under stress becomes anodic, whereas the unstressed sections become cathodic. In this way, the pipe under stress begins to corrode and weaken because of the action of corrosion.

Corrosion Caused by Nonelectrolytes

Nonelectrolytes are materials that will not conduct electricity. These materials include nonelectrolytic vapors, liquids, and bacterial organisms. Since they do not conduct electricity, they do not, in themselves, cause corrosion.

NONELECTROLYTE GASES AND VAPORS.— Nonelectrolytic gases and vapors usually must be subjected to high temperatures before corrosive action can take place. Hydrogen sulfide causes scaling of iron at temperatures from 1400° to 2000°F. High-chromium alloy steels resist this type of corrosion best. The only remedy for this type of corrosion is to keep the gases away from the metal or use a metal that can resist corrosion.

High-carbon steels are attacked by hydrogen at temperatures above 750°F. This hydrogen combines with the carbon grains in the steel and causes the metal to weaken at the grain boundaries between the iron and carbon.

Oxygen will combine directly with most metals at high temperatures. The temperature at which oxygen will combine with the metals depends mostly upon the type of metal. In the process of cutting iron with an oxyacetylene torch, the oxygen combines with the iron.

NONELECTROLYTIC FLUIDS.— Nonelectrolytic fluids include such liquids as pure water, lubricating oils, fuel oils, and alcohols. These fluids do not cause corrosion, but corrosion does occur in storage tanks that contain these liquids and in pipelines that carry them. The corrosion is not caused by the nonelectrolyte liquids, but by the foreign products in them. For example, if impure water is introduced into an oil pipeline, the water will cause the inside of the pipe to corrode. The water collects on the inside of the pipe because the pipe is usually cooler than the oil. In a storage tank, the water will settle to the bottom of the tank because water is heavier than oil, and will cause the bottom to corrode. Hydrogen sulfide and sulphur dioxide may also be introduced into the pipeline to add to the corrosiveness of the water that collects on the metal. The only way to prevent corrosion from this source is either to coat the inside of the pipeline and tanks with a protective film or to remove the water from them.

Bacterial Organisms

Bacterial organisms may also cause microbiological corrosion. Colonies of bacteria that live close to the metal surface in stationary slimy deposits produce corrosive substances such as carbon dioxide, hydrogen sulphide, ammonia, and organic and inorganic acids. These corroding substances are found only in the locality of the colony and may be undetected in the surrounding water or soil. Bacteria that cause corrosion in this way need to produce only small amounts of corrosive products for localized attack. However, colonies of bacteria that do not produce corrosive products may act as a protective film around the metal, causing unequal distribution of electrical potential, which gives rise to local anodes and cathodes. In this way, the production of local cells will cause increased corrosive action.

Biological corrosion is extremely difficult to control, since the organisms are very resistant to normal methods of sterilization. Probably the most logical method to reduce microbiological corrosion is by the use of some barrier coating between the environment and the metal.

Corrosion Caused by Electrolytes

An electrolyte is any substance that conducts electricity. It conducts electricity because it contains ions that carry electrical charges, either negative or positive, that move in electrical fields. Some of the more important electrolytes are discussed in the following paragraphs.

ATMOSPHERIC CONDITIONS.— Corrosion due to atmospheric conditions is caused mainly by the water in the atmosphere. Pure water is a nonelectrolyte, but because water is a universal solvent, it is not found to be pure very often. Rain water is often considered to be pure, but this is not true. As rain falls to the ground, it dissolves gases out of the atmosphere and becomes impure. For this reason, any water vapor in the atmosphere is also impure. If a piece of metal is exposed to atmospheric air, and the metal is cooler than the air, water vapor from the air will collect on the surface of the metal. The layer of water on the metal maybe so thin that it cannot be seen; but there is enough of it, if impure, to start corrosion. In this case, when the gases dissolve into the water, the water becomes an electrolyte. When metal is exposed to an electrolyte, galvanic cells are produced on the surface of the metal, since there are impurities in it. Each one of these cells starts to act on the metal, causing corrosion by electrochemical action.

WATER AND WATER SOLUTIONS.— If metal is exposed to water or water solutions, corrosion is likely to occur if the water or metal is impure. If the water or metal is pure, corrosion probably will not occur; however, these conditions seldom exist in nature. Impurities in the water and metal produce galvanic cells that cause corrosion.

CHEMICAL AGENTS.— Chemical agents such as acids and salts also cause corrosion. When these agents are present in the environment, direct chemical attack on metal is the result. For example, if a piece of zinc is exposed to hydrochloric acid, a definite chemical reaction takes place. The zinc and hydrochloric acid combine, producing zinc chloride and hydrogen. This action continues until the zinc is completely dissolved or the acid is too weak to act on the zinc. Corrosion causes the zinc to dissolve.

Another example that may be used to illustrate corrosion through the use of a chemical agent is to place aluminum in a lye solution. The lye will pit (corrode) the aluminum as long as chemical action continues between the aluminum and lye.

MATERIALS LEAST LIKELY TO BE AFFECTED BY SCALE AND CORROSION

Whenever installing various types of plumbing equipment in areas where corrosion is active, you should select equipment made of materials least affected by corrosion. To prevent electrochemical action in plumbing equipment, the equipment should be made of materials that are not affected by electrolysis. Plastic materials such as polyethylene polyester and polyvinyl chloride are not acted upon by corrosion. Glass is another material that is not acted on by corrosion. (This is why hot-water tanks are lined with glass.) Other materials used for the manufacture of pipe that resists corrosion are vitrified clay, cement, fiber, asbestos, and rubber. Glass fibers reinforced with epoxy or polyester resins are also resistant to corrosion.

Dielectric bushings may be installed to stop electrolytic action in plumbing systems or wherever dissimilar metals are used. These bushings are made of nylon and are usually colored. They withstand pressures to 100 psi and temperatures up to 300°F. The bushings are usually placed in pipe systems as recommended by the manufacturer. Some metals least likely to be affected by corrosion are copper, brass, Monel, and stainless steel.

COATINGS AND WRAPPINGS FOR CORROSION PROTECTION

Coatings and wrappings are commonly used to combat corrosion on exterior piping systems. There are many different types of coatings such as asphalts, coal tars, plastics, mastics, greases, and cements. These coatings are considered to be insulating materials, but each is not effective in all environments. Each one was developed for a certain type of corrosive environment.

Asphalt Coatings

Asphalt base coatings are the most common type of protective coatings used. They are produced from petroleum residue and natural sources. Asphalt base coatings can take considerable abrasion, impact, and temperature changes wit bout creating a corrosive condition. However, they absorb a considerable amount of water and dissolve easily into a form of petroleum product.

Coal Tar Coatings

Coal tar coatings are commonly used on pipelines. They possess continuity, hardness, adhesion, and corrosion resistance. Coal tar coatings are less expensive than asphalt coatings. They do not have a very good impact resistance, and a wide temperature change often causes the surface to crack.

Paint Coatings

Some of the most important paint coatings are coal tar, asphalt, rubber, and vinyl.

Coal tar paints have the outstanding characteristics of low permeability and resistance to electrolytic reaction. They are not affected by the action of water. These paints are recommended for piers, marine installations, flood control structures, sewage disposal plants, and industrial concrete pipelines.

Asphalt paints are weather resistant and durable against industrial fumes, condensation, and sunlight action. Because of their resistance against water solvency, they are used on steel tanks and concrete reservoirs.

Rubber base paints are very resistant to acids, alkalies, salts, alcohols, petroleum products, and inorganic oils. The resistance of these products makes them ideal for use on the inside of metallic and concrete storage tanks. If these structures are submerged in water or are under ground, a special form of this paint should be used because of condensation.

Vinyl paint is one of the many synthetic resin base paints. These paints dry to a film that is tough, abrasionproof, and highly resistant to electrolysis. They are odorless, tasteless, nontoxic, and nonflammable. The film is especially resistant to oils, fats, waxes, alcohols, petroleums, solvents, formic acid, organic acids, ammonium hydroxides, and phenols. Because of these characteristics, vinyl paint is very applicable for tanks, pipelines, wellheads, offshore drilling rigs, pipe used in oil industries, railroad hopper cars, dairy and brewery equipment, storage tanks, and concrete exposed to corrosive environments.

Grease Coatings

Grease is another material used to form a protective coating on structures. It is usually made from a petroleum base and resembles paraffin or wax, Grease can be applied either hot or cold. However, it must be protected by some type of wrapping to keep the grease from being displaced or absorbed by the backfill soil when it is applied to underground surfaces.

Concrete Coatings

Concrete coatings have been used with success when properly applied to pipelines to be laid in highly corrosive soils, such as areas containing acid mine drainage or in brackish marshes. Well-mixed concrete, usually a mix of one part portland cement to two parts sand, may be applied to pipelines. The thickness of the coating applied may be up to 2 inches. If the concrete is properly mixed and tamped around the pipe, it may last 40 years. However, concrete has a tendency to absorb moisture and crack, which in many ways limits its use. In fact, in places where the coating cracks, electrolysis immediately starts to corrode the metal. This corrosion can be partially prevented by painting the pipe with a bituminous primer before coating it.

Metallic Coatings

Metallic coatings such as galvanizing (zinc coating) are very effective in protecting metallic structures or pipes against atmospheric corrosion. This type of coating is ideal for cold-water lines and metals exposed to normal atmospheric temperatures. However, metals such as iron corrode rapidly when used in high-temperature equipment because at a critical temperature of approximately 140°F iron becomes anodic to zinc. This results in the iron's becoming the sacrificial anode that corrodes readily.

Plastic Wrapping

Plastic tapes for wrapping come in rolls. They may be procured in various widths. The tape is wrapped around the pipes before they are laid in the trench. The wrappings are applied by a simple device that is clamped on the pipe and turned by the UT. Pipe joints are wrapped after the pipes are laid in the trench.

GALVANIC CATHODIC PROTECTION

Galvanic cathodic protection is a method used to protect metal structures from the action of corrosion. As explained before, galvanic cell corrosion is the major contributing factor to the deterioration of metal by electrochemical reaction. The area of a structure that corrodes is the anode or positive side of the cell. Corrosion occurs when the positive electric current leaves the metal and enters the electrolyte. Galvanic cathodic protection is designed to stop this positive current flow. When the current is stopped, the corrosive action stops and the anodes disappear. This type of protection depends upon the neutralization of the corroding current and the polarization of the cathode metal areas.

METHODS OF GALVANIC CATHODIC PROTECTION

Galvanic cathodic protection is a means of reducing or preventing the corrosion of a metal surface by the use of sacrificial anodes or impressed currents. When sacrificial anodes are used, it is known as the galvanic anode method. If impressed currents are used, it is known as the impressed current method. These two methods can be used separately or with each other, depending upon the corrosive characteristics of the electrolyte surrounding the structure.

Galvanic Anode Method

The galvanic anode method of cathodic protection uses an electrode referred to as a sacrificial anode that corrodes to protect a structure. This sacrificial anode is electrically connected to and placed in the same electrolytic area of the structure. The anode used to protect iron or steel structures should be made of magnesium or zinc so it will produce a sufficient potential difference to cause the structure to become a cathode. The action of this type of galvanic protection causes the electric current to flow from the sacrificial anode through the electrolyte to the structure to be protected. The electrical connection between the two metals completes the circuit and allows the current to return to the corroding metal. The sacrificial anode becomes the anode of the established dissimilar metal galvanic cell, and the structure to be protected becomes the cathode. The current from the sacrificial anode is intense enough to oppose or prevent the positive current from leaving the anodes in the structure to be protected. These structure anodes are then suppressed, and the metal in the structure becomes a cathode. The prevention of these positive currents from the anodic areas in the structure reduces the corrosion rate to almost zero.

Galvanic cathodic protection is used in areas where the corrosion rate is low and electric power is not readily available. A typical example of galvanic cathodic protection is shown in figure 7-14.

Impressed Current Method

The impressed current method of cathodic protection is designed to protect large metal structures located in corrosive areas. With this method of protection a source of alternating current is required. Also, a rectifier is needed to obtain the required direct current potential.

The basic principle of the impressed current method is merely the application of the galvanic cell reaction. The component parts of this method are the cathode (the metal structure to be protected), the anode (made of suitable anodic material), the electrolyte or ground (the ionized corrosive material), and the rectifier and various connections that serve to complete the electrical circuit. The operation of this method depends on the rectifier forcing direct current from the anode through the electrolyte (ground) to the metal structure to be protected. This method causes the metal structure to be the cathode, suppresses the anodic currents from it, and, in turn, prevents corrosion of the structure. An impressed current method of cathodic protection is shown in figure 7-15.

FIELD TEST EQUIPMENT FOR CATHODIC PROTECTION

The items of field test equipment that the UT uses to make tests when installing, operating, and maintaining cathodic protection systems are the volt-millivoltmeter, multicombination meter, resistivity instrument, buried pipe locator, and the protective coating leak detector. This equipment is discussed in the following paragraphs.

Volt-Millivoltmeter

In corrosion and cathodic protection testing in the field, it is necessary to measure the potential of the structure being investigated as compared to the earth along the structure and to other metallic structures. It is also necessary to measure the potential of rectifiers, batteries, galvanic anodes, and sometime potentials along the earth's surface to determine the distance being protected. The potentials may vary from millivolts to 20 volts or more. Various types of voltmeters are used for this purpose. One of these instruments is the volt-millivoltmeter. It is a recording instrument designed with a chart that makes one revolution in 24 hours. The instrument will record the variations in potential and reveal the electrolytic conditions around a structure.

Multicombination Meter

The multicombination meter is used quite often in cathodic protection work. It is designed as a combination unit and actually consists of more than one instrument. The meter can be used as a high-resistance voltmeter, an ammeter, a

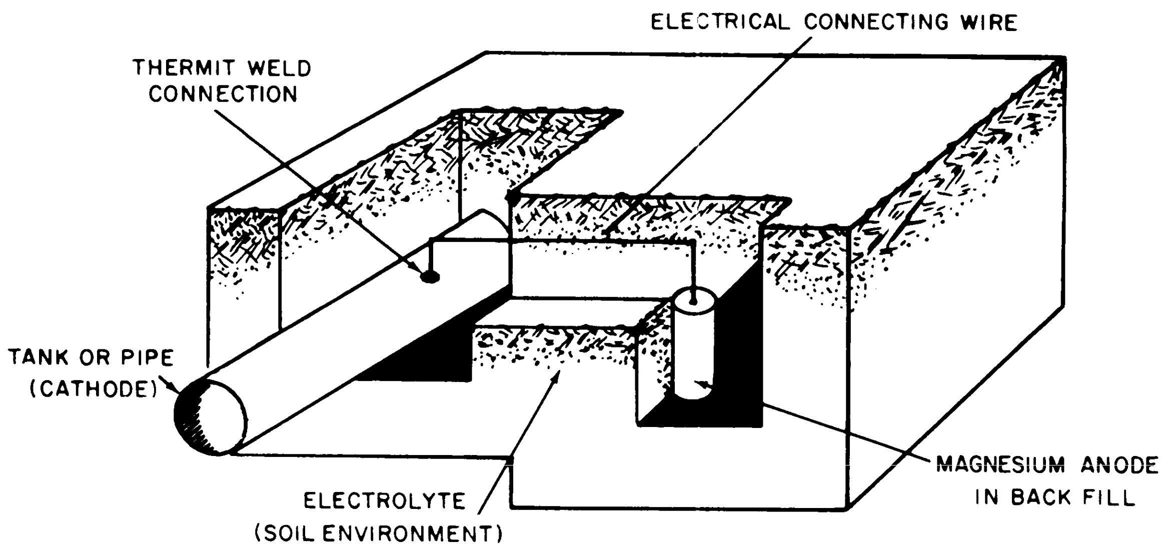

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Figure 7-14.—Galvanic cathodic protection.

milliammeter, a low-resistance voltmeter and millivoltmeter, and a potentiometer voltmeter.

The multicombination meter maybe used to measure galvanic anode current between an anode and structure, galvanic current between structures, and potentials as with other types of voltmeters and millivoltmeters.

Resistivity Instruments

Resistivity measuring instruments are units used to test the corrosive action of a soil. Tests regarding soil corrosivity are necessary when designing cathodic protection systems. Information from these tests is used to locate the most corrosive areas where a pipeline is to be laid and the most corrosive areas of an existing pipeline. It is also used to decide the location for anode beds.

One of the simplest methods for making a resistivity test is to use a single probe resistivity meter. It consists of a probe with two electrodes, an indicating instrument, switches, and the required wiring. To use this instrument, the probe is inserted into the ground and current is applied to it. The indicating instrument gives a reading that indicates the corrosiveness of the soil.

Buried Pipe Locator

In the field of cathodic protection work, it is necessary to locate pipes in order to locate interferences in the cathodic protection system. An electronic pipe locator is used for this purpose. The main components of the locator are the directional transmitter and the directional receiver. Each one of these units is carried by an operator. The operators are usually about 30 feet apart. During actual operation the transmitter sends out signals which travel along the pipeline. The receiver, in turn, picks up these signals in varying intensities, depending on the distance the operators are from the pipe. When both operators are directly over the pipe, a maximum response is obtained in the phones and on the visual meter of the receiver. Most pipe can be located easily and accurately in this manner.

Protective Coating Leak Detector

A protective coating leak detector (referred to as a *holiday detector)* is used to detect the imperfections (holidays) in pipe coatings. The holiday leak detector is an instrument that operates on an electric current. When it is being

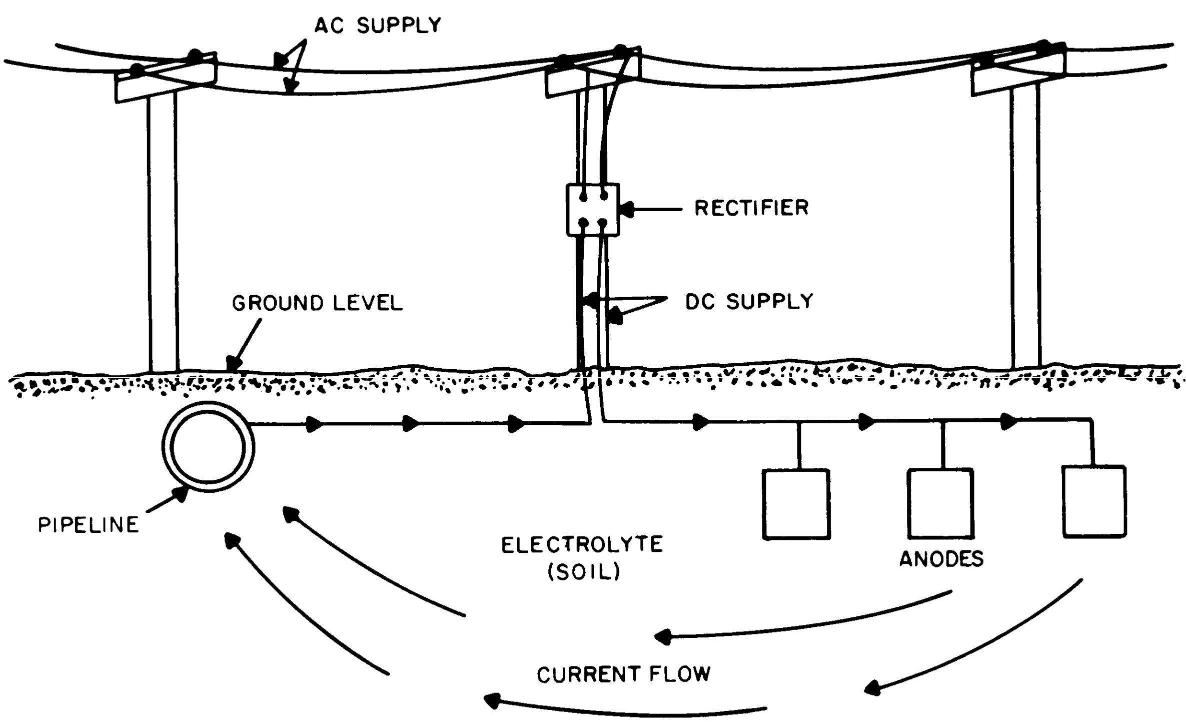

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Figure 7-15.—Impressed current method of cathodic protection.

moved along a pipe that is covered by a coating or wrapping, a completed circuit between it and the pipe reveals a holiday and causes a bell to ring or a bulb to light or a buzzer to sound.

MAINTENANCE OF ANODE SYSTEMS

The anode system of cathodic protection requires little maintenance since there is no power source.

Magnesium and zinc anodes used in the anode system sometimes suffer local or self-corrosion that reduces their efficiency. Replace the anode when the efficiency drops to a minimum. Anode life varies from 5 to 30 years, depending upon the type of anode used. It is conservative to figure that about 17 pounds of magnesium or 25 pounds of zinc are wasted away by electrolysis from an anode per ampere year. To detect the effectiveness of cathodic protection, you should install test stations in anode systems.

MAINTENANCE OF IMPRESSED CURRENT SYSTEMS

The impressed system of cathodic protection requires considerably more maintenance than the anode system. This is because an electrical current is used for the operation of the system. The current may come from any alternating current source. When alternating current is not available, you can use other generating sources to furnish the alternating current. The transformer-rectifier used in the system requires much less maintenance and servicing than other sources of current. However, systematic maintenance procedures must be used to keep these units in operating condition.

The transformer-rectifier set consists of two units, a transformer and a rectifier. The transformer steps the voltage down to a value of 12 to 40 volts. The rectifier changes the alternating current to direct current. Remember to keep all of the connections on this unit airtight.

The materials most often used for anodes with impressed current are aluminum, high-silicon cast iron, and graphite. Scrap iron and steel may be used for anodes since they waste away at a rate of 20 pounds per ampere year. Replace anodes when they are wasted away. Insulated wire that resists electrolytic action must be used to make the connections between the anodes and the structures to be protected. The insulation on existing current-carrying lines should be checked. Replace the wires if they are deteriorating. Ensure that overhead wiring is fastened securely to the poles and that all connections are tight.

CHAPTER 8

FIRE PROTECTION SYSTEMS

This chapter describes the operation, testing, and maintenance of fire protection systems for buildings and other structures. Fire protection systems include automatic sprinkler systems, standpipe and hose systems, foam extinguishing systems, gaseous extinguishing systems, and chemical extinguishing systems. Fire alarm and detection equipment are discussed, showing the relationship between the mechanical and electrical components of these systems.

Because of the large number of manufacturers and models of fire protection systems, the Utilitiesman cannot be expected to acquire a detailed knowledge of all installation and maintenance considerations involved with this equipment. The principles presented in this chapter apply on a general basis for any given device or system you may encounter in the field. Refer to the manufacturer's manuals, job specifications, the National Fire Protection Association Codes, and local codes for in-depth information regarding specific types of equipment.

AUTOMATIC SPRINKLER SYSTEM CHARACTERISTICS

Automatic sprinkler systems automatically distribute water upon a fire in sufficient quantity to either extinguish the fire or prevent its spread. All sprinkler systems have three bassic components. They are (1) a water supply, (2) a piping network to carry the water, and (3) sprinklers that distribute the water. This section discusses the three major categories of sprinkler systems with their related controlling devices, fittings, and the sprinklers that may be chosen for installation into these systems.

TYPES OF SPRINKLER SYSTEMS

There are several types of sprinkler systems. The most common ones are the wet pipe, the dry pipe (that uses the differential dry pipe valve, the low-differential dry pipe valve, or the mechanical or latched-clapper dry pipe valve), the water deluge, the pre-action, and the combined systems.

Wet Pipe System

The wet pipe sprinkler system is the most common type. This system has automatic sprinklers attached to a piping network with piping under pressure at all times. The sprinklers are actuated by the heat of a fire. A wet pipe system is generally used when there is no danger of the water in the pipes freezing or when there are no special conditions that require a special purpose sprinkler system.

The wet pipe sprinkler system may have an alarm check valve (figs. 8-1 and 8-2). This device is used to maintain a constant pressure on the system piping network above the valve. When there is a fire, the flowing water causes the clapper assembly inside the alarm check valve to open. This permits a portion of the water to flow through a port in the valve that is connected to an alarm device. To prevent false alarms, you can place a retard chamber in the piping between the alarm check valve and the alarm device.

Dry Pipe System

In a dry pipe system, the pipes normally contain either air or nitrogen under pressure. Dry pipe systems are used in areas where the water in the pipes is subject to freezing.

A dry pipe valve acts as a control between the water supply and the air under pressure in the piping network. The dry pipe valve must be in a heated enclosure because pressurized water is at the underside of the valve. A small amount of water, called priming water, is also inside the dry pipe valve itself to ensure a tight seal of the clapper and to keep the rubber gaskets pliable. The valve is usually made so that a moderate air pressure holds back a much greater water pressure. There are several types of dry pipe valves.

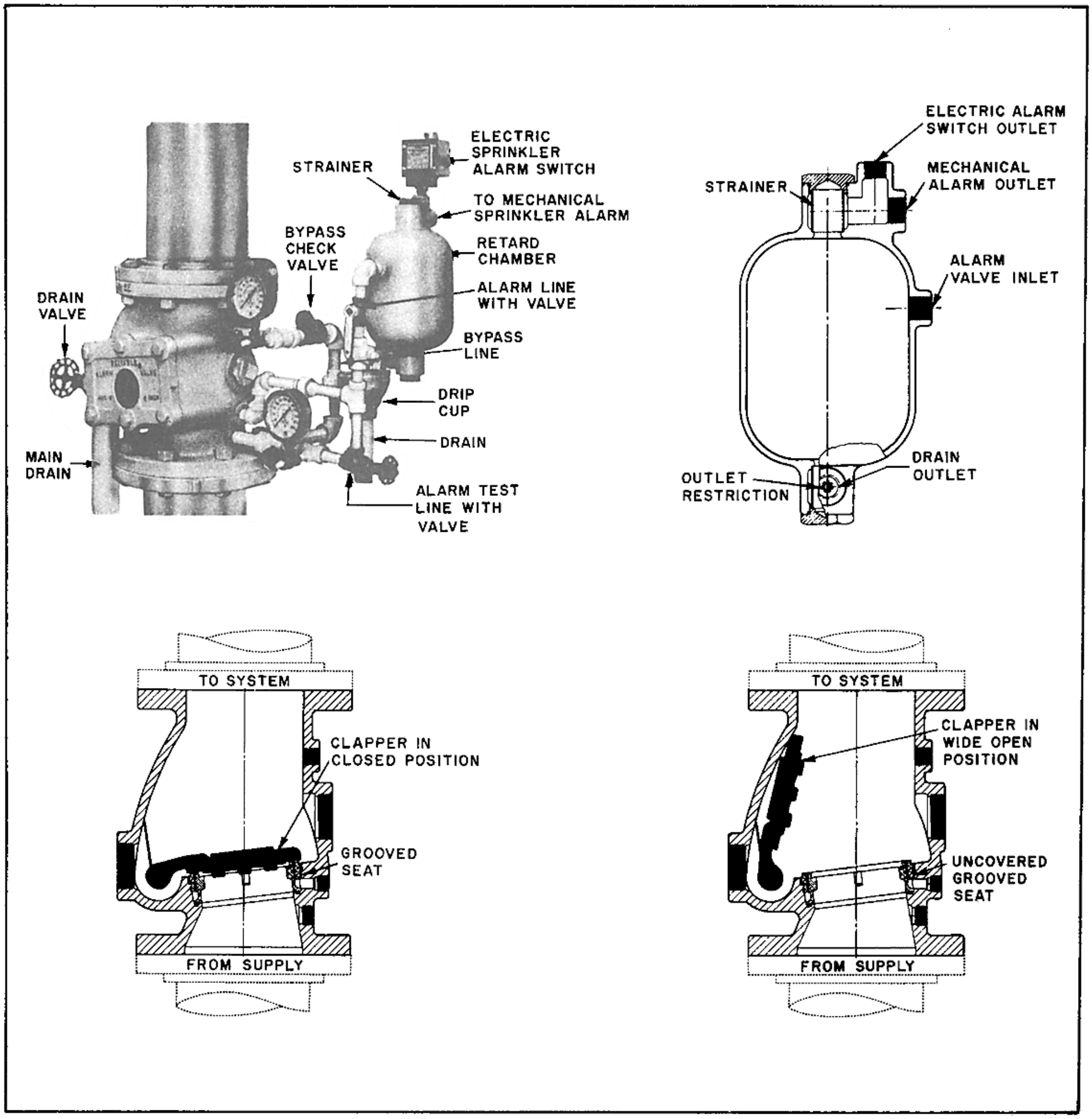

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Figure 8-1.—Alarm check valve.

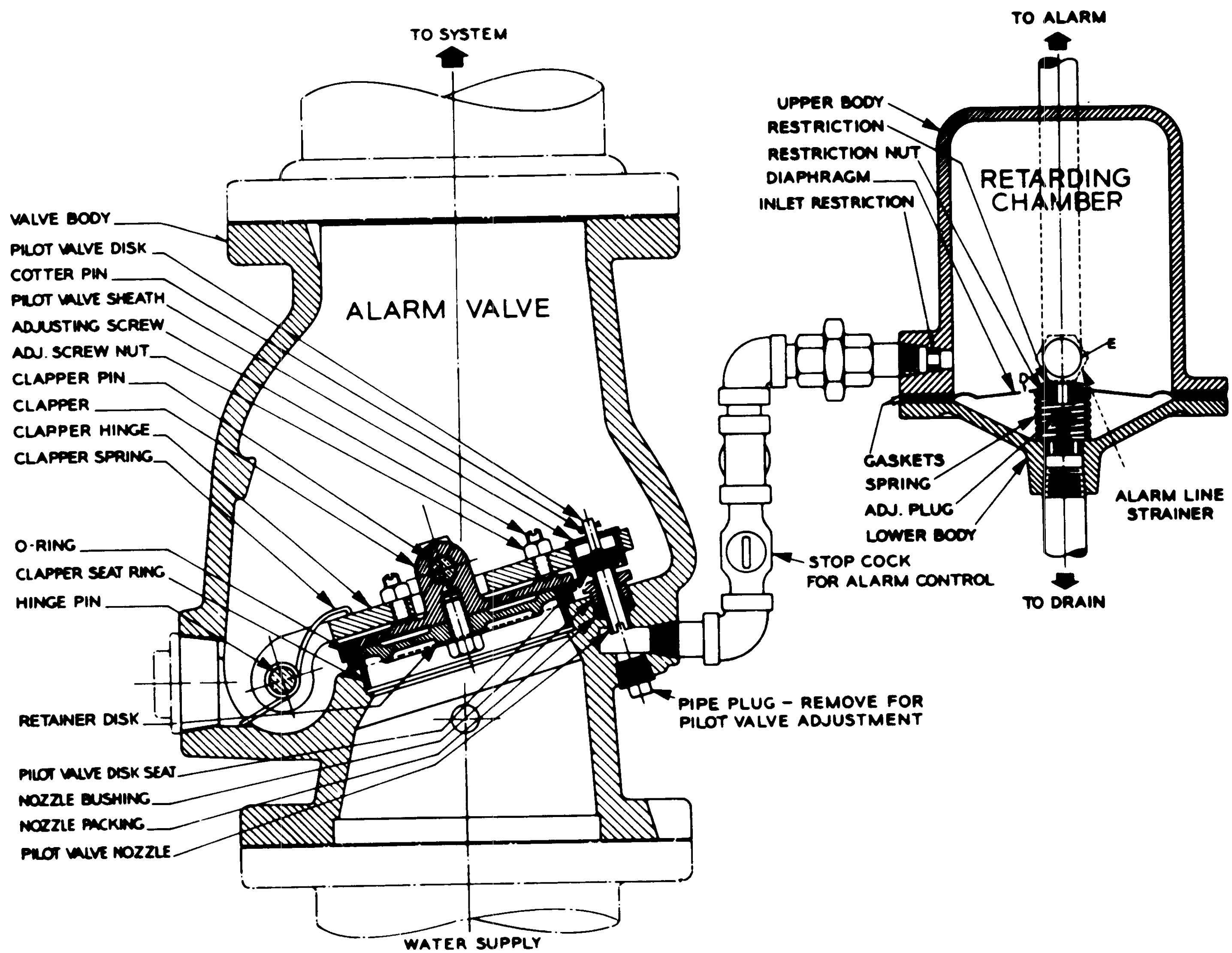

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Figure 8-2.—Alarm check valve (section).

DIFFERENTIAL DRY PIPE VALVE.—The differential dry pipe valve (fig. 8-3) has a large clapper on the air side that bears directly on a smaller water side clapper. The differential between the areas of the two clappers is approximately 6 to 1. Therefore, relatively low air pressure can hold back a much larger water pressure. For example, 30 pounds per square inch (psi) air pressure can hold back 180 psi water pressure.

To eliminate an accidental trip of the valve and false alarms, air pressure should be maintained at least 20 psi greater than the calculated trip pressure of the dry pipe valve. This is based on the highest normal water pressure of the supply system.

In operation, when there is a fire the heat actuates the sprinklers and allows the air pressure to be relieved from the piping network. The differential is destroyed. The water pressure below the valve opens the clapper, allowing water to flow through the piping to the open sprinklers. This operation has an inherent time delay between the actuation of the sprinklers and the application of water to the fire. This delay can be shortened by adding an accelerator or an exhauster to the dry pipe system.

The accelerator (fig. 8-4) allows air from the system's piping to enter the intermediate chamber in the dry pipe valve, destroy the differential, and open the clapper.

The exhauster (fig. 8-5) opens and exhausts air from the piping system faster than through the sprinklers, destroying the differential sooner.

LOW-DIFFERENTIAL DRY PIPE VALVE.— Occasionally the water supply to dry pipe valves contains debris. With a differential dry pipe valve, the high velocity of water entering the system when the valve trips can carry the debris into the system, plugging system piping and sprinklers. If debris in the water is a problem, the low-differential dry pipe valve (fig. 8-6) may be useful.

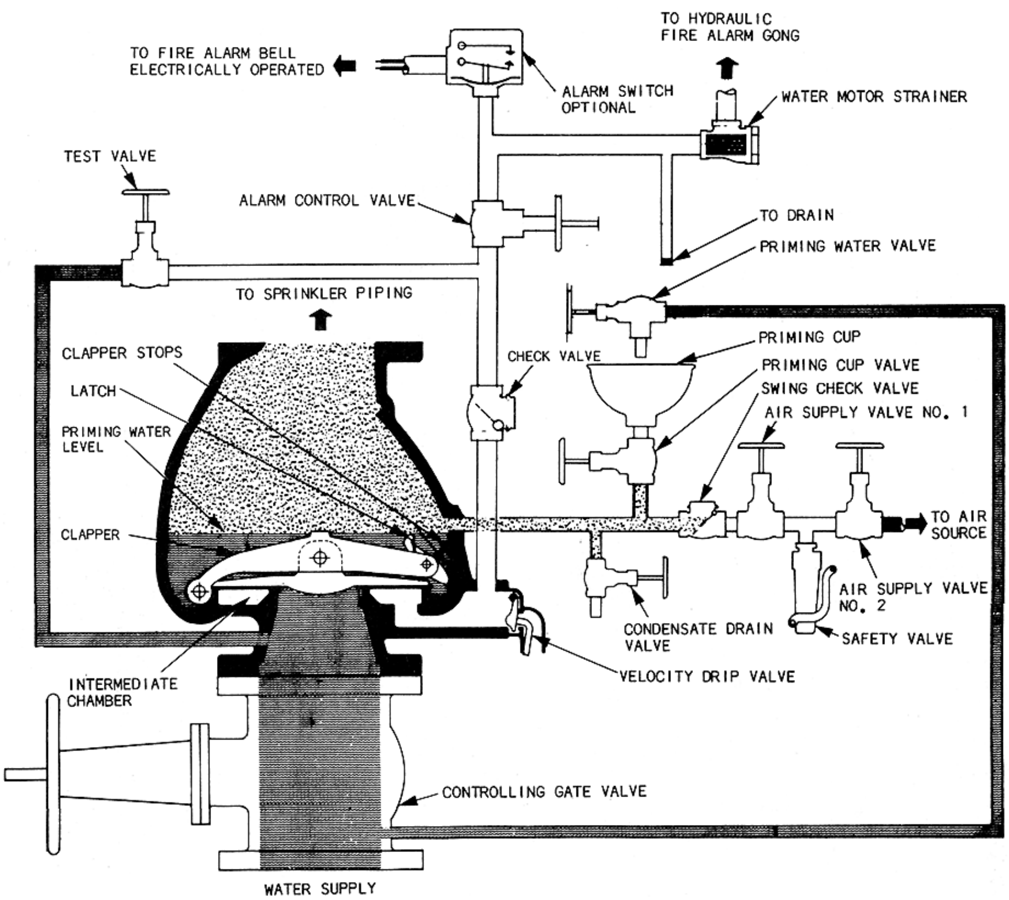

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Figure 8-3.—Differential dry pipe valve.

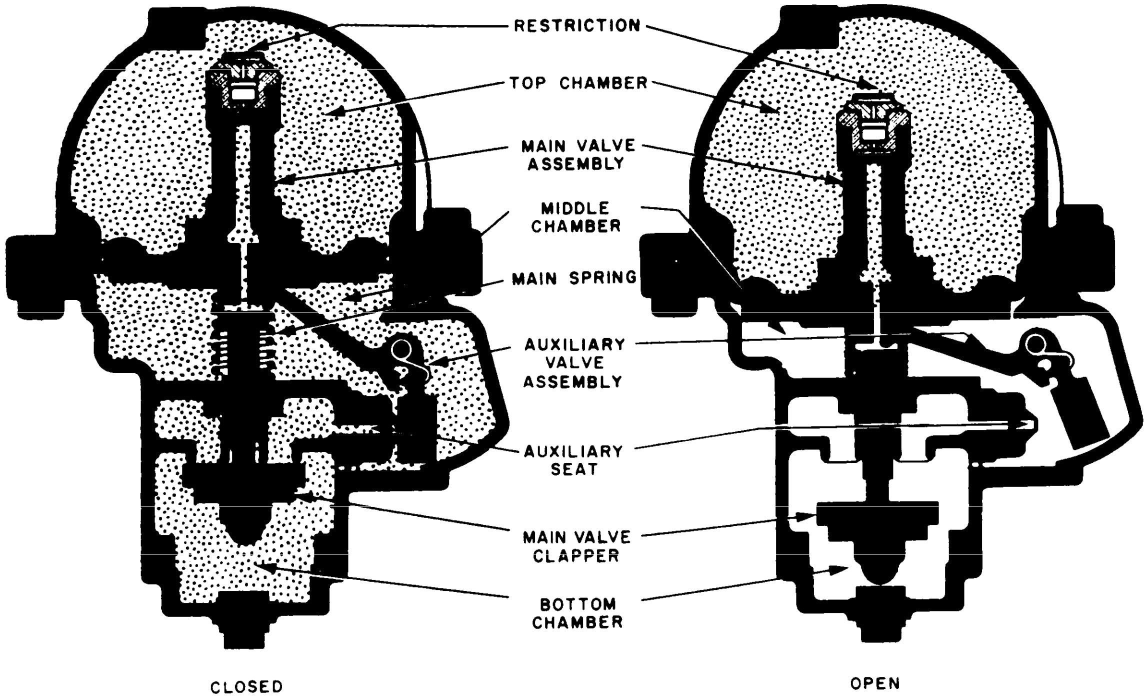

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Figure 8-4.—Dry pipe system accelerator.

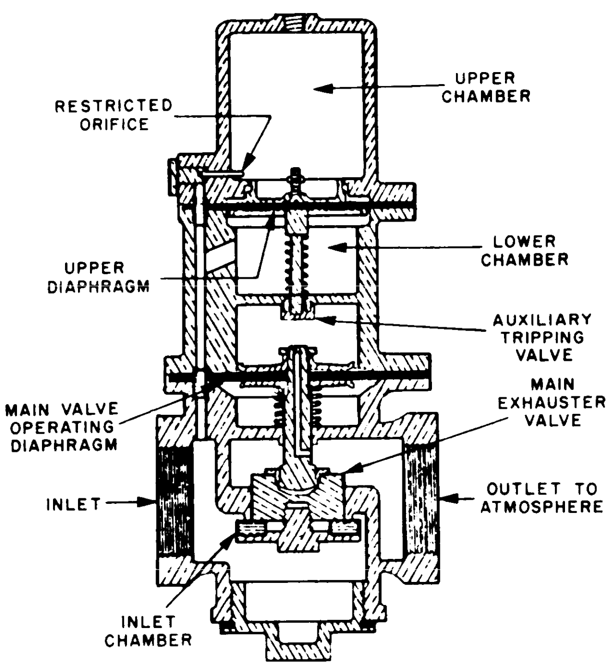

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Figure 8-5.—Dry pipe system exhauster.

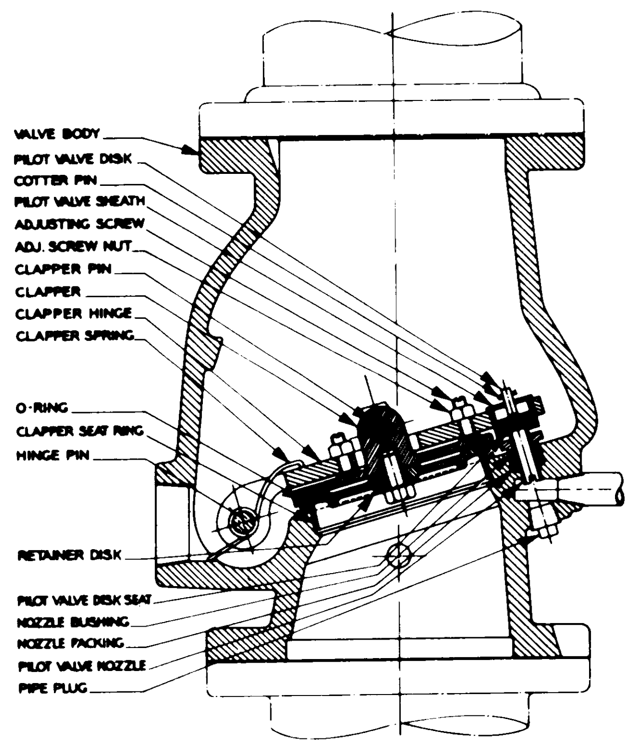

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Figure 8-6.—Low differential dry pipe valve.

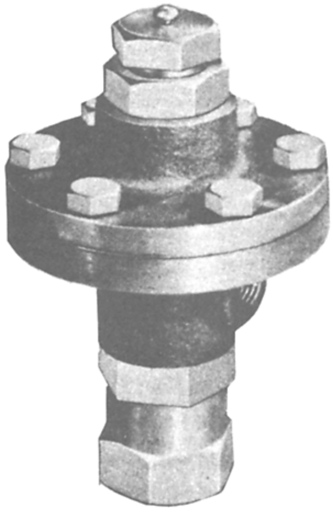

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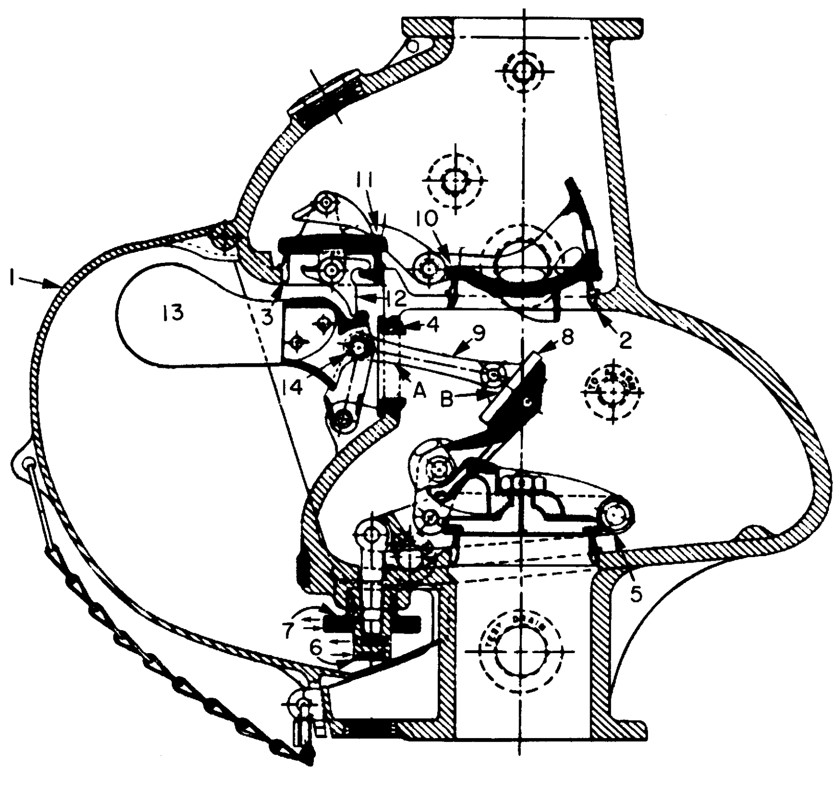
Figure 8-7.—Air pressure maintenance device.

The clapper in the low-differential dry pipe valve is only slightly larger on the air side than on the water side. The air pressure in the system is maintained approximately 15 to 20 psi greater than the water pressure. Because the sprinkler system piping contains air pressure about equal to the water pressure, the sudden rush of water is slowed and only a slight amount of water is diverted into the branch lines, which do not have operating sprinklers after the valve opens.

With either a differential or low-differential dry pipe valve an automatic air maintenance device (fig. 8-7) must be used to maintain air pressure and prevent accidentally tripping the dry pipe valve. Also, an automatic drain or high-water-level alarm is required for the priming water level so the water does not accumulate. (If there is too much priming water, the valve cannot operate.)



1. BALL WEIGHT COVER
2. WATER AND AIR CLAPPER SEATS
3. AUXILIARY CLAPPER SEAT
4. INTERMEDIATE CLAPPER SEAT
5. WATER CLAPPER
6. ADJUSTING NUT
7. ADJUSTING SCREW LOCKNUT
8. INTERMEDIATE CLAPPER
9. INTERMEDIATE CLAPPER LINK
10. AIR CLAPPER
11. AUXILIARY CLAPPER
12. TRIGGER
13. BALL WEIGHT
14. BALL WEIGHT PIN

87.356

Figure 8-8.—Mechanical dry pipe valve.

MECHANICAL OR LATCHED-CLAPPER DRY PIPE VALVE.— The mechanical or latched-clapper dry pipe valve operates under the same theory as other dry pipe valves. It has system air pressure against a small disk, diaphragm, or clapper. An Arrangement of levers, links, and latches on the valve clapper provides the leverage for the closing force placed on the water clapper (fig. 8-8).

Water Deluge System

A water deluge system (fig. 8-9) is used where there is an extra hazard, such as areas where flammable liquids or propellants are handled or stored, or where there is a possibility that a fire might grow faster than ordinary sprinkler systems can control. These systems are also often used in aircraft hangars where ceilings are unusually high and where drafts may deflect the direct rise of heat so that sprinklers directly over the fire would not open promptly but others, at some distance away, might open without having any effect on the fire.

In the water deluge system, all sprinklers connected to the piping network are open and the water supply is controlled by a water deluge

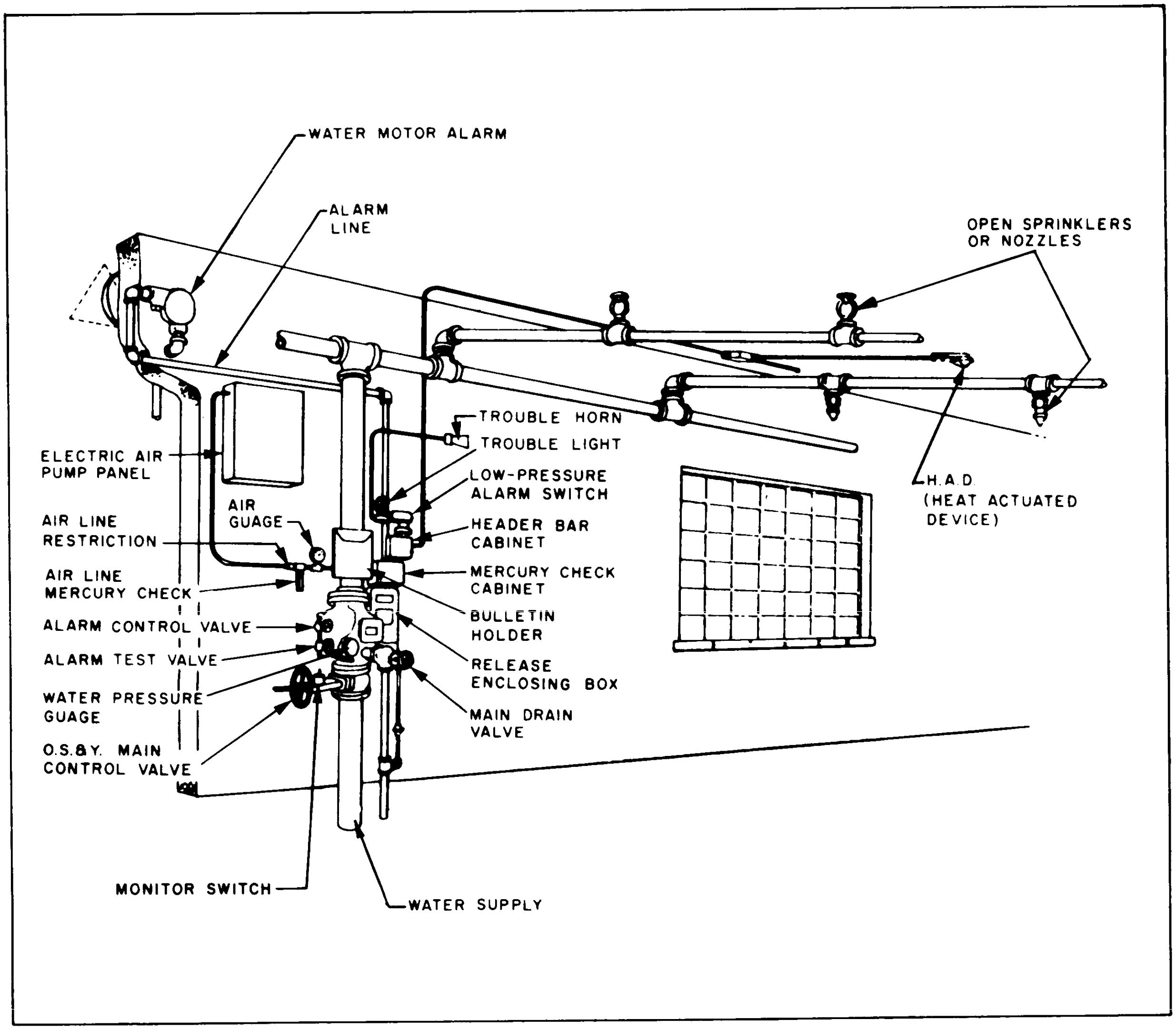


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Figure 8-9.—Deluge system.

valve (fig. 8-10). The water deluge valve remains closed until a fire is detected by a heat-actuated device that in turn causes the valve to open. Heat-actuated devices (H.A.D.) can be either mechanical or electrical in operation. They are discussed in further detail later in this chapter.

The deluge system has a time delay between detection of a fire and the discharge of water at the sprinkler heads. This delay is due to the time required to operate the valve and fill the piping network with water, similar to the dry pipe system. To reduce the delay, the deluge system may be pre-primed by filling the piping network with water downstream from the deluge valve. To prevent water from escaping from the sprinklers, pre-prime plugs (fig. 8-11) are placed on the sprinklers. These plugs blow out of the sprinklers at approximately 20 psi water pressure.

Pre-Action System

A pre-action system differs from a deluge system only in that it has normally closed automatic sprinklers. When the fire detecting device is actuated, the water control valve opens and admits water into the piping system. The system then acts the same as a wet pipe system. Individual sprinklers are opened by the heat of the fire. The advantage of the pre-action system is that the probability of inadvertent water discharge is minimized because operation of both the detection system and automatic sprinklers is necessary for discharge of extinguishing water.

It is incorrect to refer to pre-action systems as dry pipe sprinkler systems. It is true that the pre-action system piping does not contain water. However, the term *dry pipe system* refers to the type of sprinkler system and the type of water control valve that operates the system.

There are two types of pre-action systems. First is the supervised system, which has air introduced into the system piping at a pressure of approximately 5 psi. This air pressure "supervises" the piping to detect leaks. The pressure switches used for detection of low air pressure on

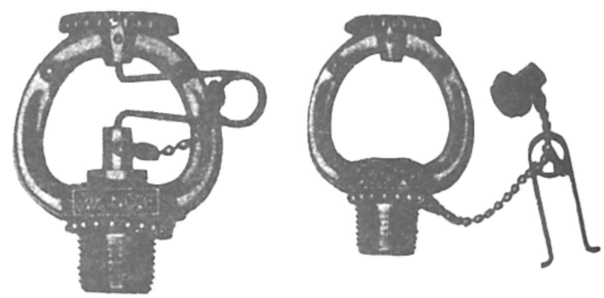

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Figure 8-11.—Sprinkler pre-prime plugs.

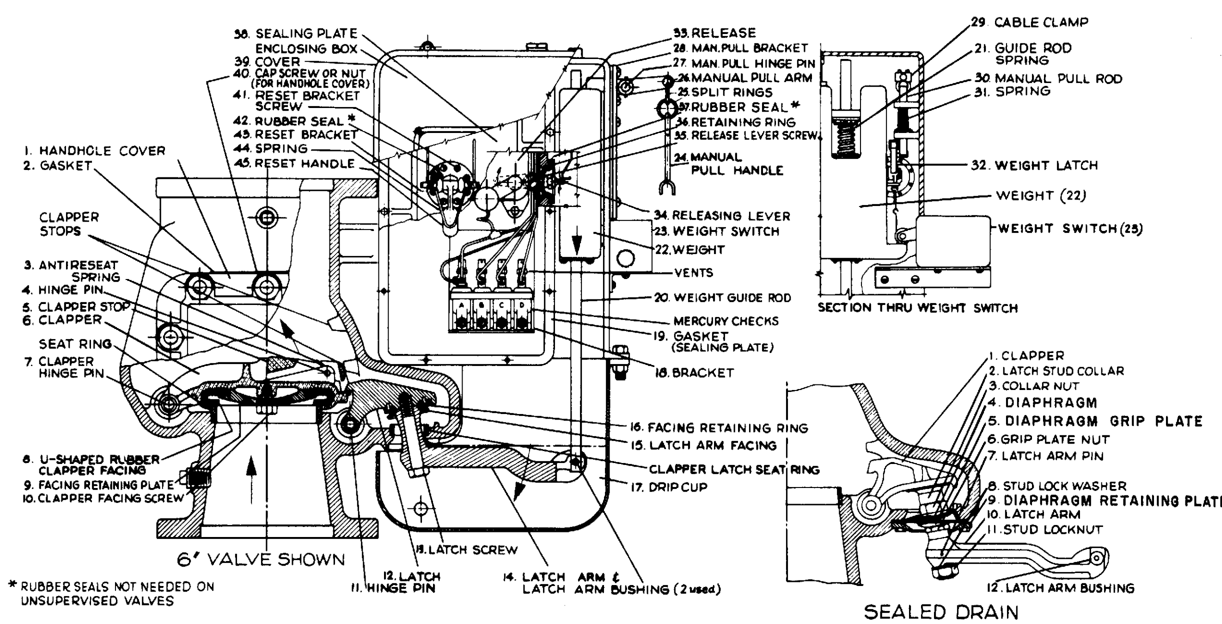

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Figure 8-10.—Deluge valve.

the supervised system should record in inches of water rather than pounds per square inch. The second system is the unsupervised pre-action system. It has no means of continuous monitoring.

Combined System

A combined system (fig. 8-12) is a special purpose arrangement using two modified dry pipe valves connected to tripping devices and piped in parallel to supply water to the same sprinkler system. The piping net work is filled with air under pressure. When a fire is detected, an exhauster at the end of the system opens and releases the air within the system. The system then operates the same as a pre-action system. However, if the detection system fails, the combined system acts the same as a dry pipe system and allows water to be admitted to the system when the sprinklers open, discharging the air from the piping network.

TUBING OR WIRING TO FIRE DETECTION SYSTEM

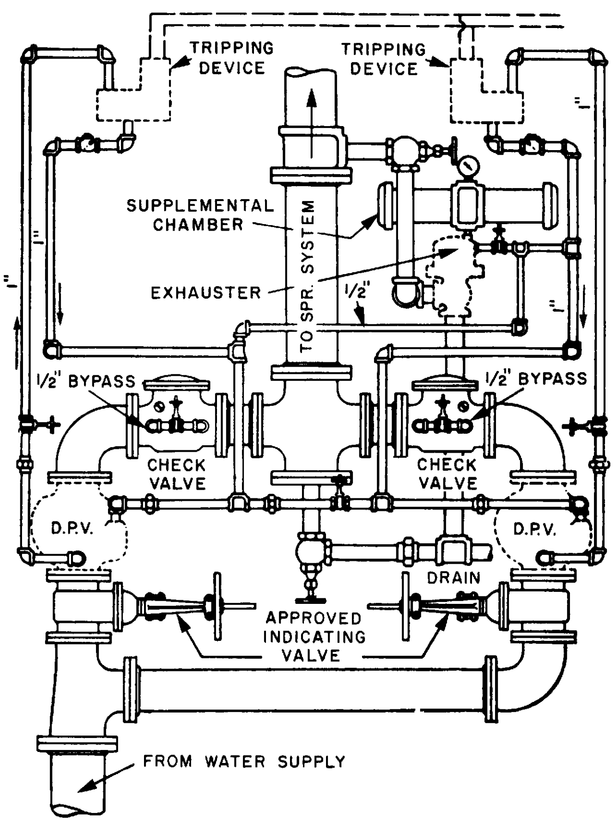

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Figure 8-12.—Combined system header arrangement.

TYPES OF SPRINKLERS

Sprinklers are nozzles placed at intervals along the piping network to distribute a uniform pattern of water on the area being protected. To attain maximum efficiency, the stream of water must be broken into droplets. A deflector (part of the frame of the sprinkler) breaks up the water.

You, as a UT, will generally install sprinklers to meet the specifications and plans of a project. When you require more information on proper locating of sprinklers, refer to the *National Fire Protection Association Code Book Number 13* (NPFA #13), entitled *Installation of Sprinkler Systems.*

Automatic sprinklers are designed for specific applications based on orifice size, deflector design, frame finish, and temperature rating. Sprinklers have orifices ranging in size from 1/4-inch to 1/2-inch diameter graduated by 1/16-inch increments. There is also one 17/32-inch size orifice. Deflectors give different patterns of water distribution and allow the sprinkler to be placed in various locations such as upright, pendent, or sidewall (fig. 8-13). Next, sprinkler frames may

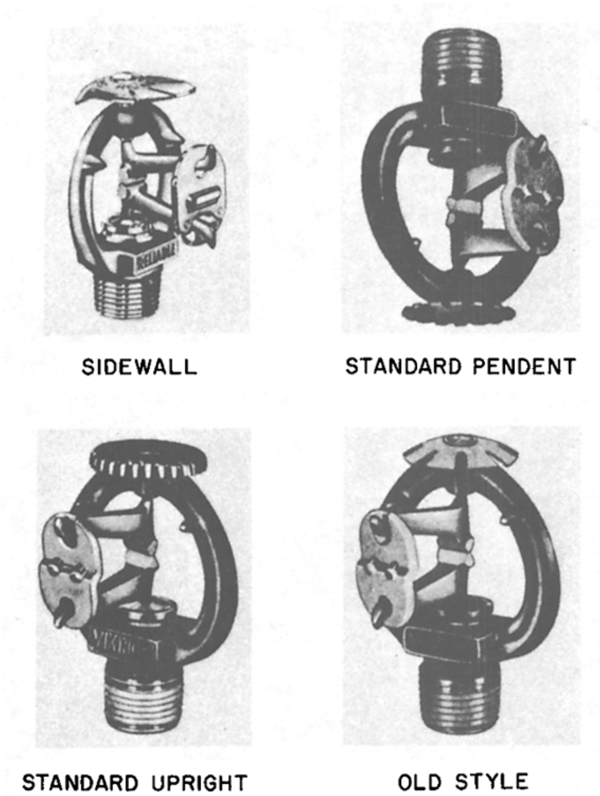

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Figure 8-13.—Sprinkler deflector styles.

be plated for appearance or they maybe coated for protection from an adverse environment. For example, sprinklers that will be used in corrosive atmospheres are either lead- or wax-coated. Finally, automatic sprinklers are normally held closed by heat-sensitive elements that press down on a cap over the sprinkler orifice and are anchored by the frame of the sprinkler. The heat-sensitive elements melt and release at different temperatures depending on application. Sprinklers are color coded to identify the temperature range rating of the fusible element (table 8-1). Color coding is not required for plated sprinklers, ceiling sprinklers, or similar decorative types.

There are basically four types of *release mechanisms* for automatic sprinklers. They are the fusible link, frangible bulb, frangible pellet, and bimetallic element.

The *fusible link sprinkler* (fig. 8-14) is kept closed by a two-piece link held together by a solder with a predetermined melting point. When the solder melts, the levers pull the two-piece link apart and fly away from the sprinkler. Pressure in the piping network pushes the cap from the orifice of the sprinkler to discharge water.

The *frangible bulb sprinkler* (fig. 8-15) has a small bulb made of glass between the orifice cap and the sprinkler frame. The bulb is partially filled with a liquid. Air fills the remaining space. Heat from a fire will cause the liquid to expand against the air causing the glass bulb to shatter and opening the sprinkler for water discharge.

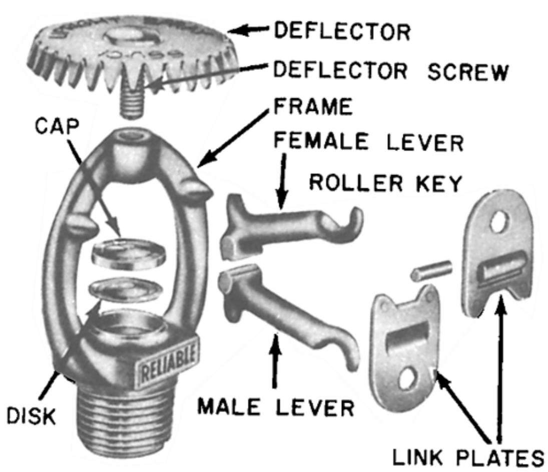

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Figure 8-14.—Fusible link automatic sprinkler.

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Figure 8-15.—Frangible bulb automatic sprinkler.

Table 8-1.—Sprinkler Temperature Ratings

MAXIMUM AMBIENT CEILING TEMPERATURE (°F)	TEMPERATURE RATING (°F)	TEMPERATURE CLASSIFICATION	SPRINKLER COLOR CODE
100	135 to 170	Ordinary	Uncolored
150	175 to 225	Intermediate	White
225	250 to 300	High	Blue
300	325 to 375	Extra High	Red
375	400 to 475	Very Extra High	Green
475	500 to 575	Untrahigh	Orange

A *frangible pellet sprinkler* (fig. 8-16) has a rod between the orifice cap and sprinkler frame. The rod is held in place by a pellet of solder under compression. When the solder melts, the rod moves out of the way of the orifice cap. The cap is pushed off by the water pressure in the piping network.

The *bimetallic element sprinkler* (fig. 8-17) uses a disk made of two distinct metals as a heat-sensitive element. When the sprinkler is off, the disk maintains pressure on a piston assembly. When a fire occurs and the temperature reaches the sprinkler's rating, the disk flexes and opens, releasing pressure on the piston assembly and allowing a small amount of water to bleed out of the piston chamber faster than it can be replaced through a restrictor. The water pressure in the piping network pushes the piston down and allows water to discharge from the sprinkler. When the temperature of the heat-sensitive element is reduced, the element returns to its normal position and allows water to pass through the restrictor, filling up the piston chamber, forcing the piston into the closed position, and stopping water discharge. This sprinkler can be used to automatically cycle on and off as necessary; for example, to put out a rekindled fire.

Other sprinkler heads that do not have release mechanisms include the dry pendent sprinkler, the open sprinkler, and water spray nozzles.

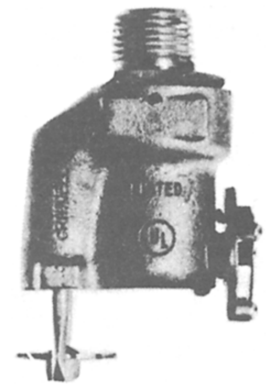

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Figure 8-17.—Bimetallic element automatic sprinkler.

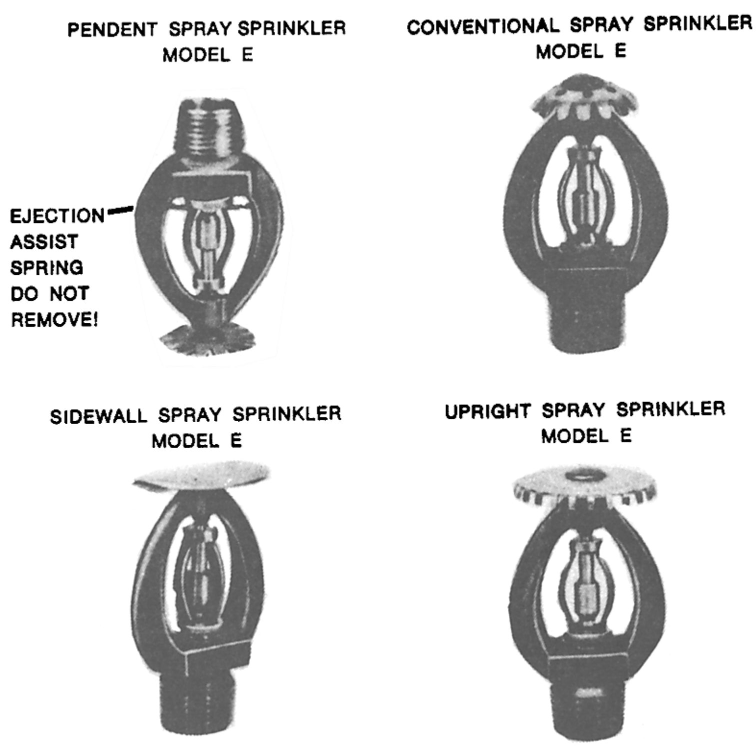

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Figure 8-16.—Frangible pellet automatic sprinkler.

A *dry pendent sprinkler* (fig. 8-18) is used when pendent sprinklers must be placed on dry pipe systems or in wet pipe systems when the area to be protected is subject to freezing (such as a walk-in reefer or outside shop area) and the piping network is installed in a heated area. This sprinkler is fitted with a tube within an attached pipe. The tube holds the water sealing elements in place against a watertight seal at the top of the pipe. When the sprinkler is actuated, the tube drops down and releases the elements through the tube and out the open sprinkler with the water discharge.

Open sprinklers consist only of a sprinkler frame and deflector. They are used on special sprinkler systems such as deluge or rapid reaction systems (fig. 8-19).

Water spray nozzles (fig. 8-20) are used for special application of water in various patterns (for example, wide or narrow angle, long throw or flat patterns). The different patterns may be achieved by either internal or external deflection of the water stream depending on the type of nozzle.

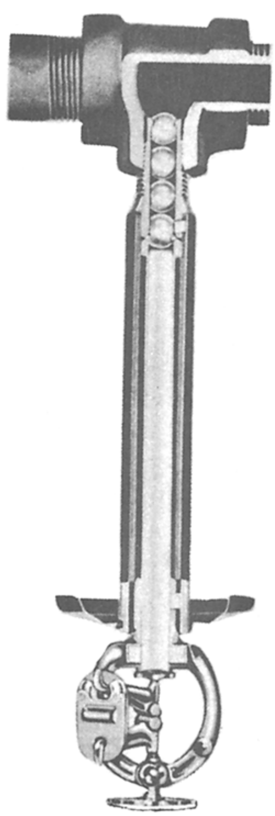

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Figure 8-18.—Dry pendent automatic sprinkler.

SPRINKLER SYSTEM DETECTION AND INDICATING DEVICES AND FITTINGS

Sprinkler systems have many different controlling devices and fittings. These can be classified as detecting or initiating devices or fittings. Their function is to detect system operation and to initiate system operation or alarm systems connected to the sprinkler system. This section discusses these devices and fittings to aid you in installing and troubleshooting sprinkler systems and understanding the interface between the mechanical and electrical functions of these devices.

Water-Flow Actuated Detectors

Sprinkler water-flow detectors are generally pressure-actuated or vane-actuated. Pressure switches are used on both wet and dry pipe systems. Vane switches are widely used on wet pipe sprinkler systems. They cannot be used on dry pipe systems because the initial rush of water into the pipe could damage the vane and mechanism.

Dry pipe system alarms tend to be slow-acting because it takes time to lose sufficient air through a fused sprinkler to trip the system. Various methods are used to speed up dry pipe systems as discussed earlier.

Wet pipe system alarms have a different problem. Fluctuating water pressure frequently causes flow into a sprinkler system, equalizing the sprinkler system pressure with the supply pressure. Such surges of water or of pressure cause false water-flow alarms if some method of slowing

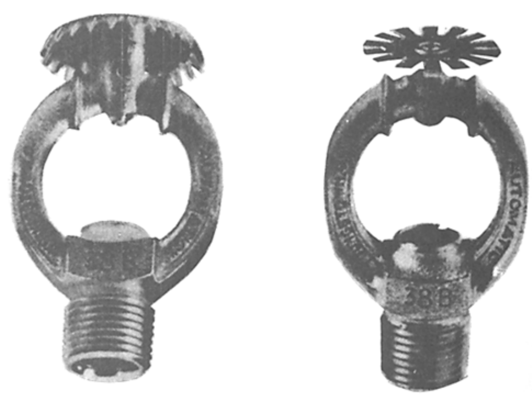

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Figure 8-19.—Open sprinklers.

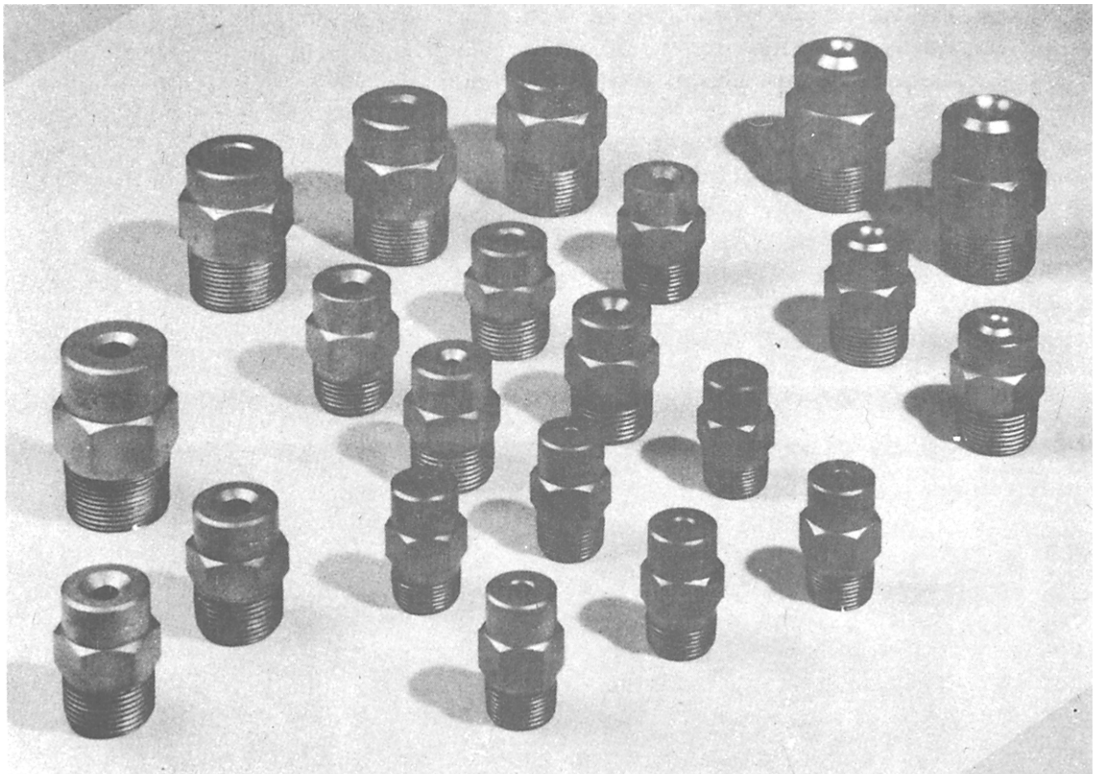

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Figure 8-20.—Water spray nozzles.

down the switch response to the surge is not used. Various retarding techniques are used, some associated with the sprinkler piping and some with the water-flow detector.

The pressure increase type of water-flow detector (fig. 8-21) comes in numerous styles. It is found in wet or dry pipe sprinkler systems. The usual arrangement for switch actuation includes a sealed accordionlike bellows that is assembled to a spring and linkage. The spring-tension setting controls the pressure at which the flow detector is actuated. It can be field adjustable and/or factory set to the desired pressure that activates the electrical switch. If this pressure switch is to be used on a wet pipe system, it is usually mounted at the top of a retarding chamber. This reduces the speed of pressure buildup at the switch. Other styles of this switch incorporate a pneumatic retarding mechanism within the detector housing. The retard time is adjustable to a maximum of 90 seconds. Usual settings are in the range of 20 to 70 seconds. The retard switch is connected to the alarm port of a wet sprinkler system alarm check valve. It is usually set for a pressure range of 8 to 15 psi.

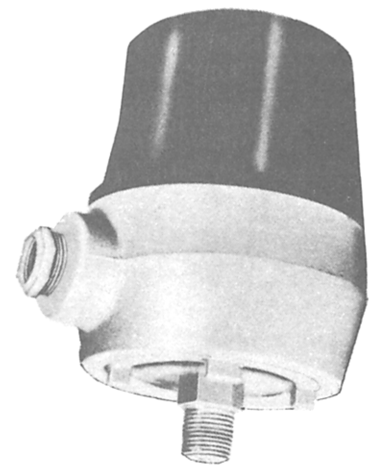

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Figure 8-21.—Pressure increase type of water-flow detector.

Pressure drop detectors can be used in wet pipe sprinkler systems equipped with a check valve (alarm check or swing check) that holds excess pressure on the system side of the check valve. These detectors are frequently used where a water surge or hammer causes false alarms with other types of water-flow detectors. The construction of pressure drop detectors is similar to the pressure increase detectors. The switch for a pressure drop detector is arranged to actuate on a drop in pressure. There is no retarding mechanism or chamber. A typical switch of this type would be adjusted for a normal operating pressure in the range of 50 to 130 psi. The alarm pressure would be adjustable between 10 to 20 psi below normal pressure.

A vane type of water-flow detector (fig. 8-22) is used only in wet pipe sprinkler systems. The detector is assembled at the pipe by drilling a hole in the wall of the sprinkler pipe, inserting the vane into the pipe, then clamping the detector on with U-bolts. When the sprinkler system is actuated by fire, the water flowing through the pipe causes the vane to move. A mechanical linkage connects the vane to an adjustable retarding device, usually a pneumatic dashpot. The retarding device actuates the alarm switch or switches and/or signal transmitter. The retarding device setting is usually in the range of 30 to 45 seconds. A maximum setting may be as high as 90 seconds if necessary.

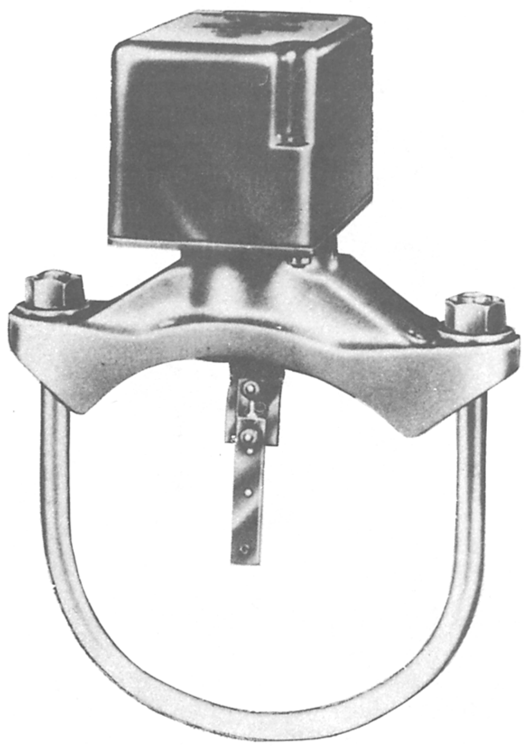

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Figure 8-22.—Vane type of water-flow detector.

The pressure pump/pressure drop type of water-flow detector is used in large sprinkler systems and in those systems with inadequate water pressure to reliably operate one of the other types of water-flow detectors. These detectors are also known as fixed-pressure, water-flow detectors, with pump (fig. 8-23). This detector has a pump, pump motor, and control unit. It is arranged for strap-mounting to the sprinkler system riser. The device provides a water-flow alarm signal, a low system water pressure supervisory signal, and excess pressure in the system to prevent surges in the supply pressure from opening the alarm check valve and causing operation of the water motor gong or other alarm indicators.

A typical detector of this type is adjusted to maintain the system pressure at 25 to 50 psi above supply pressure. A slow leak at the alarm check valve or anywhere in the system will cause the system pressure to drop slowly. When pressure decreases to 2 psi below the preset value, a pressure switch closes, causing the pump to start pumping water from the supply side to the system side of the alarm check valve at a rate of about 1 gallon per minute (gpm). If the total system leaks less than 1 gpm, the pressure switch opens and stops the pump when the preset pressure is reached. However, if the system leaks are greater than 1 gpm, system pressure will continue to drop even with the pump running. If system pressure decreases to 4 psi below the preset value, a trouble pressure switch opens to indicate that there is a leak greater than 1 gpm. If the water pressure continues to drop to 6 psi below the preset value, an alarm pressure switch closes, signaling a water-flow alarm. Some water-flow detectors of this type have an additional switch that disconnects pump power when the supply water pressure drops below 14 psi. This prevents pump burnup in case of total supply shutdown or a break in the supply line.

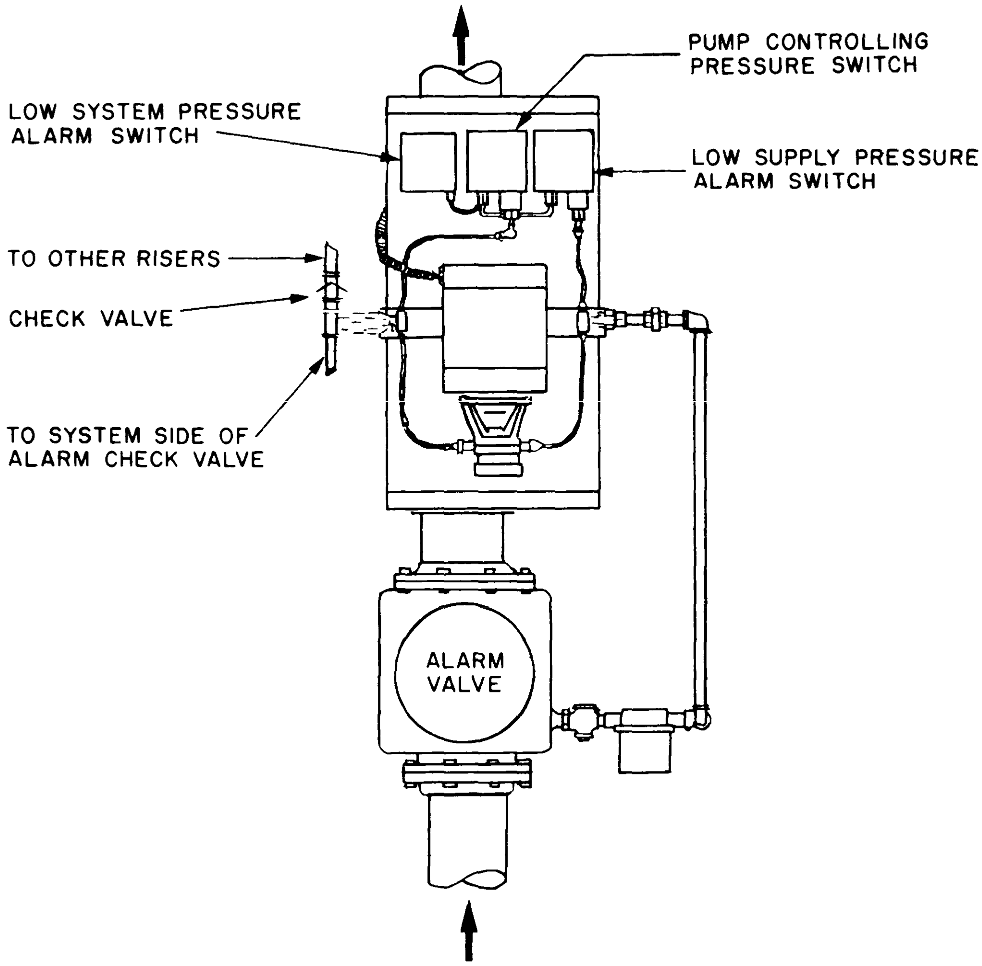

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Figure 8-23.—Fixed pressure water-flow detector with pump.

The electronic pressure drop detector is often used in sprinkler systems that must maintain a high excess system pressure over supply pressure that would delay actuation of a vane type of water-flow detector. It is normally mounted to the riser pipe with a flexible hose connection to the system side of the check valve. This device requires a pressure drop of 5 to 20 ounces per square inch continuing over a period of at least 3 seconds to signal an alarm. A pressure drop at a slower rate or of a shorter duration causes no alarm. A slow pressure drop to 15 psi or less causes a trouble signal indicating a system leak and low supply pressure. Pressure increases do not cause an alarm, but an over pressure condition (200psi) causes a trouble signal. Trouble signals will also be initiated when the detector's cover is opened, supply voltage is outside normal ranges, and an internal circuit fails, interfering with detector function.

Supervisory Alarm Initiating Devices

Supervisory alarm initiating devices cause a signal at the supervisory control unit and/or remote receiver when an abnormal fire protection system condition occurs. In general, supervised valves are never closed unless a sprinkler system requires maintenance. Valves that control water flow to a water-flow detector or valves in a sprinkler header room or fire pump room that are normally closed may be supervised. Supervisory devices for normally open valves signal when the valve is closed no more than two turns or 20 percent of its total travel. Supervisory devices for normally closed valves signal when the valve is opened no more than two turns or 20 percent of its total travel.

Outside screw and yoke (OS&Y) valve position indicators (figs. 8-24 and 8-25) are firmly attached to the valve yoke (fig. 8-26). The spring-loaded switch-operating lever or plunger rests in a smoothly tapered notch in the valve stem. When the valve is operated, the stem moves in or out; the lever or plunger moves up the incline at the edge of the notch. The switch is actuated before the lever or plunger is out of the notch. This causes a supervisory signal at the control unit and/or remote receiver.

A post indicator valve (PIV) will have a position indicator mounted to it (fig. 8-27). Usually a PIV is located outside the building and may be mounted on the ground or on the building wall. A spring-loaded lever rests against the side of the open/shut indicator, called a target. As the valve is operated, the target moves. The switch follows this movement. The position indicating switch is adjusted to cause a supervisory signal before the operating nut has rotated two turns or 20 percent of its full travel.

Nonrising stem valve position indicators are attached to nonrising stem valves, usually installed underground. The housing of the device is made of a noncorroding material such as brass. The switch itself is a magnetically operated, sealed reed switch. As the valve is operated, the magnet moves away from the reed switch. After the valve has

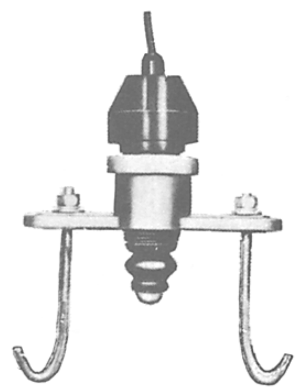

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Figure 8-24.—OS&Y valve position switch (plunger type).

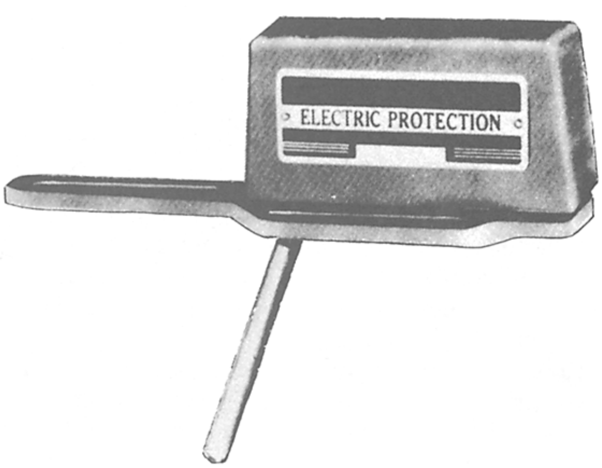

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Figure 8-25.—OS&Y valve position switch (lever type).

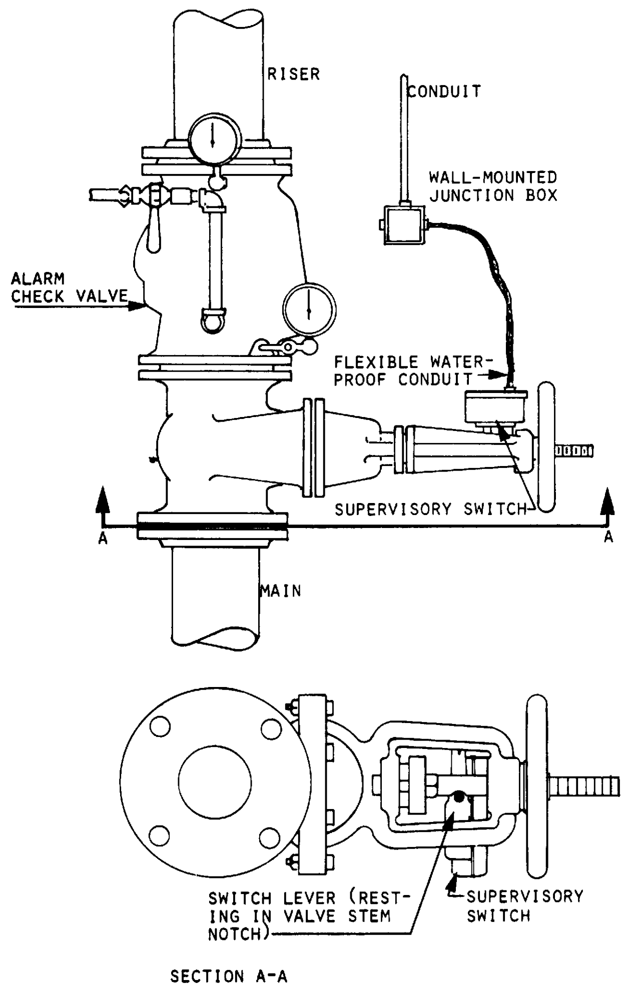

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Figure 8-26.—OS&Y valve position supervisory switch installation.

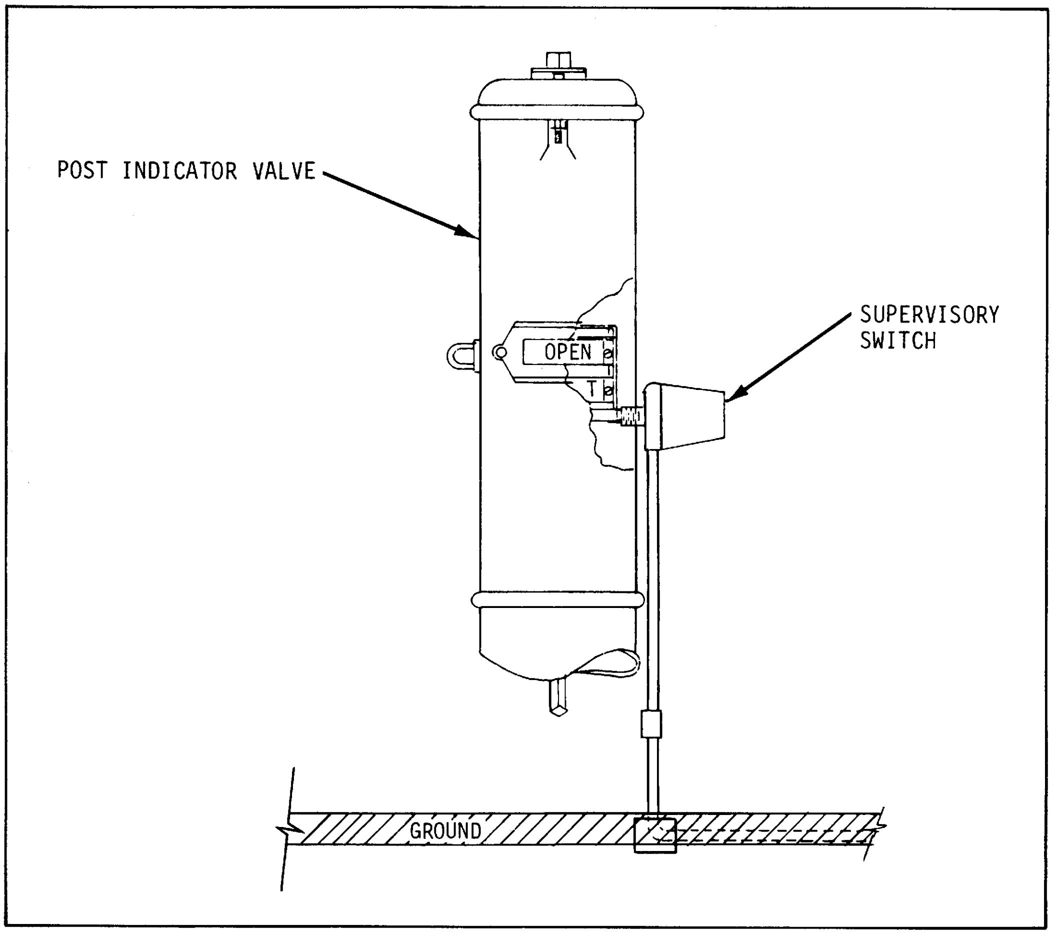

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Figure 8-27.—PIV position supervisory switch installation.

been opened two full turns the magnet is far enough away from the reed switch to actuate it, causing a supervisory signal at the control unit and/or remote receiver.

Water level in sprinkler system reservoirs must be maintained within certain limits. There are usually automatic controls for maintaining the desired water level. Water level supervisory devices cause a supervisory signal when the water level is not maintained between the desired high and low limits.

A float-actuated level indicator (fig. 8-28) is mounted outside on the wall of a tank with its float and lever extended into the tank. The lever arm pivots at the tank wall and rises or falls with the water level. A switch or switches (one for high level, one for low level) are actuated when the float moves outside

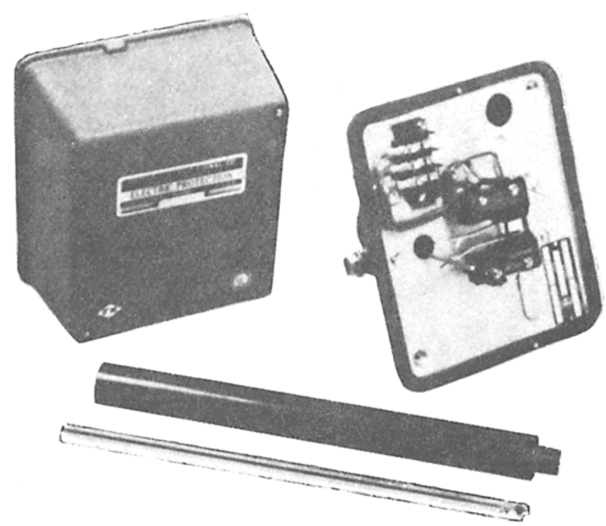

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Figure 8-28.—Water level switch (float actuated).

of normal limits. Figure 8-29 shows a typical high-low water level supervisory device installed in a sprinkler system reservoir.

A pressure-actuated level indicator is physically very similar to the bellows-operated pressure switches used for water-flow detection (fig. 8-21). As the water level changes in a reservoir, the water pressure at the supervisory switch also changes. The switch can be adjusted to actuate when pressure indicates a low water level or a high water level. This device is generally installed in the piping near the bottom of the reservoir.

Electronic level indicators may also be found in some systems. These indicators read the conductivity of water to cause an electrical signal. These devices are most frequently used to sense high water levels. They are not commonly used in fire protection systems.

Temperature supervisory devices are used to prevent water freezing in fire protection systems.

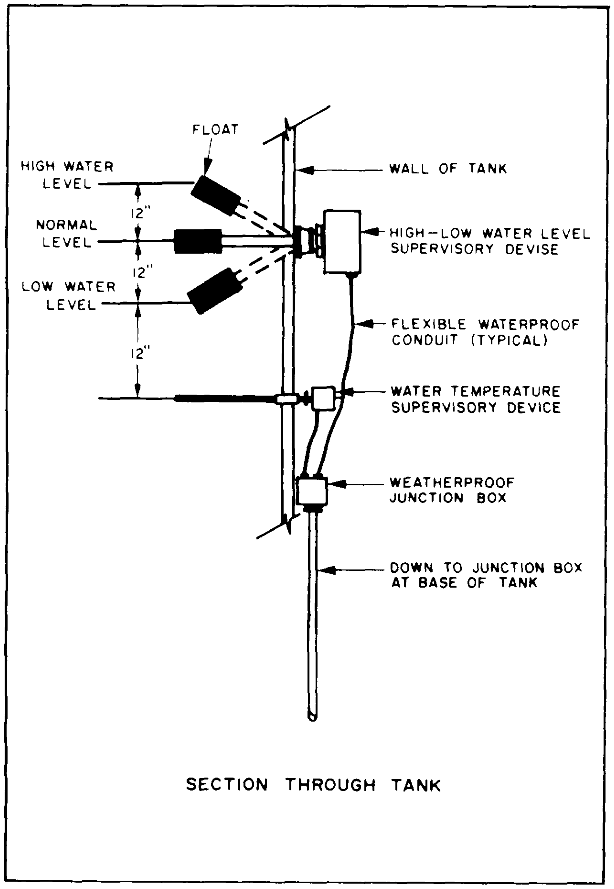

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Figure 8-29.—Installation of water level and water temperature supervisory devices.

Utilitiesmen will most commonly work with low water temperature indicators. These are usually sealed, factory-set thermostats and may be installed in system pipe or reservoirs. The most frequent low temperature setting is 40°F. Figure 8-29 shows a low water temperature indicator installed in a system reservoir.

You may find other supervisory devices in use. They will usually be specifically designed for a particular system. The principles of operation are generally the same as those already discussed. Physical mounting provisions or other details may vary. Refer to NAVFAC MO-117, manufacturer's manuals, and NFPA #13 for more complete information, when you must install or maintain these devices.

WATER SUPPLY REQUIREMENTS

Water supplies that serve sprinkler systems must be adequate and reliable. To determine the amount of water necessary for a sprinkler system, the rate of flow and pressure needed for effective performance must be known. If additional fire hose streams from outside the building will be required, these should also be included. The combined water needed for all fire-fighting equipment is known as the *fire flow demand.*

An adequate system can deliver the required fire flow for a specified time with normal water consumption at the maximum rate. To be reliable, the system must also be able to deliver the fire flow demand under certain emergency conditions, such as when a supply main or pump is out of service. The desired reliability of the system depends upon the nature of the protected structure (people, property, or mission). Water may be supplied by public or base sources, water tanks, or fire pumps.

For specific information regarding the fire flow demands of sprinkler systems, refer to NFPA #13, chapters 2, 7, and 8. These chapters will give you the information required for the sizing of each particular type of sprinkler system hazard based on residual pressure, acceptable flow rates, and duration times.

INSPECTION, TESTING, AND MAINTENANCE REQUIREMENTS

Sprinkler systems, when properly installed, are an effective means of fire protection for life and property. To make sure these systems are reliable, periodic inspection and maintenance of system components are required. Inspection should include a visual check and, if possible, a test of the components to be sure a working condition exists. The frequency of the overall testing and inspection process is summarized in table 8-2.

INSPECTION AND TESTING

During inspections of sprinklers, certain conditions indicate maintenance requirements. If these conditions are not corrected, they will reduce the reliability of the system. These conditions and

Table 8-2.—Summary of Inspection and Test Frequencies for Sprinkler Systems

	WEEKLY	MONTHLY	QUARTERLY	ANNUALLY	EVERY 3 YEARS
Check general condition of sprinklers and sprinkler systems				x	
Conduct flow tests of open sprinklers				x	
Conduct main drain tests			x		
Test water-flow alarms		x			
Check air and water pressure in dry pipe systems	x				
Trip-test dry pipe valves				x	
Drain low points in dry pipe systems				x	
Trip-test deluge and pre-action systems				x	X[1]*
Trip-test high-speed suppression systems					x
Check general condition of standpipe systems			x		
Perform water-flow tests				x	
Check general condition of hydrants				x	
Check general condition of fire department connections				x	
Check water levels in tanks	x				
Check general condition of water storage tanks				x	
Check water level and air pressure in pressure tanks	x				
Check general condition of pressure tanks				x	
Check tank heating systems				x	
Inspect and test cathodic protection equipment				x	
Start fire pumps	x				
Check fuel supply to engine drivers	x				
Perform fire pump flow tests				x	
Inspect and test controllers				x	
Inspect valves for open position		x			
Conduct general preventive maintenance inspection of valves				x	
Inspect check valves, water-flow meters and backflow preventers					X*
Test pressure regulating and altitude valves				x	

1—Annual trip test may be dry; wet trip test including flow of water through heads/nozzles shall be conducted a minimum of once every 3 years. *

some remedial actions are discussed in the following sections,

Automatic Sprinklers

Conditions that indicate the need for maintenance for automatic sprinklers include the following:

- Mechanical injury such as bent or loose deflectors or bent frames. Where sprinklers are subjected to continual damage, provide approved sprinkler guards.

- Corrosion such as marked discoloration or hard deposits. Use lead-coated or wax-coated sprinklers to prevent corrosion.

- Overheating causes soldered joints and cracked quartz bulbs to give way. Temperature ratings for soldered link sprinklers should be 50 “F above (for quartz bulb sprinklers 25 ‘F above) normal room temperature.

- Freezing produces reduced tension in soldered links, bent struts, and distorted caps.

- Loading is deposits of paint or other foreign materials.

- Need for replacement or relocation. Major construction and occupancy changes and changes to heating, lighting, and air-conditioning systems may require relocation or replacement of sprinklers or additions to the system. Changes in sprinkler location and pipe sizes should be based upon an engineering evaluation.

- Where sprinklers are installed in areas where there is stockpiling of materials a clearance of at least 18 inches under the sprinklers is necessary for proper water distribution.

Keep a supply of extra sprinklers for the various types and temperature ratings required and a sprinkler wrench.

Outside Open Sprinklers

When you are servicing outside open sprinklers, you should do the following:

- Visually check the general condition of sprinklers.

- Close windows and doors and take proper precautions to avoid water damage to property before making flow tests.

- Conduct the flow test by opening the control valve.

After making flow tests, remove and clean any plugged or obstructed sprinklers.

Piping and Hangers

In servicing piping and hangers, check for mechanical injury and corrosion. Replace bent or damaged piping and fittings and replace or repair missing or loose hangers. Make sure that piping is not used to support stock, equipment, or other material.

Make sure wet pipe system piping is properly protected against freezing. Before and during freezing weather, check piping of dry pipe systems for proper drainage. During freezing weather, open drains for outside sprinkler systems. Drain water from low point drains and drum drips on dry pipe systems before freezing weather occurs.

Obstructed Piping

When evidence of obstruction of piping has been found, check for the following sources of obstructing material:

- Improperly screened inlets from open bodies of water
- Poorly maintained elevated gravity tanks
- Dead end of extensive water distribution systems
- Poorly installed underground mains
- Highly acid, alkaline, or saline water
- Active chemicals in water supply
- Use of secondhand materials in the sprinkler system
- Frequent operation of systems (especially dry pipe systems) introducing additional foreign material and free oxygen

Alarm Check Valves

Perform a 2-inch drain test quarterly to test alar m check valves. Open the 2-inch drain valve fully and record pressure on the gauge located below the clapper at the lowest point. Close the 2-inch drain valve and record pressure at the stabilization point. Notice whether pressure returns quickly or slowly. Maintain a continuous record of drain tests. If recorded pressure when the valve is wide open is similar to previous recordings and pressure returns quickly, it is normal.

If recorded pressure when the valve is wide open is significantly lower or pressure is slow to return when the valve is closed, there may be an obstruction in the waterway. Check for the following problems:

- Partially closed valves to sprinkler system

- Obstruction in alarm valve preventing clapper from opening freely

Test local water-flow alarm operation monthly by opening the test connection at the end of the system. Where there is no test connection, the alarm may be tested by opening the bypass valve to the circuit opener or closer or by opening the 2-inch drain valve about two and one-half turns. Do not test water motor alarms during freezing weather. To find principal causes of alarm failures, check for the following:

- Failure of automatic drain on retard chamber to close

- Closed or partially closed valve on piping to alarm devices

- Plugging of bell casings of water motor gongs by foreign material

- Corrosion of moving parts of water motor gongs

- Detachment of shaft couplings from water motor gongs

- Insufficient water flow to operate devices

- Alarm check valve corroded shut (this failure is not common and will not occur when systems are properly maintained)

To find principal causes of false fire alarms, check for the following:

- Improper drainage of retard chamber (correct this by opening the chamber and cleaning or repairing the automatic drain)

- Pressure surges through the alarm check valve

Fill wet pipe sprinkler systems slowly through throttled valves and open the control valve wide after the system has been filled. Be sure there is no drainage from retard chambers. Leakage means that the alarm valve clappers are not seating properly. They require cleaning and possibly overhauling.

Make internal inspections of alarm valves when normal testing procedures indicate the need.

- Examine valve body for tuberculation.

- Check clapper operation—the clapper should move freely without sticking or binding.

- Replace clapper facings as required.

- Resurface seat rings as required.

Dry Pipe Valves and Air Check Valves

Air check valves are special, small, dry pipe valves that are usually connected to a wet pipe system. The alarms are actuated at the wet pipe system riser when the air check valve “trips.” To prevent premature operation, the valves should be fitted with an air chamber to maintain at least 50 gallons of air in the chamber and on the system.

Perform the 2-inch drain test quarterly by opening the 2-inch drain valve fully and recording the pressure at the lowest point. Close the 2-inch drain valve and record the pressure at the stabilization point. Notice whether pressure returns quickly or slowly. Maintain a continuous record of drain tests.

If the recorded pressure when the valve is wide open is similar to previous recordings and pressure returns quickly, it is normal.

If recorded pressure when the valve is wide open is significantly lower or pressure is slow to return when the valve is closed, there may be an obstruction in the waterway. Check for partially closed valves to the sprinkler system.

Because dry pipe sprinkler systems are installed in areas where temperatures are expected to drop below freezing, all parts of the system must be airtight and kept free of water. Complete drainage is essential.

Each fall, before freezing season comes, check the pitch of all piping carefully using a spurt level to detect dips and small pockets in the lines. Check for:

- broken, loose, or missing hangers; and
- water in low point drains.

Check air and water pressures weekly. If air pressure losses exceed 10 psi, check the entire system for tightness and eliminate air leaks. Principal checking methods are as follows:

- Put a strong smelling oil, such as oil of peppermint, into the air supply. This will produce a strong odor at the point of leakage.
- Paint fittings with a soapy water solution and watch for bubbles.

Check the temperature of valve enclosure and maintain a temperature above 42°F.

Make certain that the valve between the intermediate chamber and the alarm devices is open on dry pipe valves.

Check drip valves at intermediate chambers, making certain that clappers or balls are in a position to allow drainage. This is done by lifting push rods or by inserting a pencil in the opening. Water leakage through this valve is an indication that the water clapper is not holding tightly to the seat.

Check the air pressure. The air pressure versus water pressure for differential dry pipe valves should be as outlined in table 8-3 unless otherwise specified by the manufacturer's operating instructions. Certain mechanical dry pipe valves are designed to trip at a fixed pressure of 10 to 15 psi. Maintain 30 psi air pressure on these valves.

Basic inspections for accelerators and exhausters include the following:

- Check air pressure. The system and the quick-opening device air pressure should be the same.
- Relieve excess pressure in the quick-opening device by opening bleeder valves or loosening air gauges.

If the system pressure is high, relieve the excess pressure through the priming water test valve. Close the valve as soon as pressures balance. To avoid the possibility of tripping the dry pipe valve, do not open the priming test valve more than one turn and keep the valve to the quick-opening device closed while the priming test valve is open.

To make sure that dry pipe valves will operate effectively in fire situations, they should be trip-tested annually as follows:

1. Close the main control valve.
2. Open the 2-inch drain.
3. Open the main control valve until 5 psi pressure shows on the water gauge.
4. Close the 2-inch drain valve slowly.
5. Open the inspector's test connection of the system. Where there is no test connection, use the most remote low point drain.
6. As soon as the dry pipe valve trips, close the main control valve and open the 2-inch drain. This is particularly important in permanently cold areas.
7. Record initial air and water pressures, air pressure at the trip point, and time required for tripping.
8. Examine and clean the dry pipe valve interior. Replace facings and gaskets if needed.
9. Reset the dry pipe valve and the open control valve.
10. When a dry pipe valve fails to trip or when a clapper fails to latch in the open position, notify the person responsible for fire protection so that a qualified sprinkler contractor may be contacted.

To test dry pipe valves you should do the following:

1. Close the main control valve and open the 2-inch drain valve and low point drain valves.

Table 8-3.—Differential Dry Pipe Valve Air Pressure Specifications

MAXIMUM WATER PRESSURE psi	AIR PRESSURE RANGE psi
50	15-25
75	20-30
100	25-35
125	30-45
150	35-50

Close low point drain valves when water stops flowing.

2. Clean clapper facings and seats.

3. Clean the valve interior.

4. Place clappers on seats and make certain the antiwater column latch is in place. Bolt on the cover. Do not use grease or other material to help seat clappers. Fill the system with 10 psi air pressure to blow out any residual water through low point drains.

5. Open valves at the top and bottom of the priming chamber and priming test valves.

6. Admit water to the priming chamber until water flows out of the test valve. Close this valve.

7. Close the priming chamber valves.

8. Admit air pressure to the system.

9. Open the main control valve slowly.

10. Close the main 2-inch drain valve, except where water hammer conditions exist. In this case, leave the 2-inch drain valve open until pressures stabilize.

To check air supply piping, do the following:

Note air pressure within 12 to 24 hours after resetting the dry pipe valve. If air leakage exists, test sprinkler piping for leaks.

Make sure the valves to manually operated compressors are tightly closed. A slow air leak back through one of these valves can trip the dry pipe valve.

Examine restriction orifices in air piping and air pressure regulators, if used, from automatic air compressors to dry pipe valves.

Deluge and Pre-Action Valves

To test deluge and pre-action valves, perform the 2-inch drain test quarterly by opening the 2-inch drain valve fully and recording pressure at lowest point. Close the 2-inch drain valve and record pressure at the stabilization point. Notice whether pressure returns quickly or slowly. Maintain a continuous record of drain tests.

If the recorded pressure when the valve is wide open is similar to previous recordings and pressure returns quickly, it is normal.

If the recorded pressure when the valve is wide open is significantly lower or pressure is slow to return when the valve is closed, there may be an obstruction in the waterway. Check for partially closed valves to the sprinkler system. Check the water pressure and the local water-flow alarm through the bypass connection.

Some deluge systems have both open and closed sprinklers. Make sure heat-responsive devices are provided in areas with both open and closed sprinklers and are in service. Fusing of a sprinkler will not operate a deluge valve. Where conditions permit, trip-test each deluge valve every 3 years by flowing water through the heads/nozzles. To conduct a deluge valve dry trip-test, do the following:

1. Close the main control valve.

2. Apply an electric heat lamp to at least one heat-actuating device in each circuit, testing one circuit at a time. Note the time required to trip the valve. Where flammable vapors may be present, use a hot cloth or hot water in place of the electric test set.

3. Reset the deluge valve and trip, using the manual release.

4. Where fixed temperature releases are involved, wait 15 minutes and trip by removing a fusible element from the tubing or a heat-responsive device.

5. When tests are complete, reset valves and open the main control valves.

Because there are so many designs of heat-responsive devices, test procedures for each cannot be included here. See the individual manufacturer's information for detailed testing procedure. During routine inspections, check for painted or corroded contacts, plugged vents, or painted domes. Clean or replace affected devices.

Cathodic Protection Equipment

Inspect cathodic protection equipment as follows:

1. While equipment is operating, note and record current flow shown by meters. If there is no current, check for blown fuses, electrodes touching the tank, ground-wire connection to tank, or electrodes not immersed in the water. If equipment operates at voltages or amperages over those listed on the nameplate, the rectifier may be damaged. Check polarity and direction of current flow. (If connections to rectifier are reversed, rapid damage to the tank occurs.)

2. Check condition of electrodes that deteriorate because of action of current passing from electrodes to water. Replace worn electrodes. (Watch for diminishing current flow on the ammeter; this is a sign that the electrodes may be failing.)

3. Protect electrodes from ice. If ice formation is a serious problem, turn off current and remove and store the electrodes during the freezing season. Tank protection will continue for about 3 weeks after the unit is out of operation. Reinstall the electrodes at the end of the freezing season.

Nonfreeze Systems

No special testing of nonfreeze systems is required, other than an annual check of the specific gravity of the non freeze solution. If the specific gravity indicates a need for replenishing the nonfreeze agent, be sure to add the same agent as was previously used.

High-Speed Suppression Systems

Full operational testing of high-speed suppression systems is conducted at intervals not to exceed 3 years except when mission requirements justify change. A detector or a manual release station must be actuated. Check to be certain that all nozzles are operating. Then, follow these steps to reset the system:

1. Replace pre-prime caps and/or rupture disks.
2. Refill piping with water.
3. If the system uses an explosive valve, replace the firing squib and the squib holder.

MAINTENANCE REQUIREMENTS

The need for maintenance is shown by periodic inspections. It should include replacement of worn or broken components and cleaning and flushing of systems. A regular schedule of maintenance requirements should be devised. Logs recording accomplished tasks should be maintained as a record of the system's history. Be sure to include manufacturers' manuals for the system components and consult them when making repairs and adjusting or troubleshooting the system.

GASEOUS EXTINGUISHING SYSTEMS

Gaseous extinguishing systems are generally found in areas where equipment is installed that would be highly vulnerable to destruction from water or dry chemical extinguishing agents. Computer rooms, electronic gear such as radio receiving and transmitting equipment, and power generating facilities are examples of areas where gaseous extinguishing system installation would be desirable. In the Navy today, the Utilitiesman will come in contact with two commonly used systems. These are the carbon dioxide and the halogenated gas systems. Each of these systems is discussed in this section.

Gaseous extinguishing systems can be divided into three general categories: local application, total flooding, and hose line systems. *Local application systerms* discharge agent onto the burning material and are commonly used for protection of paint dip tanks, restaurant range hoods, and special motors. *Total flooding systems* discharge agent into and fill enclosed space. They are commonly found in flammable liquid storage rooms, computer installations, and transformer vaults containing oil-filled equipment. *Hose line systems* discharge extinguishing agent through manually operated nozzles connected to a fixed supply by piping and/or hoses. At present, carbon dioxide is the only gaseous agent approved for manual hose line systems.

CARBON DIOXIDE SYSTEMS

Here are two general methods of applying carbon dioxide to extinguish a fire. One method creates an inert atmosphere in the enclosure or room where the fire is located for a prolonged period of time. This method is called *total flooding*. The second method is to discharge carbon dioxide to the surface of liquids or noncombustible surfaces coated with liquid flammables. This method is known as *local application*.

Carbon dioxide is electrically nonconductive. It is used extensively for the protection of

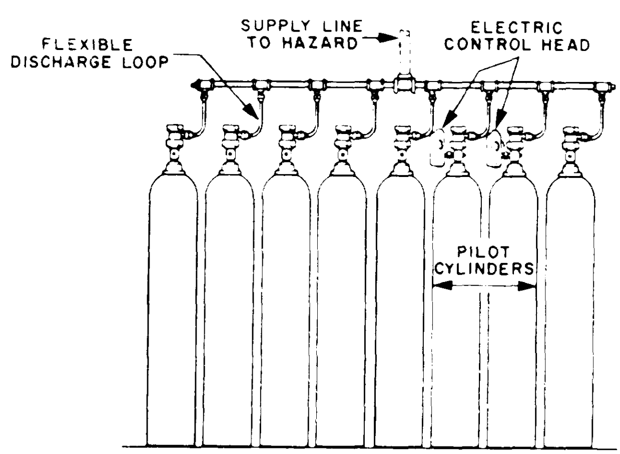

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Figure 8-30.—Typical cylinder arrangement for high-pressure CO_2 system.

electrical equipment. The nondamaging quality of this agent makes it useful as an extinguishing agent for computer rooms and computer tape vaults.

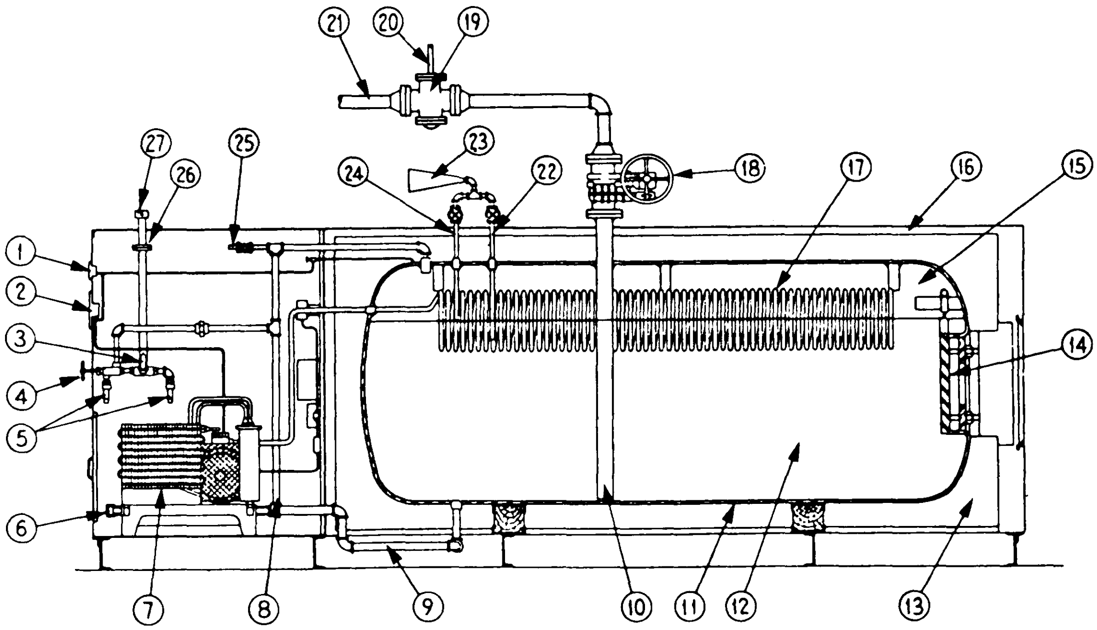
There are two general types of carbon dioxide extinguishing systems, high pressure and low pressure.

High-Pressure Systems

In the high-pressure system, high-pressure cylinders are used to store liquid carbon dioxide at ambient temperatures (fig. 8-30). Normal cylinder pressure is nominally 600 psi and varies with the ambient temperature of the storage area. Storage area ambient temperatures should not exceed 130°F or be less than 32°F. For safety purposes, high-pressure cylinders have a frangible disk that will burst at 3,000 psi to prevent cylinder rupture as a result of overpressurization.

Low-Pressure Systems

Low-pressure systems have a pressure vessel maintained at 0°F by insulation and refrigeration equipment (fig. 8-31). At this temperature, the pressure in the container is approximately 300 psi. Because the container is kept at a low temperature, the container can be filled to 90 to 95 percent of capacity. For safety purposes a relief



1. Carbon dioxide pressure gage
2. Carbon dioxide liquid-level gage
3. Bleeder relief valve, 341-lb (2350 kPa)(23.5 bars) diaphragm type
4. Pressure-relief-valve selector
5. Pressure-relief valves, 357-lb (2460 kPa)(24.6 bars) spring-loaded type
6. Carbon dioxide filling connection
7. Refrigerating unit
8. Carbon dioxide vapor-equalizing pipe
9. Carbon dioxide liquid-filling pipe
10. Dip tube
11. Pressure vessel, ASME Code
12. Carbon dioxide liquid
13. Insulation, 5-in. (127-mm) cork
14. Manway cover
15. Carbon dioxide vapor
16. Sheet-metal outer casing
17. Cooling coil
18. Manual shutoff valve
19. Master discharge valve
20. Carbon dioxide gas-pressure pipe from discharge control
21. Carbon dioxide supply pipe to selector valves
22. 90 percent carbon dioxide liquid-content check tube with control valve
23. Discharge test horn for checking carbon dioxide liquid content
24. 100 percent carbon dioxide liquid-content check tube with control valve
25. Carbon dioxide gas-pressure supply pipe to discharge control
26. Pressure relief, 600-lb (4140 kPa) (41.4 bars) frangible-disk type
27. Pressure-relief vent to atmosphere

87.379

Figure 8-31.—Refrigerated low-pressure CO_2 storage tank.

valve is installed to bleed off pressure at 341 psi. Another relief valve operates at 357 psi for rapid release of excess pressure. There is also a frangible disk designed to burst at 600 psi should the relief valves fail to control pressure buildups.

Advantages/Disadvantages of CO_2 Systems

There are advantages and disadvantages to each type of carbon dioxide system. Low-pressure storage units have a liquid level gauge that continuously monitors the amount of carbon dioxide in storage. High-pressure systems require weighing the cylinders. High-pressure systems permit storage of almost the exact amount of carbon dioxide required to protect a hazard area because of the flexibility and selection of cylinders in 50-, 75-, or 100-pound sizes. The smallest low pressure is 750 pounds. High-pressure systems require refilling and hydrostatic testing every 12 years. Low-pressure systems have no such requirement. Pressures in high-pressure systems vary with the ambient temperature; this affects the discharge rate of the system. Low-pressure systems keep the liquid carbon dioxide at 0°F and 300 psi at all times, assuring a uniform discharge rate. Another advantage of low-pressure systems is their ability to allow automatic, simultaneous discharge for more than one hazard area on an engineered basis. Hose reels can also be attached to these systems to operate simultaneously with hazard protection. A reserve supply can be provided by increasing the storage unit size of low-pressure systems. High-pressure systems require manifolding and valving arrangements to achieve a reserve supply.

Storage of the carbon dioxide is also a consideration in showing advantages or disadvantages of these systems. High-pressure systems require approximately 3 pounds of equipment for every pound. Usually, low-pressure systems require less floor space for storage of equal amounts of carbon dioxide as compared with high-pressure systems. In many instances, low-pressure storage containers may be placed outside of the buildings. High-pressure systems allow flexibility in space requirements since multiple cylinder banks may be stored in several smaller locations. Low-pressure systems require one large, single area for the refrigerated storage unit.

Operating Devices

As with all fire protection systems, carbon dioxide systems must have operating devices for discharge of the extinguishing agent and to cause alarms to be actuated. Many of the operating devices discussed earlier in this chapter can be used. Most commonly used are the heat-actuated devices (H. A. D.) or smoke detecting devices. Manual controlling devices are also used in carbon dioxide systems. Whether the agent release is automatic or manual, an alarm at the alarm system control unit should be actuated.

Piping

Carbon dioxide fire protection system pipe and fittings are selected to have suitable low temperature characteristics and good corrosion resistance inside and out. Ferrous metals are galvanized steel, copper, brass, and other materials having similar mechanical and physical properties are acceptable. Copper tubing with suitable flared or brazed connections is also acceptable. Cast-iron (gray) pipe and fittings are not used.

Pipe and fittings for high-pressure systems have a minimum bursting pressure of 5,000 psi. In low-pressure systems, pipe and fittings have a minimum bursting pressure of 1,800 psi.

Between the storage tank and selector valves, black steel pipe may be used because of the larger sizes involved and its airtightness.

The supply piping is usually routed to prevent unnecessary exposure to high temperatures from ovens or furnaces or to direct flame impingement

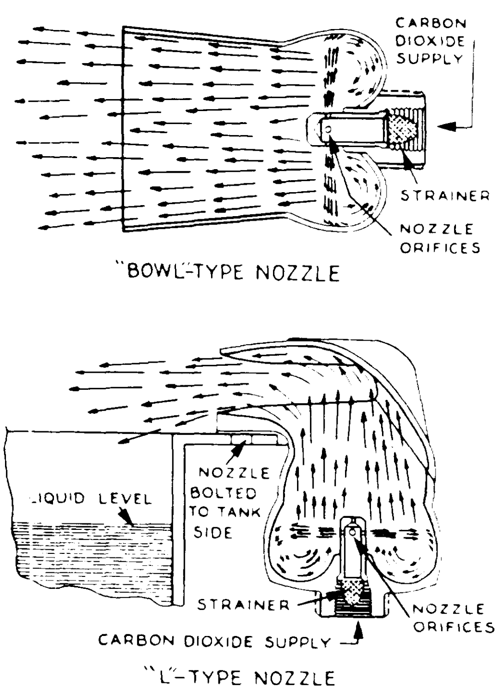


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Figure 8-32.—Carbon dioxide nozzles.

before discharge. Hot piping causes excessive vaporization of carbon dioxide and a resultant delay in effective discharge.

Pressure relief devices or valves that prevent entrapment of liquid carbon dioxide may be installed on sections of piping that can be closed off. On high-pressure systems, relief devices usually operate at 2,400 to 3,000 psi, and, on low-pressure systems, at 450 psi.

Nozzles

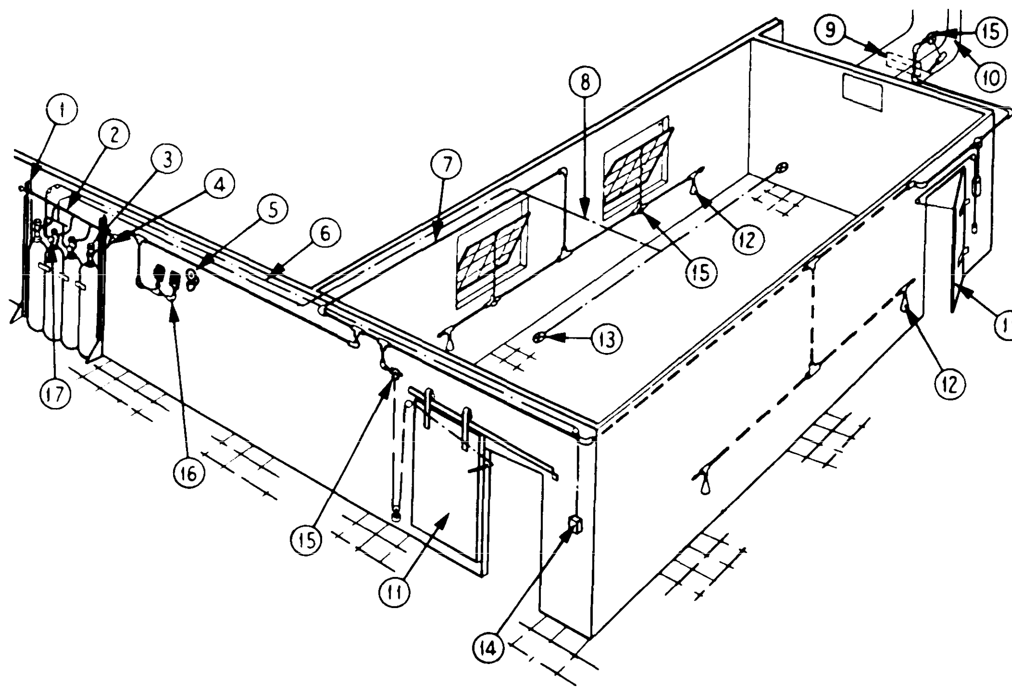
Nozzles are of various designs and discharge patterns. Two common types are shown in figure 8-32. Nozzles are marked with a code number indicating the diameter in 1/32-inch increments of a single orifice standard nozzle having the same flow rate. A No. 5 nozzle, for example, has the same flow rate as a 5/32-inch-diameter standard orifice. A plus sign (+) after the number indicates a 1/64-inch larger size. Decimals are sometimes used to indicate sizes between the whole numbers.

TOTAL FLOODING SYSTEMS

Total flooding systems are used for rooms, ovens, enclosed machines, and other enclosed spaces containing materials extinguishable by carbon dioxide.

For effective total flooding, the space must be reasonably well enclosed. Openings must be arranged to close automatically and ventilation equipment to shut down automatically, no later than the start of the discharge. Otherwise, additional carbon dioxide must be provided to compensate for the leakage.

Automatic closing devices for openings must be able to overcome the discharge pressure of the carbon dioxide. Conveyors, flammable liquid pumps, and mixers associated with an operation may be arranged to shut down automatically on actuation of the protection system. A typical arrangement of a total flooding carbon dioxide system is shown in figure 8-33.



1. Cylinder framing
2. Cylinder manifold
3. Pressure-operated discharge head
4. Flexible connection
5. Alarm gong
6. Remote-control cable (1/16-in.)(1.6-mm), run in 3/8-in. (9.5-mm) galvanized pipe or conduit with corner pulleys at all changes in directions; no bends or offsets allowed
7. Carbon dioxide piping
8. Actuator tubing, run in ½-in. (13-mm) conduit
9. Self-closing weight-operated damper
10. Air-exhaust duct
11. Fire door
12. Nozzle
13. Actuator on ceiling
14. Remote-control pull box
15. Pressure-operated trip to release self-closing dam fire doors, and windows
16. Pressure-operated switches to sound alarm and s down fan
17. Pneumatic-control head with local manual contr

Figure 8-33.—Total flooding carbon dioxide system installation.

LOCAL APPLICATION SYSTEMS

Local application systems are used to protect hazards, such as oil-filled transformers and paint dip tanks. Ventilating fans, conveyors, flammable liquid pumps and mixers associated with the operation may be interlocked to shut down automatically when the protection system is activated.

A typical arrangement of a local application carbon dioxide system is shown in figure 8-34.

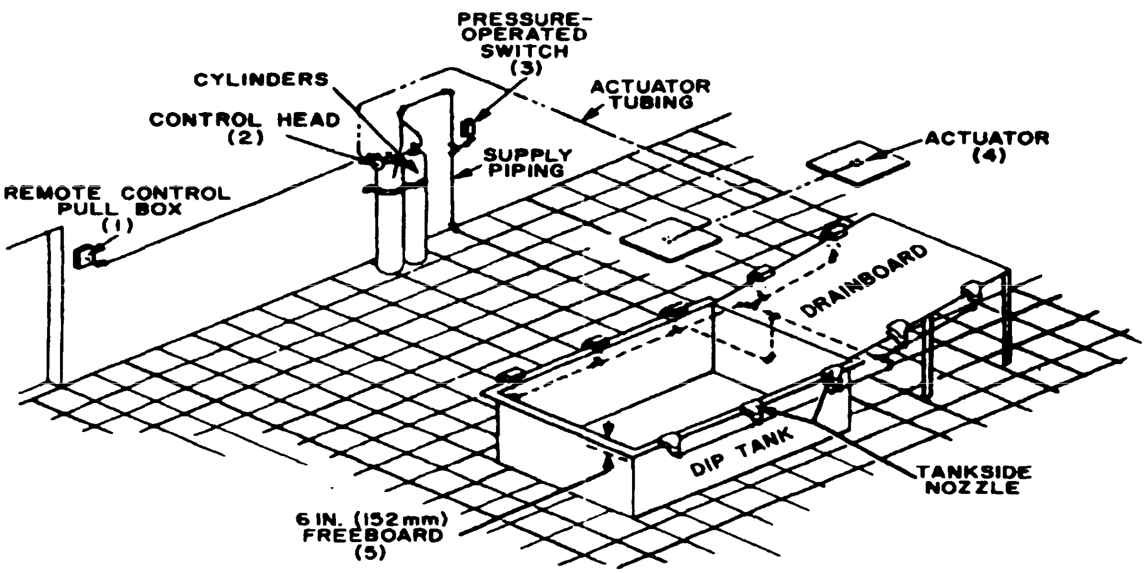
HALOGENATED GAS SYSTEMS

Several types of halogenated gas systems have been developed for fire protection purposes: Halon 104, Halon 1001, Halon 1011, Halon 1202, Halon 1211, Halon 1301, and Halon 2402. The numbers relate to the chemical formulas of the gases. The first digit identifies the number of carbon atoms in the chemical molecule; the second digit identifies the number of fluorine atoms; the third digit identifies the number of chlorine atoms; the fourth digit identifies the number of bromine atoms; and a fifth digit, if any, identifies the number of iodine atoms present. Primarily, Halon 1301 and Halon 1211 are in general use in the United States today. These two types are recognized by the National Fire Protection Association (NFPA). Standards for their installation and use are published in the National Fire Codes.

Halogenated gas systems are used in the following situations:

- A clean extinguishing agent is needed.

- Energized electrical or electronic circuits are to be protected.



1. Normal manual control, pull box, and cable
2. Pneumatic control head with emergency manual control
3. Pressure-operated switch to shut down conveyor, etc.
4. Actuator mounted under 2- by 2-ft (0.6- by 0.6-m) baffle plate
5. Tank freeboard to be at least 6 in. (152 mm)

Figure 8-34.—Local application carbon dioxide system installation.

- Flammable liquids or flammable gases are present.

- Surface-burning combustible solids are to be protected.

- For high value objects or processes.

- The area to be protected is occupied by people.

- Availability of water or space for other types of systems is limited.

Generally, Halon 1211 and Halon 1301 are used in total flooding applications.

For effective fire-fighting purposes, a minimum concentration of 5 percent is recommended for total flooding systems for surface fires of ordinary combustibles. Deep-seated fires, as in cable insulation, require much larger concentrations and extended holding times.

Halon 1211 is toxic to people when concentrations exceed 4 percent. This prevents its use as a total flooding agent for areas occupied by personnel. Halon 1211 is normally used in portable extinguishers because it is not in enough concentration to be a hazard for people. Equipment for halon fire extinguishing systems is similar to that used for high-pressure carbon dioxide systems. Halon 1301 is stored in a cylinder super pressurized with nitrogen to 600 psi (at 70°F) to provide an expellant pressure for the agent in excess of the agent's normal vapor pressure.

Because of the high ozone depletion factor of halons, installation of new Halon 1301 systems are prohibited except by special approval from NAVFACENGCOM.

Halon 1301 is the least toxic of the halongenated gases and does not harm personnel when concentrations are below 10 percent. Systems that remain in use are located in computer rooms.

PHASE OUT OF HALONS

Because of the high ozone depletion potential of CFCs, HCFCs, and halon gases, the EPA enacted the provisions of the Montreal Protocol into regulations for the United States. This will eliminate the production of halons by the year 2000. If you are maintaining a system that contains halon gas, consult engineering for information pertaining to system conversion.

GASEOUS EXTINGUISHING SYSTEM ALARMS

There are special considerations for gaseous system alarms because of possible toxic effects on personnel, the need for a reasonably fast response, and reliable operation. Response time for gaseous extinguishing agents is not usually as urgent as foam agents, considering the types of hazards protected. Personnel safety precautions also effect the speed requirement. Heat and /or smoke detectors are frequently used as initiating devices.

Cross-zoning is also frequently used for gaseous extinguishing systems. The first detector (zone) actuation is arranged to cause a local audible and/or visual signal. The second detector (zone) actuation causes a distinctive local signal to warn personnel that the extinguishing agent is about to be released.

Some gaseous extinguishing systems, usually those protecting populated spaces, have an abort feature to avoid unnecessary discharge of an expensive, possibly toxic gaseous agent. Extinguishing systems with the abort feature have a time delay between actuation of the second (or only) detector and release of the agent. The delay may be factory-set or adjustable. It is usually set in the range of 15 to 60 seconds, so personnel can leave the area before release of the agent and to allow for manual interruption of the agent release sequence. If the situation is not dangerous, the sequence can be interrupted by a manual abort switch. When the detectors and control unit have been restored to their normal condition, the abort switch can be restored. The abort switch is usually designed to be held in (until the control panel is reset) so that the agent discharge cannot be accidentally impaired when the switch is unattended.

Initiating Devices

Frequently used detectors for gaseous agents are spot-type ionization smoke detectors and rate-compensated heat detectors. Factors affecting detector effectiveness, such as electrical power and air pressure, if pertinent, are supervised.

One or two manual methods for release of the gaseous agent are usually provided.

- Manual fire alarm devices are frequently connected to the alarm system control unit to cause immediate discharge of the gaseous agent, regardless of cross-zoning and time delays otherwise provided.

- Manual devices may also be connected electrically to cause direct release of the agent, independent of the alarm system.

- Direct mechanical release of agent maybe by manual actuation of a control valve.

Whether the agent release is caused by an alarm control unit auxiliary output or by an independent manual method, there should be an alarm at the alarm system control unit. Manual release of the gaseous agent usually causes an alarm by actuating a pressure switch that senses the increase in pressure in the gas line or manifold between the release valve(s) and the nozzles.

Sequence of Alarms

The normal circuit arrangement for a building alarm system to release a gaseous extinguishing agent is the same as for a building system with added features such as cross-zoning, the abort feature, manual release of agent, and other specific auxiliary functions of the alarm system. Alarm systems that release a gaseous extinguishing agent use auxiliary alarm outputs to segregate the protected area and reduce dispersion and dilution of the agent. Typical auxiliary functions are fan shutdown, door (and window) closure, and closure of air-handling system dampers. Gaseous agent-releasing alarm systems applied to computer room installations also shut down computer power at the time the agent is released to eliminate the heat source for possible electrical fires.

A typical sequence of alarm system-initiated events in a computer room installation that includes all the usual features is as follows:

- Detection of fire by first detector in an area causes local and remote alarm indication, fan shutdown, door and damper closure, and other miscellaneous auxiliary functions through interlocks with building systems.

- Detection of fire by second detector in the area (cross-zoned with first detector) causes a distinctive local audible signal and initiates a time delay during which agent release and computer power shutdown may be aborted.

- At the end of an adjustable delay (normally 20 seconds), assuming the release is not aborted, computer power is shut down and the extinguishing agent is released into the protected area.

INSPECTION, TESTING, AND MAINTENANCE OF GASEOUS SYSTEMS

Inspection, testing, and maintenance of gaseous fire extinguishing systems are required to be sure they are in proper operating order. Inspection and test frequencies for these systems are summarized in table 8-4.

Carbon Dioxide High-Pressure Systems

Check hoses and nozzles, cylinders, and cylinder pressure as follows:

Weekly, check that all nozzles and hand hose lines are clear and in the proper position and that all operating controls are properly set.

Semiannually, weigh cylinders and replace any that show a weight loss of greater than 10 percent. To weigh cylinders, do the following:

- Loosen each cylinder support and disconnect each discharge head. Discharge heads are designed to be removed and replaced without tools.

Table 8-4.—Summary of Inspection and Test Frequencies for Gaseous Systems

	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY
Check CO_2 and Halon nozzles and hand hose lines	x			
Weigh cylinders			x	
Check liquid level in low-pressure CO_2 storage tanks	x			
Check devices and connections of low-pressure CO_2 systems for leakage		x		
Test tank alarm pressure switch and identification device			x	
Conduct actuating and operating tests of CO_2 and Halon system cylinders				x
Hydrostatic test of cylinders and hoses	(See text for frequency)			

- Weigh cylinders with a beam scale or with a platform scale. To weigh with a platform scale, remove the cylinders completely from the rack and lift them on to the scale.

Test cylinders and hoses hydrostatically as follows:

Hydrostatically test cylinders to a minimum pressure of 3,000 psi. The frequency for testing is as follows:

- If discharged after 5 years from date of last test, perform hydrostatic test.

- If not discharged after 12 years from date of last test, discharge cylinder and perform hydrostatic test.

Hydrostatically test hoses to a minimum pressure of 1,250 psi. The frequency of testing is the same as for cylinders.

Carbon Dioxide Low-Pressure Systems

Check nozzles, pressure and level gauges, and for leaks in all devices.

Weekly, check to see that all nozzles are clear and in the proper position and that all operating controls are properly set. Check and record the reading on the liquid level gauge of all storage tanks. Refill tanks when the quantity is less than the minimum required to protect the largest single hazard, including any required reserve supply.

Monthly, check for leaks on all devices and connections under continuous pressure, including valve packing glands, screwed connections, and safety relief valves.

Semiannually, test the tank-alarm pressure switch and the operation of the alarm bell or light by reducing and increasing the pressure. Perform this test as follows:

- Close valve on the piping from the vapor space to the alarm pressure switch.

- Remove the test plug to reduce pressure.

- Increase pressure by connecting a high--pressure cylinder to the test opening.

- After testing, disconnect the high-pressure cylinder, replace the test plug, and reopen the valve on the alarm pressure switch piping.

- If the bell or light fails to operate on the pressure test, repair or replace, and test again.

Check the liquid level and pressure gauges for accuracy once each year.

Replace frangible disks on the storage tanks once every 5 years. Maintain refrigeration equipment according to the manufacturer's instructions.

Halogenated Systems

Follow these procedures to test halogenated systems. Weekly: check to see that all nozzles are clear, positioned properly, and all operating controls are set properly. Semiannually: check weight and pressure containers. (See procedures for verifying CO_2 cylinders.) If the container has a loss in net weight of more than 5 percent or a loss in pressure (after adjusting for temperature) of more than 10 percent, you must either refill or replace the container. When a factory-charged nonrefillable container does not have a pressure indicator that shows a loss in net weight of more than 5 percent, you must replace the container. Annually: test all actuating and operating devices. Use a cylinder containing carbon dioxide in the place of a halon cylinder or perform a simulated test of pressure-operated devices.

Alarm Systems

You should perform tests and maintenance of detectors, circuits, control units, annunciators, relays, and power supplies, as described in *Maintenance of Fire Protection Systems*, NAVFAC MO-117, chapter 3,. Some additional steps are required to test cross-zoned detectors, electrically operated releases for gaseous agents, and an abort feature.

Release Devices and Auxiliary Functions

Test electrically operated release devices for gaseous extinguishing systems annually. Combine this test with tests of detectors and the total alarm system. If you cannot perform an actual discharge test, be sure to prevent gas discharge and computer power shutdown, if provided, while observing electrical functions. This may require valve closure or partial disassembly of diaphragm piercing, solenoid plunger-type valves, and manual override of the computer shutdown feature. Refer to system instructions from the equipment manufacturer or installing company. The same method, once determined, is normally used for testing manual devices connected electrically to cause direct actuation of gas release devices. After taking necessary steps to prevent gaseous discharge, you should cause the necessary alarm conditions to activate the extinguishing system by actuating the detectors or manual initiating devices. At the end of the time delay intend, release device actuation should be evident. Verify that relays for auxiliary functions actuate. Take notes on which event relays actuate at the first cross-zoned detector alarm, second cross-zoned detector alarm, and at the end of the timer intend. Note the amount of time delay between the second detector actuation and the delayed functions.

If release devices or auxiliary functions fail, you should replace the control unit in the alarm condition and check appropriate output voltages at the control unit and at the failed device. If voltages are improper, troubleshoot the control unit or circuit as indicated. Cross-zoned systems require an alarm condition on both initiating circuits to actuate release devices and some auxiliary functions. If a timed fiction fails, check input voltage to the timer and the delayed output voltage from the timer with a voltmeter. Replace the timer if input is proper but output is not. If voltages are proper, check solenoid and relay coil continuities with one side of their respective energizing circuits open to the control unit. (See testing and maintenance for foam systems, *Maintenance of Fire Protection systems*, NAVFAC MO-117, *section 7.3.1.)* Replace defective devices and/or wiring.

Abort Feature

In gaseous extinguishing systems with an abort feature, test the feature annually along with the other elements of the system. To test the abort feature, first determine the timer setting from prior test records or installation data. Then cause first and second cross-zoned detect or alarms. The second detector alarm starts the timed period during which the gaseous agent release and other abortable functions may be activated. Operate the abort switch approximately in the middle of the time interval. Perform this test with the agent release and computer shutdown features disabled. At the end of the time interval, confirm that the aborted functions do not occur. Possible causes of abort failure are as follows:

- a defective abort switch,

● a defect in the wiring between the abort switch and the main control unit, or

● an improper abort feature installation or an improper timer setting (low).

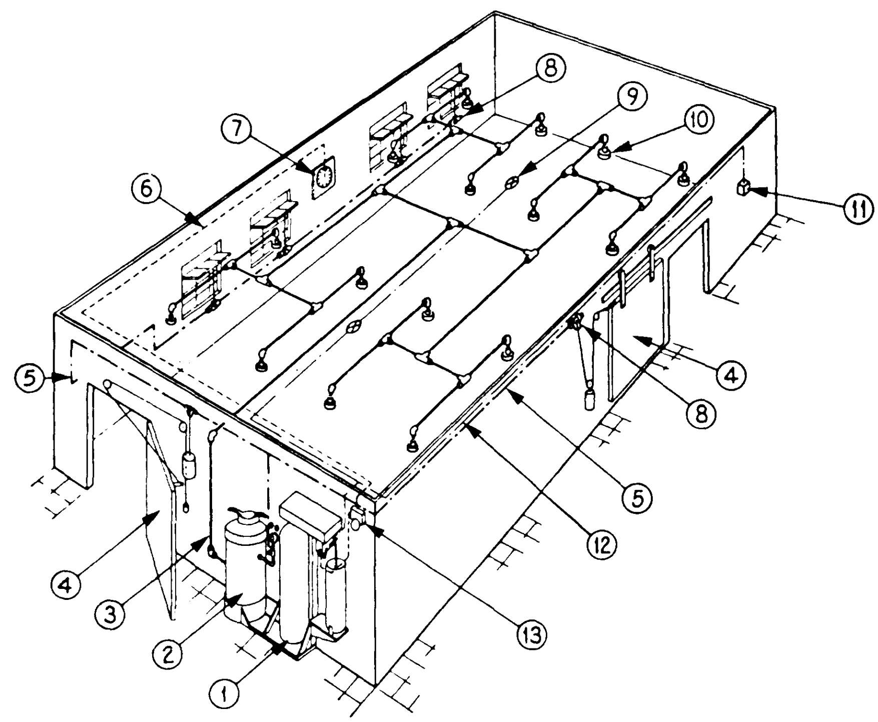
During troubleshooting, disable the extinguishing agent release and the computer shutdown feature, if provided. Check the abort timer setting according to the manufacturer's instructions. If the timer setting is quite low, 15 seconds or less, increase the setting to 20 seconds or more (as determined by local authorities to be adequate to prevent unnecessary discharge of the agent).

If actuating the abort switch has no effect, check the switch continuity with an ohmmeter while actuating it disconnected from its wiring. If the switch continuity shows alternating readings of zero ohms and infinite resistance, as it should when being repeatedly actuated, check that the OFF and ON positions of the switch are not reversed. (Such reversal may be caused by connecting the wires to the wrong pair of switch terminals or inverting the switch when mounting it.) If the switch has no defect, check its circuit continuity with an ohmmeter at the control unit and with at least one wire disconnected from the control unit. Observe switch action at the ohmmeter by actuating the switch repeatedly. Correct any circuit defects or wiring errors. Replace the switch if it is defective.

DRY CHEMICAL EXTINGUISHING SYSTEMS

Dry chemical extinguishing systems are very similar in construction and operation to gaseous extinguishing systems. There are three general categories of chemical extinguishing systems: total flooding, local application, and hose line systems.

Total flooding systems are arranged to discharge the agent into enclosed spaces. Such systems are used for the protection of flammable liquid storage rooms and paint drying ovens (fig. 8-36). Ventilating equipment, conveyors,



1. Expellant-gas container
2. Dry-chemical container
3. Dry-chemical discharge piping
4. Fire door
5. Expellant-gas piping to pressure trips
6. Electric-shutdown and alarm circuit
7. Ventilating fan (shuts down on operation of system)
8. Pressure trip (closes windows and doors on operation of system)
9. Heat-actuated device
10. Flooding nozzle
11. Remote manual-actuation box
12. Pneumatic-actuation tubing
13. Alarm bell

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Figure 8-36.—Total flooding dry chemical system installation.

flammable liquid pumps, and mixers may be interlocked with the dry chemical system and arranged to shut down automatically upon discharge of the system.

Local application systems are arranged to discharge dry chemical directly on the hazard, without any enclosure (fig. 8-37). Typical local application systems are used for the protection of paint dip tanks and restaurant range hoods. Ventilating fans, conveyors, flammable liquid pumps, and mixers may be interlocked to shut down automatically upon discharge of the system.

Hose line systems discharge dry chemical through manually operated nozzles connected by hose or by piping and hose to a fixed supply (fig. 8-38).

Dry chemical used in approved systems is mostly sodium bicarbonate, very finely ground, to which has been added other ingredients to keep it free flowing and to resist caking. Other agents used in dry chemical extinguishing systems include potassium bicarbonate, potassium chloride, and monoammonium phosphate—multipurpose type.

The dangers dry chemicals used in fire extinguishing concentrations cause exposed personnel are temporary breathing difficulty and reduced visibility. In areas using total flooding systems, suitable means should be provided to permit evacuation of personnel. In areas using local application systems where the dry chemical is not confined, there is little hazard to personnel.

Dry chemical systems are used primarily for extinguishing fires in flammable liquids. Bicarbonate base dry chemical can be particularly effective for extinguishing fire in deep fat fryers caused by overheating. The *saponification* reaction between the dry chemical and fat or grease prevents re-ignition by turning the fat to soap. Multipurpose dry chemical will not react with the fat or grease and can prevent the saponification reaction between the fat or grease and any bicarbonate base dry chemical subsequently used.

Dry chemical systems are not suitable for fires in materials (such as cellulose nitrate) that contain their own oxygen supply. They are not normally used for fires involving delicate electrical equipment such as telephone switchboards, computers, and certain other electronic equipment because the dry chemical will insulate the fine and delicate contacts. The contacts will then need complete cleaning.

Monoammonium phosphate and potassium chloride are slightly acidic, and in the presence of moisture can corrode metals such as steel, cast iron, aluminum bronze, and titanium. Corrosion can be minimized by prompt cleanup. Most dry chemical agents can be cleaned up by wiping, vacuuming, or washing the exposed materials or surfaces. Monoammonium phosphate will require some scraping and washing if exposed surfaces were hot when the agent was applied.

TYPES OF SYSTEMS

There are basically two types of dry chemical systems.

1. Gas cartridge systems that use a container of expellant gas that, when released by manual

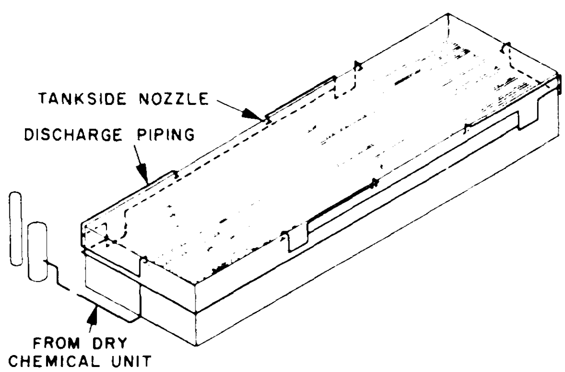

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Figure 8-37.—Local application dry chemical system installation.

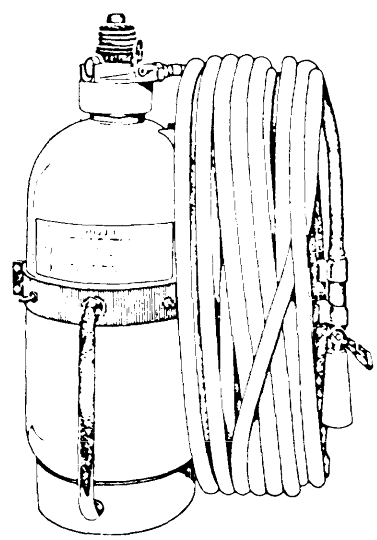

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Figure 8-38.—Stored pressure dry chemical cylinder with hose line.

or automatic means, pressurizes the container of dry chemical and forces the agent through the piping network or hose lines (fig. 8-39).

2. Stored pressure systems that consist of a container of dry chemicals that is constantly pressurized, usually with nitrogen.

SYSTEM COMPONENTS

Operating devices are used to release the expellant gas from its container for the pressurization of the dry chemical tank or to release the dry chemical if it is stored under pressure.

In fixed systems, expellant gas is released from its container by electrically, pneumatically, or mechanically dropping a weight that opens a cylinder valve or by mechanically releasing a spring that punctures the sealing disk of a gas cartridge. The dry chemical when stored under pressure is released by pneumatically or mechanically dropping a weight that opens the discharge valve. Pressure trips may be used to release the weights of more than one unit for simultaneous discharge of expellant gas. Pressure trips are operated by gas pressure taken from the low-pressure side of the expellant gas regulator.

Hose line systems are actuated at the cylinder by turning a handwheel or by moving a lever.

The distribution system (piping) should be constructed of standard weight (schedule 40) galvanized steel pipe and standard weight galvanized steel or malleable iron fittings.

It is important for the piping system to be balanced, so the pressure drop to any one nozzle is about the same as to any other nozzle. Although dry chemical suspended in a gas may be homogeneous during flow, certain effects, such as inertia and sudden expansion of the gas, may cause some separation of the two phases. For example, if several nozzles are installed consecutively at right angles to a straight run of pipe, the inertia of the dry chemical carries most of it past the first nozzles. Therefore, these nozzles discharge more gas and less dry chemical than those farther down the piping system. To eliminate this, you can balance all branch piping by the use of tees (the dry chemical enters the side port and leaves through the two end ports).

Nozzles have various designs and discharge patterns. Nozzles used for distributing the dry chemical must be approved for a particular application.

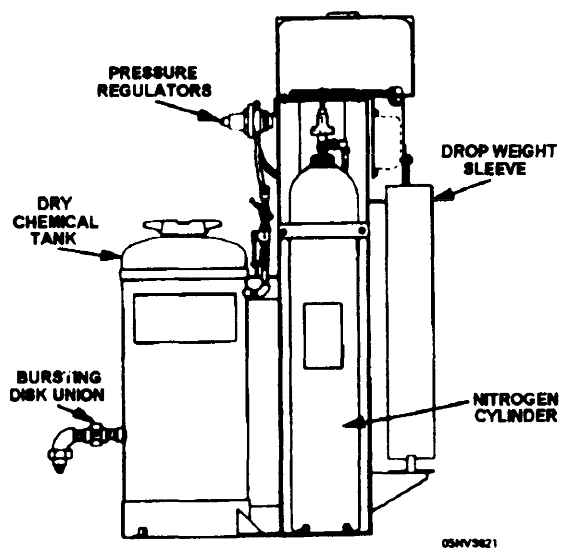

Figure 8-39.—Dry chemical and expellant gas storage cylinders with piping connection.

CHAPTER 9

WATER TREATMENT AND PURIFICATION

As a Utilitiesman, you are responsible for ensuring that an adequate supply of safe water is available for domestic and fire protection uses. In meeting this responsibility you must consider several factors, such as the selection of a water source, ways to develop the water source, contaminants you may encounter, and methods you can use to remove these contaminants. In this chapter, each of these considerations is discussed.

WATER SOURCE SELECTION

You must consider three factors for a water source: quantity, quality, and reliability.

SOURCE QUANTITY

Water sources developed for military use are referred to as water points. Water points are classified as follows:

1. Surface water (streams, lakes, and rivers)
2. Groundwater (wells and springs)
3. Seawater
4. Rain, snow, and ice

When selecting a water source, you must consider the amount of water available and what the demand is for water.

The amount of water that collects in any surface source depends on the amount of precipitation, the size of the drained area, geology, ground surface, evaporation, temperature, topography, and artificial controls.

The available water at a source can be estimated by using some simple calculations. To calculate the quantity of water (gallons per minute) flowing in a stream, use the following formula:

$Q = 6.4 \times A \times V.$

Q = Quantity of water in gallons per minute (gpm).

6.4 = A constant-There are 7.5 gallons of water per cubic foot. However, because of error in stream measurement, 7.5 has been reduced to 6.4.

A = The area of the stream in square feet obtained by multiplying the width times the average depth of the stream.

V = The velocity of the stream in feet per minute obtained by measuring the time it takes a floating object to travel a known distance.

An example of this calculation would be a stream having an average depth of 2 feet and a width of 16 feet, and a twig is noted to flow at 13.3 feet per minute. To find the amount of water flowing in the stream, you should work the equation as follows:

$$Q = 6.4 \times A \times V$$

$$Q = 6.4 \times (2 \times 16) \times 13.3$$

$$Q = 6.4 \times 32 \times 13.3$$

$$Q = 2{,}723.84 \text{ gpm}$$

To calculate the quantity of water in a lake or pond having little or no runoff, multiply the surface area by the average depth. The answer is cubic feet. Multiply by 7.5 to obtain gallons at the water source. An example of this is a pond with an average depth of 7 feet and a surface area of 2,864 square feet. It is calculated as shown below:

Q= Ax D x 7.5
Q = 2,864 x 7 x 7.5
Q = 150,360 gallons

Lakes and ponds are usually located within the water table, and the hydraulics of the water feeding the lake or ponds are similar to that of wells. Therefore, a drawdown test, using a method similar to the one described below for wells, may be used to calculate the quantity of water. To perform the test, you should draw down the static water level to 1 or 2 feet and then record the recovery time. Also, devise a method to discharge the water being pumped so it does not return to the source during the test.

To calculate the quantity of water that can be supplied from newly constructed or existing wells, you must make a drawdown test. To perform this test properly, you must understand the hydraulics of a well.

Before being pumped, the level of water in a well is the same as the level of the water table in the water-bearing formation in which the well is completed. This is called the static level in the well and in the foundation. (fig. 9-1). The depth from the ground surface to the static water level should be measured and this distance used to describe its position. Thus if the water in the well is 25 feet below ground, the static water level is said to be 25 feet for this well. Elevation of the static water level above mean sea level can also be used to describe its position.

When a well is pumped, the water level drops. After several hours of pumping at a constant rate, it stabilizes itself in a lower position. This is called the pumping level or dynamic water level for this rate of pumping (fig. 9-2).

The distance the water is lowered by pumping is called the drawdown. It is the difference between the static level and the pumping level. The drawdown in the well, resulting from pumping, lowers the water pressure in the well, but the surrounding water-bearing formation retains its original pressure. In response to this difference in pressure, water flows out of the pores of the formation into the well.

The water-bearing formation does not furnish its water all at once to the well being pumped. The flow of water into the well is held back by the frictional resistance offered by the formation to the flow of water through its pores. The resistance varies in each formation and is developed in direct proportion to the rate of movement or velocity of the water in the formation. The rate of flow, resulting from a given pressure difference, depends on the fictional resistance to flow developed in the formation. The term used to describe this characteristic of a porous material is *permeability.*

For a particular type of well, the yield of the well for any given drawdown is

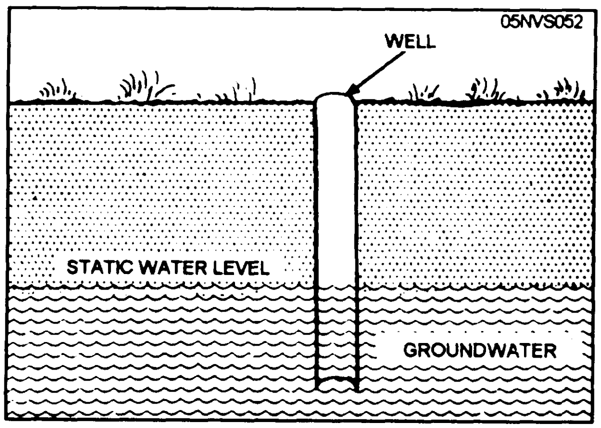

Figure 9-1.—Static water level before pumping.

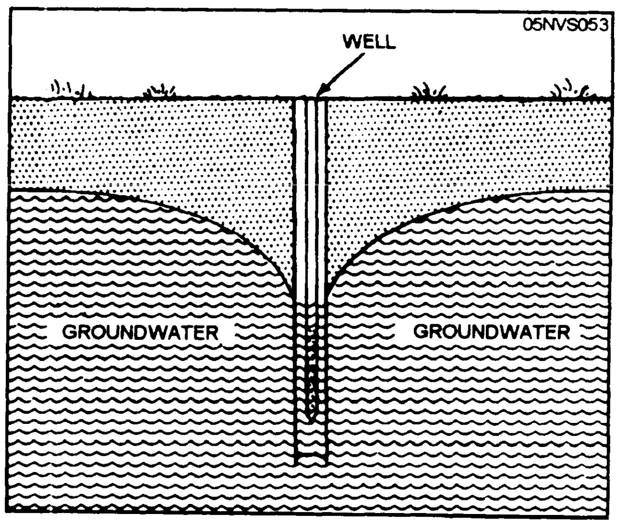

Figure 9-2.—Pumping level.

directly proportional to the permeability of the formation. This property of the formation varies through wide ranges, the value for a coarse sand stratum being several hundred times that of a fine sand stratum of the same thickness. It increases with the coarseness of the sand and decreases with the compactness of the material. It increases where the sand grains are more nearly uniform in size. It decreases when fine sand and silt fill the voids between larger particles. The permeability of a rock formation, like limestone, varies with the number and sizes of the fractures, crevices, and solution channels.

The measurements that should be made in testing wells include the volume of water pumped per minute or per hour, the depth to the static water level before pumping is started, the depth to the pumping level at one or more constant rates of pumpage, the recovery of the water level after pumping is stopped, and the length of time the well is pumped at each rate during the testing procedure. The testing described in this chapter is essentially the measurement of the hydraulic characteristics of a particular well.

The pump and power unit used for testing a well should be capable of continuous operation at a constant and variable rate of pumpage for a period of over 24 hours. It is important that the equipment be in good condition for an accurate test, since it is undesirable to have a forced shutdown during the test. The test pump should be large enough to test to the expected capacity of the well, even though this may be far beyond the amount of water required and may exceed the capacity of the permanent well pump. Pumping by airlift maybe a practical method, provided that meters are not used for measuring the flow. The test should run at least 24 hours. Longer tests, up to several weeks' duration, may be desirable to verify adequacy of the formation.

To determine the safe yield of the well, the pump should be operated at a rate that will cause only about 50 percent of the maximum possible drawdown. The drawdown should not exceed a point 5 feet above the topmost screen slot. For example, a 125-foot well has a static water level of 25 feet and a pumping level of 75 feet or a 50-foot drawdown. The satisfactory pumping level is 50 feet or 50 percent of the maximum drawdown. Therefore, a safe well capacity is established and maintained for that condition regardless of the yield. The safe pumping yield is the withdrawal rate that will not cause a lowering of the water table, and should cause no more than 50 percent of maximum drawdown. A chart, similar to the one shown in figure 9-3, should be

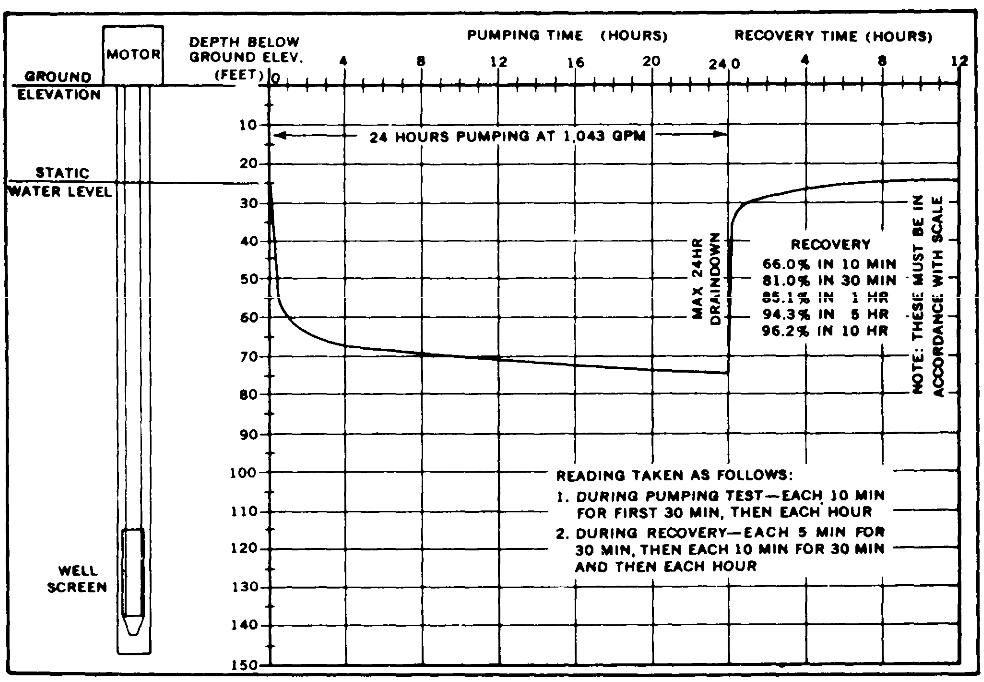

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Figure 9-3.—Well chart.

included in the test report. The complete test report will include the following:

1. Initial static water level

2. Pumping rates, at least every hour

3. Drawdown data, at least every hour

4. Rate of recovery

The simplest way to measure the water pumped is to catch it in a steel drum or other tank of known volume. The time required to fill the tank is determined as accurately as possible. The rate of pumpage in gallons per minute is then calculated. For reasonable accuracy, the tank should be large enough to hold the water pumped during a period of at least 2 minutes. This limitation makes the method practical only for relatively small wells, since large tanks will not usually be available.

Water meters offer a definite advantage in measuring the water being pumped. The amount of water pumped may be recorded from the meter at desired intervals. The total discharge may be recorded for any individual phase of the drawdown test.

The most accurate way to measure depth to the static level and to the pumping level in a well is with a chalked tape. A steel tape with a weight to make it hang straight is chalked at the lower end with blue carpenter's chalk and lowered into the well until 1 or 2 feet of the tape is submerged. The proper length to lower the tape may have to be determined by experiment. The wetted length of the tape shows up very clearly on the chalked portion of the tape. This length is subtracted from the total length lowered below the reference point; this gives the depth to water.

The drawdown observed during a well test is the difference in feet between the

Table 9-1.—Daily Water Requirements in Temperate Zone

Unit consumer	Conditions of use	Gallons per unit consumer per day	Remarks
Man	In combat:		
	Minimum	½ - 1	For periods, not exceeding 3 days, when operational rations are used.
		2	When field rations are used.
	Normal		
		3	Drinking plus small amount for cooking or personal hygiene.
	March or bivouac	2	Minimum for all purposes.
	Temporary camp	5	Desirable for all purposes (does not include bathing).
	Temporary camp with bathing facilities	15.	
	Semipermanent camp.	30 - 60	Includes allowance for waterborne sewage system.
	Permanent camp	60 - 100.	
Vehicle	Level and rolling country.	1/8 to 1/2	Depending on size of vehicle.
	Mountainous country	1/4 to 1	Depending on size of vehicle.
Hospital	Drinking and cooking.	10 per bed	Minimum, does not include bathing or water for flushing.
	With waterborne sewage.	50 per bed	

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pumping level and the static water level before pumping was started. The specific capacity of the well is the yield or discharge in gallons per minute divided by the drawdown in feet.

Water needs should be estimated, using per capita requirements and other controlling demands as factors in arriving at the estimate. Other controlling demands may be the water requirements for such items as fire protection, industrial uses, lawn sprinkling, construction, leakage, and water delivered to other activities, and vehicles. Table 9-1 shows the per capita daily water requirements for different situations, and the daily average requirements for vehicles. Table 9-2 indicates the requirements that may be needed for construction equipment. Compare the yield of the source with the needs of the activity.

SOURCE QUALITY

The quality of water is the ability of water to be potable and palatable (water that is safe to drink, being free of harmful characteristics that could cause odor, foul taste, bad color and/or disease).

Practically all water supplies have been exposed to pollution of some kind. The general growth of population and the increasing use of streams and other bodies of surface water for the disposal of wastes have been detrimental to water sources.

Impurities in water are either suspended or dissolved. The suspended impurities are usually more dangerous to health. They include mineral matter, disease organisms, silt, bacteria, and algae. These must be destroyed or removed from water that is to be consumed. While some of these impurities can be seen by the naked eye, others

Table 9-2.—Quantity and Quality of Water Needed by Construction Equipment

Equipment	Size	Quantity	Purity of water
Rock crusher	225-T	60,000 gpd	No special purification. Seawater usable.
Concrete mixers		18,000 gpd	Potable; minimum of organic matter. Acid alkali free. Seawater may be used but decreases concrete strength by 20%. Extra cement may be used to offset this effect.
Concrete paver		60,000 gpd	
Asphalt plant		1,000 gph	Alkali free. Low sulfates.
Steam jenny			Potable; low calcium and magnesium.
Steam boiler	200-hp	2,000 gpd	" " " "
	w/receiver	1,000 gpd	" " " "
Three car heater (for asphalt plants).		50 gph	" " " "
Water distributor	1,000 gal	1,000 gal per 100 yd of 8 ft road.	No special purification. Salt water acceptable.
Compaction		Variable	Any available water accepted. Seawater actually preferable for certain jobs.
Vehicle radiators		Variable	Potable; calcium and magnesium lower than 400 ppm.
Asphalt rollers		Variable	Potable; free of organic matter.

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can be detected by laboratory tests only. Table 9-3 identifies some of the common impurities in water and summarizes their effect on water quality.

Water samples must be forwarded to a laboratory for complete mineral or bacteriological analysis.

The factors that affect and determine the quality of water, such as physical, chemical, biological, and radiological contamination, are discussed later in this chapter.

SOURCE RELIABILITY

The reliability of a water supply is one of the most important factors in the selection of a water source. The information gathered during the water reconnaissance may indicate a source of sufficient supply only to have the source dry up during periods of no rainfall. Study the hydrological data to determine the variations that may be expected at the water source.

Geological formations influence the reliability of a groundwater source. The amount of water flowing and the rate of flow maybe controlled by geological layers. The amount of water within a water table may be limited by impervious formations, as shown in figure 9-4. Therefore, it is important that information on the characteristics and properties of the geological

Table 9-3.—Common Impurities in Water

Suspended Impurities	Organisms			Some cause disease
	Algae			Cause taste, odor, color, turbidity
	Suspended solids			Cause murkiness or turbidity
Dissolved impurities	Salts	Calcium and magnesium	Bicarbonate	Causes alkalinity, hardness
			Carbonate	Causes alkalinity, hardness
			Sulfate	Causes hardness
			Chloride	Causes hardness, corrosive to boilers
		Sodium	Bicarbonate	Causes alkalinity
			Carbonate	Causes alkalinity
			Sulfate	Causes foaming in steam boilers
			Fluoride	Causes mottled enamel of teeth
			Chloride	Causes salty taste
	Iron			Causes taste, red water, incrustation on metals
	Manganese			Causes black or brown water
	Vegetable dye			Causes color, acidity
	Gases	Oxygen		Causes corrosion of metals
		Carbon Dioxide		Causes acidity, corrosion of metals
		Hydrogen sulfide		Causes odor, acidity, corrosion of metals
		Nitrogen		No effect

formations be studied when a ground source is being considered.

It may be necessary to consider numerous other factors that may affect the reliability of the source. For one example; Lake Bonnie Rose, U.S. Naval Station, Adak, Alaska, is an ample source of cool, clear water, being distributed by gravity. However, the relatively high elevation of the lake results in excessive pressure at the station. Pressures are controlled by pressure-reducing valves. The valves sometimes fail in service, resulting in damage to the water system.

Reliability of the source is further increased as the requirements for items that are subject to breakdown decrease (pumps, treatment plants, and so on).

Legal advice may be necessary when selecting a water source as the laws regulating and controlling water rights may vary considerably. The title to ground and surface water in the United States is usually regulated at the state level. Navigable waters having interstate traffic are under federal control. Some difficulty was experienced in Vietnam by SEABEES in securing water rights to surface streams. These waters were used for flooding of rice fields, and local control denied the use of these sources as water supplies.

Legal advice may also be required in securing the right for waterlines or powerlines to cross property. To cite one example, a waterline serving a naval air facility in Sicily was completed, except for a section crossing an irrigation ditch. Final completion of the waterline was delayed for 2 months, waiting to obtain the right for the waterline to cross the ditch.

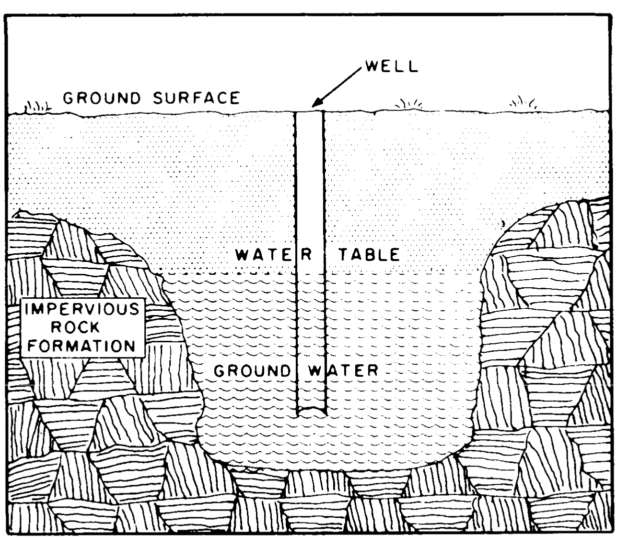

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Figure 9-4.—Limitation of water by rock formation.

DEVELOPMENT OF WATER SOURCES

Development of a water source includes all work that increases the quantity and improves the quality of the water, or makes it more readily available for treatment and distribution. The development of surface water sources, springs, and seawater sources is considered in this section.

In developing a source, dams, floats, galleries, and similar improvements may be used to increase the quantity and quality of the water. Elaborate developments should be avoided; simplicity brings more rapid results. A temporary water source should not be converted into a permanent one until the area has been reconnoitered for a source requiring less development. All intake hoses or pipes should be equipped with an intake strainer regardless of the clearness of the water source. Suction strainers should be protected from floating debris that may damage, clog, or unnecessarily pollute them. Proper anchorage of suction lines and strainers prevents (1) loss of prime, (2) punctured or kinked lines, and (3) damage to strainers. Water at the intake point should be as clear and deep as possible. The strainer on the suction hose is placed at least 4 inches below the water level. This precaution reduces the possibility of the strainer becoming clogged with floating debris, or the prime being lost because of air getting into the suction line.

SURFACE WATER DEVELOPMENT

Of the total amount of rainwater that falls upon the land surface of the earth, only a comparatively small part is absorbed by the soil. By far the greater part of it runs off the surface of the ground and is carried out to the sea by way of streams and rivers or remains stored in natural lakes and ponds and in artificial lakes and impounded reservoirs. The methods by which water supply is derived from the surface are (1) by damming of streams or rivers, (2) by using the flow from streams, (3) by pumping directly from surface streams, (4) by collecting water from the roofs of buildings, (5) by providing catchment areas for the collection of rainwater into specially constructed cisterns, (6) by solar distillation, (7) by power distillations, (8) by freezing, and (9) by electrodialysis.

For normal field water supply, surface water is the most accessible type of water source. This source also lends itself readily to the purification equipment common to most engineer units. Surface water is the most easily developed source of water. Methods of constructing intake points for land surface water sources are discussed below.

If the stream is not too swift and the water is sufficiently deep, an intake may be prepared quickly by placing the intake strainer on a rock. This will prevent clogging of the strainer by the streambed and provide enough water overhead to prevent the suction of air into the intake pipe. If the water source is a small stream or shallow lake, the intake pipe can be secured to a post or pile as shown in figure 9-5.

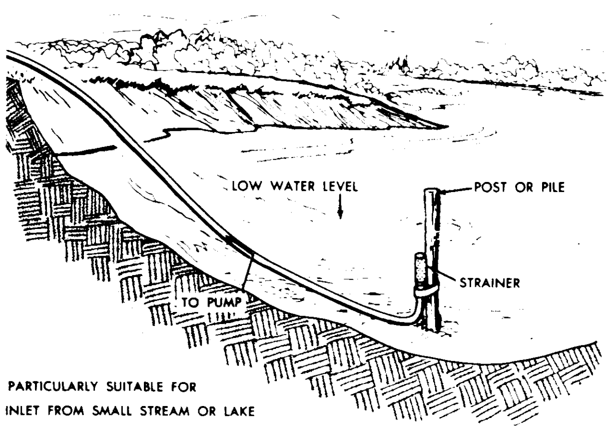

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Figure 9-5.—Direct intake with hose on bottom of water source.

When a stream is so shallow that the intake screen is not covered by at least 4 inches of water, a pit should be dug and the screen laid on a rock or board placed at the bottom of the pit. Pits dug in streams with clay or silt bottoms should be lined with gravel to prevent dirt from entering the purification equipment (fig. 9-6). The screen is surrounded by gravel to prevent collapse of the sides of the pit and also shield the screen from damage by large floating objects. The gravel also acts as a coarse strainer for the water. A similar method may be provided by enclosing the intake screen in a bucket as shown in figure 9-7.

The level of the water in small streams can be raised to cover the intake strainer by building a dam.

In swiftly flowing streams, a wing or baffle dam can be built to protect the intake screen without impounding the water.

Floats made of logs, lumber, sealed cans, or empty fuel drums can be used to support the intake strainer in deep water. Floats are especially useful in large streams where the quality of the water varies across its width or where the water is not deep enough near the banks to cover the intake strainer. The intake point can be covered by an adequate depth of water by anchoring or stationing the float at the deep part of the stream. The intake hose should be secured to the top of the float, allowing enough slack for movement

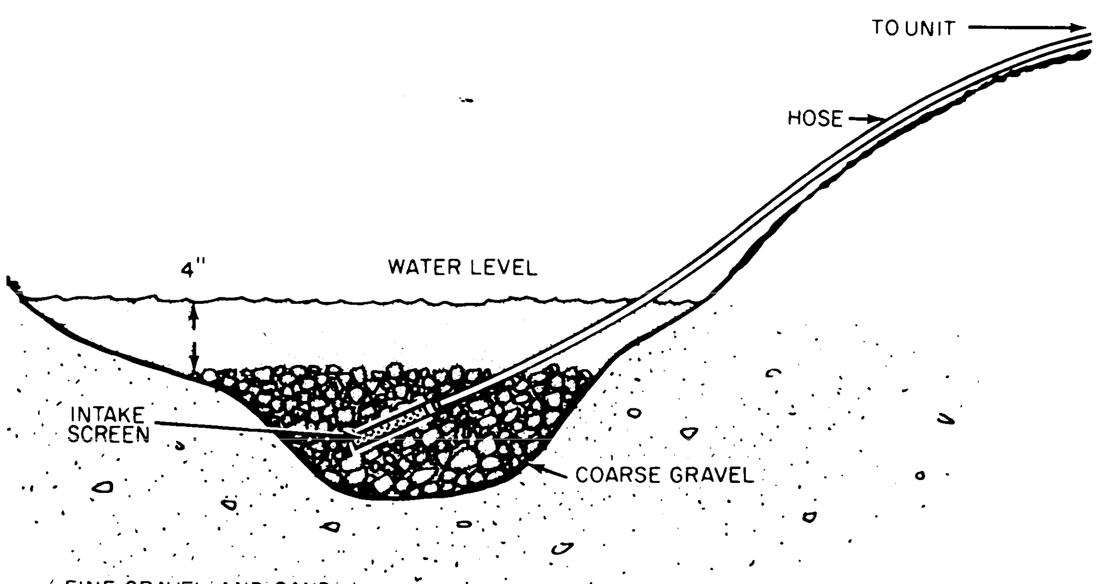

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Figure 9-6.—Surface intake with hose buried in gravel-filled pit.

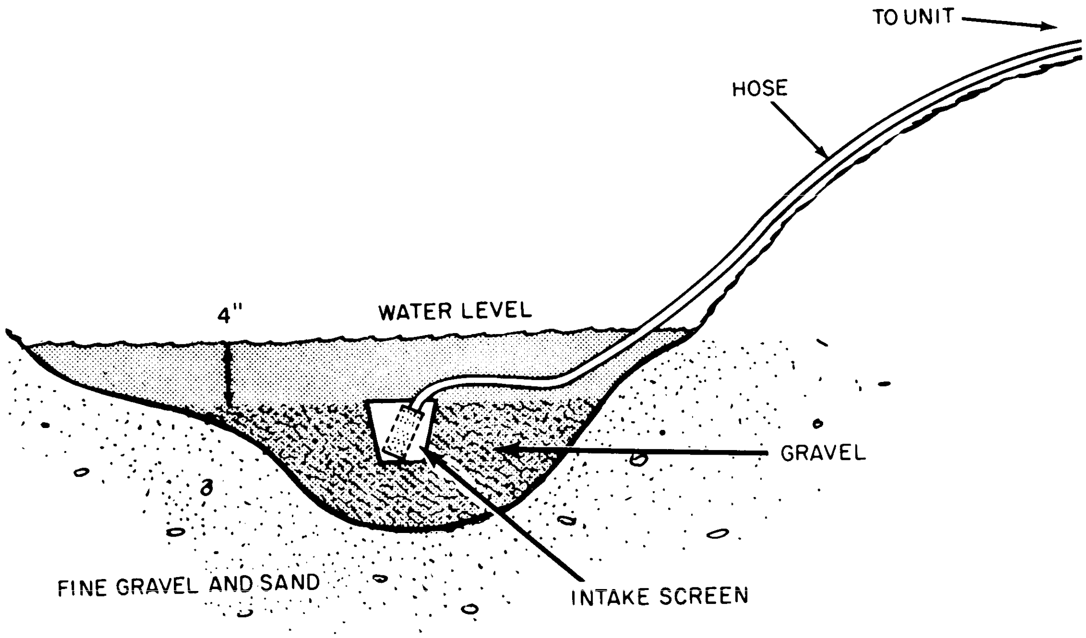

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Figure 9-7.—Use of bucket on end of surface intake.

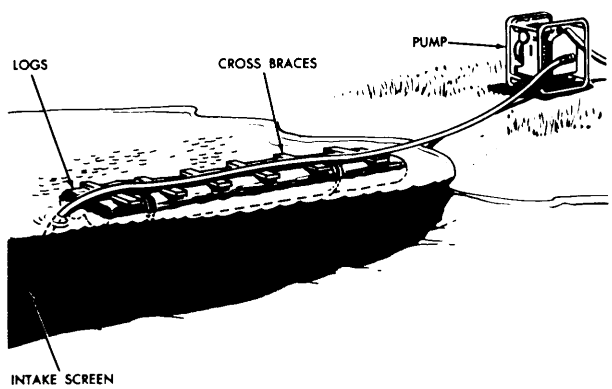

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Figure 9-8.—Float-type surface intake.

of the float. If support lines are used to secure the float to the banks, the position of the float can be altered to correspond to changes in depth by manipulation of the lines. The chief advantage of a float intake is the ease with which the screen can be adjusted vertically (fig. 9-8).

Water from muddy streams can be improved in quality by digging intake galleries along the bank. A trench is dug along the bank deep enough so that water from the stream percolates into it so it intercepts ground water flowing toward the stream. The trench is filled with gravel to prevent the sides from collapsing. The intake strainer is placed in the gravel below the water table (fig. 9-9). The amount of work required to produce

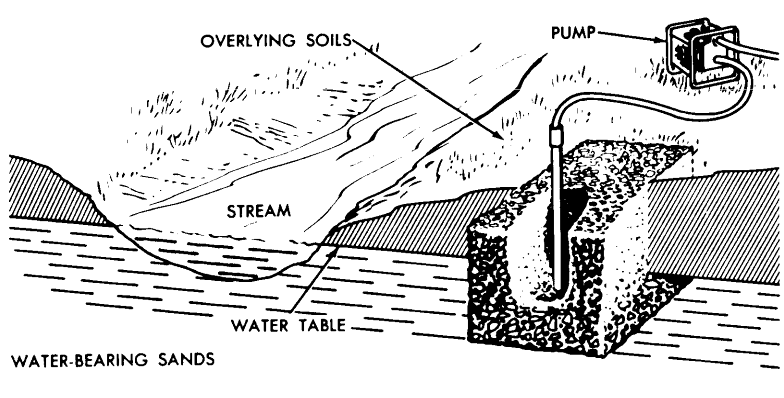

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Figure 9-9.—Gravel-filled gallery intake.

the gallery is justified by a reduction in the amount of chemicals needed to coagulate the water, the elimination of the necessity of frequently backwashing the filter, and the higher quality of water obtained.

GROUND WATER DEVELOPMENT

Moisture is held beneath the surface of the earth in three zones: (1) the zone of soil moisture, where water is temporarily held in pore spaces by capillary action or other soil conditions; (2) the zone of aeration or zone of percolation beneath the soil layer, where both water and air are present in the pore spaces; and (3) the zone of saturation, where all spaces are filled with water. *Ground water is* the term customarily used for the underground water in the saturated zone.

One possible objection to an underground water supply is that the water may be excessively hard. This condition may occur because of the percolation of the water through mineral deposits from which water-hardening constituents are leached or extracted. On the other hand, an underground supply generally has the advantage of requiring less treatment because of the natural removal of impurities as the water passes through various underground soil formations. However, these conditions are general; some mineral deposits do not contribute to hardness, and some underground formations may not be of the type that effectively removes objectionable material.

Many times it is advantageous to use shallow ground water sources or percolated waters adjacent to a turbid surface water. Well points are issued in 2-inch diameters and 54-inch lengths. A drive cap is placed over the thread and the well point is driven into the ground with a sledge. Successive sections of pipe, each 5 feet long, are added and driven until the screen is well within the water-bearing media. Several well points may be connected in parallel to supply sufficient water to the raw water pump. In developing drive point sources, it must be remembered that the practical limit of suction lift of the pumps issued with field equipment is 22 to 25 feet at sea level. Suction-lift pumps can be used, therefore, only where the pumping level in the well will be within the limit of suction llift, or 22 to 25 feet below the position of the pump. At 5,000 feet above sea level, the practical limit of suction lift is only 20 feet. It should be noted that since a suction-lift pump must create a partial vacuum in the suction line, it is necessary that the line be absolutely airtight if the pump is to function properly.

Springs yielding 20 gallons per minute or more of water can be used as a source of field water supply if properly developed. Springs may be developed by enlarging the outlet of the spring and by damming and conducting water to storage. To reduce possible pollution, springs should be cleared of all debris, undergrowth, top soil, loose rocks, and sand.

Water that flows from rocks under the force of gravity and collects in depressions can be collected in boxes or basins of wood, tile, or concrete. The collecting box should be large enough to impound most of the flow. It should be placed below the ground level so only the top is slightly above the surface. The box should be covered tightly to prevent contamination and lessen evaporation. The inlet should be designed to exclude surface drainage and prevent pollution. This requires fencing off the area and providing proper drainage. Figure 9-10 shows a spring inlet protected in this manner. The screen on the overflow pipe prevents the entrance of insects and small animals. Another screen on the intake pipe prevents large suspended particles being ingested by the pump used to distribute the springwater. This prevents mechanical failure or reduces it to a minimum.

The flow of water from a spring located on a steep slope of loose earth can be obtained by the following two methods.

- Constructing deep, narrow ditches leading from the spring to the point of collection.

- Constructing pipeline tunnels from the spring to the collecting points. Pipe of large diameter is more suitable for this purpose. The water from the tunnels can be trapped by constructing a dam at the point of collection.

Digging is a more positive and more economical method of developing a spring than blasting. You must proceed with great caution if you use exposives to develop the yield from springs. Blasting in unconsolidated rocks may shift the sand or gravel in such a way as to divert the spring to a different point.

The method used for the development of springs as a water source will depend upon the extent and characteristics of the flow. Thermal (hot) springs should not be developed since their waters are likely to be highly mineralized.

Regardless of the type of construction, all springs must be covered. Surplus water should be piped from the structure so surface water cannot

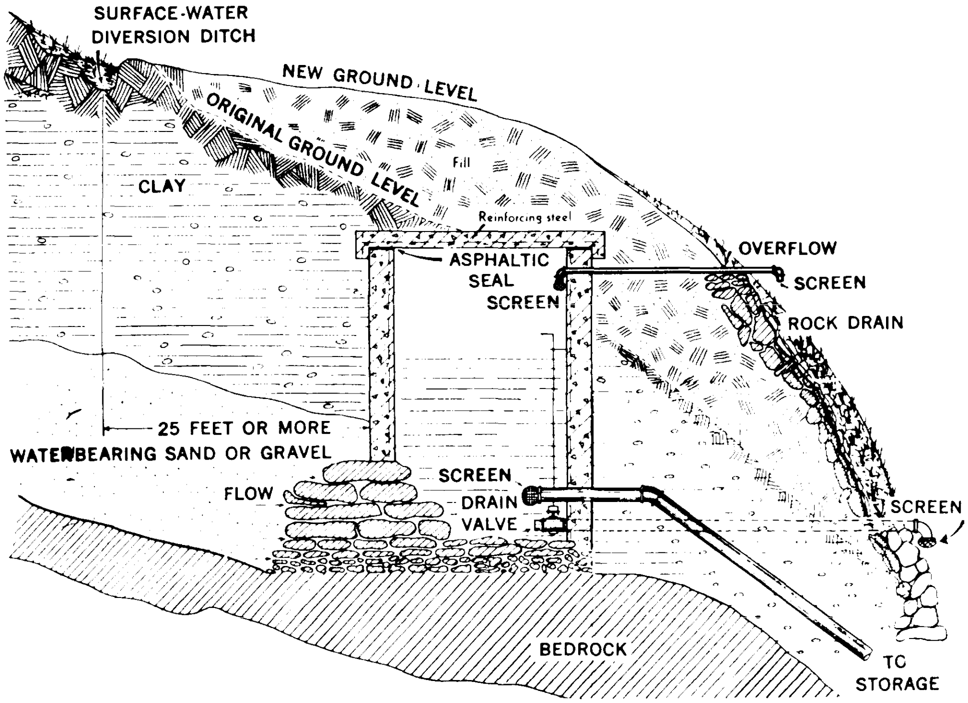

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Figure 9-10.—Protection of spring from surface contamination.

enter the spring during periods of flood. It is not necessary to ventilate spring structures; therefore, all openings should be avoided, except for an inspection manhole fitted with a tight, locked cover.

When ground and surface water supplies are inadequate or cannot be used, ground water supplies are developed by constructing wells. Wells are classified into five types, according to their method of construction. These are dug, bored, driven, jetted, and drilled wells. Each type of well has its particular advantages, which may be ease of construction, type of equipment required, storage capacity, ease of penetration into certain types of formations, or ease of safeguarding against pollution.

In the event of chemical, biological, and radiological operations, it is important to note that ground water would probably remain essentially uncontaminated by airborne or surface dissemination, in contrast to surface water, which could become severely contaminated. This does not mean that ground water is always pure and safe to drink. It can be naturally contaminated or could, in some cases, become contaminated with CBR agents. Well water should be thoroughly tested before use.

The production of ground water involves the method of recovery of water stored in the zone of saturation below the waterline or water table. The ground water table does not always remain at the same elevation, as it is controlled by rainfall, tides, the pumping rate from wells, and so forth.

A *dug well* is a large diameter well, seldom less than 3 feet in diameter, excavated with hand tools, and lined with brick, stone, steel, wood cribbing, or tile. That portion of the lining through the water-bearing formation is porous. This shallow type of well is usually dug from 20 to 40 feet deep, depending upon favorable location for water. Because of the large opening and perimeter to be protected against the incursion of surface drainage, dug wells are easily polluted by surface wash.

Bored wells are constructed in soft water-bearing formations that will not cave in while the hole is being bored. They are usually bored with hand or powered earth augers to a depth ranging from 25 to 60 feet without caving in.

Jetted wells are suitable in soft, unconsolidated, alluvial deposits. The well consists of an inner tube which is a drilling or jetting tube and an outer tube which is the well-casing. A power-driven pump with suitable hose attachments supplies continuous water pressure during drilling. One type of rig uses a block and tackle or a tripod for controlling the tools and casing. Larger rigs have a mast and hoisting block and use engine power for handling casing, drive weight, and pump. Water is led into the well through a small diameter pipe and forced downward through the drill bit against the bottom of the hole. The stream loosens the material, the finer portion of which is carried upward and out of the hole by the ascending water. During the drilling, the jet or drill is turned slowly to ensure a straight hole. Casing is sunk as fast as drilling proceeds. In softer materials, by using a paddy or expansion drill, a hole may be made somewhat larger than the casing. The casing then may be lowered a considerable distance by its own weight. Ordinarily a drive weight is needed to force it down. As a rule, one size of casing is used for the entire depth of the well. It is difficult to drive a single string of casing beyond 500 to 600 feet by this method. If a well is sunk much deeper, an additional string of smaller size must be used. In fine-textured material the hole often may be jetted to the full depth and the casing inserted afterward. The wall of the hole becomes puddled by the muddy water so it will stand alone.

A *driven well* is constructed by driving a pointed screen, or drive point, and attached pipe directly into a water-bearing formation. The finished well consists of a series of lengths of pipe fitted at the upper end with a pump and the lower end with a sand screen through which the water is admitted. The drive point consists of a perforated pipe with a mild steel point at its lower end to break through pebbles or thin layers of hard material. As the drive point is driven down, succeeding sections are screwed into place. These sections continue until the water-bearing formation is reached. The pump then is attached, and after the well has been developed, it is ready for use. Drive point wells usually range in diameter from 1 1/4 to 2 inches, but larger sizes up to 4 inches also are made. The larger sizes, although of greater weight and more difficult to drive, have the advantage that deep-well pumps can be used when necessary. The smaller sizes, because of their lesser weight and greater portability, are valuable for determining the depth of water-bearing formations and for test yields at shallow depths. The depth of the well is limited by the formations encountered and by the type of pump available. For small wells, the ground water level must be within 25 feet of the surface because suction pumps generally are used. If small self-priming centrifugal pumps are used, the lift must be less than 25 feet. If 2-inch or larger pipes are used, it is possible to lift water from a greater depth by installing a cylinder-type pump near the water level.

The following conditions are necessary for successful driven wells. The formation into which the point is being driven must not be too hard and compact. The distance to ground water must not exceed the lift of the pumps available. The water-bearing formations must have moderately high permeability to provide adequate yields in small-diameter wells. The wells must be developed properly to obtain sufficient water.

Chief disadvantages against general use of driven wells are as follows. Construction is laborious and slow when tightly compacted soils are encountered. Driving is destructive to well equipment; points frequently are stripped of mesh; pipe is bent and broken. Couplings frequently are belled by the force of the hammer blows. Belled joints always leak air and either render the well useless or seriously impair the yield of water. Yields are small from any one well point. As many as five points connected in series may be required to operate a power pump to capacity.

Successful construction of driven wells depends upon close observation and correct interpretation of events (occurring while driving) by the well driver. Accurate interpretation of such details as the penetration made with each blow, the drop and rebound of the monkey, the sound of the blow, and the resistance of the pipe to rotation enables the experienced well driver to determine the character of the materials being penetrated. An approximation of the geological section of the well can be obtained by recording these observations. Study of the logs for successive wells, coupled with a study of the results obtained from each well, assists in developing trained well drivers with each successive well.

Although a well site may have been properly selected, the strata correctly interpreted, and the presence of water accurately judged, wells may fail to yield water merely because they have not been pumped to clear the fine sediment from around the screen. When the presence of water is suspected, a simple test is to pour water into the well. If the screen is in dry sand, the water sinks downward and seeps into the formation, but if the screen is in saturated sand, the level of the added water remains nearly stationary or quickly sinks to a static level. Also the quantity of water that can be poured into the well is an index of the well capacity when pumping; when saturated, the sand yields its contents as freely as it absorbs water. Often the raising or lowering of the pipe a foot or more brings a greater length of the screen into contact with the water-bearing stratum and results in a great increase in yield.

There are two methods of drilling wells, one is the hydraulic rotary and the other is the cable-tool percussion. Drilled wells tend to be the most complicated and require a lot of equipment. In most cases Equipment Operators will be called upon to place drilled wells. The Utilitiesman may be called upon to install pumps and plumbing when the drilling is complete. Development of this type of well will then proceed in a similar manner as any other type of well.

ALTERNATIVE WATER SOURCES

In some regions of the world there is not enough surface or ground water available to support the demands for domestic and fire protection water needs. In these areas it may be necessary to develop alternate sources of water. Rainwater, snow, seawater, water barges, and mobile tanks are a few of the alternate water sources that may be considered.

In tropical regions there is an abundance of rainwater with a rapid rate of surface runoff. The construction of collection surfaces can be a solution to water needs.

For temporary or emergency water supplies, collecting surfaces may be constructed by the use of tarps, wooden platforms, metal surfaces, and so on. Usually, however, surfaces constructed for other purposes, such as building roofs, may be used.

More permanent rainwater catchment areas will be cleared, graded, and given an application of cement or other impervious mixture. The catchment area should be located at least 100 feet from any source of subsurface contamination (septic tanks, cesspools, and so on), and as far from other sources of pollution (dust, soot, and so on) as possible. The catchment area and impounding basin should be enclosed by a fence.

Collected waters should be carried by gravity or pumping to closed stowage reservoirs. As rain falls toward the earth, it absorbs dust and such gases as carbon dioxide and oxygen, and, therefore, must be considered unsafe for consumption until treated. Filtration and disinfection are the minimum required treatment.

In some locations water may be so hard to obtain or polluted that it would not be economical to develop any source. In this case, water barges or mobile tanks may be used. Barges or mobile tanks can be filled from ships, tank trucks, or other well points located some distance away. It is important to note that all mobile containers are a temporary water source. Disinfection of their surfaces that will come in contact with potable water is required.

In northern arctic areas where deep wells cannot be sunk through the thick layers of permafrost, and the surface sources are frozen solid, water must be obtained by melting snow or ice. Ice is preferred to snow because it will yield more water for a given volume. Snow or ice may be contaminated. Therefore, all melt produced should be treated before drinking. Approximately 5 cubic feet of snow is required to yield 1 cubic foot of water. In emergencies, personnel can eat small quantities of snow. This snow should be placed in the mouth, rather than being sucked, to prevent chapped or cut lips. Only small quantities of snow should be consumed in this manner because consumption of large quantities will reduce the body temperature.

Seawater is vastly different in its characteristics (as well as in the methods of purification used) from other surface sources. The chemical characteristics of seawater are such that normal coagulation and filtration are ineffective as treatment processes.

In developing seawater sources, consideration must be given to such factors as surf action, saltwater corrosion, suspended sand and silt in the water, living organisms, surface oil along beaches, and the rise and fall of the water level with the tides. If the equipment is located on sheltered bays, harbors, lagoons, or estuaries, it can be supplied by intakes built in the same way as freshwater surface intakes. On small islands where there is insufficient surface and ground water, and on or near open beaches, intakes for equipment can be built as follows:

1. Saltwater wells. Beach wells should, if possible, be used in preference to offshore intakes. Wells can be dug to tap fresh or salty ground water. This eliminates the problems caused by tides, surf, and shallow water close to shore. Such wells have an added advantage in that they can be built back of the shoreline under natural overhead concealment. Driven and jetted wells may also be used effectively at beach locations.

2. Offshore intakes. Offshore intakes are sometimes required because of lack of time, personnel, or equipment or because of coral conditions that prohibit well construction. Intakes of either the rigid pipe or float type may be used but they should be located in deep water beyond the surf. They must be positioned vertically and be off the bottom but still beneath the water surface at low tide. In this way foreign materials in the water which might cause excessive wear on equipment will be largely excluded. The rigid pipe intake can be placed on timber supports and anchored securely in position by piling or riprap. Floats securely anchored can support the intake screen in much the same manner as in surface waters. A rubber suction hose can be used to connect the rigid pipe on the sea bottom to the pipe supported beneath the float.

WATER CONTAMINATION

Water takes on various characteristics and properties as it passes over and through the earth. These characteristics and properties vary and are dependent on the materials encountered. These materials may be natural or man-made and are classified according to their means of detection.

- Physical—detected by one or more of the human senses
- Chemical—detected by chemical analysis
- Biological—detected by testing for chloroform organisms
- Radiological—detected by radiac equipment and special laboratory field tests

PHYSICAL IMPURITIES

Physical impurities in water are either suspended or dissolved. The suspended impurities are usually more dangerous to health. They include mineral matter, disease organisms, silt, bacteria, and algae. They must be destroyed or removed from water that is to be consumed by humans.

The most important physical characteristics are turbidity, color, odor, taste, and temperature. Valuable information can be obtained by observing the water with any of the five human senses and using commonsense judgment on the following characteristics:

- Color
- Turbidity
- Odor
- Taste (use with caution)
- Temperature
- Condition of vegetation around source (dead or mottled vegetation can indicate the presence of chemical agents)
- Presence of dead fish, frogs, and so forth

Before starting any treatment to remove color, turbidity, taste, or odor, you should take several preventive measures.

You must prevent the formation of algae in raw water supply points. Algae can be controlled with copper sulfate, chlorine, or activated carbon. Before deciding which method or combination of methods maybe most effective, consider the following factors:

- Volume of water to be treated
- Time of year
- The effects of treatment on fish life
- Type of secondary water treatment in use
- Equipment available
- Cost of treatment

You must also prevent the raw water source from becoming polluted by drainage from industrial waste and surface drainage from farms, mines, and watersheds.

The above conditions usually cause water to take on color due to the presence of colored substances in solution, such as vegetable matter dissolved from roots and leaves. Dissolved humus, iron, and salts could also be included. True color is due to substances in true solution, apparent color includes true color and substances suspension rather than dissolved. Color may also be caused by industrial wastes and turbidity. Color as such is harmless, but objectionable because of its appearance and the taste and odors sometimes associated with it.

Turbidity is a muddy or unclear condition of water caused by particles of sand, clay, or organic matter being held in suspension. Clay and silt remain suspended in water for the longest period of time because of their particle size and specific gravities. The removal of turbidity is essential to the production of potable water. Removal reduces water contamination, extends the time between backwashing of filters, decreases chlorine demand, improves disinfection, and enhances user acceptability of the finished water. Proper water treatment requires turbidity removal because suspended particles often contain organisms that may cause diseases.

Turbidity is removed by coagulation and sedimentation. Since the physical characteristics of raw water vary widely in different locations, dosages of coagulant chemicals must be determined at each water point to ensure maximum efficiency with minimal waste of chemicals. After coagulation and settling, the water should not have more than 20 percent of the original turbidity. Daily jar tests will help check the optimum chemical dosage required to meet this standard.

COAGULATING CHEMICALS

The type of chemicals that should be used for coagulating raw water can be determined by using the results from jar tests, plant tests, or by using the data shown in table 9-3(A). Theoretically table 9-3(A) is correct; however, these values can be misleading when applied to some types of raw water. The chemical content of water may have a considerable influence on the optimum pH range for the various coagulants. For example, coagulation with ferrous sulfate is usually best accomplished at relatively high pH values in the alkaline zone. With soil, colored waters, ferric coagulant may sometimes be used with considerable success at pH values of 4.0 or less. Because of this wide variation in the optimum pH range of coagulant (caused by individual characteristics of the raw water), the coagulant dosage and the optimum zone for floc formation should be determined by jar tests, rather than just relying on table 9-3(A).

Table 9-3(A).—Optimum pH Ranges for Common Coagulant

COAGULANT	pH
Aluminum sulfate	5.0 to 7.0
Ferrous sulfate	9.5 and above
Chlorinated copperas	4.0 to 6.5 and above 9.5
Ferric chloride	4.0 to 6.5 and above 9.5
Ferric sulfate	4.0 to 10.0

JAR TEST

The jar test is the most common method of determining proper coagulant dosages. When there is a question as to which chemical should be used as a coagulant, it is often necessary to run more than one series of jar tests. Different coagulant chemicals and pH ranges should be used to determine which one produces the most satisfactory results at the lowest cost. The step-by-step procedures for ajar test are as follows:

1. Prepare a standard solution of each

coagulant selected for trial by adding 10 grams of coagulant to 1 liter of distilled water.

2. Correct the pH of a sample of raw water to within the optimum range for the coagulant being tested (only if the pH is to be adjusted to the same extent in actual plant operation). Divide the raw water into six 1 liter samples,

3. Add 0.5 ml of standard coagulant solution to one sample of raw water, 1.0 ml to the second sample, 2.0 ml to the third sample, 3.0 ml to the fourth sample, 4.0 ml to the fifth sample, and 5.0 ml to the sixth sample. The result is a dosage of 5, 10, 20, 30, 40, and 50 mg/1, respectively.

4. Agitate samples in the jar test apparatus at a velocity about equal to the treatment equipment you are using and for the same length of time as the treatment equipment mixing time.

5. Keep the samples at the same temperature as water passing through your treatment equipment.

6. After stirring, let the samples settle for 30 minutes.

7. Siphon off a sample of the supematant and determine the turbidity by using a turbidimeter.

8. The smallest amount of coagulant that produces the lowest turbidity represents the optimum dosage. Multiply the coagulant dosage in mg/1 (step 5 above) by 8.33 to get the correct chemical feed in pounds per million gallons.

9. Repeat the steps for each chemical used until satisfactory results are obtained.

As to acceptability, the taste and odor of water must be considered from the user's point of view. Tastes and odors of water are most commonly caused by algae, decomposing organic material, dissolved gases, or industrial wastes. Potability is not fleeted by the presence of odors and tastes. On the other hand, palatability is frequently affected, particularly when a substance such as bone or fish oil is present. Tastes and odors that make water unpalatable must be removed. Use of free available chlorine, aeration, and activated carbon can do much to prevent or remove unacceptable tastes and odors from treated water.

The use of free available chlorine is advantageous because most odors and tastes are removed and rigorous disinfection is assured.

Activated carbon is the most widely used single process for taste and odor removal. Aeration and copper sulfate treatment are also used. All three methods are described below. The method used depends upon the substance or substances to be removed and the equipment available.

- Activated carbon is an excellent absorbing agent to use in ridding water of unpleasant tastes and odors. It is also an effective agent for removal of organic color. It is insoluble and tends to float unless all particles are wetted thoroughly by being made into a slurry before being added to the water. When continuous flow equipment is being used, the activated carbon should be added to the limestone feeder and added to the water with the limestone slurry. When the batch type of equipment is being used, the activated carbon can be added along with other chemicals in the coagulation tank. Being insoluble, activated carbon does not affect the pH value or chemical characteristics of water. One ounce of activated carbon per 1,000 gallons of water is usually adequate. However, dosages up to 1 pound per 1,000 gallons can be used, depending upon the kind and degree of impurities present. Use of activated carbon in much higher dosages for removal of chemical agents is discussed later in this chapter.

NOTE: Treatment with activated carbon should always be made ahead of, or part of, the coagulation process, so the activated carbon and the various impurities absorbed by it are removed.

- Aeration treatment consists of adding oxygen by exposing the water to air. The process has a two-fold action. Volatile odor-producing materials are released to the atmosphere, and the action of the air upon readily oxidizable materials causes a precipitation of insoluble oxides and hydroxides. Removal of hydrogen sulfide is an example of the formal action, while removal of iron is an example of the latter action. The aeration of water to rid it of the taste and odor of decomposing vegetable matter generally involves both actions.

- Copper sulfate controls tastes and odors caused by small living organisms. This treatment is most frequently used in lakes and reservoirs. The copper sulfate is applied by towing a porous sack containing copper sulfate crystals behind a boat or by spraying a copper sulfate solution over the surface of the water. The amount of copper sulfate you should use depends on the type and concentration of organisms present. Dosages must be controlled because amounts greater than 2.0 parts per million (ppm) kill fish in the water. The amount necessary to remove microorganisms has no detrimental effect on human beings. Copper sulfate treatment is rarely used in field water supply for several reasons.

1. The advantage to be derived from treating an entire lake or reservoir frequently does not warrant the expense of the treatment when the length of time the water source is to be used is taken into consideration.

2. The amount of copper sulfate used entails considerations of wildlife, medical effects, and total water chemistry which are beyond the water supply technician's area of operation.

3. Superchlorination and dechlorination with activated carbon are effective for short periods although they are expensive for extended operations,

Temperature must be considered in the treatment of water. Lowering the temperature of water suppresses odors and tastes and, therefore, increases its palatability. In the summer, the temperature of deep lakes and reservoirs decreases sharply from top to bottom. By shifting the depth of intake, it maybe possible to draw relatively cool water even during hot weather. Water should be drawn from the lower depths when possible. Cool water is more viscous than warm water and thus is more difficult to filter. Cool water is more difficult to coagulate and chlorinate effectively than warm water because of slower reactions. Water treatment rates should be reduced when water temperatures are less than 45°F.

CHEMICAL CHARACTERISTICS OF WATER

The most important chemical characteristics of water are its **acidity, alkalinity, hardness, and corrosiveness.** Chemical impurities can be either natural, man-made (industrial), or be deployed in raw water sources by enemy forces.

Some chemical impurities cause water to behave as either an acid or a base. Since either condition has an important bearing on the water treatment process, the pH value must be determined. Generally the pH influences the corrosiveness of the water, chemical dosages necessary for proper disinfection, and the ability to detect contaminants.

Hardness

Hardness is caused by the soluble salts of calcium, magnesium, iron, manganese, sodium, sulfates, chlorides, and nitrates. The degree of hardness depends on the type and amount of impurities present in the water. Hardness also depends on the amount of carbon dioxide in solution. Carbon dioxide influences the volubility of the impurities that cause hardness.

The hardness caused by carbonates and bicarbonates is called *carbonate hardness.* The hardness caused by all others (chlorides, sulfates, nitrates) is called *noncarbonated hardness.*

Alkalinity is usually equivalent to the carbonate hardness. Sodium, however, also causes alkalinity. In natural waters, sodium is not normally present in appreciable amounts. Therefore, in natural waters, the alkalinity is equal to the carbonate hardness. After water has been softened, a large amount of sodium remains in the treated water. In softened water, the total alkalinity is the sum of the carbonate alkalinity plus the sodium alkalinity. Hardness is undesirable in that it consumes soap, makes water less satisfactory for cooking, and produces scale in boilers and distillation units.

The following minerals cause hardness in ground and surface waters:

- Calcium carbonate. Alkaline and only lightly soluble; causes carbonate hardness and alkalinity in water.

- Calcium bicarbonate. Contributes to the alkalinity and carbonate hardness of water. Calcium bicarbonate when heated produces carbon dioxide and calcium carbonate. This calcium carbonate precipitates as scale ib boilers and distillation units.

- Calcium sulfate or gypsum. Causes noncarbonated hardness in water. Being more soluble in cold water than in hot, it separates from the water in boilers and forms scale on the boiler tubes.

- Calcium cloride. Causes noncarbonated hardness in water. In steam boilers and distillation units, the presence of calcium chloride causes chemical reactions that can pit metallic tubing.

● Magnesium carbonate (magnesite) and magnesium bicarbonate. Act the same in water as calcium carbonate and bicarbonate.

● Magnesium sulfate (epsom salts). Adds to the noncarbonated hardness of water and causes boiler scale. In amounts greater than 500 parts per million in drinking water, it acts as a laxative.

● Magnesium chloride. Has the same properties and effects as calcium chloride. However, the magnesium will contribute to the formation of magnesium hydroxide scale on boilers and evaporators.

● Iron. Iron is undesirable because it imparts a rusty color and objectionable taste to water. It also forms crusts in plumbing and piping. When iron is present in water, organisms whose life processes depend on iron compounds may also be present. These organisms may cause tastes and odors and create what is called *red water.*

● Manganese. While not encountered as often as iron, it is found in both surface and ground water. Its presence in water normally causes a grey or black color. The total concentrations of iron and manganese in potable water should not exceed 0.3 ppm.

Iron and manganese removal is not normally required in the production of field drinking water. Oxidation by aeration, followed by sedimentation and filtration, is the most common method of removing iron and manganese. They are oxidized to insoluble ferric oxide and manganese oxide by this process. The same methods may generally be used to remove both iron and manganese, although when they are present together in water, removal is more difficult. Combinations of iron and manganese with organic matter may require aeration in trickling beds containing coke, followed by sedimentation and filtration. In some cases superchlorination followed by sedimentation and filtration will in itself remove these two substances. The addition of lime, $Ca(OH)_2$, followed by sedimentation and filtration, is another method for removal of these substances.

The concentration of chemical substances present in water for military water supply should not exceed the values shown below. If local conditions or short-term requirements make the use of water containing higher chemical concentrations necessary, authorization must be obtained from the medical officer.

Chemical Substances	Maximum Values	
Copper	1.0	ppm
Iron	0.3	ppm
Manganese	0.05	ppm
Zinc	5.0	ppm
Magnesium	125.0	ppm
Chlorides	250.0	ppm
Sulfates	250.0	ppm
Phenolic compounds	0.001	ppm
Lead	0.05	ppm
Hexavalent Chromium	0.05	ppm
Fluoride	1.5	ppm
Turbidity (silica scale)	5.0	units
Color (platinum-cobalt scale)	15.0	units
Nitrate-Nitrogen	10.0	ppm
Total solids	500.0	ppm

Water softening is the term used to identify the process of treating water supply hardness. Water softening is most likely to be necessary when water is being supplied to laundries and heating units involving boilers and steam equipment.

● Lime-Soda Process. Lime-soda ash softening consists of the application of these materials to the raw water. Lime, $Ca(OH)_2$, reacts with the soluble calcium and magnesium bicarbonates and forms insoluble calcium carbonate and magnesium hydroxide. Soda ash, Na_2CO_3, reacts with the soluble noncarbonated compounds of calcium and magnesium to precipitate insoluble calcium and magnesium compounds but leaves sodium compounds in solution. The physical operation of adding lime-soda ash and removing the precipitates is similar to that in the conventional coagulation-filtration process for bacteria and turbidity removal.

● Zeolite Process. Zeolites used in water softening are complex compounds of sodium, aluminum, and silica which have the faculty of exchanging bases. They are often called *green sand* because of the color of natural zeolite. Synthetic zeolites are also available. When water containing calcium and manganese compounds passes over the zeolite, the calcium and manganese are exchanged for the sodium in the zeolite. In this way the water is softened and its sodium content increased. When the sodium of the zeolite is exhausted, it is regenerated by applying a sodium chloride solution. Another exchange is made, and the resulting concentrated solution of calcium and magnesium chloride is discharged to waste. The operating rate varies directly with the thickness of the zeolite bed. The time between regenerations depends on the characteristics of the water and the total amount of water applied. The need for regeneration will be evident when hardness is no longer removed. The zeolite process can only be used on water that has been treated for removal of turbidity.

- Ion Exchange. The ion exchange unit, when run on the sodium cycle, will significantly soften water. The ion exchange unit will also remove such undesirable ions as (hose of manganese and lead.

Dissolved Gases

The concentration of a gas in water is directly proportional to the concentration, or partial pressure, of the gas in the atmosphere in contact with the water surface. In general, this involves the water temperature, its salinity, and the altitude. The gases of primary interest to water supply are as follows:

- Oxygen. Large amounts of dissolved oxygen are found in rainwater. The amounts in surface water vary greatly, depending on the amount and type of pollution, the degree of self-purification, the action of algae, and the temperature of the water. Polluted water will exhaust the oxygen supply, while clean water will contain much dissolved oxygen. Cold water contains larger amounts of dissolved oxygen than warm; as water temperature rises, the dissolved oxygen is released to the atmosphere. Decreased pressure on water has the same effect, releasing oxygen to the atmosphere. Dissolved oxygen causes the solution of metals and, especially in the presence of carbon dioxide, causes many metals to corrode.

- Carbon Dioxide. The presence of carbon dioxide in water contributes to the degree of hardness and acidity of the water. Water acquires this gas in four ways: from the air by natural movements of water in contact with the air, such as currents and wave action; by contact with decomposing vegetation, which gives off carbon dioxide freely; by the reaction of ferric chloride and limestone in the coagulation process; and by contact with the gas in underground deposits. A high carbon dioxide content usually makes water more corrosive to metals.

- Hydrogen Sulfide. Hydrogen sulfide in solution lends a disagreeable taste and rotten-egg odor to water. Ground water absorbs sulfides by passing over sulfur-bearing rocks. Hydrogen sulfide is also responsible for the destruction of cement and concrete as well as the corrosion of metals. In small amounts, it is unpleasant but not dangerous. In large amounts it is harmful. Water that smells of hydrogen sulfide should be treated.

Dissolved gases are removed by means of aeration or the use of activated carbon. Aeration exposes as much water as possible to the air. This will release dissolved gases such as hydrogen sulfide and carbon dioxide to the atmosphere. Liberating the dissolved gas from the water by aeration permits the oxygen in the air to come in contact with the finely divided water particles, thereby increasing the dissolved oxygen content of the water. This increase of oxygen content removes the offensive taste and odor imparted by the dissolved gases. Aeration raises the pH by eliminating the carbon dioxide, but increases corrosiveness by increasing the amount of dissolved oxygen. One type of aerator consists of trays containing slats or coke over which the water is sprayed. Other methods of aeration include spraying water up over a shallow receiving basin and forcing air into a basin with diffusers or mechanical pump-type aerators similar to those used in sewage treatment. Operation of most aerators is practically automatic; operators' duties consist essentially of making sure pipes, slots, and surfaces are not clogged and that air has free access to the water. If the water is not to be filtered after aeration, aerators must be screened to keep out insects and other foreign matter.

Activated carbon is a specially treated granular powdered carbon. It absorbs or attracts large quantities of dissolved gases. It is extremely effective in taste and odor control, provided the

1. type of activated carbon used meets minimum standards,
2. dosage is correct,
3. carbon is mixed intimately with the water, and
4. carbon is in contact with the water for an adequate period.

Acceptable commercial preparations of activated carbon should meet the following minimum specifications:

1. It does not contain any soluble mineral injurious to health.
2. Moisture content is not over 8.0 percent.
3. It is powdered form that wets down and goes into suspension readily, does not settle too rapidly, and does not float on the surface when applied.
4. At least 99 percent of the carbon in water suspension passes a 100-mesh sieve and 95 percent passes a 200-mesh sieve.
5. It has enough adsorption capacity to reduce a concentration of 0.1 milligrams per liter (mg/l) phenol in distilled water to 0.01 ppm.

Because of the wide range in waters, no general rule can be given for activated-carbon dosage. The dose required at each water plant must be determined by periodic laboratory tests. The test is made by preparing a number of samples of raw water, adding the standard amount of treating chemicals and varying amounts of carbon to each sample, allowing plant contact time, filtering, and making odor tests. Numerical comparison can be made with the threshold odor test. A carbon dose of 3 ppm removes most tastes and odors from water. However, dosages can vary from 3 to 15 ppm, depending upon the odor of the water. Laboratory tests will determine the dosage.

Activated carbon is fed into the water by dry feeders. It must be handled more carefully than coagulant because it is a fine powder; therefore, the feeder must bean approved type and designed to prevent the spreading of the carbon dust and causing fires. In addition, inhaling of the dust by personnel, even in low concentration, can affect their lungs. The dry feeder room should have explosion proof electrical equipment. A spark or pilot flame can create an explosion. Dry carbon will float on the surface of the water for a long time. Therefore, it is important that the carbon be wetted thoroughly, mixed by agitation using a paddle wheel, swirling action, a spray, or so forth, in a small tank. Some dry feeders have a mixing chamber in which the carbon is wetted by the swirling action of the water.

Activated carbon may be applied to the water at one or several points, depending on the results desired. Carbon is added at one or more of the following points:

- In the raw water, as early as possible after it enters the plant. This point of application is not recommended for extremely turbid waters.

- In the mixing basin. When added before sedimentation, activated carbon not only removes foreign matter from the water, but the carbon that settles in the sedimentation basin continues to absorb products of sludge decomposition, thus preventing formation of secondary tastes and odors. Black alum is premixed activated carbon and coagulant that can be used in special situations both as a coagulant and for taste and odor control.

CHEMICAL, BIOLOGICAL, AND RADIOLOGICAL (CBR) CONTAMINATION

Should chemical or biological agents or nuclear weapons be employed during conflicts, the water supply of the area involved would, in all likelihood, become contaminated. A water source contaminated with a chemical, biological, or radiological agent can cause incapacitation or death to a consumer. Effective means for determining the presence of CBR agents, followed by proper decontamination procedures, can reduce or eliminate the hazards caused by these agents.

In the event that you are assigned to supervise or manage a field water supply point, you will be responsible for the detection and removal of CBR contaminants. The supervisor of a water point crew must be sure the crew is trained in the identification of CBR contamination by recognizing the various indications of CBR contamination of their water point as follows:

- An unusual taste or odor
- Dead fish and animals in unusually large numbers
- A sudden drop in normal pH values or a pH value of less than 6.0
- High readings on radiac equipment
- Personnel developing fevers, diarrhea, cramps, vomiting, and so forth
- Burning sensation of skin, eyes, and nose
- Runny eyes, nose, and mouth

If CBR contamination of a water source is suspected, have your crew don appropriate protective clothing and equipment before they start tests for determining the type and extent of the problem. For example, water contaminated with a nerve agent should not be allowed to come in contact with the skin nor the vapors be inhaled. Therefore, wearing a protective mask and gloves would be necessary before checking for nerve agent contamination.

Chemical Contamination

Chemical agents are classified in seven categories: nerve, blister, blood, choking, vomiting, irritant, and incapacitating. The nerve agents, blister agents, and agents containing cyanide are most dangerous because they are highly poisonous. Some are soluble in water and either are slow to decompose in solution or remain poisonous after decomposition. Water supplies are likely to become contaminated as an incidental result of widespread chemical attack, rather than as a result of direct attack on the water supply. Chemical agents are colorless, odorless, and tasteless. The first indication of their use could be the appearance of casualties. The chemicals affect people, animals, and plants but leave homes, factories, and other facilities untouched.

Biological Contamination

Water is a carrier of many organisms that cause intestinal disease. An epidemic of one of these diseases among troops can be more devastating than enemy action and can cause great damage to morale as well as health. A heavy responsibility thus rests upon the Utilitiesman, and vigilance over water purification equipment and procedures should never be relaxed. It is emphasized that water treatment methods to be used when certain chlorine-resistant organisms are encountered should be prescribed by a representative of the medical officer. The representative will recognize or anticipate the presence of these organisms and recommend such additional chlorination or other treatment methods as may be necessary.

A waterborne disease rarely produces symptoms in its victim immediately after the victim has consumed the contaminated water. A period of time, known as the incubation period, must pass before the victim comes down with the disease. During this incubation period, the disease organisms are growing and multiplying. Absence of symptoms for several days after untreated water has been consumed is, therefore, no guarantee that the water is safe. Also, absence of disease among the local inhabitants is no assurance of safety because they may have developed immunity.

Types of waterborne diseases include typhoid fever, paratyphoid fever, cholera, bacillary dysentery, amebic dysentery, common diarrhea, infectious hepatitis, and schistosomiasis. Biological water contamination causes little, if any, change in the chemical and physical characteristics of water, such as pH, alkalinity, and color. This makes it difficult to test a water source for contamination. However, when the water has an excessive chlorine demand, it should be viewed with concern. The excessive demand could be due to microorganisms. Other indicators are as follows: aircraft dropping or spraying of unidentified material; unusual types of bombs, particularly one which bursts with little or no blast; smoke and mist of an unknown substance: unusual increase in insects, such as mosquitoes, ticks, or fleas; increased occurrence of sick or dead animals; increased incidents of troop sickness and disease; or intelligence reports indicating enemy use of a biological contaminant.

Radiological Contamination

Although nuclear weapons have been used in combat, there are no reliable data as to the effect of nuclear explosions on field water supplies. However, available fallout data leave no doubt that contamination of water supplies by this means must be considered. Since radiation is not detectable by human senses, you should use instruments and laboratory tests to determine its presence.

A nuclear attack over or near a source of water supply will probably cause its contamination with radioactive materials. A nuclear explosion could cause contamination by any of the following (listed in the decreasing order of importance to the water point operator):

- Fallout of fission products
- Induced activity in the water and surrounding soil
- Blow-in or wash-in of radioactive dust
- Fallout of unfissioned uranium or plutonium

The magnitude of contamination depends upon the yield of the weapon, the location of the detonation with respect to the water source, and whether it is air, surface, or subsurface burst.

TREATMENT OF CBR CONTAMINATION

If chemical, biological, or radiological agents, or any combination of these, are used, the field water supply will inevitably be involved. It is impossible to foresee what type of agent will be used, but effective security measures can decrease and counteract the hazards of all three types of agents.

Effective security involves prompt and accurate detection. Contamination by chemical agents usually, although not always, leaves significant signs that should arouse immediate suspicion. These are drastic lowering of the pH value of the water, characteristic odors and tastes, and dead fish. If chemical contamination is suspected, the medical officer will have medical personnel test the water with the Chemical Agent Water Testing Kit M272. A complete technical and operational breakdown of this kit can be found in Army TM-3-6665-319-10.

Advice and guidance from the medical officer must be sought and followed carefully when water contaminated by CBR agents must be treated and used. Specialized training of personnel in the latest means of detection and treatment will aid water supply technicians in safeguarding the lives and health of personnel.

If contamination of any type, by CBR

agents or poisonous industrial wastes, is detected, every effort must be made to find an uncontaminated water source before considering treating and using water known to be contaminated.

When an uncontaminated source of supply is not available for use, permission must be secured from proper medical authority to proceed with treatment of the contaminated water.

Water is considered CONTAMINATED AND UNSAFE for treating if one or more of the following results are obtained from competent testing:

Arsenic test. . . . . positive
Mustard test . . . . positive
pH test . . . . .pH below 6
Chlorine demand test . . . . positive
Nerve agent test . . . . positive
Taste and odor test . . . . positive

Water is considered safe for treatment by the usual methods if the pH is above 6.0 and all other contamination tests are negative.

When contamination by a CBR (chemical, biological, radiological) agent has been determined to be present in your water source, the Reverse Osmosis Water Purification Unit (ROWPU) may be used.

The ROWPU will successfully remove 99 percent of CBR contamination from a water source. A post-treatment system in conjunction with the ROWPU will remove a total of 99.9 percent of CBR contamination.

Post Treatment

The 600-gph ROWPU post-treatment system consists of two CBR cylinders. One cylinder is for nuclear and the other is for chemical. The types of contamination present will determine what cylinder you should use. The CBR cylinder filters are capable of decontaminating water for up to 100 operating hours. The cylinder marked “nuclear” contains resin beads that absorb certain ions present on the nuclear battlefield. The cylinder marked “chemical” contains activated carbon that absorbs agents found on the chemical battlefield.

Nuclear Agent Removal

The ROWPU removes the majority of ions wit bout post treatment. The reverse osmosis (RO) removal characteristics for nuclear warfare agents are as follows:

- 95.5% of iodine, leaving the nuclear cylinder to remove 4.5%.
- 99.7% of strontium, leaving the nuclear cylinder to remove .2%
- 98.% of cesium, leaving the nuclear cylinder to remove 1.2%.

Chemical Agent Removal

The ROWPU also removes large amounts of chemical agents. RO removal characteristics for various chemical warfare agents are as follows:

- GB-99.1%, leaving the chemical cylinder to remove .7%.
- VX-99.9%, leaving the chemical cylinder to remove .1%.
- BZ-99.9%, leaving the chemical cylinder to remove .1%.

- GD-99.7%, leaving the chemical cylinder to remove .3%.

Biological Agent Removal

The ROWPU also removes biological agents from a water source. Reverse osmosis removal characteristics for various chemical agents do not exist. Any biological agent that is not removed by the ROWPU will be eliminated by the chlorine residual maintained in the product water.

WATER TREATMENT EQUIPMENT

The Utilitiesman may be called upon to select and set up various types of field water treatment equipment. You must be familiar with the theory of operation, the capabilities, the installation considerations, and the maintenance requirements of this equipment. This section covers four types of water treatment equipment. They are distillation, reverse osmosis, filtration, and disinfection units.

DISTILLATION

In areas where a satisfactory freshwater source cannot be located and existing water treatment facilities are not usable, the distillation process can be used to obtain fresh drinking water from brackish water, seawater, or water containing excessive amounts of dissolved solids. Distillation is effective for removing radioactive contaminants from water. Since the output of distillation equipment is limited and the process is expensive, its use is restricted to situations in which no other process is adequate. Continuous flow or batch type of water purification equipment is used whenever possible.

Theory of Operation

Distillation consists of heating water to form steam, separating the steam from the remaining water, and then cooling the steam so it becomes water again (fig. 9-12). As the water is heated to form steam or water vapor and the vapor is separated and then cooled, solids dissolved in the water do not vaporize but remain behind in the raw water. A large amount of heat that is not evidenced as a rise in temperature is required to change (vaporize) boiling water into steam. The process whereby latent heat is removed and steam becomes water is called *condensation.*

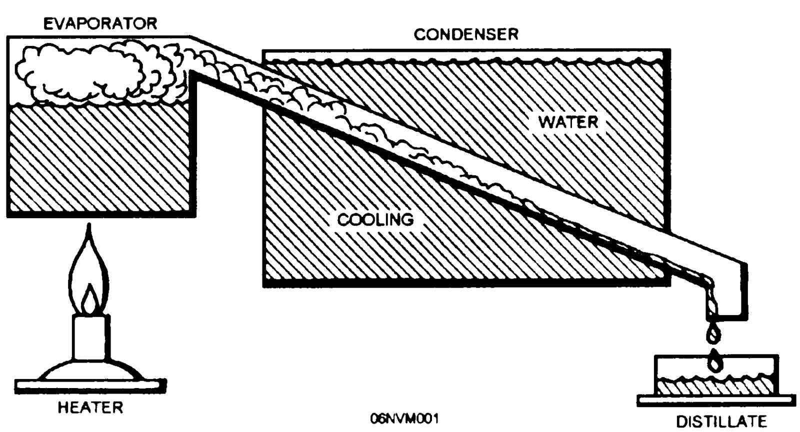

Figure 9-12.—Distillation in its simplest form.

Heat flows through the bottom of the evaporator, enters the water, and changes the water to steam. The steam is condensed in the condenser, its latent heat of vaporization being transferred to the water surrounding the tubes. A portion of the cooling water that has picked up heat in passing through the condenser is used as feedwater for the evaporator. All dissolved solids remain in the equipment and noncondensable gases are vented to the air so the resulting distillate is almost pure. Thus the distillation process is usefull in producing water of an extremely high purity and low in total solids,

Despite this high degree of purity, all distilled water must be disinfected before being consumed because of the possibility of recontamination during handling, In thermocompression distillation, the latent heat of vaporization of steam is again used to produce additional steam. The pressure and temperature of the steam generated in the evaporator are raised by compressing the steam. The compressed steam passes to the condenser section where it condenses, giving up its latent heat and causing more steam to form in the evaporator. This steam is then compressed and the cycle repeated. The use of combination evaporator-condenser with a steam compressor creates a closed heat cycle, permitting the continued reuse of the latent heat of vaporization. The compressor is driven by a gasoline or diesel water-cooled engine.

Figure 9-13 shows the operation of a simple thermocompression distillation unit. Cold raw water flows through heat exchangers where it is heated almost to boiling by the outgoing streams of distillate and brine and by water from the engine that drives the compressor. The hot raw water flows into the evaporator-condenser and is

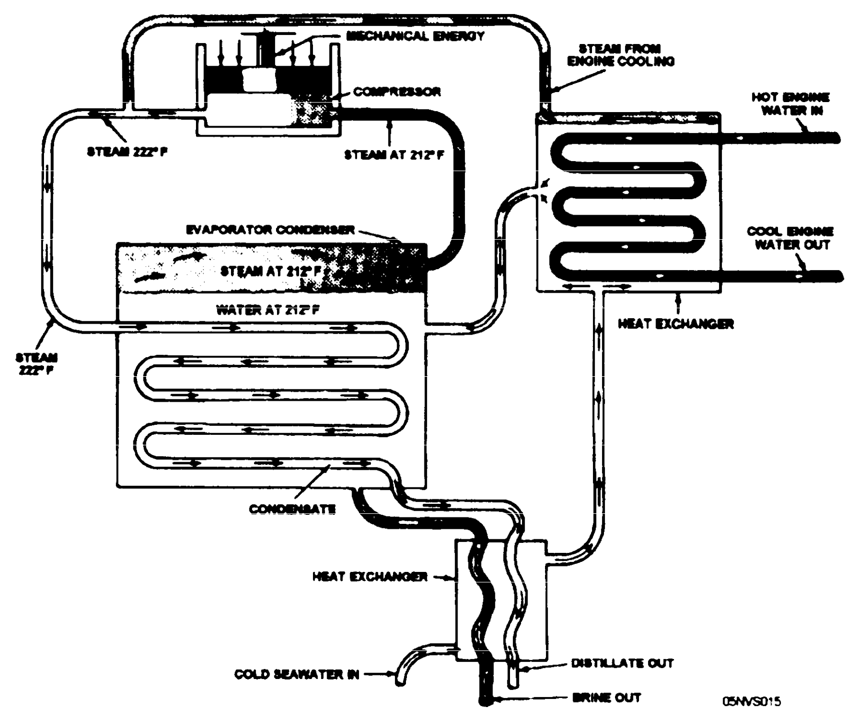

Figure 9-13.—Flow diagram-thermocompression distillation.

changed to steam by the steam condensing in the tubes. This involves the transfer of latent heat. The steam in the evaporator is drawn into the compressor where it is compressed and its temperature raised (from 212°F to 222°F). The compressed steam flows back through the coils in the evaporator-condenser where it transfers its latent heat through the walls of the coil into the water in the evaporator section. This transfer of latent heat causes the steam to condense in the coils and changes the water in the evaporator into steam. This cycle will continue as long as the compressor runs.

Installation

At permanent naval activities, the installation of distillation equipment will be designed by engineers and improvements to the system can be made over a long period of time. In the tactical field environment, it will be the Utilitiesman supervisor who must consider various factors for the installation of distillation equipment. These are as follows:

- potable water demand
- Site location
- Site drainage
- Security
- Fire protection

The demand for potable water will determine the number of distillation units, the need for storage facilities, operating hours, and so forth. You must determine the population you will be serving. Keep in mind that your water point may supply many units in an area, not just your organization.

The site location for distillation equipment must be upstream of any source of contamination. You must consider ocean currents that may change with wind direction, weather conditions, the season of the year, or tidal action. It is not efficient use of personnel or equipment if you have to relocate because the wind changed direction.

The site must also be relatively flat with a gradual slope toward the ocean. You also must allow for' maximum tidal action. In many areas the tide may rise and fall several feet, depending on the season of the year. Build low platforms to keep your equipment out of the sand and to allow air to circulate underneath tanks to prevent rot. These platforms also prevent punctures of the storage tanks by sharp objects and provide a stable working area for operating personnel.

The importance of providing adequate drainage at any water point cannot be overemphasized. Wastewater from filters, leakage from tanks, and spillage from distribution points can render a water point inoperable as well as creating an unsanitary condition.

Your water point may or may not be located in the vicinity of friendly forces. Denying the enemy information about your water point by using overhead concealment and camouflage may be necessary as well as guarding against ground attacks and sabotage with a defensive plan. Any adverse effect, from thirst to disease, the enemy can have on a water point will affect the well-being of the force using it. It will be considered in the plans of the enemy.

Distillation equipment cannot produce water quickly enough to be used for fire protection. Do not permit your treated water to be used for this purpose except in extreme emergencies. Raw water should be used whenever possible.

REVERSE OSMOSIS

The use of reverse osmosis water purification equipment by the military has produced potable water from the sources available in a combat field environment. The reverse osmosis water purification unit (ROWPU) is capable of treating **freshwater, brackish water, and seawater.** Additionally, the unit is capable of treating water contaminated with **chemical, biological,** and **radiological warfare agents.** When using the unit to treat water contaminated by CBR agents, you must use the equipment in conjunction with auxiliary ion exchange and carbon adsorption units.

The ROWPU used by the NCF is capable of producing 600 gph of product water from freshwater sources and 400 gph of product water from seawater at 70°F. The rate of water production in the ROWPU depends upon the operating pressure, normally 350 to 550 psig for freshwater and 750 to 950 psig for seawater. Temperature affects the rate of flow. Cold water decreases the flow, while warm water increases the flow.

NOTE: Maximum operating water temperature of the ROWPU feedwater is 120°F. Water temperatures above this figure may damage the membranes within the reverse osmosis modules.

Reverse osmosis (RO) is a purification process in which **filtered water is** pumped against a semipermeable membrane under great pressure. The membrane allows product water to pass through while rejecting impurities, both dissolved and suspended. You must use an extremely high pressure for a usefull volume of water to pass through a unit membrane. The reverse osmosis process is shown in figure 9-13(A). Reverse osmosis may appear to be nothing more than a filtering process, but there are distinct differences. In filtration, the entire liquid stream flows through the porous filter medium and no chemical changes take place between the feed and the filtrate. In RO, the feed flows parallel to the semipermeable membrane with a fraction of it passing through a given membrane area; dissolved ionic and organic substances are rejected by the membrane and, in this case, drained off as a brine.

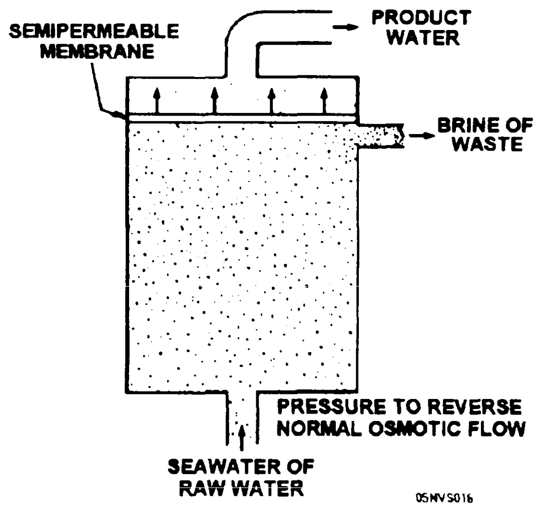

Figure 9-13(A).—Reverse osmosis process.

The following explanation is the flow process through the 600 gph ROWPU. As you read through this section, refer to the flow diagram in figure 9-13(B). Water is delivered to the ROWPU through the raw water pump. Upon entering the unit, it goes through the multimedia filter. This filter removes small and large solids. From the multimedia filter, the water is picked up by the booster pump that pushes the water through the cartridge filter. The cartridge filter takes out suspended solids that passed through the multimedia filter. From the cartridge filter, the water is picked up by the RO pump that pushes the water under high pressure through the pulse dampener and into the RO elements. The RO elements remove dissolved minerals and other bacteria that passed through the filters. The product water leaving the last element receives enough chlorine to kill any remaining bacteria.

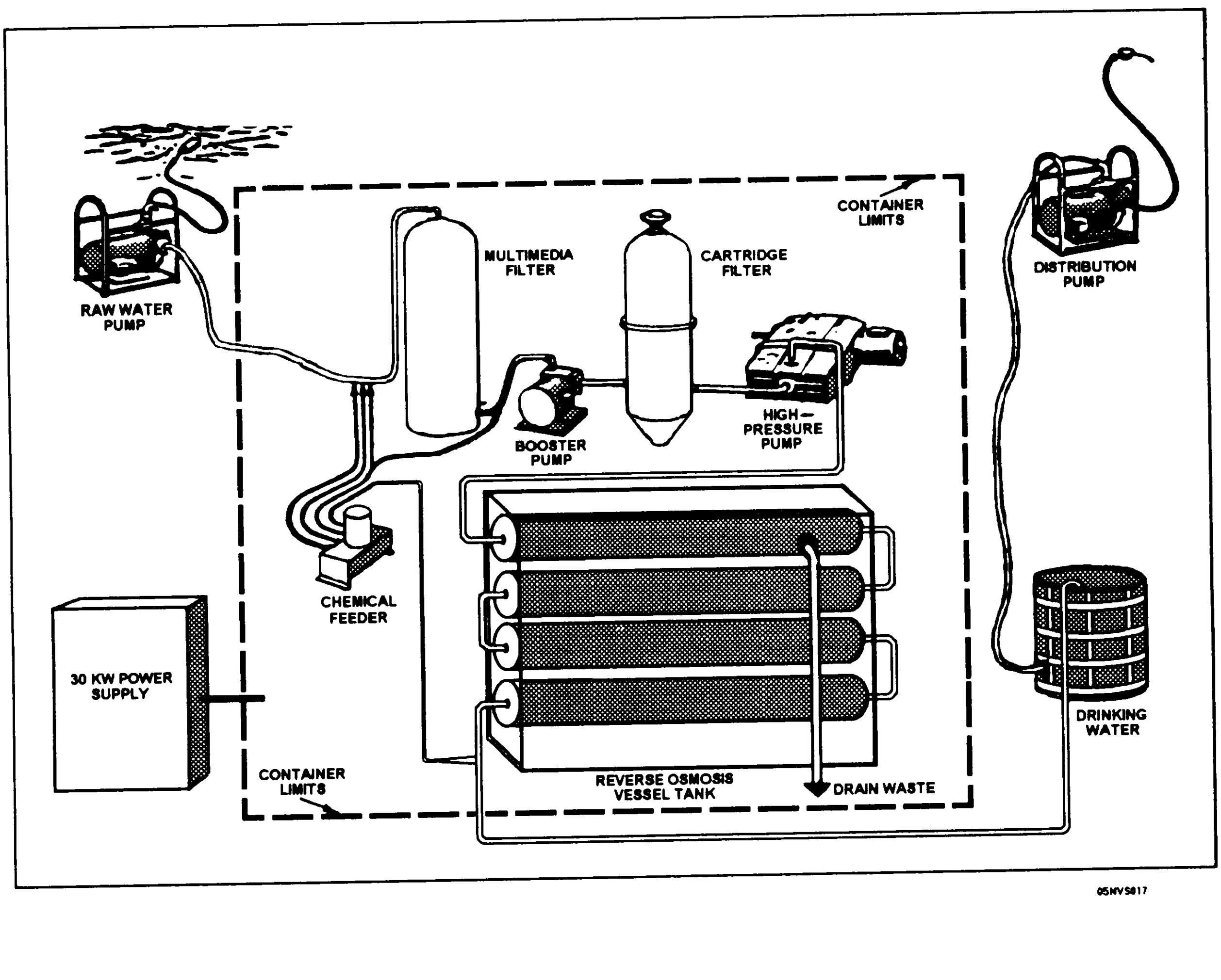

Figure 9-13(B).—Water flow through the 600 gph ROWPU.

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FILTRATION

Filtration consists of passing the water through some porous material to remove the suspended impurities. Filtration is one of the oldest and simplest procedures known to man for removing suspended matter from water and other fluids.

It is a common misconception that filtration removes suspended solids by a simple straining process whereby particles too large to pass through openings in the filter media are retained on the media. The mechanism involved in removing suspended solids by filtration is very complex. While straining is important at the filter media surface, most solid removal in deep granular filters occurs within the filter bed.

Flocculation and sedimentation in the pore spaces between filter media particles are an important removal mechanism as well as absorption of particles onto the filter media surfaces. Additional straining between media particles within the filter also contributes to overall solids removal.

The simplest form of water filter is the sand filter. This filter resembles a small reservoir, whose bottom is a bed of filter sand that rests on abed of well-graded aggregate with the largest size aggregate being at the bottom. An underdrain system of tile or brick is provided beneath the gravel to collect the water from the filter area. The underdrain system consists of a header or main conduit extending across the filter bed. Means are provided for regulating the flow of water out of the filter through this header and also for controlling the rate of flow onto the filter. This allows the filter to be operated at controlled rates that should not exceed 3.0 gph per square foot of filter area. An average filter bed consists of about 12 to 20 inches of gravel and 20 to 40 inches of sand, The depth of water over the sand bed varies from 3 to 5 feet.

The cartridge filter basically comes in two types of cartridge filtration: (1) depth filtration, where solid particles become trapped within the filter medium, and (2) surface filtration, where solid particles form a cake on the surface of the filter medium. Wound fiber cartridges function primarily as depth filters and are the standard cartridge used in the 600 gph ROWPU. (See cartridge filter in figure 9-13(C).) The most effective filtration system ever devised and one of the most effective portable systems in existence is the diatomite filter unit.

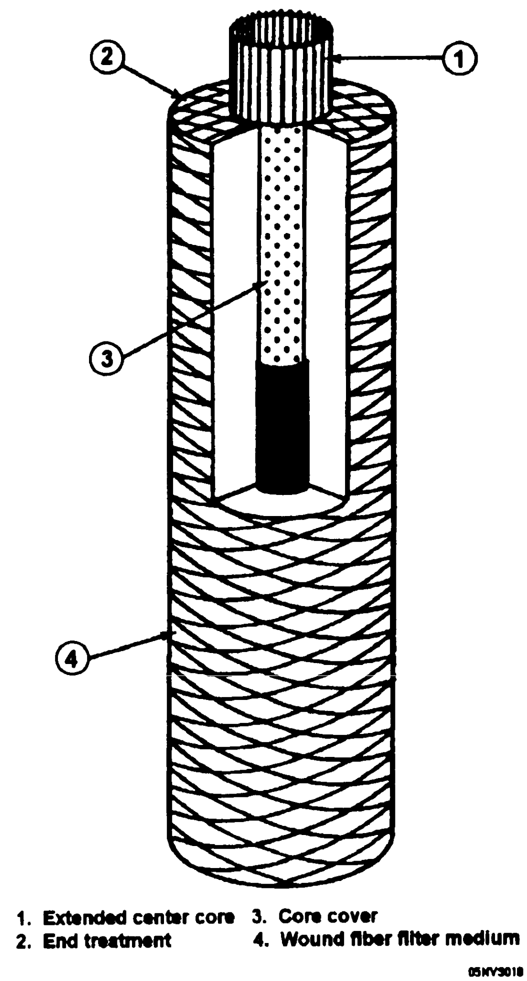

Figure 9-13(C).—Cartridge filter.

(fig. 9-14). In the diatomite filter, water is passed through a layer of diatomaceous silica (also called diatomaceous earth). It consists of skeletal remains of minute algae (diatoms) found in marine deposits that have lifted above sea level.

The diatomite filter accomplishes highly efficient filtration. Properly operated diatomite filters are capable of removing from coagulated and settled water, amoebic cysts, the cercariae of schistosomes, and approximately 90 percent of the bacteria. They also produce water with less than one unit of turbidity.

Before filtering, water is normally pretreated by passing it through sedimentation basins or holding tanks. This process removes heavier suspended solids that may cause rapid clogging of the filter. This water is brought onto the filters as the next step in the purification process. This water contains very finely divided suspended matter such as minute particles of floc, clay, and mud that have not settled, and bacteria and microscopic organisms that have not been removed by sedimentation. The purpose of the filter is to remove this suspended matter and give the water a clear, sparkling, and attractive appearance.

There are basically three types of filters. These are slow sand filters, rapid sand filters, and pressure filters.

Slow sand filters contain fine-grain sand and have low filtration rates. They are usually used when coagulation is not included in the treatment process. Their capacity is about 2 to 10 million gallons per day (mgd) per acre of filter surface. Use of slow sand filters has been practically discontinued because of their high cost per unit of capacity and the labor required to clean them. Rapid sand filters are now universally used in modern water treatment plants. There are two types, gravity and pressure. Gravity filters (fig. 9-1 5) are essentially open-top rectangular concrete boxes about 10 feet deep. An underdrain system at the bottom is covered by gravel, which, in turn, supports a 24- to 30-inch layer of fine filter sand (fig. 9-16). Gravity filters are usually designed to filter about 2 gpm per square foot of filter-bed area. However, in an emergency, up to 4 gpm per square foot can be obtained if prior treatment by flocculation and sedimentation produces very low turbidity and precholorination and postchlorination or both are effectively disinfecting the water. Approval must be obtained from the major command to operate filters at rates in excess of 2 gpm

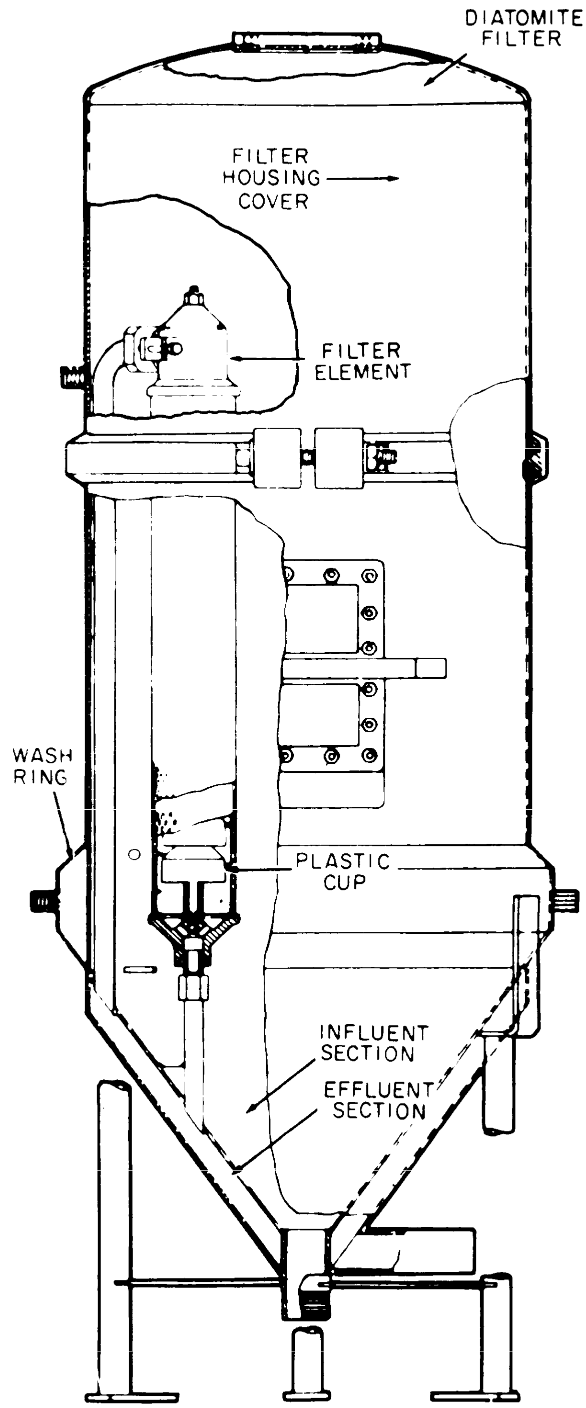

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Figure 9-14.—Diatomite filter, showing one filter element.

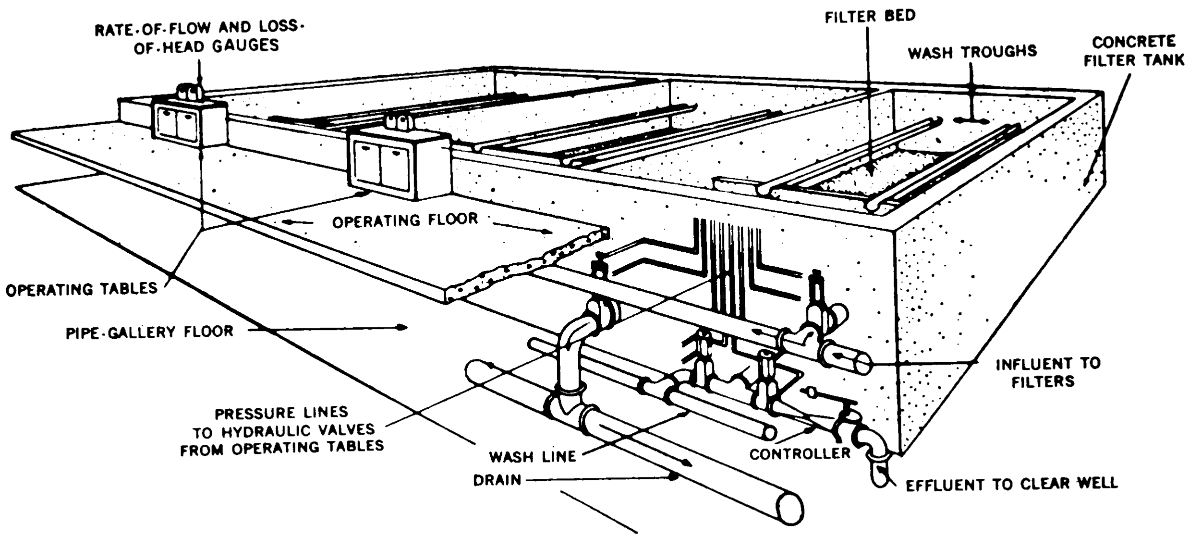

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Figure 9-15.—Battery of three gravity-type rapid sand filters.

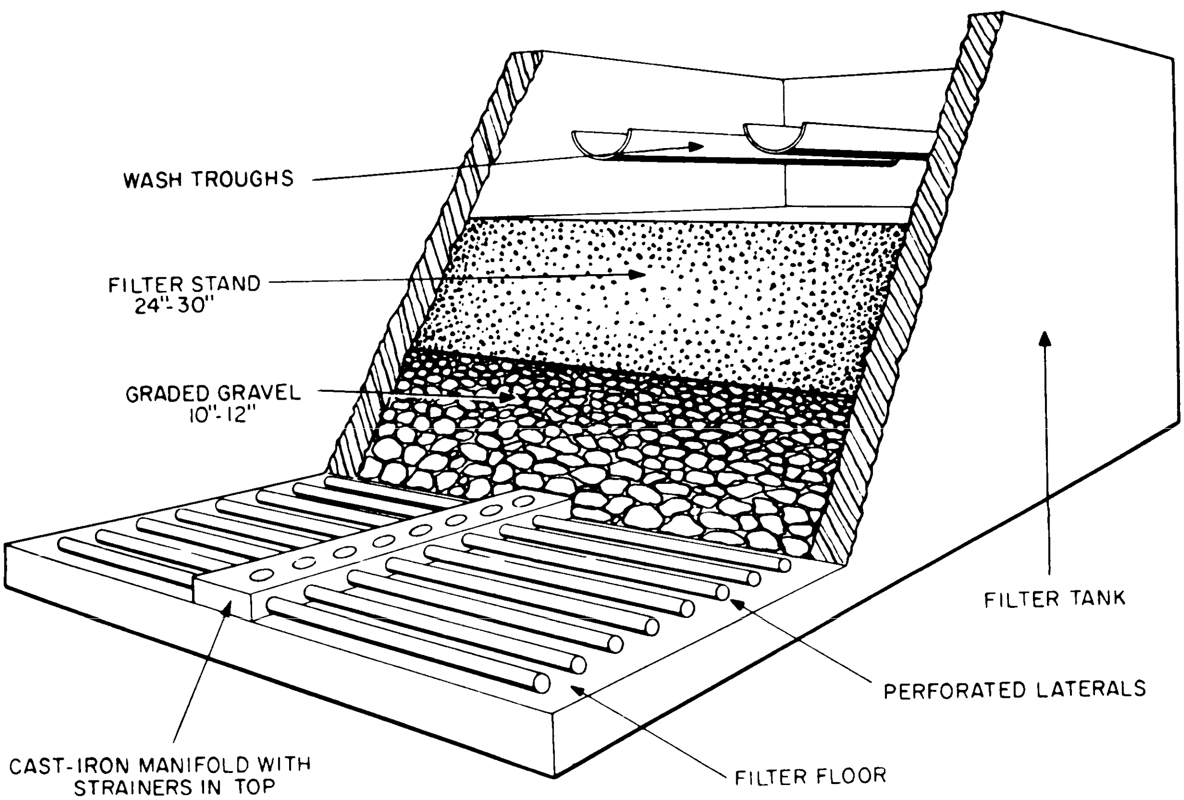

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Figure 9-16.—Typical sand filter showing relationship of filter media.

per square foot. Pressure filters (fig. 9-17) have the filter bed enclosed in a pressure vessel. Water is either pumped into the vessel and forced through the filter or is drawn into the vessel and through the filter by a pump. The diatomite filter is classified as a pressure filter.

DISINFECTION

Besides coagulation, sedimentation, and filtration, water must undergo an additional treatment step; disinfection. This is necessary because no combination of the other three steps can be relied upon to remove all disease-producing organisms from water; also because there is danger of recontamination during handling before consumption. Residual disinfection using chlorination is the final step in all water treatment processes (including distillation). Under emergency or field conditions, water may be disinfected with iodine or by boiling.

The most satisfactory means of water disinfection and provision of a residual is by means of a chemical disinfectant. The efficiency of the disinfection process is dependent upon numerous

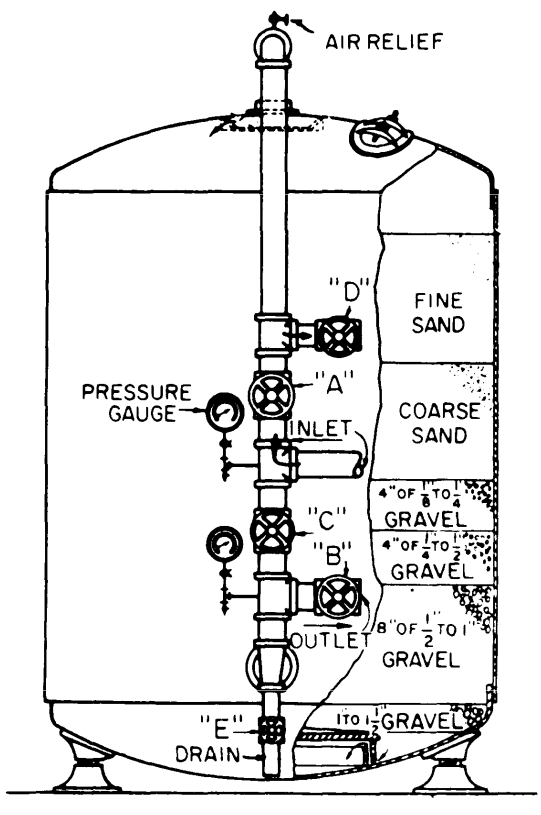

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Figure 9-17.—Pressure filter.

factors. These include the chemical used, the contact time, the type and concentration of microorganisms, the pH and temperature of the water, the presence of interfering substances, and the degree of protection afforded organisms from the disinfecting solution by materials in which they are imbedded. Therefore, various concentrations of disinfectant are required depending upon the local environmental conditions and the amount of particle removal effected.

Chlorine is the most commonly used chemical for disinfection of water. It is used in field water supply in the form of calcium hypochlorite, a standard item in the supply system (commercially known as HTH powder). When the calcium hypochlorite is dissolved, the chlorine goes into solution and a calcium carbonate sludge settles out. The chlorine is present in the solution as hypochlorous acid or hypochlorite ion (depending on the pH). Both forms are powerful oxidizing substances. The chlorine available in either form rapidly oxidizes the organic and inorganic matter, including the bacteria in the water. In this reaction the chlorine is converted to chloride and is no longer available as a disinfectant. The organic matter as well as such material as iron and manganese consumes the chlorine. The use of chlorine makes it possible to introduce an accurately measured dosage to ensure the destruction of disease-producing organisms and provide a readily measured residual to safeguard against recontamination during further handling.

Chlorine dosage is the amount of chlorine added to water to satisfy the chlorine demand as well as to provide a residual after a specified time. The amount required to disinfect water varies with the organic content and pH value of the water, the temperature, the time of contact, and the chlorine residual required. The dosage is usually stated in terms of parts per million (ppm) or milligrams per liter (mg/l).

The chlorine demand of water is the difference between the quantity of chlorine applied in water treatment and the total available residual chlorine present at the end of a specified contact period. The chlorine demand is dependent upon the nature and the quantity of chlorine-consuming agents present and the pH value and temperature of the water. (High pH and low temperatures retard disinfection by chlorination.) For comparative purposes, it is imperative that all test conditions be stated. The smallest amount of residual chlorine considered to be significant is 0.1 ppm. The relationship of the demand to the length of the contact period is discussed below.

Some of the chlorine-consuming agents in the water are nonpathogenic (nondisease-causing organisms), but this bears no relationship to the fact that they contribute to the total chlorine demand of the water. Navy policy requires that for field water supplies, the chlorine demand must be satisfied and chlorine residual must be present.

Residual chlorine is the amount of unreacted chlorine remaining at a specified time after the chlorine compound is added. Chlorine in aqueous solution is highly unstable. It may change quantitatively and qualitatively under numerous conditions, including the presence of other elements or compounds. The total residual chlorine in the water can be chemically divided into several types.

- Total available residual chlorine. This is the sum of the free available chlorine and the combined available chlorine.

- Free available chlorine. This refers to hypochlorous acid and hypochlorite ion present in water. These are the most effective disinfection forms of chlorine. The free available chlorine is a rapid-acting type, important because it can be relied upon to destroy bacteria relatively quickly, and thus is active during the period immediately following chlorination. The relative amount of each present in the water is dependent upon the pH value of the water. It is important to remember that when the pH is raised, the quantity of free available chlorine required to kill the same number of microorganisms increases. With decreasing temperature, the same situation of increasing dosage to maintain the same kill is encountered. If the contact time is varied, then the dosage applied must also be changed. For example, to shorten the contact time the dosage would have to be increased.

- Combined available chlorine. This results from the presence of ammonia or organic nitrogen that will react to form simple chloramines. Thus the term *combined available chlorine* arises from the fact that the chlorine has combined with another substance. Chloramines are a slower acting and less active form of disinfectant. Therefore, a much higher concentration than that of free available chlorine is needed to produce the same germ-destroying effect. The specific chloramines present are also a function of pH.

Chlorine demand in most water is likely to be largely satisfied 10 minutes after chlorine is added. After the first 10 minutes of chlorination, disinfection continues but at a diminishing rate. A standard period of 30 minutes' contact time is used to assure that highly resistant or high disease-producing organisms have been destroyed, providing a high enough dosage has been applied. Given a sufficiently large chlorine content, and if certain other conditions are met, even such special water purification problems as the presence of amoebic cysts or schistosomes will be solved with the 30-minute contact period.

The efficiency of the chemical disinfection process is dependent upon numerous factors. They include the type and concentration of microorganisms, the pH and temperature of the water, the presence of interfering substances, and whether or not the organisms are protected from the disinfection solution by being embedded in tissue cells, or clumps of tissue cells, or other material. Therefore, various concentrations of disinfectants are required. Minimum concentrations of disinfectants are prescribed below. Higher concentrations may frequently be prescribed by the medical officer on the basis of his knowledge of endemic disease or local environmental conditions.

SEABEE-operated mobile and portable water treatment units use coagulation and filtration as a part of the treatment process. They are capable of a high degree of removal of particulate material. When those units are used, sufficient chlorine will be added to the water, preferably before coagulation, so the residual in the finished water after 30 minutes of contact will be at least as much as that indicated by the following table.

pH	30-Minute Free Chlorine Residuals in mg/1
5	0.75
6	0.75
7	1.00
8	3.00
9	5.00
10	5.00

If adequate provisions are not made for accurate and frequent measurement of pH, 5.00 mg/1 must be used. The following guidelines were used in developing the above table:

- The water to be treated would be natural surface or ground water of average composition and not grossly or deliberately contaminated.

- Water temperature would be above the freezing point.

- Treatment would consist of coagulation, sedimentation, and filtration through diatomaceous earth. Water plant operators would be well trained and dependable.

- The prescribed concentrations of free chlorine should provide a reasonable margin of safety for all bacteria and viruses pathogenic to man. Parasitic ova (eggs) would have been removed in the coagulation and filtration steps of the treatment process.

EMERGENCY TREATMENT METHODS

Emergency treatment methods using water sterilizing bags, canteens, and other water containers do not provide for removal of impurities by coagulation and filtration. The entire reliance for rendering the water safe for consumption is placed on the disinfection process. Sufficient chlorine is added to the water so the residual, after 30 minutes of contact, will be at least 5 ppm of total chlorine. Under certain conditions, such as the presence of highly resistant disease-producing microorganisms or adverse environmental conditions, the medical officer will designate such higher residuals as may be necessary.

Boiling is a quick means of disinfecting small quantities of water in the field by individual soldiers. It is likely that all bacteria that produce diseases in man are killed by pasteurization temperatures. But there are some resistant organisms, principally viruses (such as infectious hepatitis), for which water must be boiled to achieve inactivation. A practical minimum standard for altitudes from sea level to 25,000 feet is to bring the water to a rolling boil for 15 seconds. Longer boiling times may be prescribed by the medical officer on the basis of evidence that the minimum is not inactivating all pathogenic microorganisms. Upon cooling, the boiled water should be kept in a covered uncontaminated container. Boiling is obviously a difficult way to disinfect large quantities of water.

Breakpoint chlorination is the application of chlorine to produce a residual of free available chlorine with no combined chlorine present. As chlorine is added, the total residual increases gradually after the initial demand of the water has been satisfied. At some residual concentration, depending on the water treated, free available chlorine reacts with the remaining oxidizable substances (including combined chlorine), and the residual drops sharply. When all combined chlorine has been oxidized by reaction with free available chlorine, the residual, now consisting only of free available chlorine, rises again and continues to increase in direct proportion to increased dosage. The point at which the residual again begins to increase is the breakpoint.

Figure 9-18 shows four typical breakpoint chlorination curves. Note that the curve rises at almost a 45-degree angle after the breakpoint is reached. Reactions are most rapid at pH from 6.5 to 8.5 and with increasing temperatures.

Curve 1 shows a typical breakpoint for water containing a considerable amount of ammonia. During the initial upward rise, chloramines are first formed. The curve rises until sufficient free available chlorine is developed to react with chloramine; then it falls until a point where all ammonia compounds have been oxidized.

With less organic matter in the water, as in curves 2 and 3, free available chlorine is formed sooner, destroying chloramines formed at the early stage. This results in lower combined chlorine residuals and flatter curves before breakpoint.

With practically no organic matter, curve 4 shows the chloramines are neutralized at an early stage by the upswing of the curve.

For some waters containing complex organic compounds, several intermediate breakpoints occur.

Advantages of breakpoint chlorination are high bactericidal efficiency, long-lasting residuals, and low odor and taste characteristics. It can be used only if detention periods are long enough to develop free available chlorine residual. This varies with the organic content of water. In some cases the treated water must be open to the air to permit escape of chloroorganic gases formed.

Tests for ammonia nitrogen will assist in determining the breakpoint. In practice, 10 to 25 times as much chlorine as ammonia nitrogen content may be needed to reach the breakpoint. Breakpoint chlorination, before instead of after filtration, has been found desirable. In surface water supplies with widely varying ammonia nitrogen content, the breakpoint chlorination should not be used unless trained assistance is available to make frequent tests for the breakpoint. With such water quality, the breakpoint curve can change radically in a short time.

Superchlorination is the application of more chlorine than needed for the chlorine residual essential to marginal chlorination. The surplus, which is used to control odors and tastes, is later removed by dechlorination. This method is particularly valuable in surface waters with variable ammonia and organic content. Sulfur dioxide reacts with chlorine to form acids that are neutralized by the natural alkalinity of the water. Sulfur dioxide is fed by equipment similar to that used for chlorine feeding. Activated carbon absorbs the excess chlorine, while aeration removes it by dissipating it to the atmosphere.

Water Purification System (3000D)

The 3000D Water Purification System was developed to provide a fully self-contained water purification unit for purifying turbid and bacteria-polluted water. The design of the unit allows for increased efficiency, mobility, and cost effectiveness. The unit provides trouble-flee water purification at the rate of 3,000 gph.

There are four modular components located within a single frame: diesel-powered pump, chlorinator control, filter, and supplies to produce 20,000 gallons of potable water. Subsequent water processing requires only Diatamatious earth, chlorine, and diesel fuel. Each module may be operated independently in or out of the frame by one person.

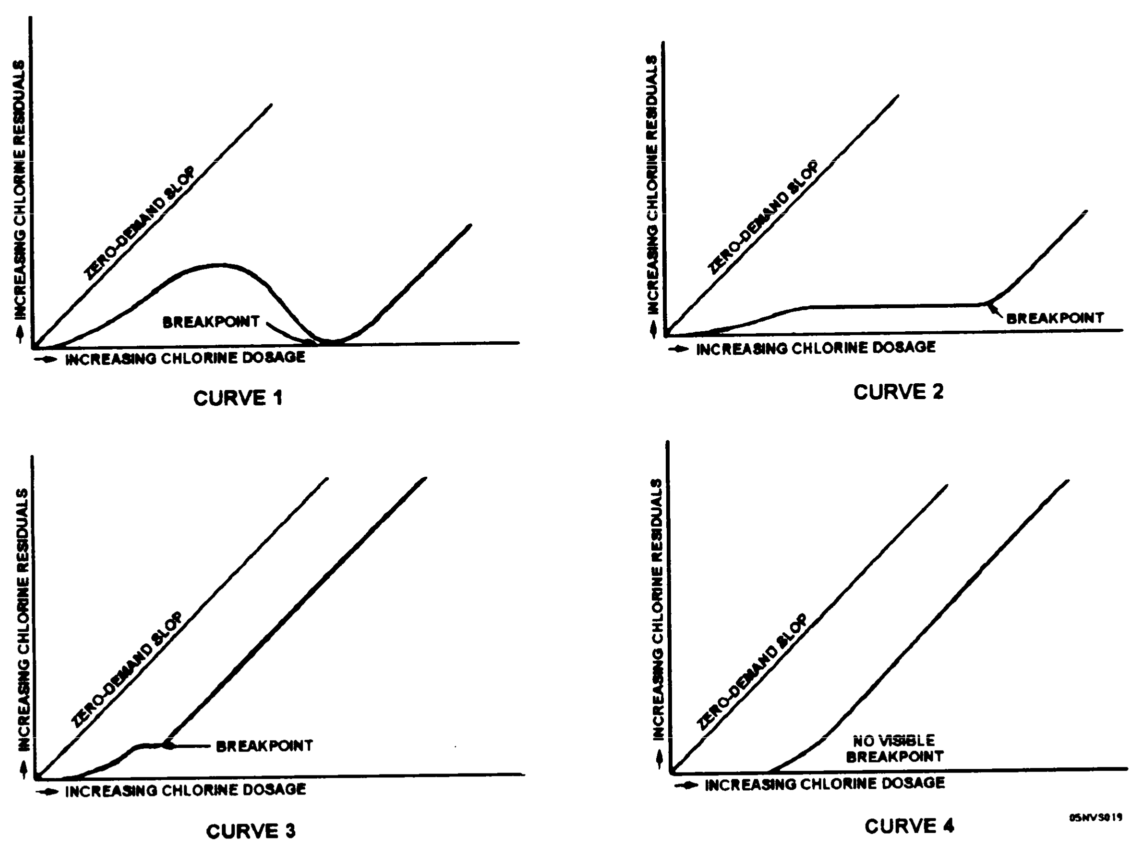


Figure 9-18.—Breakpoint chlorination curves.

CHAPTER 10

SEWAGE TREATMENT AND DISPOSAL

Sewage is the wastewater of community life. In composition it includes dissolved and suspended organic solids that are liable to become putrid and decay. Sewage contains countless numbers of living organisms, bacteria, and other microorganisms whose life activities cause the process of decomposition. When decay proceeds under anaerobic conditions (an absence of dissolved oxygen), offensive conditions result and odors and unsightly appearances are produced. When decay proceeds under aerobic conditions (dissolved oxygen present), offensive conditions do not result and the process is accelerated.

It is important to remove sewage and other wastes to an area away from the center of activity. It is only by such practices that the environment can be maintained in an acceptable and safe condition. Among the waste products of life are the disease-producing (pathogenic) bacteria and viruses that can be readily transferred by sewage from sick individuals to well ones. Procedures for proper disposal of sewage are necessary to protect the health and comfort of the people and to maintain the cleanliness of the environment.

The degree of treatment used for sewage depends on two main considerations: (1) health protection for individuals in the command and community and (2) prevention of water pollution. State and local authorities with statutory authority in pollution control have established standards of purity that are necessary to prevent pollution of natural waters. Accordingly, when a Navy installation discharges liquid waste into controlled waters, the standards set by state and local authorities must be maintained. As a Utilitiesman you may be involved in the installation, operation, and maintenance of systems designed to meet the above requirements. This chapter discusses the major sources of sewage along with sampling and testing procedures and monitoring of sewage disposal influents. In addition to these subjects, septic tanks, cesspools, and leaching fields are also discussed.

SOURCES OF RAW SEWAGE

The major sources of raw sewage are domestic sewage, industrial sewage, and storm water.

DOMESTIC SEWAGE

Domestic sewage consists of waste from toilets, lavatories, urinals, bathtubs, showers, home laundries, and kitchens. It also includes similar wastes from medical dispensaries and hospitals.

INDUSTRIAL SEWAGE

Industrial waste, depending upon the source, has characteristics that are different from domestic waste. Some of these wastes are dangerous to plant operators as well as to the treatment plant and collection system. Industrial waste sources include, but are not limited to, laundry and dry-cleaning plants, metal-cleaning and plating processes, paint spray booths, aircraft and vehicle cleaning racks, boiler plants, photographic processing systems, and fire-fighting activities. Most industrial waste requires pretreatment before being introduced into a collection system at their source.

Industrial wastes can also be very high or low in pH because of acids and/or bases used in their processes. You may expect intense colors in wastes from painting areas. Grit, salt, and dirt levels may be high from vehicle wash racks. Radioactive wastes must never be dumped into. regular collection systems. They must be handled separately and, in most cases, very carefully. Explosive or flammable liquids can often enter the system from fuel storage areas. These liquids also create a dangerous fire hazard in a sewage treatment plant.

STORM WATER

Storm water should be excluded from the sewage collection system as much as possible. Heavy input of storm water can disturb the operation of a treatment plant by sending it too much water, a problem called *hydraulic overloading.* This situation may force diverting or bypassing effluent from the treatment plant. Bypassing is normally a violation of National Pollutant Discharge Elimination System (NPDES) permits. These permits are controlled by the Environmental Protection Agency (EPA). Bypassing can result in releasing bacteria, heavy metals, and other dangerous contaminants into receiving waters. It is to be avoided whenever possible.

Very large paved or roofed areas should not be drained into the sanitary collection system. Maintenance personnel should prevent stormwater infiltration as much as possible by ensuring manholes are sealed, pipes are not cracked or broken, and all leaking joints are repaired.

SOURCE QUANTITY VARIABLES

Each military installation has different wastewater flows depending upon the types or

Table 10-1.—Characteristics of Typical Wastewater Generated at Military Facilities

Parameter	Weak	Medium	Strong
Total solids	330	700	1,200
Total volatile solids	240	420	810
Suspended solids	100	200	400
Total dissolved solids	230	500	800
Volatile suspended solids	70	130	220
Settleable solids*	2	4	6
Biochemical oxygen demand (5 day)	100	200	400
Total nitrogen as N	10	20	40
Ammonia nitrogen as N	4	10	20
Total phosphorus as P	6	10	20
Grease	50	100	150
Chemical oxygen demand	300	450	600

*All the above are measured in milligrams per liter (mg/I) except settleable solids, which are measured in milliliters per liter (ml/I).

sizes of industrial activities. Normally, 80 to 120 gallons per day per permanent resident and 30 to 50 gallons per day per transient and community labor personnel can be used as a rough volume estimate for flow.

PATTERNS OF FLOW

The amount of wastewater a treatment plant receives fluctuates from hour to hour. Changing seasons also affect the pattern flow. Peak flow of domestic wastes normally reaches a plant just after breakfast and for several hours in the early evening. Industrial wastes may reach the plant during the industry's period of operation. If the industry has two or three shifts, flow will be more constant.

The size and topography of the area served by a treatment plant also affects the flow pattern. Small plants may have large differences between peak and low flow periods. Larger plants normally have more uniform rates of flow. The period of lowest flow is usually between 2400 and 0500 hours. Unusual flow patterns help operating personnel identify and correct abnormal surges in flow in the wastewater system.

CHARACTERISTICS OF SEWAGE

Sewage is composed of many materials that are broken down into three general areas. These areas are the physical, chemical, and biological characteristics of wastewater. This section will aid you in identifying these various characteristics.

WASTEWATER COMPOSITION

The concentrations of most materials in wastewater are expressed in milligrams per liter (mg/I) and denote the strength of the wastewater. The higher the concentration, or mg/I, the higher the strength. Table 10-1 lists the most important materials that compose wastewater.

PHYSICAL CHARACTERISTICS

The physical characteristics of wastewater include those items that can be detected using the physical senses. They are temperature, color, odor, and solids.

Temperature

The temperature of wastewater varies greatly, depending upon the type of operations being conducted at your installation. Wide variation in the wastewater temperature indicates heated or cooled discharges, often of substantial volume. They have any one of a number of sources. For example, decreased temperatures after a snowmelt or rainfall may indicate serious infiltration. Changes in wastewater temperatures affect the settling rates, dissolved oxygen levels, and biological action. The temperature of wastewater becomes extremely important in certain wastewater unit operations such as sedimentation tanks and recirculating filters.

Color

The color of wastewater containing dissolved oxygen (DO) is normally gray. Black-colored wastewater usually accompanied by foul odors, containing little or no DO, is said to be *septic*. Table 10-2 provides wastewater color information.

Table 10-2.—Significance of Color in Wastewater

Unit Process	Color	Problem Indicated
Influent of plant	Gray	None
	Red	Blood or other industrial wastes or TNT complex
	Green, Yellow, Other	Industrial wastes not pretreated (paints, etc.)
	Red or other soil color	Surface runoff into influent, also industrial flows
	Black	Septic conditions or industrial flows

Odor

Domestic sewage should have a musty odor. Bubbling gas and/or foul odor may indicate industrial wastes, anaerobic (septic) conditions, and operational problems. Refer to table 10-3 for typical wastewater odors, possible problems, and solutions.

Solids

Wastewater is normally 99.9 percent water and 0.1 percent solids. If a wastewater sample is evaporated, the solids remaining are called *total solids.*

The amount of solids in the drinking water system has a significant effect on the total solids concentration in the raw sewage. Industrial and domestic discharges also add solids to the plant *influent.* There are many different ways to classify solids. The most common types are dissolved, suspended, settleable, floatable, colloidal, organic, and inorganic solids.

Part of the total solids is dissolved in wastewater. Much like sugar dissolves in coffee, many solids dissolve in water. Dissolved solids pass through a fine mesh filter. Normal wastewater processes using settling or flotation are designed to remove solids but cannot remove dissolved solids. Biological treatment units such as trickling filters and activated sludge plants convert some of these dissolved solids into settleable solids that are then removed by sedimentation tanks.

Those solids that are not dissolved in wastewater are called *suspended solids.* When suspended solids float, they are called *floatable solids* or scum. Those suspended solids that settle are called settleable solids, grit, or *sludge.* Very small suspended solids that neither float nor

Table 10-3.—Odors in Wastewater Treatment Plant

Odor	Location	Problem	Possible Solutions
Earthy, Musty	Primary and Secondary Units	No problem (Normal)	None required
Hydrogen sulfide (H_2S), "Like rotten eggs"	Influent	Septic	Aerate, chlorinate, oxonizate
"	Primary Clarifier	Septic Sludge	Remove sludge
"	Activated Sludge Aeration Tanks Trickling Filters	Septic Conditions (Anaerobic)	More air or less BOD, recirculation rate, HTH, flood
"	Secondary Clarifier	"	Remove sludge and/or grease
"	Chlorine Contact Tank	"	Remove sludge
"	General Plant	"	Good housekeeping
Chlorinelike	Chlorine Contact Tank	Improper chlorine dosage	Adjust chlorine dosage controls
Industrial Odors	General Plant	Inadequate pretreatment	Enforce sewer use regulation

settle are called *colloidal particles.* Colloidal particles are often removed in the biological treatment units. They may also be removed by chemical treatment followed by sedimentation.

All the solids discussed above may be either organic or inorganic. *Organic solids* always contain carbon and hydrogen and when ignited to high temperatures (500°C to 600°C) burn to form carbon dioxide, water, and sometimes various other compounds. The burning or volatilization of organic solids has led to the term *volatile solids.* All solids that burn or evaporate at 500°C to 600°C are called volatile solids. These solids serve as a food source for bacteria and other living forms in a wastewater treatment plant. Most organic solids in municipal waste originate from living plants or animals.

Those solids that do not burn or evaporate at 500°C to 600°C, but remain as a residue, are called *fixed solids.* Fixed solids are usually inorganic in nature and may be composed of grit, clay, salts, and metals. Most inorganic solids are from nonliving sources. Table 10-4 summarizes the types and amounts of the solids discussed in the preceding paragraphs.

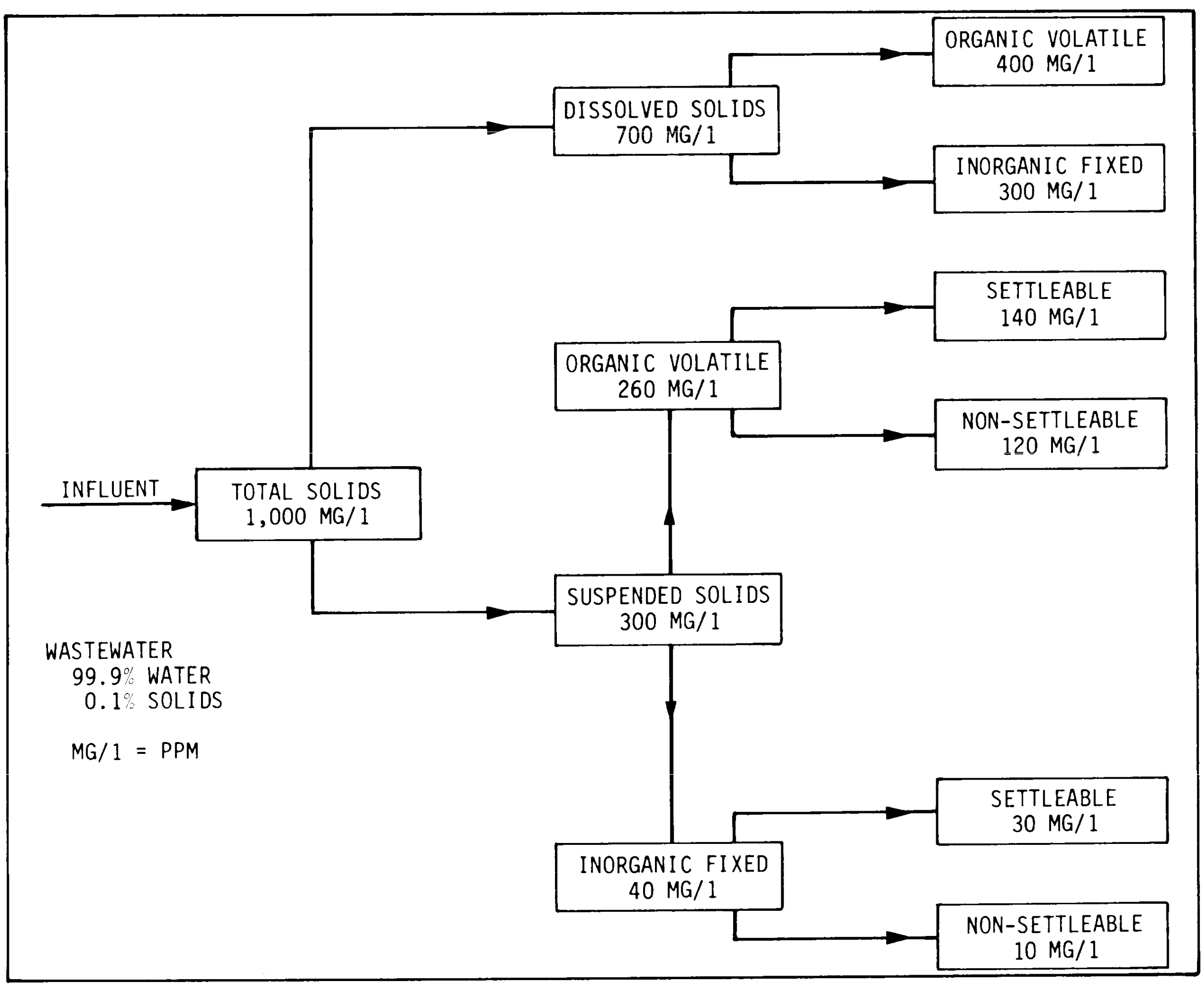
CHEMICAL CHARACTERISTICS

The chemical characteristics of wastewater of special concern to the Utilitiesman are pH, DO (dissolved oxygen), oxygen demand, nutrients, and toxic substances.

pH

The term *pH* is used to describe the acid or base properties of water solutions. A scale from

Table 10-4.-Solids of a Typical Domestic Wastewater



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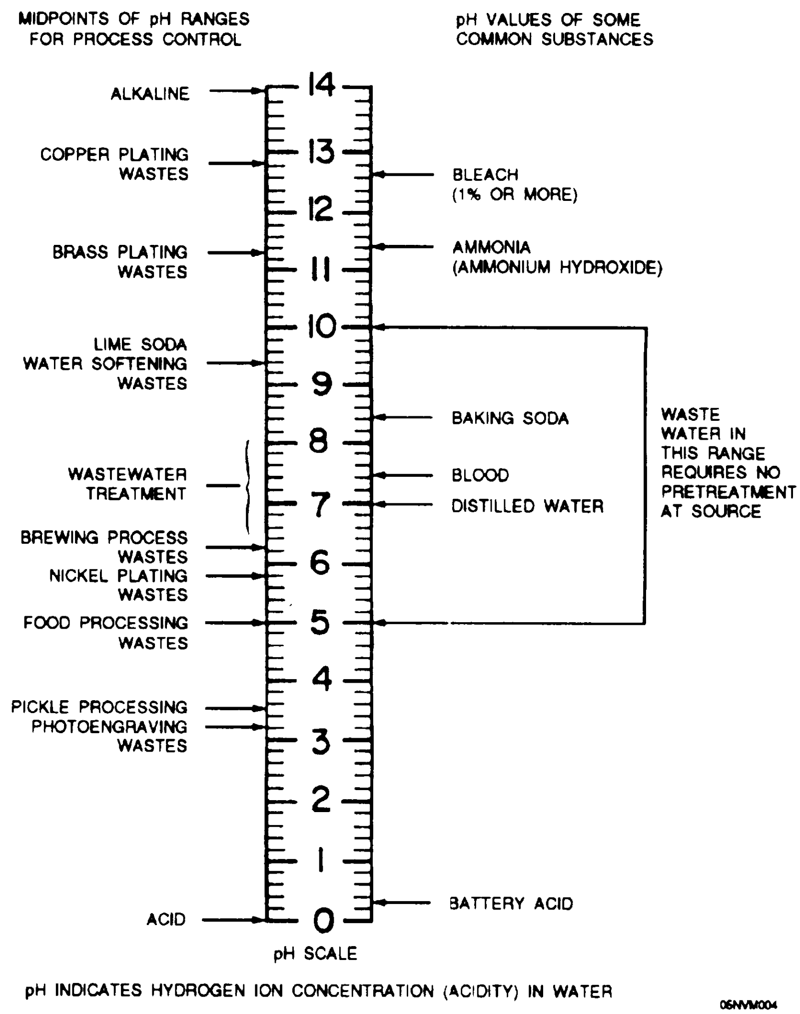
0 to 14 has been established where pH value of 7 is neutral. A pH value less than 7 is acidic. A pH value above 7 is alkaline or basic. Table 10-5 lists pH values for some common materials. A pH value less than 7 in the wastewater plant influent may indicate septic conditions of wastewater. The pH values less than 5 and more than 10 usually indicate that industrial wastes exist and are not compatible with biological wastewater operations. Pretreatment of these wastes at the source is usually required since extreme pH values may damage biological treatment units.

Dissolved oxygen

Dissolved oxygen (DO) in wastewater has a great effect on the characteristics of the water.

Table 10-5.—Common Substance pH Values



Wastewater that has DO is called *aerobic* or fresh. Aerobic raw sewage is usually gray in color and has a musty odor.

Wastewater that has no DO is called *anaerobic* or septic. Anaerobic raw sewage is usually black and has an offensive hydrogen sulfide or rotten egg odor.

Oxygen Demand

Oxygen demand is the amount of oxygen used by bacteria and other wastewater organisms as they feed upon the organic solids in the wastewater. Chemical tests such as the BOD (biochemical oxygen demand), the COD (chemical oxygen demand), the ODI (instantaneous oxygen demand or oxygen demand index), and the TOC (total organic carbon) measure the "strength" of sewage. These tests are discussed in detail later in this chapter. It is important that organic wastes be removed to protect the receiving body of water into which the wastewater plant is discharging. Sludge deposits, odors, and fish kills may occur if removal is not adequate.

Nutrients

Nutrients are life-supporting nitrogen and phosphorus. They stimulate excessive growths of algae and other aquatic plant life. They are always present in domestic wastewaters and are not removed during conventional primary and secondary treatment. Removal is accomplished by processes in addition to normal wastewater treatment or tertiary treatment, when specific reuse requirements require it.

Toxic Chemicals

Most military and industrial installations use various types of toxic chemicals, the discharges of which can be harmful to wastewater treatment processes. These toxic chemicals should be pretreated or removed before the wastewater enters the collecting system. Table 10-6

Table 10-6.—Chemicals and Discharges Commonly Found at Military Installations

Physical	Chemical	Biological
Solids from:	Heavy Metals (in solution)	Bacteria—Fecal Coliforms
	Chrominum, Nickel, Lead	Iron and Sulfur Bacteria
Paint	Zinc, Copper, Iron Oxide	Special Slimes, Fungi, and
Photo Lab	Chlorine, Aluminum, Mercury	Oil Related Growth
Sandblasting	Cyanides	Algae—Green and Blue-green
Grease—Valve, etc.	Phenols	Snails and Clams
(oils)	Acids—Sulfuric, Hydrochloric, Nitric	Viruses
Cutting Oils	(H_2SO_4) (HCL) (HNO_3)	
Heavy Metals—$Cr(OH)_3$	Base—Caustic Soda (NaOH)	
Rust (Oil)	Lime—$Ca(OH)_2$	
Fiber—(Bacterial Slime)	Quick Lime–CaO	
Misc. Solids (Trash)	Salts—Alum	
Grit—Rocks—Sand	Brine—Sodium Chloride (NaCl)	
Color—Dyes	Copper Sulfate	
H_2S—Metal Sulfides	Ship Chemicals—Cleaning	
	Gases—SO_2 (H_2S)	
	Cl_2	
	Ozone—O_2	
	Pesticides—Soln (Solid Waste)	
	Germicides	
	Solvents—Refrigerants	
	Ketones	
	Ethylene Glycol Diethyl Ether	
	Detergents	
	Adhesives and Resins	
	Grinding and Polishing Compounds	
	Carbon—Spent	
	Bentonite and Coagulant Aids (Clays)	
	Polymers	
	Polyelectrolytes	
	Diatomaceous Earth	
	Iron Chlorides, Ferric and Ferrous	
	Chlorides or Sulfates	

lists several examples of these types of wastes.

BIOLOGICAL CHARACTERISTICS

The three biological organisms present in wastewater are bacteria, viruses, and parasites.

Bacteria

Sewage consists of vast quantities of bacteria, most of which are harmless to man. However, pathogenic (disease-causing) organisms such as typhoid, dysentery, and other intestinal disorders may be present in wastewater. Tests for total coliform and fecal coliform nonpathogenic bacteria are used to indicate the presence of pathogenic bacteria. Because it is easier to test for coliforms, fecal coliform testing has been accepted as the best indicator of fecal contamination. Fecal coliform counts of 100 million per 100 milliliters may be found in raw domestic sewage. Detectable health effects have been found at levels of 2,300 to 2,400 total coliforms per 100 milliliters in recreational waters. Disinfection, usually chlorination, is generally used to reduce these pathogens. Breakdown or malfunctions of chlorination equipment will probably result in excessive discharge of pathogenic organisms and can seriously affect public health.

Bacteria can also be classified according to their dissolved oxygen requirement. Aerobic bacteria are bacteria that require dissolved oxygen to live. Anaerobic bacteria cannot live if dissolved oxygen is present. *Facultative* bacteria can live with or without dissolved oxygen.

Viruses

Wastewater often contains viruses that may produce diseases. Outbreaks of infectious hepatitis have been traced through water systems because of wastewater entering the supply. sedimentation, filtration, and disinfection, if used efficiently, usually provide acceptable virus removal.

Parasites

There are also many species of parasites carried by wastewater. The life cycle of each is peculiar to the given parasite. Some are dangerous to man and livestock, particularly during certain stages of the life cycle. Amoebic dysentery is a common disease caused by amoebic parasites. Chlorination, chemical precipitation, sedimentation, or sand filtration is used to ensure protection against parasites.

SEWAGE SAMPLING

Samples of sewage are taken to find out how well a treatment plant is working and what operating changes may need to be made, Some samples show how much the plant is reducing pollutants like BOD, solids, and so forth. Raw sewage entering the plant must be tested as well as the effluent from the plant and the receiving stream above and below the discharge point to determine how well the plant is removing pollutants. Since wastewater flows often change a great deal, daily sampling is suggested.

REPRESENTATIVE SAMPLING

A sample should be taken in a way that will represent the wastewater being treated. No matter how good the lab analysis is, if the sample was not correctly collected, the lab data will not be correct. With the large changes in composition and flow rate, getting a representative sample can be very hard. Careful thought, planning, and training must be used to develop and carry out a good sampling program.

Samples may be taken by hand or automatically. Taking samples by hand may be as simple as tying an open bottle to a pole that can be lowered into the wastewater. Table 10-7 explains some of the things that should be done when taking samples by hand. The automatic samplers may be made by the operator or bought.

GRAB SAMPLING

A grab sample is a single sample of wastewater taken over a short span of time, usually less than 15 minutes. This type of sample yields data about the wastewater at one time and place. The grab sample should be used where the wastewater does not change suddenly or change a great deal. For example, grab samples may be used to determine pH and temperature. Grab

Table 10-7.—Procedures for Manual Wastewater Sample Collection

Procedures	Special Cautions
1. Samples should be taken where wastewater is well mixed.	1. Weirs are not good sampling points since settling of solids is enhanced upstream and greases and oils build up downstream from the weir.
2. Sampling should be done in the center of the flow channel. To avoid floating scum, the mouth of the container should be held below the liquid surface.	2. Solids often build up near the sides and bottom of the flow channel.
3. A representative sample should be taken.	3. Raw wastewater should be sampled after screening and grit removal. Deposits or nonrepresentative materials such as grease or scum should be excluded from the sample. Particles larger than 0.25 inch (6 mm) in diameter should be excluded.
4. When compositing samples into other containers, the contents of each should be well mixed before pouring.	4. If dissolved gases or volatile substances are to be tested, turbulence may be produced by gentle stirring.
5. The sampling containers and sampling devices should be clean, uncontaminated, and suitable for the planned analysis.	5. Before the sample is taken, the container should be rinsed several times with the wastewater.
6. Sampling places should be easy to reach and safety precautions should be observed.	6. Proper sampling equipment should be available.

samples are also used when a batch dump or sludge discharge is seen.

COMPOSITE SAMPLES

A composite sample yields data about the wastewater over a longer span of time. A series of grab samples may be taken over a certain amount of time and combined to form a composite sample. These samples should show the time and frequency of the sample; for example, an 8-hour composite of 30-minute grab samples. The composite sample is used to find BOD, COD, suspended solids, and nutrients.

FLOW-PROPORTIONAL SAMPLES

The composite may be flow proportional. For this type of sample, the volume of the sample changes in proportion to the flow. The flow-proportional composite sample is most often run for 24 hours with a 2-hour interval between each collection. To collect this kind of sample, the volume needed for the tests and the average daily flow for the plant must be known. Table 10-8 shows the volumes required for some tests. The following formula may be used to find the volume of sample to be taken at each interval.

$$\text{Liters required} = \frac{\text{Flow at sampling time}}{\text{Average flow}} \times \frac{\text{Total sample size}}{\text{Number of samples}}$$

For example, to collect an 8-hour composite sample with a 2-hour interval, five samples would be needed. If a total sample of 2 liters was needed, the average daily flow was 60,000 gallons (227 cubic meters), and the flow at the first sample time was 45,000 gallons per day (170 cubic meters),

Table 10-8.—Recommendation for Sample Volume and Preservation of Sample

Measurement	Type of Sample	Vol. Req. (ml)	Container	Preservative	Holding Time
Acidity	G*	100	P, G**	Cool, 4°C***	24 hr
Alkalinity	G	100	P, G	Cool, 4°C	24 hr
Arsenic	PC****	100	P, G	HNO_3 to pH 2	6 mo
BOD	PC	1,000	P, G	Cool, 4°C	6 hr
Bromide	G	100	P, G	Cool, 4°C	24 hr
COD	PC	50	P, G	H_2SO_4 to pH 2	7 days
Chloride	G	50	P, G	None req.	7 days
Chlorine	G	50	P, G	Cool, 4°C	24 hr
Color	G	50	P, G	Cool, 4°C	24 hr
Cyanides	G	500	P, G	Cool, 4°C NaOH to pH 12	24 hr
Dissolved Oxygen					
Probe	G	300	G only	Det. on site	No holding
Winkler	G	300	G only	Fix on site	No holding
Fluoride	G	300	P, G	Cool, 4°C	7 days
Hardness	G	100	P, G	Cool, 4°C	7 days
Iodine	G	100	P, G	Cool, 4°C	24 hr
MBAS	G	250	P, G	Cool, 4°C	24 hr
Metals					
Dissolved	PC	200	P, G	Filter on site HNO_3 to pH 2	6 mo
Suspended	PC			Filter on site	6 mo
Total	PC	1,100		HNO_3 to pH 2	6 mo
Mercury					
Dissolved	PC	100	P, G	Filter HNO_3 to pH 2	38 days (glass) 13 days (hard plastic)

Table 10-8.—Recommendation for Sample Volume and Preservation of Sample—Continued

Measurement	Type of Sample	Vol. Req. (ml)	Container	Preservative	Holding Time
Nitrogen					
Ammonia	G	400	P, G	Cool, 4°C H_2SO_4 to pH 2	24 hr[2]
Kjeldahl	PC	500	P, G	Cool, 4°C H_2SO_4 to pH 2	24 hr[2]
Nitrate	PC	100	P, G	Cool, 4°C H_2SO_4 to pH 2	24 hr[2]
Nitrate	G	50	P, G	Cool, 4°C	24 hr[2]
NTA	PC	50	P, B	Cool, 4°C	24 hr
Oil & Grease	PC	1,000	G only	Cool, 4°C H_2SO_4 to pH 2	24 hr
Organic Carbon	PC	25	P, G	Cool, 4°C H_2SO_4 to pH 2	24 hr
pH	G	25	P, G	Cool, 4°C Det. on site	6 hr
Phenolics	G	500	G only	Cool, 4°C H_3PO_4 to pH 4 1.0 g $CUSO_4$/1	24 hr
Phosphorus					
Ortho-phosphate, dissolved	G	50	P, G	Filter on site Cool, 4°C	24 hr[2]
Hydrolyzable	G	50	P, G	Cool, 4°C H_2SO_4 to pH 2	24 hr[2]
Total	PC	50	P, G	Cool, 4°C	24 hr[2]
Total, dissolved	PC	50	P, G	Filter on site Cool, 4°C	24 hr[2]
Residue					
Filterable	PC	100	P, G	Cool, 4°C	7 days
Nonfilterable	PC	100	P, G	Cool, 4°C	7 days
Total	PC	100	P, G	Cool, 4°C	7 days
Volatile	PC	100	P, G	Cool, 4°C	7 days

Table 10-8.—Recommendation for Sample Volume and Preservation of Sample—Continued

Measurement	Type of Sample	Vol. Req. (ml)	Container	Preservative	Holding Time
Settleable Matter	PC	1,000	P, G	None req.	24 hr
Selenium	PC	50	P, G	HNO_3 to pH 2	6 mo
Silica	PC	50	P only	Cool, 4°C	7 days
Specific Conductance	G	100	P, G	Cool, 4°C	24 hr[3]
Sulfate	PC	50	P, G	Cool, 4°C	7 days
Sulfide	G	50	P, G	2 ml zinc acetate	24 hr
Temperature	G	1,000	P, G	Det. on site	No holding
Threshold Odor	G	200	G only	Cool, 4°C	24 hr
Turbidity	G	1,000	P, G	Cool, 4°C	7 days

*Type G sample = Grab. **P, G = Plastic or Glass.
***4°C = 4 Celslus. ****PC = Proportional Composite.

[1] If samples cannot be returned to the lab in less than 6 hours and holding time exceeds this limit, the final reported data should show the actual holding time.

[2] Mercuric chloride may be used as an alternate preservative at a concentration of 40 mg/1, especially if a longer holding time is requried. However, mercuric chloride should not be used if something better is available.

[3] 1f the sample is stabilized by cooling, it should be warmed to 25°C for reading, or temperature correction made and results reported at 25°C.

Note: It has been shown that certain samples properly preserved may be held beyond the recommended holding time. Consult designated authority.

then the milliliters required for the first sample could be figured like this:

$$\text{Liters required} = \frac{45{,}000 \text{ gal/day}}{60{,}000 \text{ gal/day}} \times \frac{2 \text{ liters}}{5 \text{ samples}}$$

$$\text{Liters required} = \frac{170 \text{ cubic meter/day}}{227 \text{ cubic meter/day}} \times \frac{2 \text{ liters}}{5 \text{ samples}}$$

Liters required = .30

Milliliters required = 300

NOTE: 264 gallons = 1 cubic meter (m^3)

Gallons × 0.003785 = cubic meters (m^3)

1 liter = 1,000 milliliters

SAMPLE STOWAGE

To get the best results, samples should be analyzed as soon as possible after they are collected. Some tests, such as DO, temperature, and pH must be performed at the time of collection since the results can change while the sample is being carried to the lab. Some other tests may be delayed if the sample is properly stored. The most common means of preserving a sample is to cool it to 2°C to 10°C. Table 10-8 shows some ways to preserve the sample.

Table 10-9.—Important Laboratory Tests

Test to be Performed	Sampling Point	Recommended Means of Collection	Recommended Frequency of Collection
Settleable Solids	1. Influent 2. Final effluent	Grab or Composite	Daily
Suspended Solids	1. Influent 2. Final effluent	Proportional Composite	Weekly Weekly
BOD_5 or COD	1. Influent 2. Effluent 3. Stream—above & below discharge	Proportional Composite	Weekly
Dissolved Oxygen	1. Influent 2. Final effluent 3. Stream—above & below discharge	Grab	Daily
pH	-----	Grab	Daily
Fecal Coliform	Final Effluent	Grab	Weekly
Alkalinity	1. Final effluent 2. Digester	Proportional Composite or Grab	Daily
Chlorine Residual	Final effluent	Grab	Daily (at least)

IDENTIFYING SAMPLES

After the sample is collected, it should be identified with a label. The label should include the following information:

- Where the sample was taken
- The date and time of collection
- The type of sample (grab or composite with the appropriate time and volume information)
- Anything that might change before laboratory testing such as temperature, pH, and appearance
- The initials or name of the person who took the sample

SEWAGE TESTING

Laboratory reports are useful in the operation of a wastewater treatment plant. The operator can use laboratory test results to keep the plant working at its best and to give early warning of operating problems. Laboratory testing programs vary with the type of treatment, size of the plant, local water quality requirements, and the NPDES permit requirements. Some of the most common laboratory tests for wastewater treatment plants are shown in table 10-9. They are discussed later in this chapter. Laboratory tests required by NPDES are determined for each treatment plant

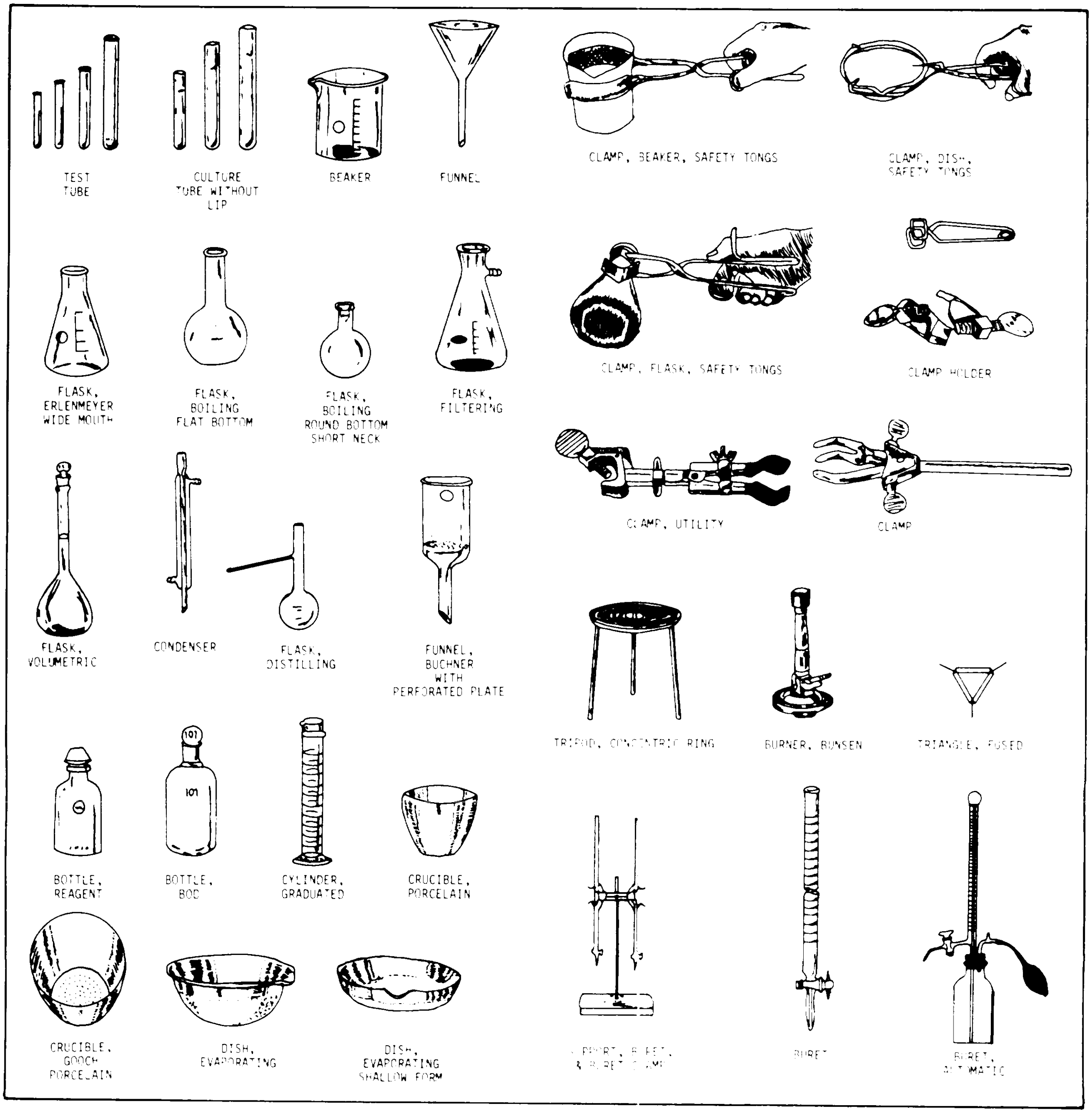


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Figure 10-1.—Illustrations of laboratory apparatus.

and are cited in the discharge permit. The normal procedures for these tests are given in the *Standard Methods for the Examination of Water and Wastewaters* and the *Methods of Chemical Ana[y-sis of Water and Wastes* published by the EPA.

LABORATORY EQUIPMENT

Examples of the various types of laboratory equipment are shown in figure 10-1. In order for the operator to conduct accurate sewage tests, the laboratory must be equipped with a minimum of equipment. Table 10-10 lists the types of equipment needed for some of the basic laboratory tests.

The operator should always maintain (his equipment in a high state of repair and cleanliness, Any contamination of the test equipment may adversely affect the results. Refer to the

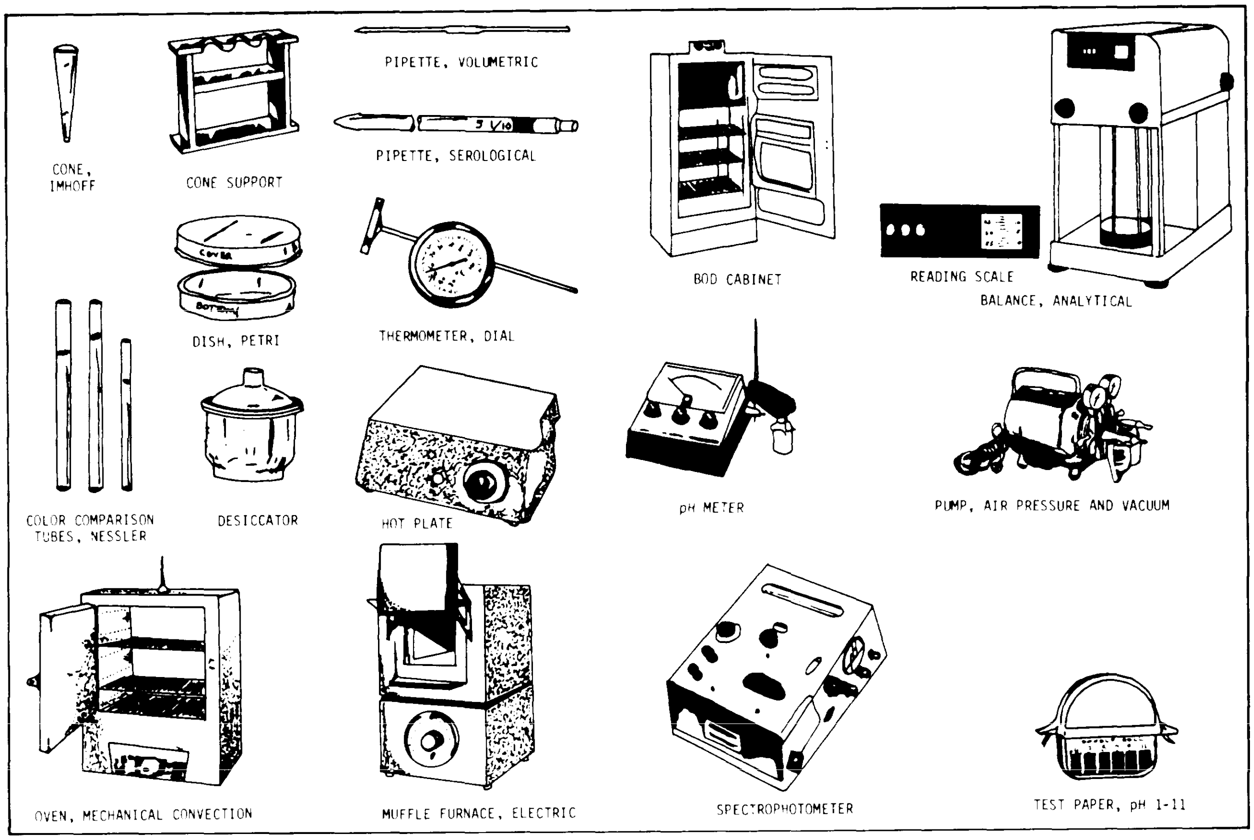

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Figure 10-1.—Illustrations of laboratory apparatus—Continued.

manufacturer's instructions for the proper maintenance procedures for each piece of equipment. Table 10-11 gives some basic guidelines for the maintenance and use of various types of laboratory equipment.

Safety should be vital to all personnel conducting sewage tests. Good housekeeping is essential in a laboratory to prevent mishaps and damage to expensive equipment. Each piece of equipment should be cleaned and returned to its proper place after being used.

When conducting sewage tests, it is always wise for the operator to avoid actual contact of the hands with the sewage samples or other filth. Hands must be kept out of the nose, mouth, and eyes. It is particularly important to use gloves when the hands are chapped, or burned, or the skin is broken from any wound. Operators should thoroughly wash their hands with plenty of soap and hot water before eating.

DISSOLVED OXYGEN TEST

The DO test finds the milligrams per liter (mg/l) of oxygen that is dissolved in water or wastewater. Oxygen exists as a gas and can dissolve in water in only a limited amount. Pure water at 20°C at sea level can hold a maximum of 9.17 mg/l of DO. Raising the temperature, salt content, or altitude will lower the DO level in the water. An important thing to remember is that this test should be run as soon as possible after the sample is taken. It must always be run as a grab sample. It is best to test several samples taken at different times during the day because the DO content of wastewater may vary. If incoming wastewater has no DO, it is septic. Most wastewater treatment plants are not built to treat septic wastewater. A great deal of plant and animal life that lives in water and wastewater, including necessary microorganisms, needs DO just as we need oxygen from the air. If the DO is used up, aerobic organisms will die and the water will become anaerobic or septic and foul

Table 10-10.—Types of Equipment Needed for Various Laboratory Tests

	EQUIPMENT NEEDED*																												
CONSTITUENTS TO BE ANALYZED	Atomic Absorption	600 °C Muffle Furnace	103 °C Drying Oven	Analytical Balance	Imhoff Cone	pH Meter	Lamotte Kit	BOD Incubator	Vacuum Pump	Hot Plate	Kjedahl Unit	Condenser/Extract. Eq.	DO Meter & Probe	Autoclave	Amperometric Titrat.	35 °C Incubator	Gas Analyzer	Steam Bath	Magnetic Stirrer	Blender	Turbidity Meter	Carb. Adsorp. Unit	Desiccator	Spectrophotometer	Stirring Equip.	Vibrating Shaker	Total Org. Carb. Analy	Purity Meter	Water Still
Volatile Solids		o	o	o																			o						
Total Solids			o	o																			o						
Settleable Solids					o																								
pH						o																							
Total Sulfides							o																						
BOD								o																				o	o
COD										o		o								o								o	o
Suspended Solids				o	o				o														o						
Dissolved Oxygen													o																
Chlorine Residual															o														
MPN Coliform**																													
Volatile Acids										o		o																o	o
Alkalinity						o													o										
Gas Analysis																	o												
Grease				o	o				o	o		o						o											
Total Organic Carb.																											o		
Turbidity																					o								
Volatile SS		o	o	o					o														o						
Total Phosphorus										o																			
MBAS***																									o				
Sludge Filterability						o			o																				
Ash Analysis		o		o																									
Jar Test																									o				
Apparent Density				o																						o			
Isotherms			o	o					o												o					o			
Calcium Content				o																			o						
Ammonia Nitrogen										o		o																	
Organic Nitrogen										o	o	o																	
Nitrate Nitrogen																								o					
Heavy Metals	o																												

*The equipment needed is subject to plant size and complexity of processes and the degree of control required.

**MPN = Most probably number

***Methylene Blue Active Substance

Table 10-11.—Maintenance Guide

Equipment	Function	Used for	Instructions*
ANALYTICAL BALANCE	Precision weighing.	Preparation of standards. Weighing samples of total and suspended solids, sludge moisture, oils, and grease.	Install on heavy shockproof table away from vibration and extreme temperature variations. Keep level at all times.
TRIP BALANCE	Course weighing.	Weighing samples of MLSS, wet sludge filter cake, grit, and chemicals.	Maintain and use according to manufacturer's instructions.
pH METER	pH measuring.	Analysis of wastewater, industrial waste, and determining endpoints of alkalinity, acidity and ammonia tests, also streams, surface water, and various solutions.	Calibrate frequently with buffers at pH 4.0, 7.0, and 10.0. Be sure buffers are fresh. Immerse electrodes in distilled water while not in use. Discard electrodes with broken tips and deep scratches. Keep electrode reservoir filled. Rinse electrodes with distilled water after each operation. Keep sample mixed during test. Observe temperature of sample and adjust meter.
DRYING OVEN	Controlling drying of samples and glassware.	Drying samples suspended and dissolved solids and sludge. Also drying chemicals and glassware.	Equip with accurate thermometer. Be sure temperature controls are working properly. Keep doors fitting tight to prevent heat loss. Clean the oven frequently. Arrange samples to prevent cross-contamination. Locate away from heat-sensitive equipment.

*Always follow manufacturer's instructions for maintenance and operation.

Table 10-11.—Maintenance Guide—Continued

Equipment	Function	Used for	Instructions*
MUFFLE FURNACE	Igniting (burning) volatile substances.	Determining amount of volatile and fixed solids in suspended, total, activated, and digester solids and/or sludge samples. Igniting barium sulfate precipitates in sulfate testing.	Be sure the furnace is equipped with an accurate temperature control. Keep heat chamber clean. Check frequently for deposits of soot and ash. Be sure that fumes are properly exhausted. Locate away from heat-sensitive equipment.
DESICCATOR	Providing moisture-free atmosphere for temporary storage of glassware, chemicals, and samples.	Drying chemical powders. Cooling glassware and samples before reweighing.	Check doors or lids for tight seal. Keep closed at all times except when inserting or removing materials. Be sure desiccant material is active. Replace or replenish inactive desiccant.
BOD INCUBATOR	Providing constant light-free temperature for BOD samples.	Incubating BOD samples at 20°C for 5 days.	Check temperature controls for accuracy. Be sure proper temperature is maintained at all times. Be sure door closes and seals properly. Keep chamber clean and free of biological growths.
WATER DISTILLATION UNIT	Distilling water to laboratory standards.	Providing high-quality water for chemical solutions, BOD dilution, bacteriological and chemical analyses. Also water for rinsing analytical glassware.	Check temperature control for accuracy. Be sure boiler, condenser coils, and tubing are free of deposits and scale. Clean frequently. Use borosilicate glass storage containers with tight covers to exclude airborne dust, gases, and organisms. Test pH and conductivity frequently to help ensure purity.

*Always follow manufacturer's instructions for maintenance and operation.

Table 10-11.—Maintenance Guide—Continued

Equipment	Function	Used for	Instructions*
DEIONIZER	Purifying water by ion exchange rather than by distillation.	Same as for water distillation unit.	Use ion exchange cartridges of proper type. Discard cartridges at once when exchange capacity is exhausted. Be sure water feed rate is not exceeded. Store deionized water same as distilled water.
CALORIMETER OR SPECTROPHOTOMETER	Quantatively measuring water quality by calorimetric method.	Testing for phosphorus, nitrate, nitrite, hexavalent chrome, color, sulfate by turbidity method, phenols, residual chlorine, and others.	This equipment is delicate. Handle with care. Keep adequate stock of replacement parts. Be sure the equipment is properly calibrated before use for transmittance or absorbance readings. Be sure to use proper filter for test being performed.
REFRIGERATOR	Low temperature storage	Storage of wastewater and sludge samples at 4°C. Also storage of unstable chemicals.	Check temperature controls for accuracy. Keep interior clean and free of biological growths. Provide refrigerator(s) with adequate capacity for laboratory needs.
AUTOCLAVE	Sterilization by steam.	Sterilization of dilution water, glassware, sample media, and related items for bacteriological testing.	Check time, temperature, and pressure controls for accuracy. Confirm sterilization by use of test strips or other indicators. Be sure sterilized materials are properly wrapped, sealed, and stored to prevent contamination.

*Always follow manufacturer's instructions for maintenance and operation.

Table 10-11.—Maintenance Guide—Continued

Equipment	Function	Used for	Instructions*
HOTPLATE OR HEATER	Healing liquids and solids	Preparing analytical solutions. For evaporation concentration, hydrolysis digestion, and other analytical operations.	Check temperature controls for accuracy. Be sure units are adequate for laboratory needs. If controls are manual, do not leave hotplates unattended.
DISSOLVED OXYGEN ANALYZER	Instrumental measuring of dissolved oxygen.	Testing wastewater, industrial waste, streams, and BOD samples for dissolved oxygen.	Check accuracy of instrument frequently. Recalibrate, if necessary, using approved standards. Store probe in water or in moisture-saturated air. Keep probes clean. Change membranes and replace electrolyte as recommended by manufacturer.
BACTERIA INCUBATOR	Providing constant temperature during incubation of samples.	Coliform and other bacteriological tests.	Check accuracy of temperature controls. Keep storage chamber clean and free of spillage and bacteriological growths. Check door(s) for proper closing and sealing. Locate unit where not exposed to extreme temperature changes.
WATER BATH INCUBATOR	Providing constant temperature for water bath incubation of sample.	Testing coliform and nitrate samples. Also digestion of wastewater samples.	Check accuracy of temperature controls. Keep storage chamber clean and free of rust, scale, and sediment. Check cover and seal for proper fit. Maintain bath water at correct level.

*Always follow manufacturer's instructions for maintenance and operation.

Table 10-11.—Maintenance Guide-Continued

Equipment	Function	Used for	Instructions*
CONDUCTIVITY METER	Measuring electrical conductance/resistance of a solution.	Testing distilled water, water, and wastewater samples.	Calibrate frequently against known reference. Keep electrode clean and stored in distilled water between tests. Observe between tests. Observe sample temperature and make necessary adjustment.
TOTAL ORGANIC CARBON ANALYZER	Analyzing carbon fractions by combustion/infrared methods.	Rapid analysis of total inorganic and organic carbon in water and wastewater samples.	Due to the complexity of this unit, problems should be referred to specially trained technicians.
ATOMIC ABSORPTION SPECTROPHOTOMETER	Analyzing metal ions by atomic absorption/emission method.	Testing samples for heavy metal or toxic metal ions.	Be sure the unit is properly installed with fume exhaust system. Problems with the unit should be referred to a specially trained technician.

*Always follow manufacturer's instructions for maintenance and operation.

odors will develop. If this occurs, you should check for flow problems within the sanitary system upstream of the treatment plant.

HYDROGEN ION CONCENTRATION (pH VALUE) TEST

The measure of acidity or basicity (alkalinity) of something is called the pH. The effect of pH on some parts of wastewater treatment makes it an important test. A low pH of domestic wastewater may mean that the wastewater is septic, or it can mean that industrial or commercial acid wastes are entering the system. A pH of 6.5 to 8 is about right for treatment plant influent. Test results showing a very high or low pH may mean someone is breaking sewer use regulations. Sudden changes of 0.5 or more on the pH scale may mean that operating problems are starting. Grab samples should be taken for pH tests.

SETTLEABLE SOLIDS TEST

The settleable solids test on wastewater can tell the operator a lot about what kind of wastewater is coming into the plant and how the solids are settling. Also, the settleable solids test can help the operator estimate the volume of sludge to be expected in the clarifier.

Either grab or composite samples will work for this test. The test is done using an Imhoff cone. The Imhoff cone (fig. 10-1) can be either glass or plastic. It can hold 1 liter and is marked off in milliliters (ml).

Before running the test, you should allow the sample to settle for 45 minutes. After 45 minutes, you should run a glass or plastic rod gently down the inside of the cone and turn it to loosen solids clinging to the sides. Settling should then continue for another 15 minutes. The depth of the solids in the bottom is then read from the scale and recorded as milliliters of settleable solids per liter of wastewater.

ACTIVATED SLUDGE SETTLEABILITY TEST

The settleability test is often used with all kinds of activated sludge plants to find the amount of solids in aeration units. The results help the operator to decide when to waste sludge and to find the rate of sludge return. The activated sludge settleability test can be run in a 1,000 ml graduated cylinder or in any clear, widemouthed container. The container should be ruled off into 10 units such as centimeters, milliliters, or inches. The sample is poured into the cylinder or jar up to the top mark and allowed to settle. Readings are taken from time to time to find settling rates. The sample should be allowed to settle for about 30 minutes.

FIVE-DAY BIOCHEMICAL OXYGEN DEMAND (BOD_5) TEST

The BOD_5 test is the most important test for finding the polluting strength of a wastewater. It is the most widely used way to check how the treatment plant is running. The BOD_5 test indirectly measures the amount of organic material in the sample. Either grab or composite samples may be used for this test.

NPDES permits often state that influent and effluent *flow-proportional* composite samples be taken for the BOD_5 test. Normal domestic wastewater coming into the plant should be in a 200 to 300 mg/l BOD_5 range. The effluent must comply with the plant's NPDES permit.

To run the test, the amount of oxygen is measured in a portion of diluted wastewater, and another portion like the first one is stored at 20°C for 5 days. The glass bottles shown in figure 10-1 are used for this test. During the 5 days, the microorganisms eat the organic matter in the wastewater and use oxygen at the same time. At the end of 5 days, the amount of oxygen consumed by the microorganisms times the dilution factor of the sample gives the sample's 5-day BOD. The dilution factor is the number of milliliters of dilution water added to a given number of milliliters of sample.

CHEMICAL OXYGEN DEMAND (COD) TEST

Like the BOD_5 test, the chemical oxygen demand (COD) test finds the amount of oxygen required to consume the organic matter in a wastewater sample. The COD test does not measure the amount of oxygen used by the microorganisms. It uses a strong, chemical concentrated sulfuric acid silver sulfate solution. It is a good operating control test because the results can be obtained in as little as 1 hour. COD test results are equal to or greater than BOD_5 test results. The chemical used in the COD test attacks more organisms in the wastewater than the slower BOD_5 organisms. BOD_5 data can often be related to COD data by a multiplying factor. For instance, the 200 to 300 mg/l BOD_5 of normal wastewater influent is about two-thirds of its usual 300 to 450 mg/l COD value. If such a factor can be figured for a certain kind of wastewater, COD data can be used to predict BOD 5 test results that will not be known for 5 days.

TOTAL SUSPENDED SOLIDS TEST

Total suspended solids are those solids in wastewater that can be taken out with a filter having a specified pore size. Suspended solids are made up of settleable solids and nonsettleable solids. Suspended solids tests can be run with either grab or composite samples, but flow-proportional composite samples are the best for this test. Influent wastewater may have as much as 400 mg/l of suspended solids.

MIXED LIQUOR SUSPENDED SOLIDS (MLSS) TEST

The suspended solids test that is run on the aeration tank mixed liquor is called the mixed liquor suspended solids test or MLSS test. It is used as a control test to help find out whether to increase or decrease the rate of sludge return and when to waste sludge. The very high solids content of mixed liquor requires a larger diameter filter (11 centimeters instead of 2.4 centimeters) to prevent rapid clogging.

CHLORINE RESIDUAL TEST

When chlorine is used to disinfect the effluent, tests are needed to see if the chlorine residual requirement has been met. The chlorine residual test may be run using the *iodometric* or *amperometric* methods. Since grab samples are used for these tests, most states suggest that the test be run within 30 minutes after taking the sample.

FECAL COLIFORM TEST

The fecal coliform test is an indicator of harmful bacteria in the wastewater. Both the membrane filter and most probable number (MPN) can be used to run the test. If the sample is not prepared for the test on the site, it should be cooled to 4°C within 30 minutes and then tested within 6 hours.

ALKALINITY

The alkalinity test can tell the operator a lot about the wastewater in the plant. A very high alkalinity in the wastewater may mean that an alkaline industrial waste has entered the system. The alkalinity test is often used to see how the anaerobic sludge digesters are working. The alkalinity in treatment lagoons usually goes down as the lagoon becomes septic. The alkalinity usually shows a 20 to 30 mg/l change before there is a change in pH.

LABORATORY RECORDS

Records can be used to find the best operating controls for a wastewater plant, problems that might arise in the plant, and the future needs of the plant. Records may also be used in court if a lawsuit is filed against the treatment plant.

The treatment plant should keep three kinds of records. These three types are physical records that describe in detail all areas of the plant itself, maintenance records that show what repair and cleaning has been done or needs to be done, and performance records that show the plant's operating data.

Physical records include operation and maintenance (O&M) manuals, actual plans and blueprints for the plant, shop drawings, O&M guides from equipment manufacturers, costs for all units, a hydraulic profile showing the height of water in all treatment units, and an equipment record. Under Public Law (PL) 92-500, consulting engineers are required to provide operation and maintenance (O&M) manuals for the treatment plants they design. These O&M manuals must meet the requirements of *Considerations for Preparation of Operation and Maintenance Manuals,* EPA, Washington, D.C., 1974.

Preventive maintenance in the treatment plant can reduce costly repairs and downtime on equipment. One of the key steps in a good maintenance program is keeping records. These records include the data needed to make a maintenance schedule, to estimate a maintenance budget, and to build up enough spare parts.

A record of all equipment in the plant must be made. This can be done on index cards. Each piece of equipment should be given a number based on where it is located in the plant. This number is written on an index card with the name of the equipment, where it is located in the plant, the name and address of the manufacturer or supplier, the cost, and when it was installed. The card should also have the type, model, serial, and any other code numbers, along with the capacity or size rating. The same card or another set of cards should include the type of maintenance required and how often it is needed; the special lubricants or coatings needed; and a record of all work done on the unit, including the labor, parts, and total cost. This data should be considered when planning to buy new equipment and making a maintenance schedule.

Making a maintenance schedule requires careful thought. Good records can serve as a guide. Some large treatment plants now use a computer to plan maintenance schedules and keep records up-to-date. Preventive maintenance should be scheduled so it can be done during good weather and not during times of peak load at the plant. Also, the schedule must leave time for repair work. A large chart showing what needs to be done daily, weekly, monthly, quarterly, semiannually, and annually can help in setting up a work schedule.

A spare parts inventory should be established. Many spare parts must be ordered several days or weeks before they are delivered. These spare parts should be stocked at the treatment plant so the plant won't have to be shut down until the part arrives. A list or inventory of spare parts makes reordering simpler. A written record of parts used and replaced should be kept. The operator should record the date an item was ordered, the date delivered, its cost, and the name of the supplier, each time a part is ordered and delivered.

In addition to the above records you must also maintain performance records. There are three types of performance records. These are the laboratory records, operator's log, and NPDES forms.

A complete set of laboratory records should be kept for all laboratory tests. The laboratory record should have the date and time the sample was taken, the method used to take the sample, the name of the person who took the sample, where the sample was taken, the test performed on the sample, and the results of the laboratory test. These records should be kept in a bound notebook so they can be used as a part of legal testimony about the operation of the plant if need be. A monthly or quarterly report is also required at most plants.

A monthly report is required for all wastewater plants on a military installation. Since no two treatment plants are exactly the same, the operator will find that a special log designed for the treatment plant is helpful. The operator should report on special features of the treatment plant under the blank columns in the log. Operators at each treatment plant are required to complete the log. Navy plant operators use the Wastewater Treatment Plant Operating Record, NAVFAC 11340/1 (6-75).

Finally, every treatment plant that discharges to a body of water must get an NPDES permit from the EPA or the designated state agency. The permit lists standards for the effluent, tests required, how often the tests must be run, and the sampling method of each test. The treatment plant must submit a monthly or quarterly report to the EPA or the designated state agency with all the laboratory tests required by the permit. These reports and laboratory records must be kept for at least 3 years.

Use performance records to check the plant. The performance records at a treatment plant can provide good process control data to the operator. Results of laboratory tests that differ a lot from previous records may show an equipment breakdown, an industrial waste discharge, or a break in the collection system. Table 10-12 shows

Table 10-12.—Variations in Performance and Some Common Causes

Variation	Possible Cause	Solution
BOD_5 (or COD): Increase	Increased organic loading, Population growth. Imdustrial expansion.	Identify source of increase. If overloading is permanent, adjust treatment plant processes for maximum efficiency. Require adequate pretreatment. Enforce sewer use regulations if violations are found. Install holding tanks (ponds) if feasible. Modify or expand treatment units.
	Septic influent.	Freshen by aeration or chlorination.
	Septic conditions in treatment plant units.	Check on detention time and sludge pumping schedule. See if dissolved oxygen requirements of aerated units are being met.

Table 10-12.—Variations in Performance and Some Common Causes

Variation	Possible Cause	Solution
BOD_5 (or COD): Decrease	Decrease in organic loading.	No problem.
	Wastewater organisms killed by toxic waste.	Find source of toxic waste. Require neutralization or exclude from treatment facility by enforcing sewer use regulations. When toxic waste is found, immediately notify appropriate military and regulatory authorities. Immediately seek advice from qualified specialists as to disposal of toxic waste remaining in the plant. Disposal after neutralization and/or dilution may be no problem.
Suspended Solids: Increase	Industrial expansion or population increase. Changes in industrial processes.	Generally, same procedure as for BOD_5 increase. Unless growth and expansion are the causes, check pretreatment for operation. Also check for industrial "dumping." Enforce sewer use regulations, if applicable.
Suspended Solids: Decrease	Collection sewers blocked (clogged).	Inspect, clean and flush if needed.
	Broken or completely blocked sewer resulting in bypassing.	Clean and flush sewer if clogged. Repair or replace if sewer is broken or settled out of position. If wastewater is bypassing, treat with chlorine at once.
pH: Increase	Industrial discharge. Inadequate pretreatment.	Try to find source of alkaline (basic) discharge and require pH adjustment before discharge to collection system. Check on operation of pretreatment units.
pH: Decrease	Industrial discharge. Inadequate pretreatment.	Try to find source of acidic discharge and proceed as suggested above.
	Septic influent.	Check sewers for low velocity (flat grades) and blockage (clogging). Clean and flush sewers. Chlorinate if necessary. Check lift station wet wells for proper detention time (not more than 30 minutes in warm weather). If the cause cannot be remedied, then freshen the septic wastewater at the head of the treatment plant by using aeration and/or chlorine. If the pH remains too low for satisfactory operation, adjust by applying alkaline chemical such as lime or soda ash.

Table 10-12.—Variations in Performance and Some Common Causes—Continued

Variation	Possible Cause	Solution
Wastewater Flow: Increase	Population and industrial expansion.	Consider installing holding ponds or tanks. Consult with industry to prevent "dumping" during high flow periods. If increased flow is expected to be continually above treatment plant design capacity, plant expansion and/or modifications should be considered.
	Infiltration-Inflow.	Check collection system for unauthorized storm and surface water connections. Enforce sewer use regulations. Repair or replace broken or cracked pipes and leaky joints. Raise or provide good surface drainage for manhole covers in low areas. Install holding ponds or tanks.
Wastewater Flow: Decrease	Bypassing leakage (exfiltration).	Check collection system for leaks and bypassing. Make necessary repairs. Notify appropriate regulatory officials at once. Request their advice.
	Decreased water use.	Recirculate enough of the treatment plant effluent to primary clarifier, trickling filter (or other unit) to prevent excessive detention time and provide better operation.
Temperature Influent: Increase	Discharge of hot wastes.	Enforce sewer use regulations if temperature is high enough to hinder operation.
Temperature Influent: Decrease	Infiltration—inflow of storm water.	Locate points of entrance. Repair if needed. Enforce sewer use regulations, if applicable.
Chlorine Demand: Increase	Inefficient operation due to septic conditions, poor settling, and other operating problems.	Check on efficiency of each treatment unit. Adjust controls to secure maximum efficiency. Check sludge-pumping schedule and rate, recirculation of effluent, aeration rate, trickling filter operation, and return of digester supernatant. Check for proper detention time in clarifiers and aeration tanks.
	Industrial discharges. Slug loading or "dumping."	If possible, secure cooperation of industry in controlling time and rate of discharging strong waste.
	Chlorine feed equipment not properly working.	Check accuracy of dosing equipment. The problem could be improper dose instead of increased chlorine demand. Find out if chlorine and wastewater are being properly mixed.
	Temperature.	Wastewater with high temperature usually requires more chlorine to satisfy the chlorine demand.

some changes from normal values and some causes for these changes.

DISPOSING OF AND MONITORING SEWAGE EFFLUENTS

The wastewater treatment process includes taking the solids out of the wastewater, getting rid of the solids, and getting rid of the treated wastewater or effluent in a way the federal and state regulating agencies approve. Sludge handling and disposal are covered in chapter 13. This chapter describes many ways to dispose of plant effluent.

All plants that discharge an effluent must have NPDES permits issued by the EPA or by a state agency for the EPA. Before these permits are given to the plant, officials make a careful survey of the water use nearby that might be hurt by the effluent of the treatment plant. The permit may list top, bottom, or average limits for some kinds of pollutions. It may also state in what way the plant can dispose of its effluent. If the plant does not meet the limits on the permit, the operator should contact the regulating agency at once. The permit can be changed or revoked by the agency. Sometimes the plant may be allowed to discharge more than the limit on the permit, but that is up to the regulating agency. The purpose of the permit is to protect human health and natural resources. All operators should know the permit limits and make every effort to ensure that the treatment plant complies with them.

EFFLUENT DISCHARGE METHODS

The two major methods of discharging effluent are continuous discharge and intermittent discharge.

Most treatment plants discharge an effluent to a receiving water all the time. The effluent may go to an ocean, gulf, bay, lake, or stream. The point of discharge may be above or below the surface of the receiving water. *Continuous discharge* is often cheaper than other methods because it takes less manpower, equipment, and storage to operate. However, a very good monitoring program must be used to make sure toxic waste is not discharged. After a toxic waste is discharged, there is no practical way to stop or isolate the toxic substance.

Intermittent discharge means that the effluent is not discharged all the time, but only from time to time. This type of discharge requires a place to store the effluent. It is not often used at large plants. But it does work well at lagoons and small treatment plants that have holding or "polishing" ponds.

Intermittent discharge lets the operator choose the time and rate of discharge. A controlled amount of effluent can usually be discharged without hurting the quality of the receiving water if the operator picks the right time for all discharges. In some cases, the receiving water has even been improved. Intermittent discharge may cost more to build, but it does not require as costly a monitoring program. When there is no discharge, there is no effluent to be tested.

A special type of intermittent discharge is seasonal discharge. This type of discharge is often used to protect high-quality streams, especially during the season when the stream is used a great deal for recreation. More storage is needed for seasonal discharge because there are usually only two discharges, one in spring and one in autumn. The effluent is discharged under controlled conditions approved by the regulating agencies.

METHODS OF DISPOSING AND MONITORING SEWAGE EFFLUENTS

Several methods of disposing of sewage effluents are used today. All methods must conform to the NPDES permit requirements and must be closely monitored. This section discusses these methods as well as troubleshooting problems with sewage effluent quality.

Direct Discharge to Receiving Water

Most treatment plants discharge effluent right into the receiving water. The abilities of the receiving water to dilute and accept the effluent is shown in the NPDES permit limits. The NPDES permit also considers the use of the receiving water. The effluent may come from a final clarifier, a disinfection contact basin, a lagoon, a polishing pond, or a storage pond. However, it must pass through some type of outfall sewer to the point of discharge.

The outfall sewer may be an enclosed pipe or an open channel or some of both. It is used to transport the effluent from the final treatment or storage unit to the point of discharge. The outfall sewer may be built to include cascades or stairsteps, channels, mechanical aerators, or a filter bed of coarse rock. The purpose of these aerators is to increase the DO content of the effluent.

The NPDES permit requires that certain tests be made on the effluent on a regular schedule. Effluent testing may include, but is not limited to, flow measurement, temperature, BOD or COD, suspended solids, pH, DO, coliform count, and chlorine residual. Test results must be reported to the regulating agency. Along with the required tests, operators should check the receiving water, especially on small streams and lakes. Laboratory tests and visual checks may show that a problem exists in the receiving water and that something needs to be done. Plant operators cannot usually test large rivers, bays, lakes, and gulfs.

If an effluent containing a toxic substance is accidentally discharged to a receiving water that is used downstream as a drinking water supply, for recreation, or for livestock watering, operators must call the regulating agency and the downstream water users at once. Regulating agencies can then help curb the problem, and drinking water suppliers will have enough time to close their water intake lines until the problem is stopped. This will also warn people in recreation areas and give farmers and ranchers time to move livestock to a safe water supply.

Discharge for Recycling

In some areas where there is a shortage of water, wastewater effluent is recycled for industry, recreation, irrigation, and fire control use. Many industries can use treated wastewater for cooling and cleaning. Often this is cheaper for the industry than using potable (drinking) water. Lakes for fishing and boating have been maintained with recycled wastewater. Records show that these man-made lakes are often no more hazardous to the users than natural lakes. Recycled wastewater is seldom used as a drinking water supply.

Monitoring of effluent discharged for recycling is very important. Only by monitoring can the operator be sure that the effluent is good enough to be used. Recycling units may include extended settling and biological stabilization in holding ponds, sand filtering, and disinfection. Quality control is a must since the recycled water must be safe.

Discharge for Land Application (Irrigation)

Irrigation with wastewater effluent is frequently used in some areas. Before irrigating, it is necessary to consider the contour of the area for irrigation, soil type, ground water table, and potential damage to water supplies. The joint EPA/Army manual, EPA 625/1-77-008 *Process Design Manual for Land Treatment of Municipal Wastewater,* provides further guidance on this subject.

Hillsides and other areas with steep slopes are not often used for irrigation. Too much runoff may occur. Irrigation equipment is harder to move, control, and maintain. Each area to be used for irrigation should be surveyed by a qualified person. Often, areas with slopes on which normal farm machinery can be used can be irrigated by a sprinkler system or by a jet or spray gun. Terracing and contour furrowing help prevent runoff. Flooding, overland flow, and furrow irrigation may require special work done to the land. This may include leveling, grading, ditches, and dikes.

Soil type and structure affect the rate at which the wastewater can be applied and absorbed. Average loams and sandy loams absorb and filter well. Clay and other types of tight soil are not as good. Deep plowing and chiseling make these soils better for wastewater irrigation. Very sandy or gravelly soils have very high percolation or absorbing qualities. But when these soils are in contact with the ground water table, pollutants may get into underground water supplies before they can be filtered out. Tight, sandy, and gravelly soils can be improved for absorbing and filtering by plowing crops under.

Row crops may be watered by furrow, spray, and/or sprinkler irrigation. Spray irrigation is used where gravity flow is not practical in all parts of an effluent disposal plot or field. There should be gravity flow from one end of the row to the other. A lot of grading is needed to prepare a field for furrow irrigation. Long rows without enough slope will result in boggy parts of the field while other parts will not get enough water. Furrow irrigation on steep slopes may cause too much erosion. Operators in charge of this type of irrigation need special skill and experience to make sure a fairly even amount of water reaches all parts of the field.

Grass crops are often easy to irrigate. The grasslands may be pastures, meadows, parks, turf, or sodded areas of airfields and golf courses. The amount of water applied and how often it is applied are not as important as for row crops. Effluent can be applied to grassland by overland flow, sprinkler heads, or by jet or spray guns. The stems, leaves, and roots of the grasses make a good filter and help prevent rapid runoff. Grasses and some other plants purify and release to the air large amounts of moisture when they are growing. During times of sunny, hot, and dry weather with strong breezes, as much as 25 percent of the water applied to the land may evaporate, either straight from the plants or from the surface of the soil.

Wooded areas and some wastelands have been used for effluent disposal. In these areas the disposal of the treated wastewater is most often the only reason for applying the effluent since crops are not grown there. These areas may absorb and filter the wastewater very well. The amount of wastewater applied to these lands is not as important as it is with crop irrigation.

The use of wastewater irrigation for vegetable and fruit crops that can be eaten uncooked may be restricted to protect public health. The health department or local regulating agency should be contacted before wastewater irrigation is applied to fruit and vegetable crops.

Wastewater effluent is often held in storage ponds or basins before it is used for irrigation. All discharge permit requirements must be met before the effluent can be used. Wastewater used on parks, golf courses, and other recreation areas should be disinfected just before it is applied. A chlorine contact chamber installed just upstream of the irrigation should be enough, but disinfection must meet the rules of the regulating agencies.

Testing of surface and subsurface water supplies in the immediate area of irrigation is important and must not be forgotten. Samples should be taken from all surface waters exposed to drainage and seepage of the irrigation water. Ground water should be tested using samples from existing wells or from test wells dug for that purpose. In areas where the water table is only a few feet below ground level, tests should be run very often. It is not as hard or as costly to prevent pollution as it is to clean up polluted water. Qualified laboratory technicians should check the soil to see if it is being hurt by buildups of toxics or by too many plant nutrients. Grazing and/or harvesting crops may help control soil conditions.

There must be enough storage capacity to hold the wastewater effluent until it is time to irrigate. The weather, type of soil, and type of crop are important in finding out how much to apply and how often to apply it. The wastewater should be disinfected before it is used for recreation. A power unit and a pump must be used unless gravity flow can be used to transport and distribute the effluent. A lightweight pipe like an aluminum alloy or plastic is often used to carry the wastewater. Quick-coupling joints are needed so the pipe can be put together and taken apart easily. Sections of flexible hose are needed for mobile spray equipment and can also be used for bends in pipelines carrying the effluent. Valves are needed to control the amount of flow. Pressure release or bypass devices are needed to control pressure. Spray or sprinkler nozzles, heads, and guns must be able to adapt to the volume of water to be applied. They must also be designed to work in the range of water pressure maintained.

Evaporation and Percolation Basins

Evaporation and percolation basins are used to dispose of wastewater effluent by letting it evaporate and by letting it percolate or seep into the soil. The correct use of these ponds depends on the area of the basin compared to the amount and kind of the wastewater effluent to be processed. The larger the surface and bottom of the pond, the faster the wastewater evaporates and percolates. The climate and kind of soil are important in finding out whether this type of disposal can be used in a given area. This kind of system can be a good and cheap way to dispose of wastewater effluent.

It is often better to build two basins or one basin with a dike that separates it into two parts. After a time, suspended solids will change to settleable solids and build up in the pores or openings of the soil. Percolation will slow down and sooner or later will stop. To get the basin back in working order, it must be drained, dried, and cleaned. Scars must be cut in the bottom. With two basins, one can be kept in service while the other is being restored. The bottoms of the ponds should be sloped for quick and complete draining.

The berms or dikes must be checked often for erosion and rodent damage. The dikes and surrounding areas should be mowed often to keep vegetation at a maximum height of 6 to 10 inches (15 to 25 centimeters). This will help keep rodents out of the area. The area should be fenced to keep out larger animals.

Signs should be built to show that the ponds are wastewater treatment plants and are dangerous. As with wastewater lagoons, trees should not be allowed to grow within about 500 feet (150 meters) of the pond. There must be enough surface drainage around the edge of the pond to keep surface water from entering the unit.

Since there is no discharge from the system, there is no need for testing the pond effluent. All bodies of surface water and all wells in the area should be tested often to see if they have been polluted by the pond. Too many suspended solids discharged to the pond will stop up the unit. A suspended solids test must be performed daily (or at least very often) to find out if the treatment plant units are working well or if operative controls need to be changed. The ponds should be checked each day. Any changes in the way the plant looks or smells or any changes from normal operation need to be checked out. Laboratory tests may help find the problem and suggest ways of correcting it.

Troubleshooting

Table 10-13 describes some problems and solutions for these problems with wastewater effluent. Refer to manufacturers' manuals for more specific troubleshooting and operating guides for various types of treatment plants. Effluent quality usually depends on the operation and maintenance of upstream process units.

Odors and unsightly conditions are the most common subjects of complaints. Toxic wastes and wastes with high fecal coliform count are more dangerous but are more difficult to detect. Therefore, fewer complaints are made regarding these two hazards.

Complaints must be received with courtesy and investigated at once to see if the complaint is valid. Be sure to inform the complaining person(s) as to your findings, what can be done or what is being done to remedy the problem. A careful investigation may show that the source of the problem is not related to the wastewater treatment plant.

If the treatment plant is the source of the problem, use all available operating controls to obtain maximum plant efficiency. Notify designated regulatory officials at once as to the nature of the problem. If the solution to the problem appears to be beyond operator control, request advice and/or assistance.

Table 10-13.—Troubleshooting Effluent Disposal

INDICATOR	LIKELY CAUSES	ACTIONS TO TAKE
Effluent BOD or COD too high.	1. Organic overload.	1. Control organic loading by sewer use regulations. Improve plant upkeep. Use all available operating control.
	2. Septic conditions in plant units and the collection system.	2. Check sludge pumping schedule for proper removal. Inspect pumps to see if they are working. Inspect sludge pipes and valves for clogging, check for sludge deposits (pockets) that are not being pumped out of the clarifiers. Inspect all plant units whether primary or secondary for proper operation. Refer to manufacturer's instructions for process information. Inspect the collection system, including lift stations, for septic conditions.
	3. Not enough aeration.	3. Maintain the recommended DO level in all aerated units usually about 2 mg/1. Inspect air diffusers for even distribution of air and good mixing.
Effluent settleable solids content too high.	1. Hydraulic overload. 2. Sludge collection and removal equiment not working right.	Try to control hydraulic loading by maintaining the collection system. Install holding ponds or tanks to handle peak load. Check on wastewater flow rate often to see if plant capacity is exceeded, Inspect settling tanks for short circuiting (channeling).

INDICATOR	LIKELY CAUSES	ACTIONS TO TAKE
Effluent suspended solids content too high.	1. Secondary units organically overloaded.	1. Keep organic loading of secondary units within design capacity if reasonably possible. Carefully inspect aerated units for DO content and mixing.
	2. Hydraulic overload.	2. Same action as for too many settleable solids in the effluent due to hydraulic overload.
Effluent pH too low or too high.	1. Industrial discharges not properly pretreated.	1. Inspect and sample the wastewater from the collection system to find the source. Require or provide proper pretreatment.
	2. Septic conditions in collection system or in the treatment plant.	2. Inspect both collection system and plant for detention time in sewer pipes, wetwell, and clarifiers. Clean and flush clogged or partly clogged sewers. Aerate and/or chlorinate the influent wastewater for temporary relief.
Wastewater organisms killed, very little treatment being provided.	Toxic material leaking or being discharged to the collection system.	Immediately notify downstream users and regulatory authorities, giving all available information as to type and quantity of toxic substance, also time of release. If the operator has advance warning of a spill or discharge of toxic waste, then all available storage should be used to contain the toxic material instead of letting it pass through the plant. If it cannot be contained, use all available methods to neutralize and/or dilute the toxic waste. Try to find the source of the toxic material and use every reasonable means to prevent its discharge to the system.
Coliform count above permit requirement.	1. Not enough chlorine being applied.	1. Test several times daily for “free” chlorine residual, especially during and immediately after peak flows. Adjust dose of chlorine according to test results. Inspect chlorine feed pump for working condition. If chlorine compounds such as HTH and others are being used, be sure of its percentage of chlorine content when adjusting the feed rate (dose).
	2. Chlorine not well mixed with the wastewater.	2. Inspect mixing equipment to be sure the chlorine and wastewater are well mixed immediately. Test for free chlorine residual in several areas of the contact tank to be sure of proper mixing.
	3. Contact time too short.	3. Carefully check the contact (detention) time of the tank to be sure that 15 to 30 minutes’ contact time is provided. Remove sludge deposits, if any are present, from the contact tank.

SEPTIC TANKS, CESSPOOLS, AND LEACHING FIELDS

Septic tanks, cesspools, and leaching fields are used for sewage treatment processes where common sewers are not available. These facilities are for the most part underground receptacles. If properly designed, constructed, located, and operated, these receptacles work without objectionable odors over long periods of time with a minimum amount of attention.

SEPTIC TANKS

Septic tanks may be used to serve small or scattered installations where the effluent can be disposed of by dilution, leaching wells or trenches, subsurface tile, or artificial subsurface filter systems (fig. 10-2).

The septic tank capacity should equal a full day's flow plus an additional allowance of from 15 to 25 percent for sludge capacity. The minimum acceptable size of septic tank is 1,000 gallons. Table 10-14 outlines the minimum tank capacities required by the *National Standard Plumbing Code.*

Septic tanks are constructed of reinforced concrete. The length of the tank should be not less than two nor more than three times the width. The liquid depth should not be less than 4 feet for the smaller tanks and 6 feet for the larger ones. Manholes should be provided over the inlet and outlet pipes and over the low points in the

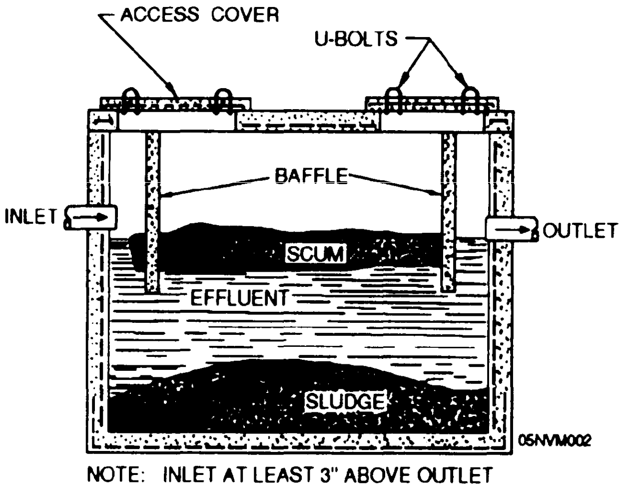

Figure 10-2.—Septic tank

Table 10-14.-Capacity of Septic Tanks

Single family dwellings—number of bedrooms	Multiple dwelling units or apartments—one bedroom each	Other uses—maximum fixture units served	Minimum septic tank capacity in gallons
1-3		20	1,000
4	2 units	25	1,200
5 or 6	3	33	1,500
7 or 8	4	45	2,000
Extra bedroom 150 Gal.ea. Extra dwelling units over 10,250 Gal. ea. Extra fixture units over 100, 25 gallons per fixture unit.	5	55	2,250
	6	60	2,500
	7	70	2,750
	8	80	3,000
	9	90	3,250
	10	100	3,500

bottom of hopper-bottom tanks. The roof of the tank may be covered with earth, but access openings should extend at least to the ground surface. Although ells or tees may be used at inlet and outlet connections, straight connections are better for rodding. Instead of ells, wooden baffles, located approximately 18 inches from the ends of the tank and extending 18 inches below and 12 inches above the flow line, are provided. Elevations should permit free flow into and out of the tank. The bottom of the inlet sewer should be at least 3 inches above the water level in the tank. The inlet and outlet connections should be sufficiently buried or otherwise protected to prevent damage by traffic or frost.

When a tank will discharge into a leaching field greater than 500 feet in length, a dosing tank and siphon should be incorporated into the system (fig. 10-3). The rush of sewage that occurs when the siphon discharges results in better distribution throughout the leaching field. While the dosing tank is refilling, the resultant resting period is favorable to maintaining aerobic conditions in the receiving soil. The dosing tank should have a capacity about 60 to 75 percent of the interior capacity of the leaching pipe to be dosed at one time and should automatically dose once in 3 to 4 hours. Double the amount of dosing siphons for each additional 500 feet of leaching tile or pipe.

Although properly designed septic tanks require little operating attention, they must be inspected periodically. The frequency is determined by the size of the tank and the population load. The minimum frequency should be once every 2 months at periods of high flow. The inspection should assure that the inlet and outlet are free from clogging, that the depth of scum and sludge accumulation is not excessive, and that the effluent passing to subsurface disposal is relatively free from suspended solids. A high concentration of suspended solids in the effluent quickly clogs subsurface disposal facilities. Sludge and scum accumulation should not exceed one-fourth the tank capacity. It should not be assumed that septic tanks liquefy all solids, that they never need cleaning, and that the effluent is pure and free from germs. Perhaps 40 to 60 percent of the suspended solids are retained and the rest are discharged in the effluent.

Separating sludge and scum from the liquid in septic tanks is difficult. In small tanks these wastes are customarily mixed, and the entire contents are removed when the tanks are cleaned. The

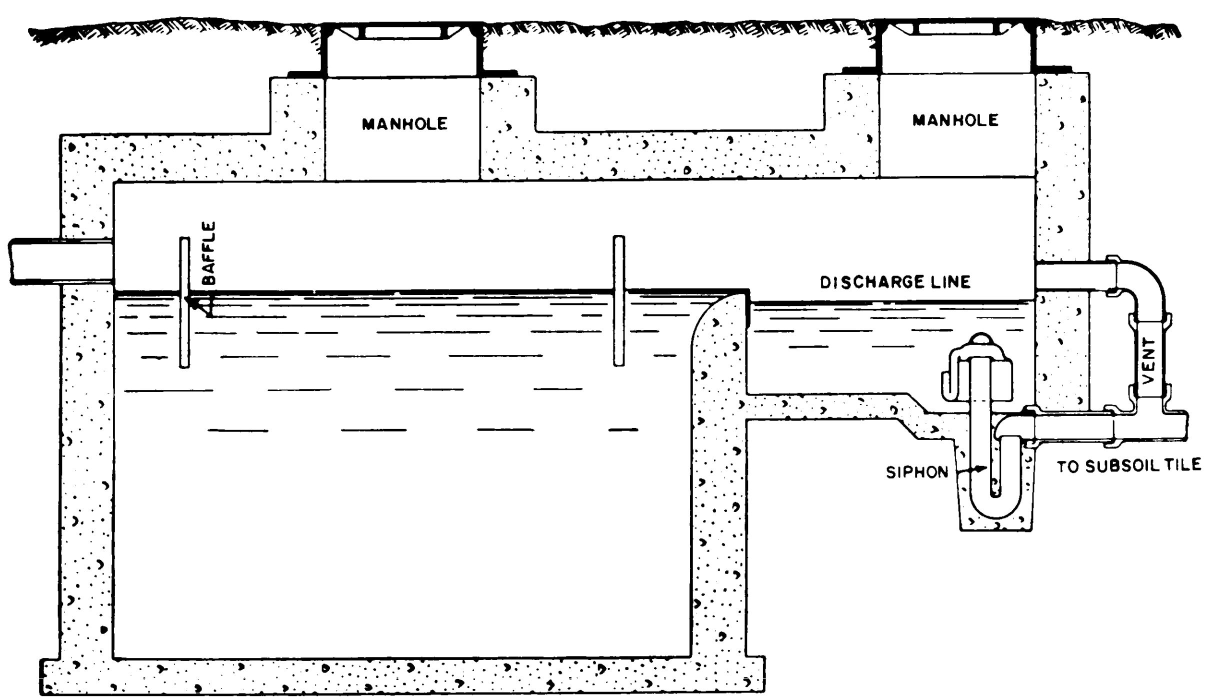

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Figure 10-3.-Septic tank with dosing siphon.

material removed contains fresh or partially digested sewage solids. It must be disposed of without endangering public health. Disposal through manholes in the nearest sewer system, as approved by local authorities, or burial in shallow furrows on open land is recommended. A diaphragm type of sludge pump is best suited for removing the content of the tank. The contents should be transported in a watertight, closed container.

When installing a septic tank system for sewage treatment, you must take into consideration the location with respect to wells or other sources of water supply, topography, water table, soil characteristics, area available, and maximum building occupancy. Building occupancy is a key factor in determining tank size. Table 10-15 shows common sewage uses based on type of facility and gallons per person per day of usage.

The physical location of a septic tank in relation to wells must be no closer than 100 feet from a shallow well and no closer than 50 feet from a deep well. In general, a shallow well is less than 100 feet in depth and a deep well is more than 100 feet in depth. Figure 10-4 shows a typical septic tank system layout with minimum distances noted. Keep in mind that septic tanks, cesspools, and leaching fields must be located downhill from any water source.

CESSPOOLS

Sewage from private dwellings and farmhouses in outlying areas may discharge into cesspools if a common sewerage system is not available. Cesspools are usually dry-laid masonry or brick-lined wells without any masonry at the bottom. The sewage flows into them and leaches out into the soil. Floating solids collect at the top and settling solids collect at the bottom of the well. The leaching capacity of the well is exhausted when the solids accumulate and clog the soil. The use of chemicals is not recommended

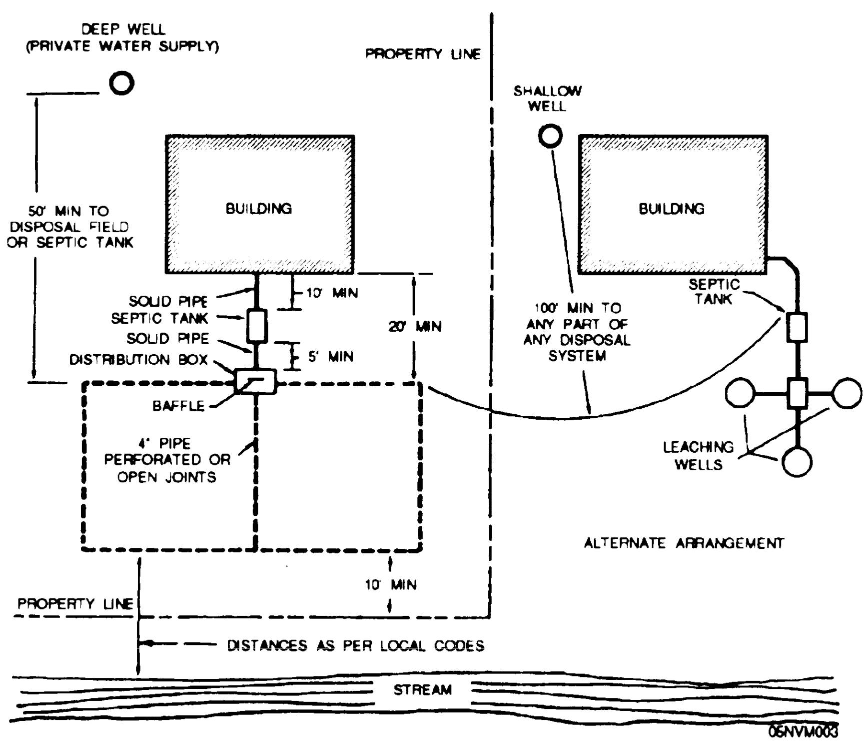

Figure 10-4.—Minimum distance for location of components of a private sewage disposal system.

Table 10-15.—Sewage Flows According to Type of Establishment

Type of Establishment	Gallons used
Schools (toilet and lavatories only)	.15 gal per day per person
Schools (with above plus cafeteria)	.25 gal per day per person
Schools (with above plus cafeteria and showers)	.35 gal per day per person
Dayworkers at schools and offices	15 gal per day per person
Daycamps	25 gal per day per person
Trailer parks or tourist camps (with built-in bath)	.50 gal per day per person
Trailer parks or tourist camps with central bathhouse	.35 gal per day per person
Work or construction camps	.50 gal per day per person
Public picnic parks (toilet wastes only)	5 gal per day per person
Public picnic parks (bathhouse, showers, and flush toilets)	.10 gal per day per person
Swimming pools and beaches	.10 gal per day per person
Country clubs	25 gal per locker
Luxury residences and estates	150 gal per day per person
Rooming house	.40 gal per day per person
Boardinghouses	50 gal per day per person
Hotels (with connecting baths)	.50 gal per day per person
Hotels (with private baths--two persons per room)	100 gal per day per person
Boarding schools	100 gal per day per person
Factories (gallons per person per shift exclusive of industrial wastes	.25 gal per day per person
Nursing homes	.75 gal per day per person
General hospitals	150 gal per day per person
Public institutions (other than hospitals)	100 gal per day per person
Restaurants (toilet and kitchen wastes per unit of serving capacity)	.25 gal per day per person
Kitchen waste from hotels, camps, etc. Serving 3 meals per day	.10 gal per day per person
Motels	50 gal per bed space
Motels with bath, toilet, and kitchen wastes	60 gal per bed space
Drive-in theaters	5 gal per car space
Stores	400 gal per toilet room
Service stations	10 gal per vehicle served
Airports	.3-5 gal per passenger
Assembly halls	2 gal per seat
Bowling alleys	75 gal per lane
Churches (small)	3-5 gal per sanctuary seat
Churches (large with kitchens)	.5-7 gal Per sanctuary seat
Dance halls	2 gal per day per person
Laundries (coin operated)	400 gal per machine
Service stations	1,000 gal (First bay)
	500 gal (each add. bay)
Subdivisions or individual homes	75 gal per day per person
Marinas—Flush toilets	36 gal per fixture per hr
Urinals	10 gal per fixture per hr
Washbasins	15 gal per fixture per hr
Showers	150 gal per fixture per hr

to increase the useful life of a cesspool. See figure 10-5.

When the first cesspool becomes filled, a second well may be built to take the overflow from the first. In such cases, the first cesspool should operate as a septic tank to collect the settling and floating solids and provide a trapped outlet on the connection leading to the next leaching cesspool. Septic tanks may be placed advantageously ahead of leaching cesspools in larger installations. Leaching cesspools should not be placed closer together than 20 feet by out-to-out measurement of walls.

Leaching cesspools should be used only where the subsoil is porous to a depth of at least 8 or 10 feet and where the ground water is normally below this elevation. When they are located in fine sand, the leaching area can be increased by surrounding the walls with graded gravel.

The number and the size of cesspools required depend on the quantity of sewage and the leaching characteristics of the total exterior percolating area above the ground water table, including bottoms and sidewalls below the maximum-flow lines. The allowable rate of sewage application per square foot per day, based on the recommended leaching test, is given below. Soils that require more than 30 minutes for a fall of 1 inch are

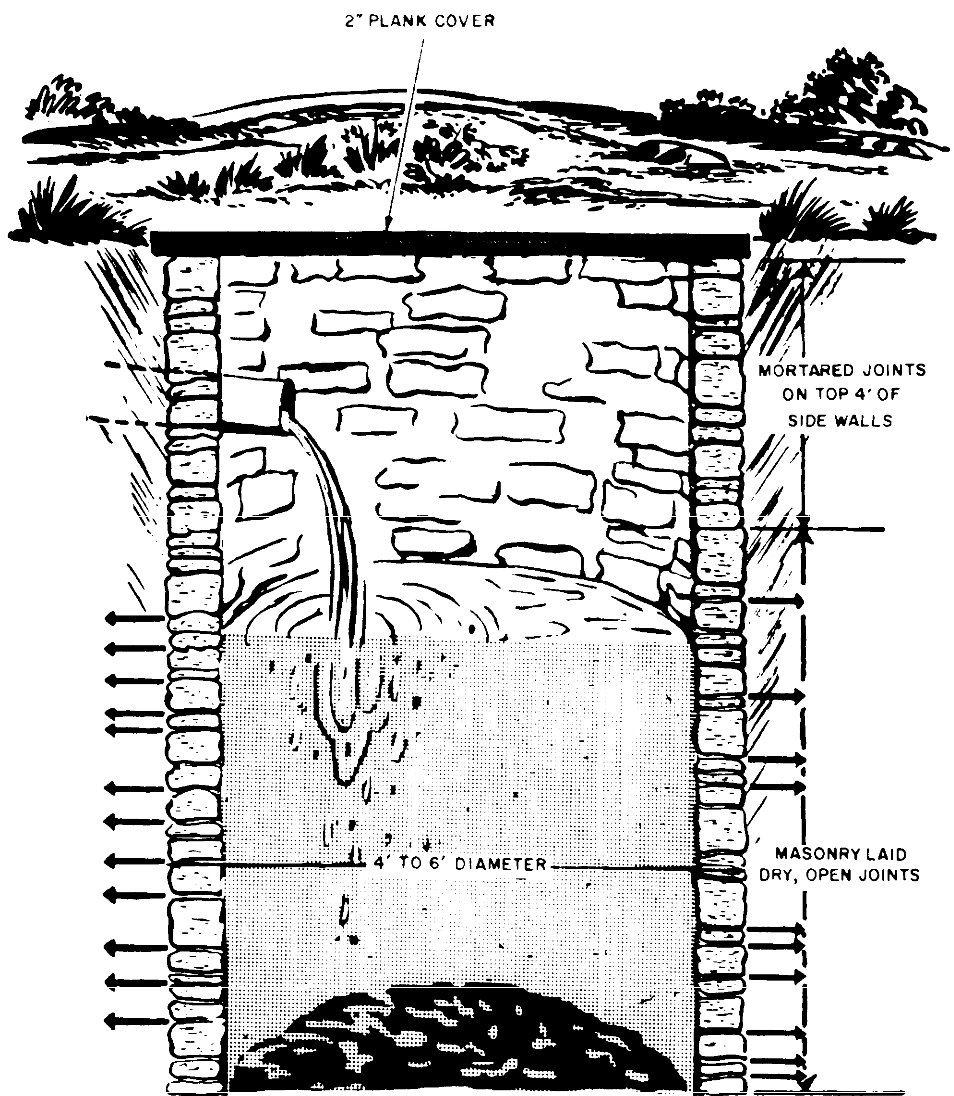

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Figure 10-5.—Leaching cesspool.

unsatisfactory for leaching. Some other disposal method should be used.

Time for water to fall 1 inch (minutes)	Allowable rate of sewage application (gallons per sq ft of percolating area per day)
1	5.3
2	4.3
5	3.2
10	2.3
30	1.1

The test for leaching should be made by digging a pit about one half of the proposed depth of the cesspool, with a test hole 1 foot square and 18 inches deep at the bottom. The test hole is filled with 6 inches of water and allowed to drain off. Six inches of water is again added, and the downward rate of percolation is measured in minutes required for the water surface to lower 1 inch in the hole.

LEACHING FIELDS

Leaching fields are an integral component of a septic tank individual sewage disposal system. Leaching field may be referred to as tile fields or absorption trenches. Whichever term is used, the function, testing, construction, and maintenance techniques of this component remain the same.

The lines in a leaching fields are built of 4-inch PVC perforated pipe. Many types of perforated pipe are commercially available for use in leaching-field construction.

The following conditions are important for the proper functioning of a leaching field:

- Groundwater levels well below that of the leaching field

- Soil of satisfactory leaching characteristics within a few feet of the surface extending several feet below the leaching pipe

- Subsurface drainage away from the field

- Adequate area

- Freedom from polluting drinking water supplies, particularly from shallow wells in the vicinity

Before installing a leaching field in a specified area you must perform a percolation test. This test determines whether the area selected is suitable for subsurface sewage disposal; it also helps you to determine the overall size of the leaching field in relation to trench dimensions and pipe lengths.

The test consists of digging a test pit 2 feet square and at least 1 foot in depth. The optimum depth should be at the deepest point that the leaching pipe will be laid. Next dig a hole 1 foot square by 1 foot deep in the test pit. Fill this hole with 7 inches of water for wetting purposes. Allow the water to drop to 6 inches before recording the drop time. Then note the time required for the level to drop 1 inch (from 6 to 5 inches) in depth. You can then determine the length of pipe in the leaching field by using table 10-16. Note that this table is based on the assumption that 4-inch pipe will be used as recommended by the *National Standard Plumbing Code.*

In the construction of a leaching field, the installer takes into consideration the results of the percolation test, type of soil, size of pipe, depth in reference to the ground water level and frost line, and standard requirements of materials

Table 10-16.—The Tile Length for Each 100 Gallons of Sewage PerDay

Time in minutes for 1 inch drop	Tile length for trench widths of		
	1 ft	2 ft	3 ft
1	25	13	9
2	30	15	10
3	35	18	12
5	42	21	14
10	59	30	20
15	74	37	25
20	91	46	31
25	105	53	35
30	125	63	42

placed in the absorption trench. Figure 10-6 shows a typical layout of a leaching field.

The type of soil at the location of the field will dictate the width of the trench. Sand and sandy loam require a width of 1 foot, loam and sand and clay mixture 2 feet, clay with some gravel 3 feet. Note these are minimum trench widths based on the type of soil encountered at the jobsite.

Placing the leaching pipe below the frost line to prevent freezing is not necessary. Under no circumstances can you lay leach pipe below the ground water level. When digging the absorption trenches, you must consider the lengths of each lateral and their spacing in relation to each other.

Do not make any lateral longer than 100 feet in length. Table 10-17 shows the size and spacing requirements for disposal fields.

After the trenches are laid out and dug, filler material must be placed along with the actual pipe. The filler material may be washed gravel, crushed stone, slag, or clean bank-run gravel ranging in size from 1/2 to 2 1/2 inches. Filler material in the trench should not be less than 6 inches deep below the bottom of the pipe. It should be at least 2 inches above the pipe. To prevent backfill soil from filling the voids in the filler material, it is recommended that a 3-inch

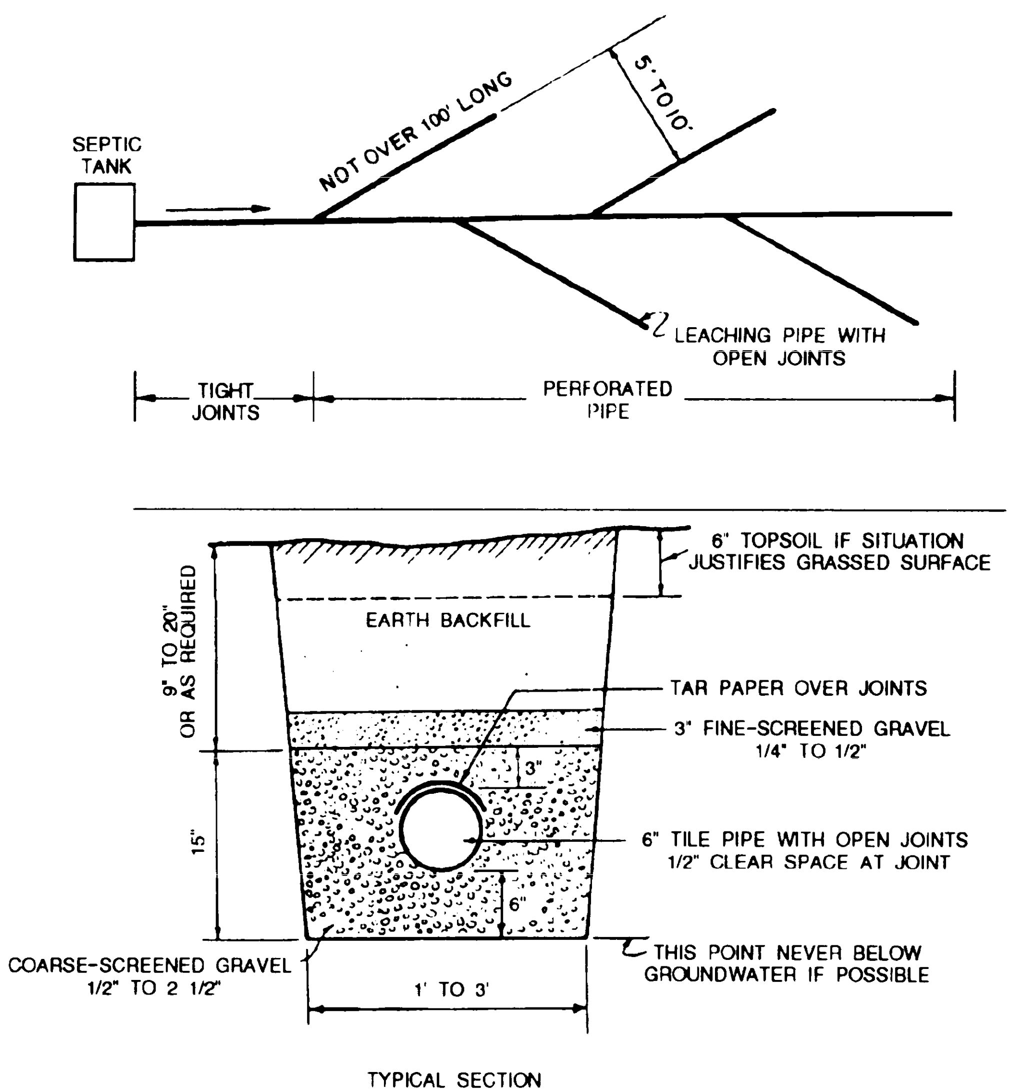


Figure 10-6.—Typical layout of a subsurface tile system.

layer of medium-screened gravel with another layer of fine-screened gravel, untreated paper, or straw of 2 to 3 inches in depth in the trench.

Pipe should be laid with a minimum pitch of 2 inches to a maximum pitch of 4 inches per 100 feet, When open joints are used, they must not be spaced more than 1/2 inch apart. Asphalt-treated paper should be used to cover the joint. The open joint allows for free discharge of solids from the line to the trench. The asphalt-treated paper prevents gravel from entering the pipe.

The layout of the field requires attention to detail to prevent future maintenance and operation troubles. When the field is laid on sloping ground, the flow must be distributed so each lateral gets a fair portion of the flow. Individual lines should be kid nearly parallel to land contours, Leaching fields are commonly laid out either in a herringbone pattern (fig. 10-6) or with the laterals at right angles to the main distribution pipe. Little or no maintenance is required for leaching fields. Preventive measures, such as excluding all vehicle traffic and not planting trees or shrubs in the field area, should ensure trouble-free operation for many years. When a leaching field becomes inoperable, you must replace it with a new system. Tree or shrub roots are a major factor in leaching-field failure. This requires the replacement of field components and complete root removal.

Table 10-17.—Size and Spacing for Disposal Fields

Width of trench at bottom (in.)	Recommended depth of trench (in.)	Spacing tile lines * (ft)	Effective absorption area per lineal ft of trench (sq. ft.)
18	18 to 30	6.0	1.5
24	18 to 30	6.0	2.0
30	18 to 36	7.6	2.5
36	24 to 36	9.0	3.0

* Greater spacing is desirable where available area permits.

CHAPTER 11

COMPRESSED AIR SYSTEMS

The Utilitiesman is involved in the installation of compressed air systems. The senior UT must be capable of identifying and directing the proper construction techniques for installation of fittings and components. You will also be involved in the maintenance of systems installed previously. In this chapter compressed air systems and air quality requirements are also discussed.

SYSTEM CLASSIFICATIONS

Compressed air is a form of power that has many important uses in industrial activities. An air compressor plant (fig. 11-1) is required to supply air of adequate volume, quality, and pressure at the various points of application. Compressed air is stated as pounds per square inch gauge (psig). These plants or systems are classified as

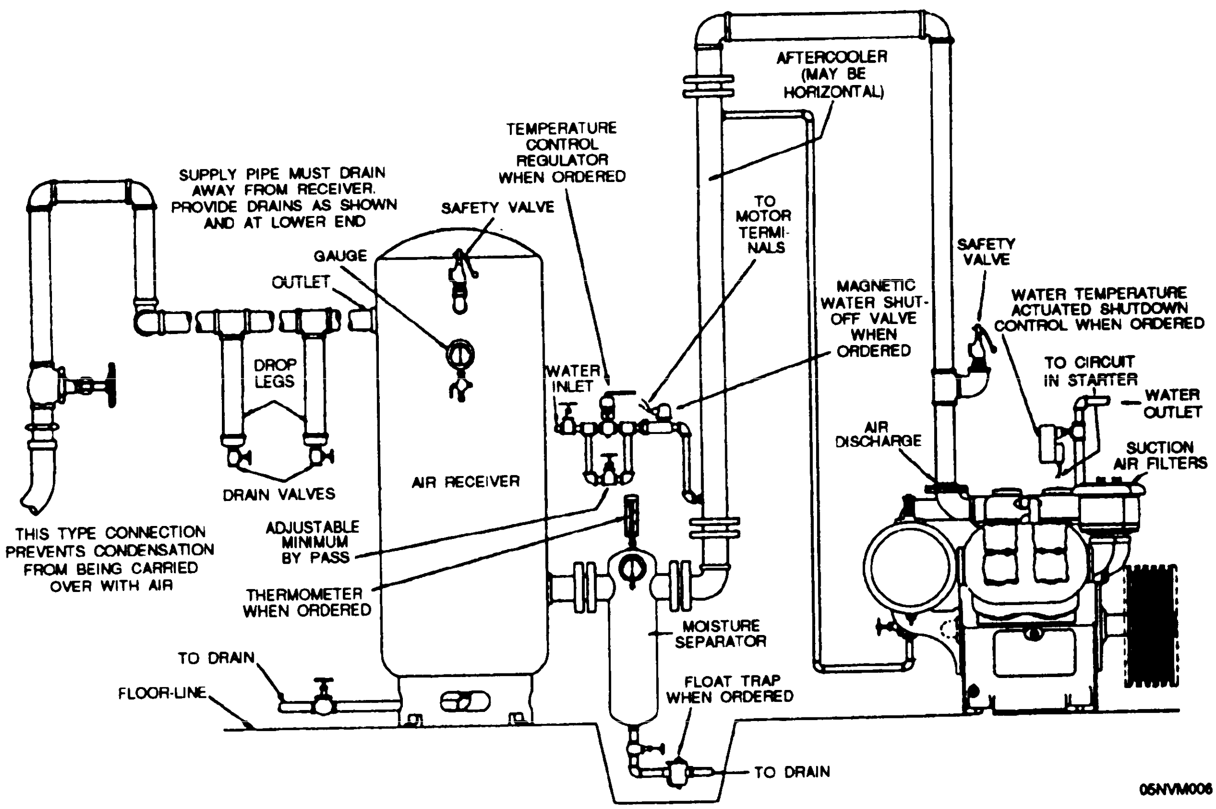


Figure 11-1.—Components of a compressed air plant.

low-pressure (0 to 125 psig), medium-pressure (126 to 399 psig), or high-pressure (400 to 6,000 psig) systems.

LOW-PRESSURE SYSTEMS

Low-pressure systems provide compressed air up to 125 psig pressure. When you are installing a low-pressure system, pressure is usually reduced at reducing stations for branches requiring lower pressures. Several air pressure requirements for low-pressure air consumers are listed below:

Laboratories	5 to 50 psig
Shops	60 to 125 psig
Laundries and dry cleaning plants	70 to 100 psig
Hospitals	20 to 50 psig
Ordinary service (tools, painting, and so forth)	60 to 80 psig
Soot blowing for boilers	80 to 125 psig

MEDIUM-PRESSURE SYSTEMS

Medium-pressure systems provide compressed air within the range of 126 to 399 psig pressure. These systems are not extensive and are generally provided with individual compressors located near the loads. Medium-pressure systems are mainly used for the starting of diesel engines, soot blowing of boilers and high-temperature water (HTW) generators, and hydraulic lifts.

HIGH-PRESSURE SYSTEMS

These systems provide compressed air within the range of 400 to 6,000 psig pressure. Hazards that increase with higher pressures and capacities can be minimized by the use of separate compressors for each required pressure. Systems operating at 3,000 psig may require small amounts of air at lower pressures, which is supplied through pressure-reducing stations.

Caution must be used with high-pressure systems because when high-pressure air enters suddenly into pockets or dead ends, the air temperature in the confined space increases dramatically. If there is any combustible material in the space and the air temperature increases to the ignition point of the material, an explosion may occur. This is known as auto ignition or diesel action. Explosions of this type may set up shock waves that travel through the compressed air system. This travel may cause explosions at remote points, Even a small amount of oil residue or a small cotton thread may be sufficient to cause ignition.

Some common pressure requirements for high-pressure systems may be as follows:

Torpedo workshop	600 to 3,000 psig
Ammunition depot	100, 750, 1,500, 2,000, and 4,500 psig
Wind tunnels	Over 3,000 psig
Testing laboratories	Up to 6,000 psig

AIR QUALITY REQUIREMENTS

The quality of air supplied from a compressed air system will vary with application. The installer and maintenance personnel should consider the class of air entrapment and specific air quality requirements for each application,

CLASSES OF AIR ENTRAPMENT

The classes of air entrapment may be subdivided into inert and chemical particulate, chemical gases, oil, and water. To prevent contamination of an air compression system by these types of entrapments, you should follow certain guidelines for each situation of possible contamination.

Particulate

Intake structures or openings should be free of shelves, pockets, or other surfaces that attract and accumulate particulate. Properly designed intakes are large enough to produce a low-velocity airflow. This limits the size of the particles that may be picked up by the intake suction.

Some particulate may contain active chemicals that may form acids or alkalines in the inevitable presence of water. These chemical particulate can accelerate damage to compressor surfaces.

Particulate are sized in microns or micrometers. This measurement is size, not weight. One micron is a unit of length equal to one millionth of a meter. Particles larger than 10 microns are visual to the naked eye. Filter systems are required for all air compressors. Generally, filters should be able to remet'e particles down to 1 to 3 microns in size.

Gases or Fumes

Cases or fumes are fully airborne and generally independent of air velocity. They can be strong acid, alkaline, or otherwise corrosive to the internal surfaces or lubricants of the compressor. In addition, gases or fumes may be prohibited by the end-use process, such as medical gases or breathing air and for environmental or odor reasons. Intakes near normal flow paths of engine exhausts should be avoided.

Oil

Oil fumes, vapor, or mist can be as difficult to handle as particulate or gases. Even though many types of compressors are oil lubricated, the oil ingested may not be compatible and compressor load may be increased.

Water

Waste and water vapor are always present in air intakes. Installation of intakes should prevent the accumulation of free water. Free water ingested into the compressor causes damage to internal components.

Since water vapor with chemical content corrodes steel piping, precautions must be taken to protect materials from corrosion. Galvanizing, applying protective coatings, or using plastic or stainless steel piping for air intakes are some suggested methods to retard or prevent corrosion. Also be sure to install intakes in a manner that excludes rainfall, snow, or spray by applying a weather hood.

SPECIFIC AIR QUALITY REQUIREMENTS

The diverse uses of air are accompanied by specific air quality requirements. These vary from high purity requirements through the need to introduce materials into a system to be carried along with the air. This section will discuss these specific air quality requirements.

Commercial Air

Commercial compressed air is graded according to its purity. The purest is grade A running alphabetically to grade J, the least pure. The Compressed Gas Association has set guidelines for the grading of commercial compressed gas. The application of commercial compressed air is varied and generally specified for each individual installation by engineers. The full extent of the quality requirements for commercial compressed air applications can be located in the Compressed Air Association publication *Commodity Specification for Air,* G-7.1 (ANSI 286.1-1973).

Breathing Air

Breathing air must be of high quality for obvious reasons. Federal Specification BB-A-1034 (fig. 11-2) outlines the specific requirements for breathing air.

	Source I (Pressurized Container Air)		Source II (Compressed Air)	
Component	Grade A	Grade B	Grade C	Grade D
Oxygen (by volume) percent	20 to 22	19 to 23	20 to 22	19 to 23
Carbon dioxide (by volume)	500 parts per million (ppm) max	1,000 ppm max	500 ppm max	1,000 ppm mac
Carbon monoxide (by volume)	10 ppm max	10 ppm max	10 ppm max	10 ppm max
Oil (mist and vapor) and particulate matter (weight/volume)	0.005 miligrams (mg) per liter, max	0.005 mg per liter, max	0.005 mg per liter, max	0.005 mg per liter, max
Separated water	None	None	None	None
Total water (weight/volume)	0.02 mg per liter, max	0.3 mg per liter, max (Dew point— 20 degrees F.)	0.02 mg per liter, max	0.3 mg per liter, max (Dew point— 20 degrees F.)

Figure 11-2.—Breathing air requirements, Federal Specification BB-A-1034A AM 1.

Special attention must be given to eliminating carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons, odor, and water from breathing air. Carbon monoxide has first priority as its effects are cumulative and very small concentrations can cause problems. Whenever possible, carbon monoxide monitoring should be provided at the compressor intake. This monitoring equipment should sound an alarm or shut down the system when CO is detected.

Carbon dioxide is found in combustion flue gases such as boiler stacks. Do not place compressor intakes near or downwind of the stacks.

Systems should be kept free of oil to limit the possible concentration of hydrocarbons or petroleum products. For breathing air, compressors should be oil free rather than using auxiliary petroleum removal equipment. The heat caused by compression may cause thermal breakdown of oil or an explosion danger may exist as a result of drawing hydrocarbons into the air system.

Water content is kept below saturation to prevent condensation at points that cannot be cleaned. It is recommended that refrigerant or dessicant dryers be used to remove moisture from a breathing air system. This will limit the vapor clouding (fogging) of glasses and visors.

Medical Air

Medical air quality must be the same or better than breathing air. Whatever quality is established must be strictly adhered to.

Instrument and Control Air

Air quality requirements for instrument and control air should place emphasis on cleanliness and low moisture content. The Instrument Society of America (ISA) has established the following requirements:

- Dew point, exterior: 18°F (–7.8°C) below minimum recorded ambient temperature
- Dew point, interior: 18°F (–7.8°C) below minimum interior temperature but not higher than 35°F (1.7°C)
- Particle size: 3 microns maximum
- Oil content: As close to zero as possible but not over 1 ppm
- Contaminates: No corrosives or hazardous gases

Water content must be low enough to prevent condensate accumulations. Special attention should be given to ensure that intake air is filtered and oil or water removed. A refrigerant dryer with a dew point at least as low as 30°F (–1.1°C) is recommended for these services.

Aircraft Starting and Cooling Air

Aircraft starting air requires reasonably clean air to prevent introduction of excessive levels of oil, water, or particulate into engine systems. Normal intake filtering and oil/water separation should be adequate.

Aircraft cooling air is intended for electrical load cooling to prevent malfunction of the equipment. Cooling air should be reasonably clean. This air may also be used for breathing. If it is, then breathing air quality standards should be maintained.

Air for Pneumatic Tools

When compressed air is intended for use with pneumatic tools, it should be filtered for particulate and water should be separated out. Oil is usually required to be ingested into the air for tool lubrication. Mist injection is preferred for tools to ensure dispersion and maximum settlement. Note that pressures in excess of 400 psig may cause compression combustion when oil is present.

High-Pressure Air Systems

Air quality must be carefully analyzed to minimize not only the normal hazards of high pressure, but the internal explosive hazards that exist with high-pressure systems. Of particular danger is the introduction of oil and hydrocarbons during compression and their remaining and accumulating throughout the system. A high--pressure system of 500 psig or higher is subject to rapid local heat buildup whenever there is a rapid filling of a component or vessel. The heat buildup (combined with oil and foreign material) that permits the oil to wick or vaporize can readily cause an explosion or fire. Any explosion in the system may produce several shock waves to travel the system, compounding the damage. Because of this problem, special attention is required to clean the intake air, limit the introduction of lubrication oil, and remove oil after completion of the compression process.

AIR COMPRESSORS AND AUXILIARY EQUIPMENT

There are basically two types of compressors: positive displacement and dynamic. This section will discuss the reciprocating air compressors, the rotary air compressors, the helical screw compressors classed as positive displacement compressors, and the dynamic centrifugal compressors.

General auxiliary equipment will also be discussed. Auxiliary equipment consists of any device(s) that may be added to the system to improve its efficiency or provide a specific function. It provides a safe condition under which the compressor system will be operating.

RECIPROCATING AIR COMPRESSORS

The most commonly used stationary air compressors are the reciprocating, positive displacement design. They may be single acting or double acting, single stage or multistage, and horizontal, angle, or vertical in design.

In a single-stage unit there is but one compressing element; it compresses air from the initial intake pressure to the final discharge pressure in one step. A multistage machine has more than one compressing element. The first stage compresses air to an intermediate pressure, then one or more additional stages compress it to the final discharge pressure.

In the reciprocating compressor the compression cycle is composed of three phases: intake, compression, and discharge.

During the intake stroke the downward movement of the piston creates a partial vacuum inside the cylinder. The spring-operated intake valve is forced open by the differential pressure between free air on one side and the partial vacuum inside the cylinder. As the valve opens, air fills the cylinder. The piston now moves into the compression stroke, forcing the intake valve closed and raising the pressure of the air trapped in the cylinder. When the pressure of this air is great enough to overcome the force of the spring-operated discharge valve, the valve opens and the compressed air is discharged from the cylinder.

Compressors are classified as low pressure, medium pressure, or high pressure. Low-pressure compressors provide a discharge pressure of 150 psi or less. Medium-pressure compressors provide a discharge pressure of 151 psi to 1,000 psi. Compressors that provide a discharge pressure above 1,000 psi are classified as high pressure. Note that compressors are classified at different pressures than those for classifying total compressed air systems discussed earlier.

Most low-pressure air compressors are of the two-stage type with either a vertical or a vertical W arrangement of cylinders. Two-stage, V-type, low-pressure compressors usually have one cylinder that provides the first (low-pressure) stage of compression and one cylinder that provides the second (high-pressure) stage, as shown in figure 11-3. W-type compressors have two cylinders for the first stage of compression and one cylinder for the second stage. This arrangement is illustrated in figure 11-4.

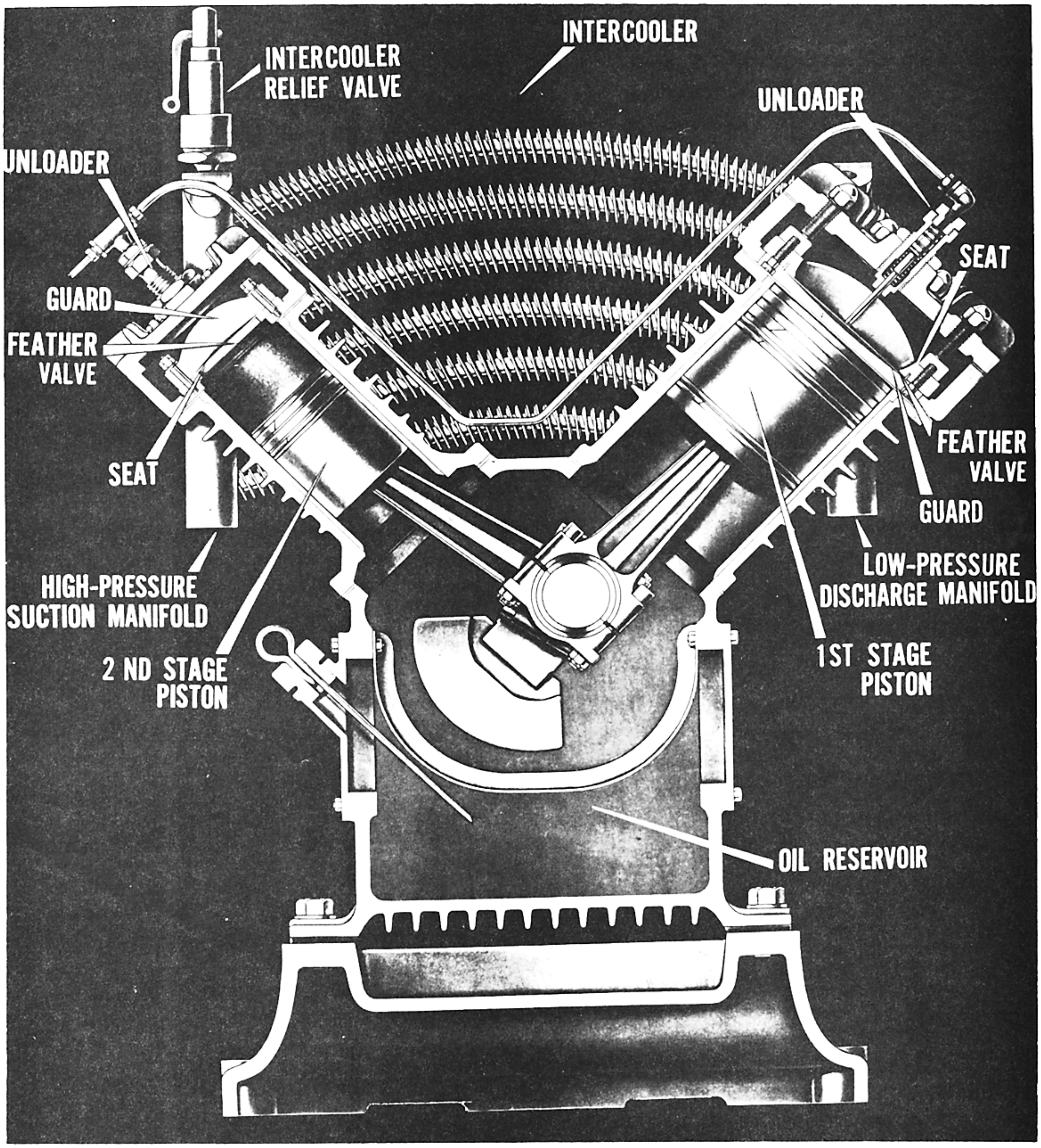
Compressors may be classified according to a number of other design features or operating characteristics.

Medium-pressure air compressors are of the two-stage, vertical, duplex, single-acting type. Many medium-pressure compressors have differential pistons, as shown in figure 11-5. This type of piston provides more than one stage of compression on each piston.

ROTARY AIR COMPRESSORS

Rotary sliding vane compressors are machines in which longitudinal vanes slide radially in a slotted rotor that is mounted eccentrically in a cylinder. The rotor is fitted with blades or vanes that are free to slide in and out of longitudinal slots and maintain contact with the cylinder walls by centrifugal force. In operation, as the blades are forced outward by centrifugal force, compartments are formed in which air is compressed (fig. 11-6). Each compartment varies from a maximum volume on the suction side of the revolution to a minimum volume on the compression half of the revolution. This gives a positive displacement-type suction and pressure effect.

Another type of rotary compressor is the twin-lobe unit sometimes referred to as a blower



47.152

Figure 11-3.—A typical two-stage reciprocating low-pressure air compressor.

(fig. 11-7). This unit consists of two impellers mounted on parallel shafts that rotate in opposite directions within a housing. As the impellers rotate, they trap a quantity of air themselves and the blower housing and move the air around the casing to the discharge port. This action takes place twice each revolution of an impeller and four times per revolution of both impellers. The impellers are positioned in relation between to each other by timing gears, located at the end of each shaft and external to the blower housing.

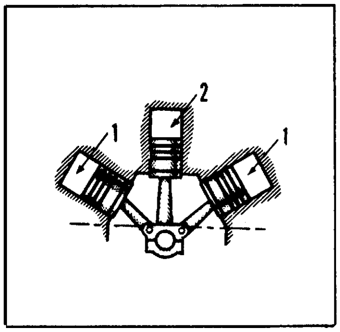


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Figure 11-4.—W-type, two-stage, three-cylinder arrangement.

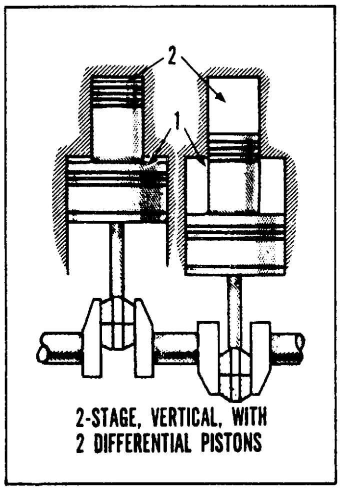

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Figure 11-5.—Differential piston with a two-stage, vertical arrangement.

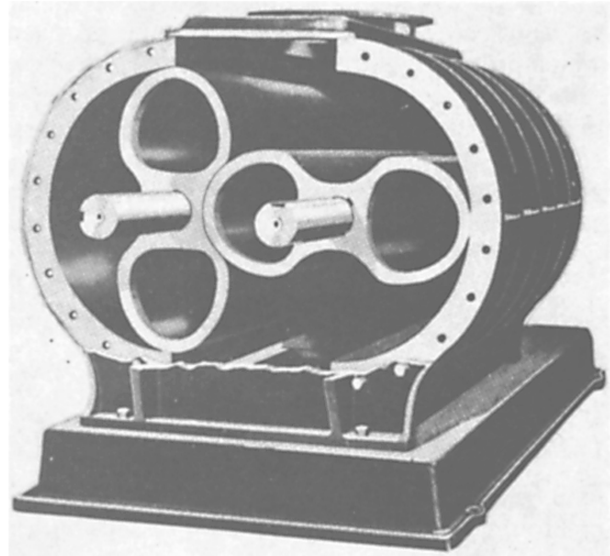

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Figure 11-7.-Twin-lobe rotary compressor.

You should always use maintenance and service literature provided by manufacturers when you are working with rotary compressors. Maintenance information is given in *Operation and Maintenance of Compressed Air Plants,* NAVFAC MO-206.

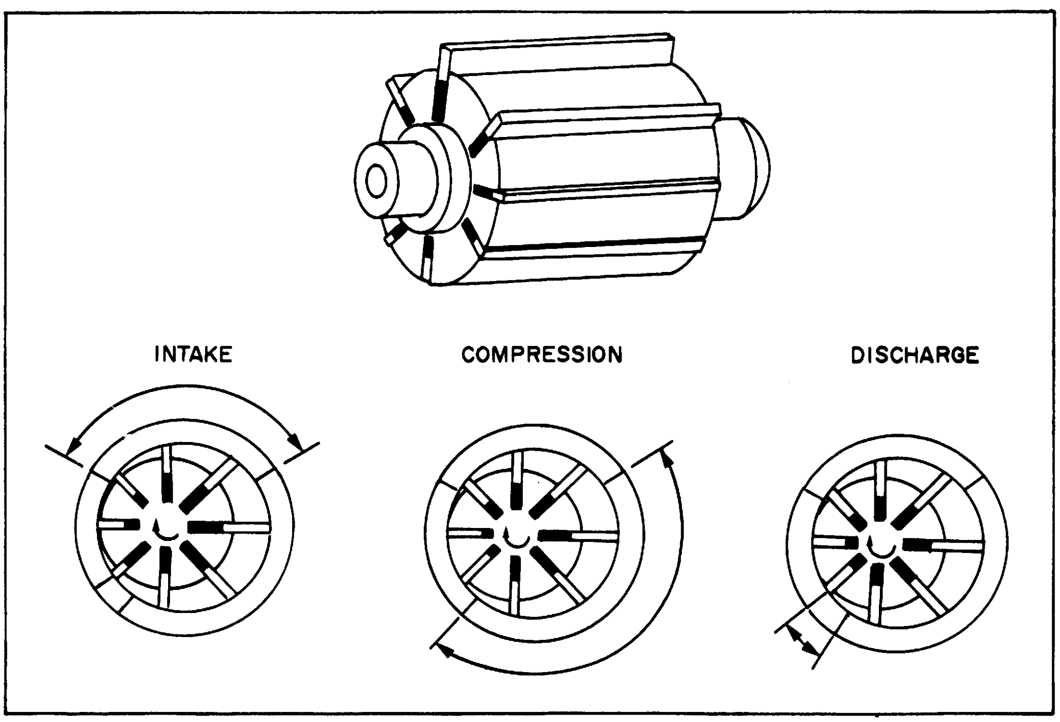


Figure 11-6.—Compression cycle of rotary compressor.

HELICAL SCREW COMPRESSORS

Helical screw compressors contain two mating rotating screws, one locked and one grooved, which provide the driving force. The unit's screws take in air, decreasing its volume as it progresses in a forward-moving cavity toward the discharge end of the compressor. Figure 11-8 shows a typical single-stage compressor and a double-stage helical screw compressor. These compressors are best used in booster or near constant-load conditions at low-pressure, oil-free application. Helical screw compressors may also be found in aircraft start facilities.

DYNAMIC CENTRIFUGAL COMPRESSORS

Dynamic compressors are high-speed rotating machines in which air is compressed by the action of rotating impellers or blades that impart velocity and pressure to the air. Figure 11-9 shows the internal parts of a multistage centrifugal compressor. This type will deliver air at an essentially constant pressure over a wide range of capacities. The direction of airflow is radial with respect to the axis of rotation.

Centrifugal compressors have a lower limit of stable operation called the surge point. Operation below this point results in pumping or surging of the airflow. Prime movers are normally electric motors or steam turbines.

Centrifugal compressors are intended for near continuous industrial air service when the load is reasonably constant. These compressors also work well when oil-free air is required and can be used for breathing air.

Table 11-1 shows typical application recommendations for both positive displacement and dynamic class compressors.

AUXILIARY EQUIPMENT

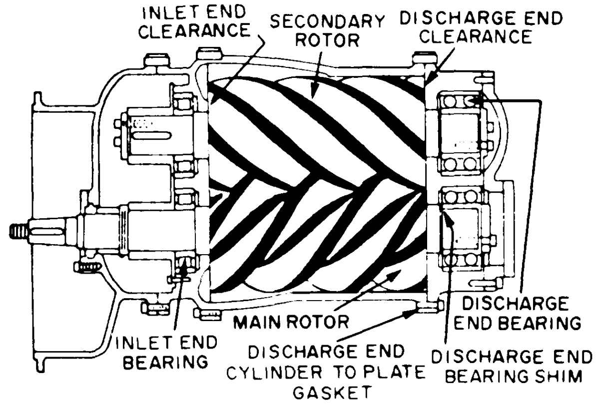
A system that functions to provide a continuous supply of usable compressed air requires certain auxiliary devices in addition to the air compressor. Most compressed air systems require a minimum of auxiliary equipment that should include air intakes, intake filters, silencers, intercoolers, aftercoolers, air discharge systems, separators, dryers, receivers, and so forth. These auxiliary equipments will be discussed in this section in addition to less common auxiliary equipment.

Air Intakes

Air intakes should be located high enough to eliminate intake of particles of dust, smoke, dirt, water, and snow. Carbon monoxide sources should not be able to discharge into compressor intakes. Special attention should be given to the elimination of flammable fumes into the compressed air system.

Whenever air intakes must be placed through a roof that is surrounded by parapets, they should be 8 to 10 feet above the roof.

Noise may be generated by air intakes and must be considered during installation. Reciprocating compressors are most likely to develop resonance through intake piping. If this possibility exists, the use of intake dampeners or surge chambers will help. High velocities present noise level problems. Intake pipe velocities should be limited to 1,000 fpm in open areas or 350 fpm across filters. Acoustical silencers combined with filters and/or pulse dampeners are available and



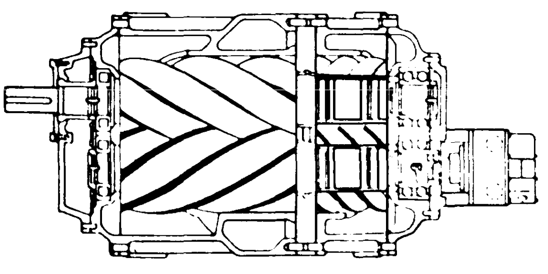


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Figure 11-8.—Rotary helical screw compressors.

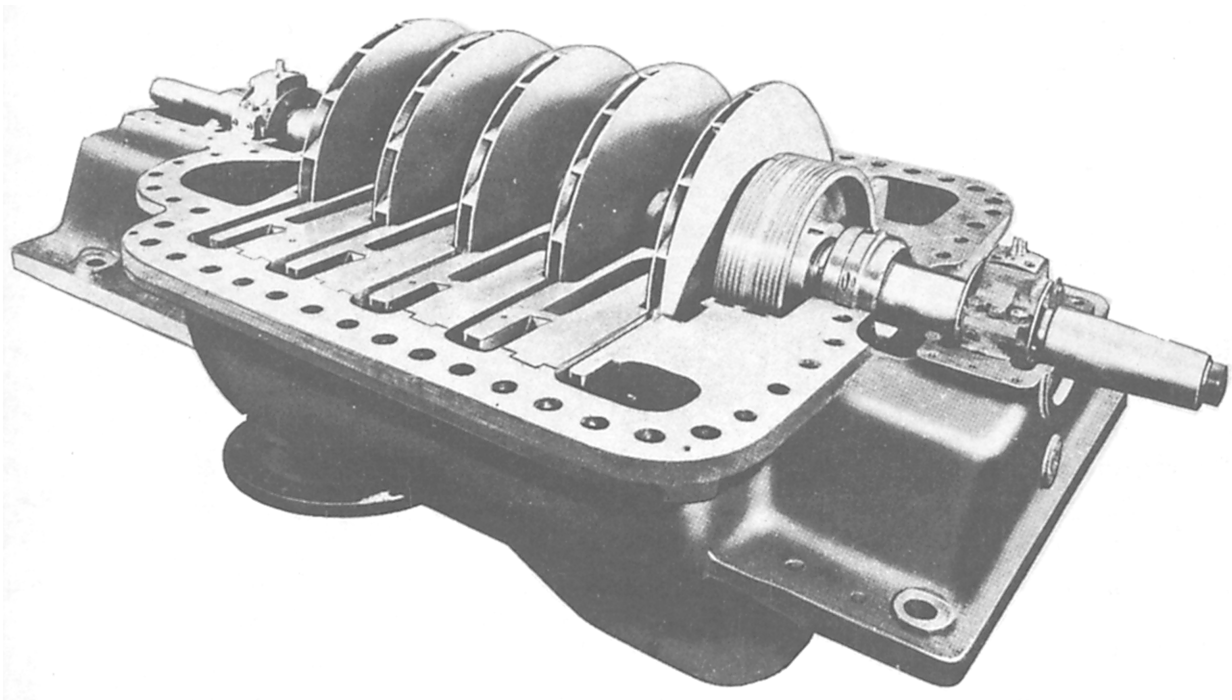

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Figure 11-9.—Internal view of a multistage centrifugal compressor.

Table 11-1.—Summary Application Recommendations, Types of Compressors

Type	Air* Delivery Quality	Pressure Range scfm Range Horsepower Range	Remarks
Reciprocating, single-stage, air cooled	L	100-125 psig, to 50 scfm, to 10 hp	Intermittent light duty
Reciprocating, two-stage, air cooled	L	100-125 psig, to 200 scfm, to 50 hp	Low volume requirements
Reciprocating, two-stage, air cooled	N	100-125 psig, to 50 scfm, to 15 hp	Low volume requirements
Reciprocating, two-stage, water cooled	L	100-150 psig, 400-1,000 scfm, 75-200 hp	Wide application range
Reciprocating, two-stage, water cooled	N	100-125 psig, 400-1,000 scfm, 75-200 hp	Wide application where required
Reciprocating, two-stage, water cooled, duplex and/or double acting	L	100-150 psig, 1,000-5,000 scfm, 200-1,200 hp	High volume requirements

(1 psig = 6.90 kPa gauge, 1 scfm = 0.0268 mm 3 /min, 1 hp = 0.746 kW)
*L—Lubricated
N—Nonlubricated

Table 11-1.—Summary Application Recommendations, Types of Compressors—Continued

Type	Air* Delivery Quality	Pressure Range scfm Range Horsepower Range	Remarks
Reciprocating, multi-stage, water cooled	L, N	150-6,000 psig, 10-100 scfm, 3-1,000 hp	Medium and high pressure
Rotary, sliding vane, single-stage	L, N	5-50 psig, 50-3,000 scfm, 0.5-300 hp	Match to load only pressure booster
Rotary, sliding vane, two-stage	L, N	60-100 psig, 100-3,000 scfm, 15-500 hp	Match to load only pressure booster
Rotary, sliding vane, single- or two-stage oil injected	L	80-125 psig, 120-600 scfm, 15-200 hp	Wide application range
Helical screw, single-stage, lubricated	L	To 35 psig, 30-12,000 scfm, to 1,200 hp	Match to load only single rating point
Helical screw, two stage lubricated	L	60-100 psig, 30-12,000 scfm, to 2,000 hp	Match load only. Single rating point. Aircraft air start. Aircraft cooling
Helical screw, single-stage, oil injected	L	To 125 psig, 40-1,500 scfm, 10-400 hp	Wide application range
Dynamic, centrifugal, single-stage	N	To 35 psig, 1,500-15,000 scfm, 100-1,000 hp	Match load
Dynamic, centrifugal, two-stage	N	35-70 psig, 1,500-15,000 scfm 100-2,000 hp	Match load, breathing air
Dynamic, centrifugal, three-stage	N	70-125 psig, 1,500-15,000 scfm, 200-3,500 hp	High volume requirements, breathing air
Dynamic, centrifugal, four or more stages	N	125 psig or more, 1,500-15,000 scfm, to 3,000 hp	Medium pressure high volume
Dynamic, axial or radial barrel, multi-stage	N	200 psig or more, 1,500 scfm or more, high horsepower	Medium and high pressure, high volume

(1 psig = 6.90 kPa guage, 1 scfm = 0.0268 mm^3/min, 1 hp = 0.746 kW
*L—Lubricated
N—Nonlubricated

should be used whenever potential noise level difficulties are anticipated.

Intake resistance to airflow should be no more than necessary to maintain air quality. The resistance created by the air intake system will reduce compressor performance and efficiency. Refer to the compressor manufacturer's manual for maximum resistance requirements.

Intake Filters

Air filters are provided on compressor intakes to prevent atmospheric dust from entering the cylinders and causing scoring and excessive wear. The two most common types of elements in use are the VISCOUS IMPINGEMENT and the OIL BATH. Both types are illustrated in figure 11-10.

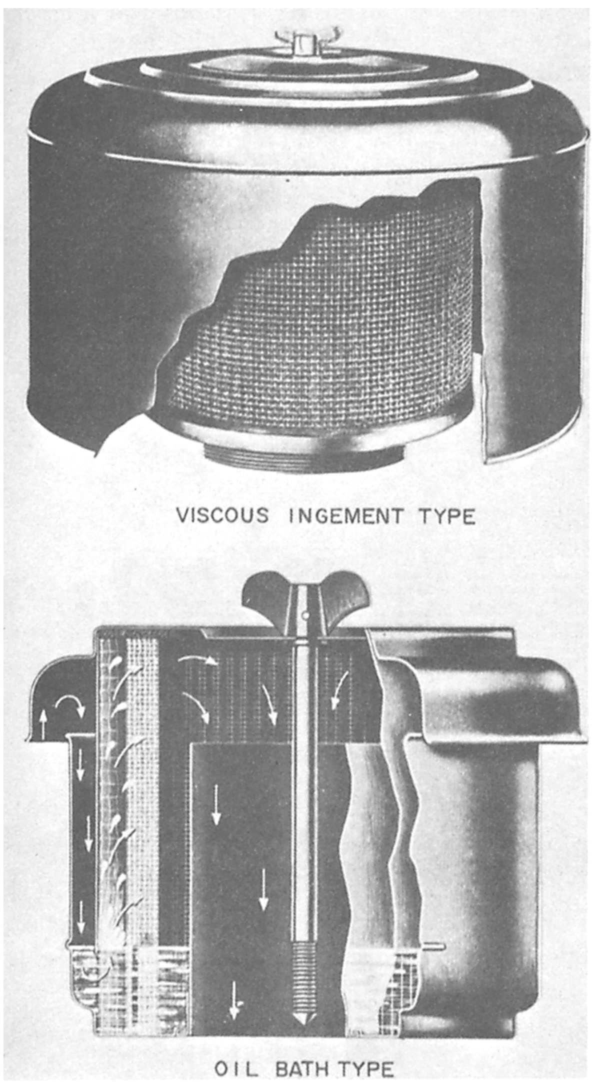

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Figure 11-10.—Compressor intake filters.

In the oil bath type, air must pass through an oil seal that removes dirt particles, and then pass on through a wire mesh element, which is saturated by oil carry-over. Any remaining particles of dirt are removed by the wire mesh element. Captured dust particles settle to a sump at the bottom of the filter housing. Oil bath filters are recommended where dust concentrations are present in the atmosphere.

The viscous impingement filter consists of a wire mesh filter element, which is coated with oil. Air passing through the filter element must change directions many times, causing any dust to adhere to the oil film.

Silencers

Silencers are similar to mufflers and function simply to eliminate objectionable compressor suction noise. Figure 11-11 illustrates a standard

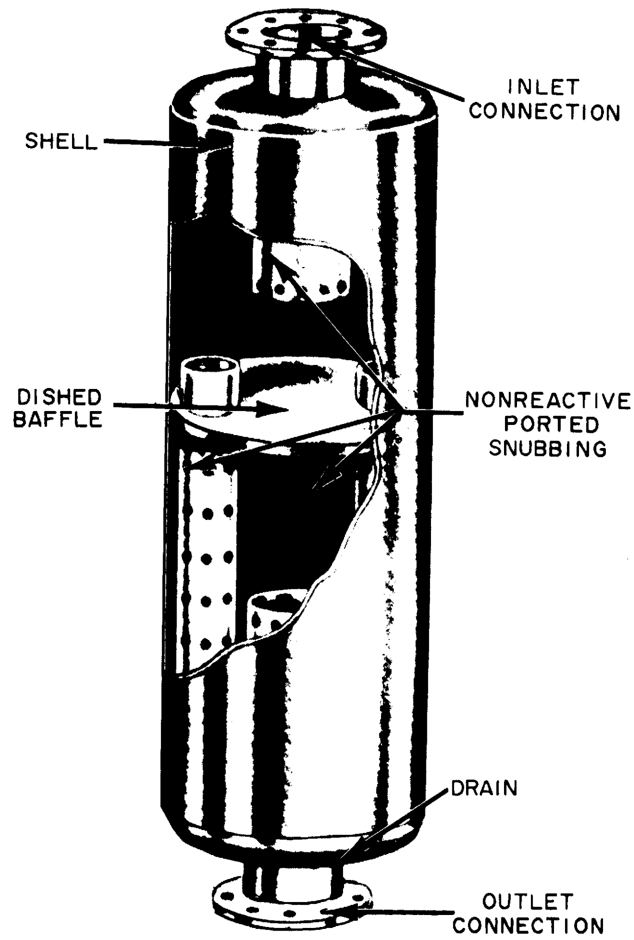

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Figure 11-11.—Intake silencer.

intake silencer. Some compressors are equipped with combination filter-silencer units that have the filter elements contained within the silencer housing.

Intercoolers

When air is compressed to 100 psi without heat loss, the final temperature is about 485°F. The increase in temperature raises the pressure of the air under compression, thus necessitating an increase in work to compress the air. After the air is discharged into the receiver tank and lines, the temperature falls rapidly to near that of the surrounding atmosphere, thereby losing part of the energy generated during compression. The ideal compressor would compress the air at a constant temperature, but this is not possible. In multistage compressors, the work of compressing is divided between two or more stages, depending on the final discharge pressure required. An INTERCOOLER is used between the stages to reduce the temperature of compression from each stage. Theoretically, the intercooler should be of sufficient capacity to reduce the temperature between stages to that of the low-pressure cylinder intake. Actually, intercooling has three purposes: to increase compressor efficiency, to prevent excessive temperatures within the compressor cylinders, and to condense out moisture from the air.

Most intercoolers are either the shell and tube, air-to-water heat exchangers or the air-cooled radiator-type heat exchangers. Figure 11-12 illustrates a typical water-cooled inter-cooler. The air-cooled type is shown in figure 11-3.

Aftercoolers

Moisture carried in air transmission lines is undesirable because it causes damage to air-operated tools and devices. AFTERCOOLERS are installed in compressor discharge lines to lower the air discharge temperature, thus condensing the moisture and allowing it to be removed. Also, the cooling effect allows the use of smaller discharge piping. A water-cooled aftercooler is illustrated in figure 11-13.

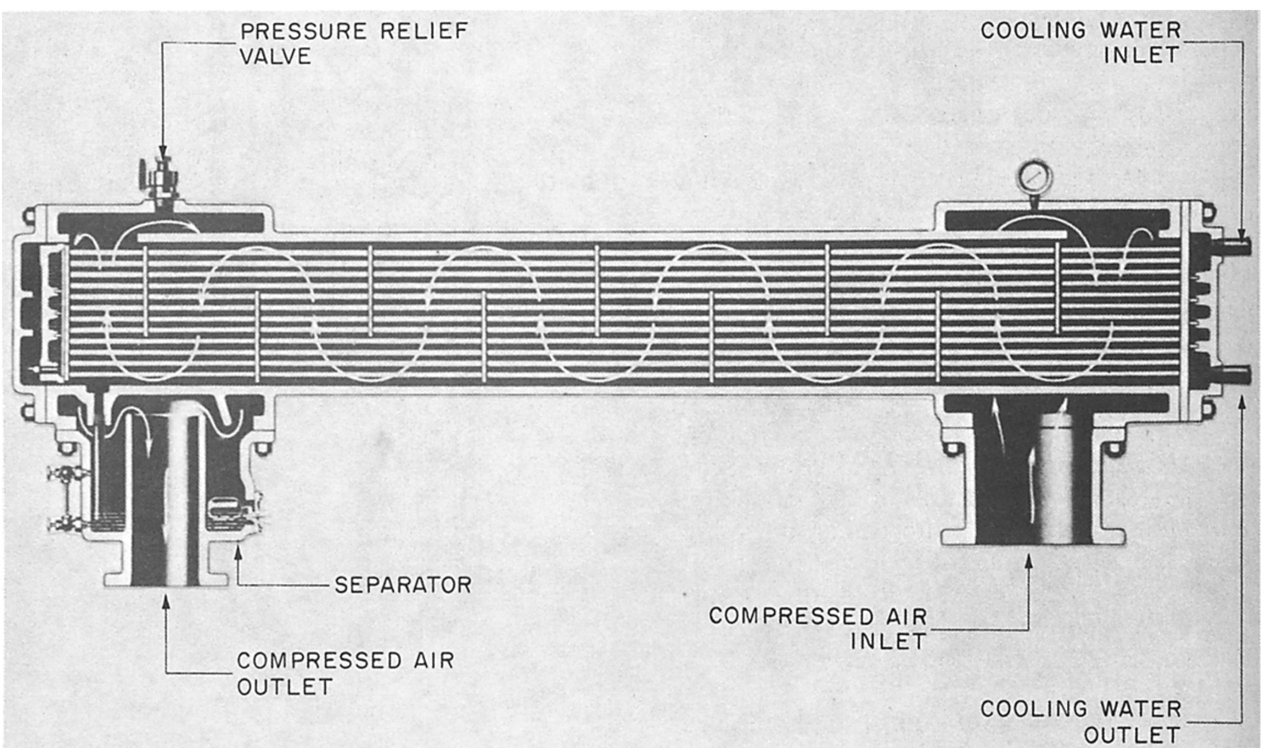

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Figure 11-12.—Typical water-cooled intercooler.

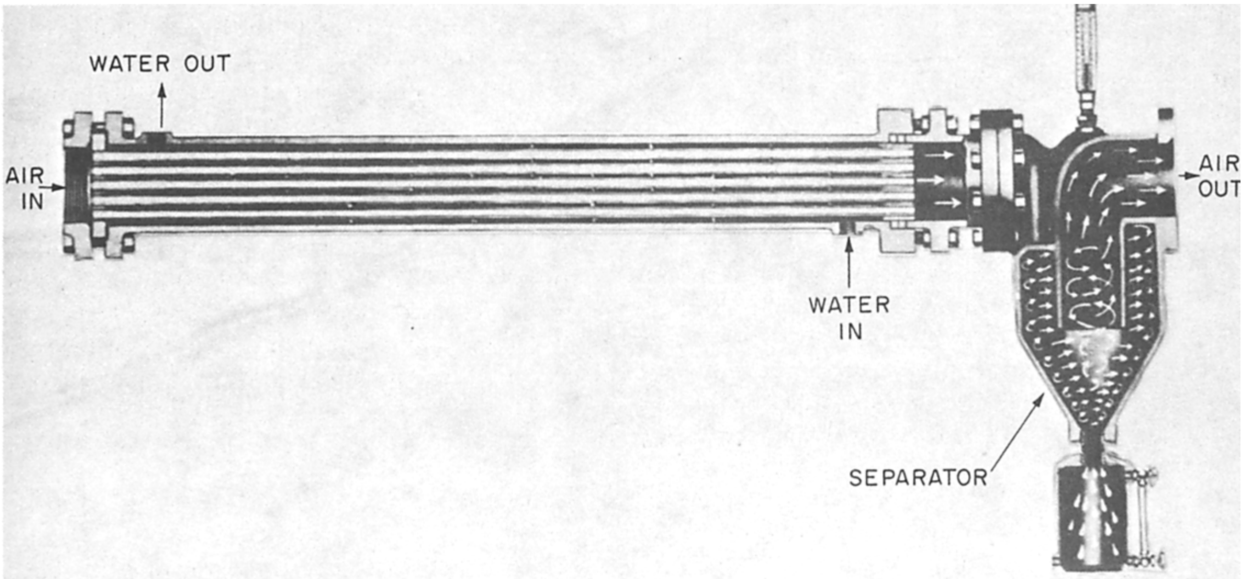

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Figure 11-13.—Typical water-cooled aftercooler.

Air Discharge Systems

Some discharge systems require special consideration for the placement of auxiliary equipment. All positive displacement compressors require a relief valve on their discharge side to protect the equipment and piping upstream of the first shutoff valve. Relief valves should be sized for at least 125 percent of the maximum unit flow capacity and should carry the American Society of Mechanical Engineers (ASME) stamp, listing the capacity and pressure setting of the valve.

Separators

Water and oil separators are required to separate and free excess water from the discharge air or gas. This is necessary to prevent corrosion, deposit buildup, and water or oil buildup in the piping or service. For example, water will cause rust in piping, wash away lubricants, and plug nozzles. Oil will contaminate many industrial processes and may present an explosion hazard. The need for water or oil separators will be determined by the end use of the compressed air.

A centrifugal separator is illustrated in figure 11-14. Air is directed into this unit in a manner that creates a swirling motion. Centrifugal force throws the moisture particles against the wall where they drain to the bottom.

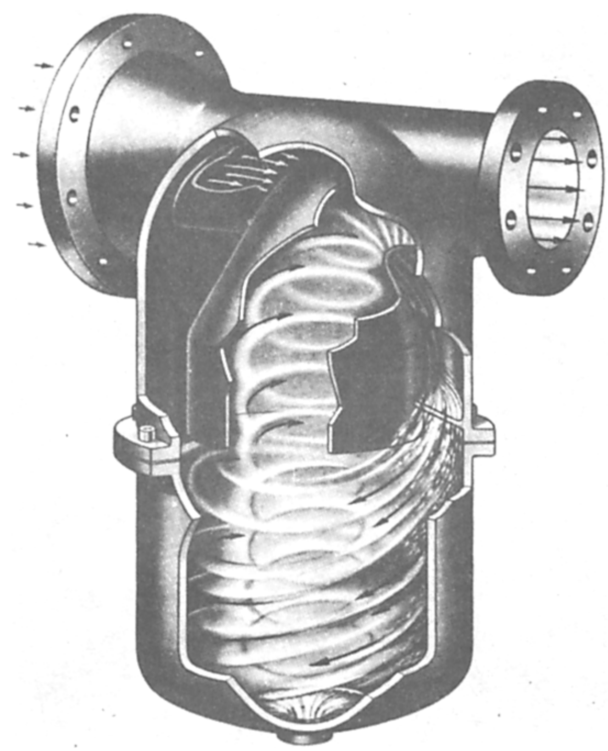

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Figure 11-14.—Centrifugal-type moisture separator.

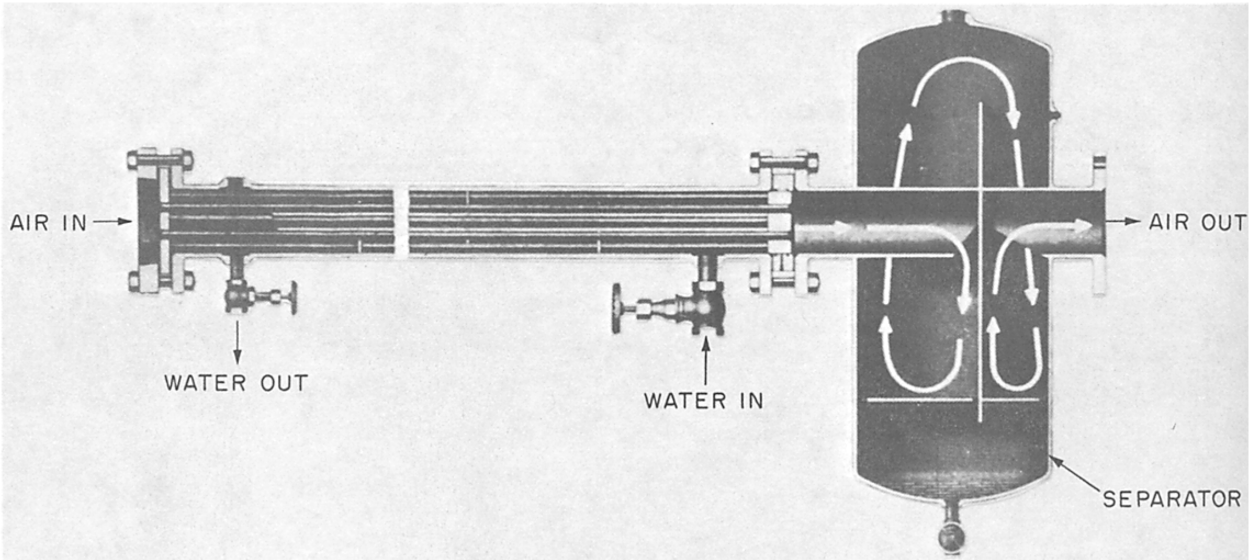

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Figure 11-15.—Baffle-type moisture separator.

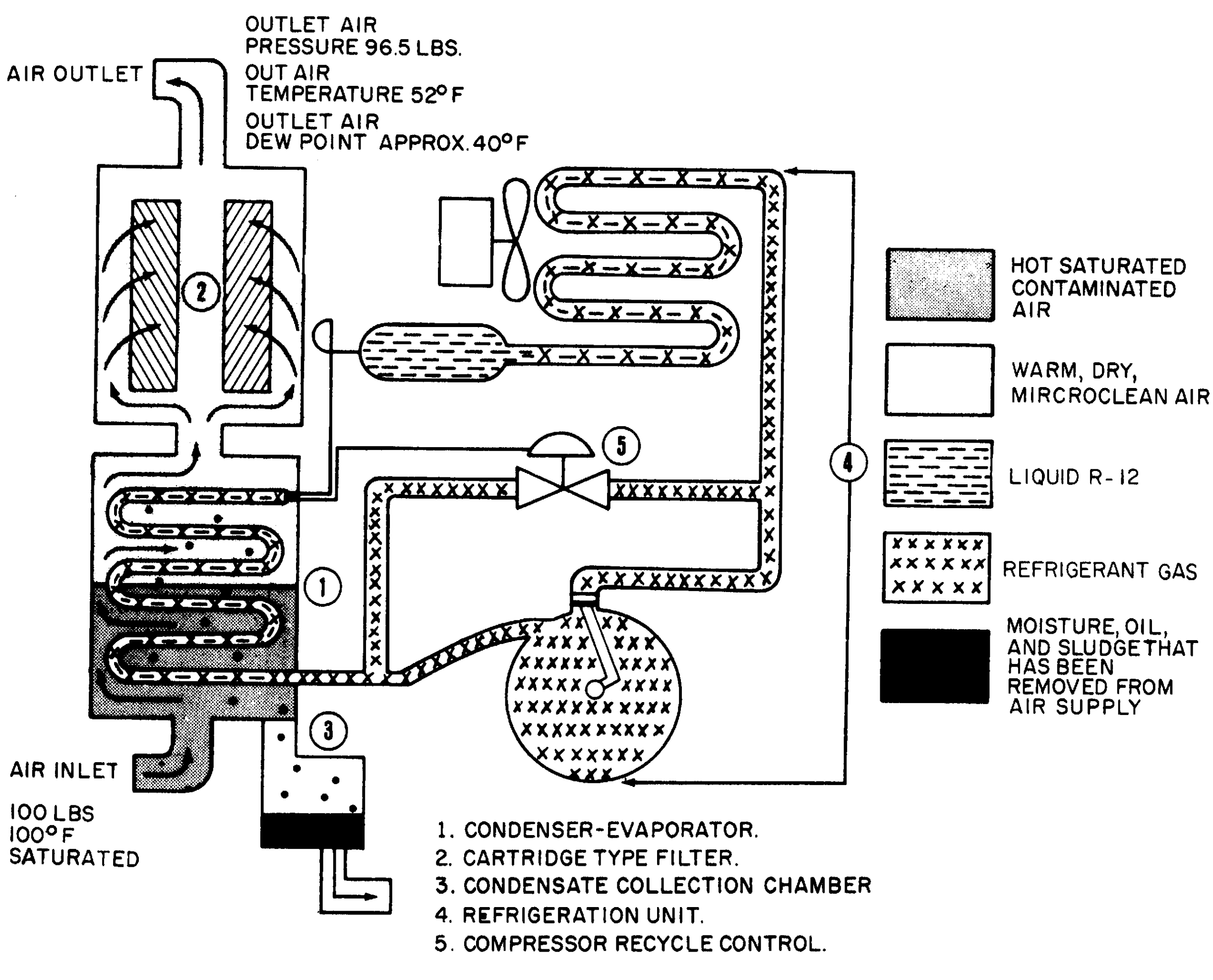

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Figure 11-16.—Flow process of refrigeration-type air dryer.

A baffle-type separator is illustrated in figure 11-15. In this unit the air is subjected to a series of sudden changes in direction that result in the heavier moisture particles striking the baffles and walls, then draining to the bottom.

Dryers

Some compressed air supplies require dryers that ensure removal of all moisture that might otherwise condense in air lines, air-powered tools, or pneumatic instruments. Small amounts of moisture can cause damage to equipment from corrosion, freezing, and water hammer and can result in malfunctions of instruments and controls. The cost of dryers is often justified by the reduction in maintenance costs, production time lost in blowing down piping, and compressed air lost during blowdown.

There are three basic designs of dryers: two absorption types and a condensation type. One type of absorption unit consists of two towers, each containing an absorbent material. Reactivation is accomplished by means of electric or steam heaters embedded in the absorbent or by passing dried-process air through it.

Another type of absorption unit consists of a single tank or tower containing a desiccant (drying agent) that dissolves as it absorbs moisture from the air and drains from the unit with the condensate. The drying agent must be replenished periodically.

The third type removes moisture from the air by condensation through the use of a mechanical refrigeration unit, or where available, cold water. Inlet air passes over cold coils where moisture is condensed out of the air and is drained from the unit by a trap. This process is illustrated in figure 11-16.

Receivers

Air receiver tanks in compressed air plants act as surge tanks to smooth the flow of air from the action of the compressor to discharge; they collect excessive moisture that may condense from the cooled air and provide a volume of air necessary to operate the pressure control system. A typical air receiver is shown in figure 11-17. Related components include a relief valve, pressure gauge, drain valve, service valve, and inspection opening.

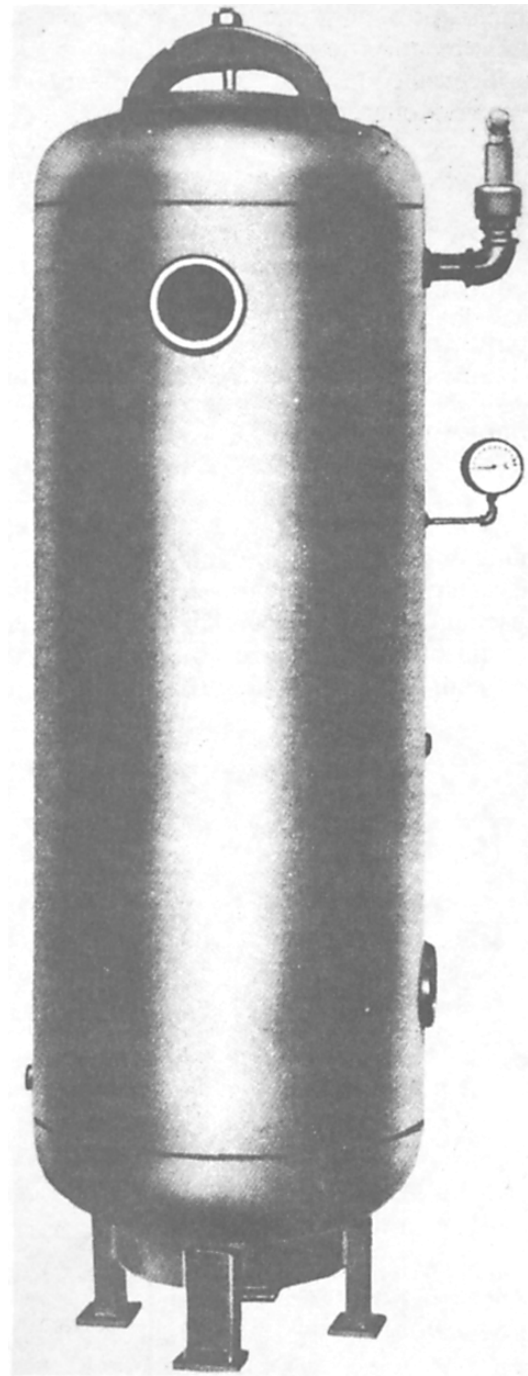

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Figure 11-17.—Air receiver.

Lubrication

Compressors must receive adequate lubrication using clean oil of characteristics recommended by the compressor manufacturer. The manufacturer will usually specify oil requirements by characteristics, such as viscosity at one or more temperatures, pour point, flash point, and in some cases, by specific brands.

Typical compressor cylinder oils will have the following characteristics:

Flash point, °F	350	minimum
Viscosity at 210°F	45	min - 90 max
Pour point, °F	+35	maximum
Neutralization number	0.10	maximum
Conradson carbon residue, %	2.0	maximum

Where cylinder lubrication is separate from frame and bearing lubricants, a modified set of characteristics may be specified. Synthetic oils must conform to the manufacturer's requirements and must be used with care as many synthetic oils may cause swelling and softening of neoprenes and certain rubbers or may not be compatible or separable from water.

Some special considerations for lubricants include the provision of a lubrication oil heater to ensure adequate viscosity during cold weather start-up. High compressor discharge temperatures require lubrication flows and characteristics that still lubricate when subjected to 300°F or higher discharge air temperature conditions. Finally, oil injection or oil-flooded compressors need adequate oil flow and characteristics to maintain lubrication of temperatures within the cylinders or screws.

A typical lubrication arrangement is shown in figure 11-18.

Discharge Pulsation

Reciprocating compressor discharge lines are subject to pulsations caused by the compressor-forcing frequency. This sets up a resonant frequency in the discharge piping, and the resulting vibration amplification will cause noise, support damage, and piping damage. There

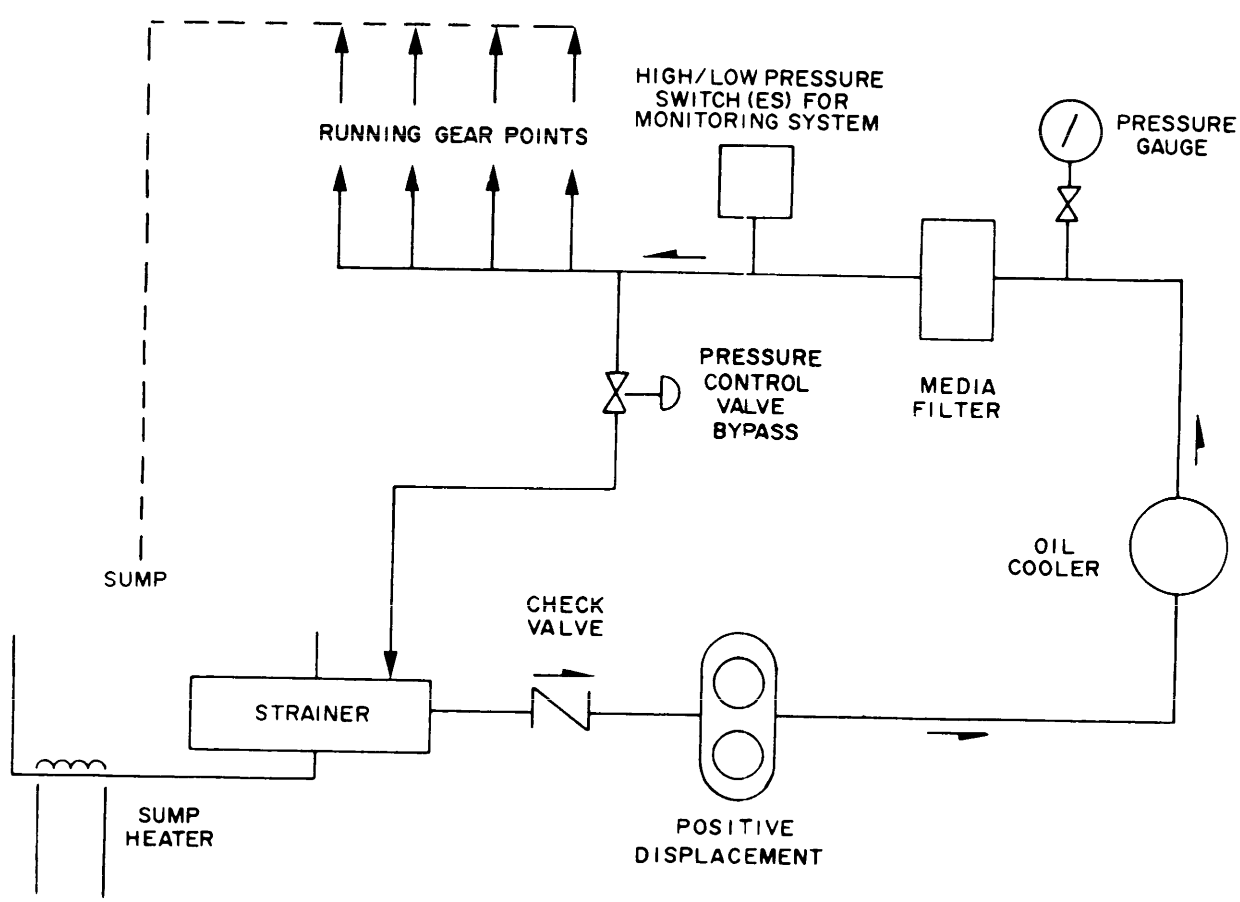

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Figure 11-18.—Typical pressure lubrication system.

is no single solution to this problem, but some specific guidelines will be discussed below.

Pulsation dampeners serve as pulsation and noise mufflers by providing acoustical chambers with the dampener. Manufacturers generally provide dampeners to a specified discharge pulsation peak of ± 2 percent of line pressure. Figure 11-19 shows several typical pulsation dampeners. These units should be used whenever reciprocating and centrifugal compressors serve the same compressed air main, because the pulsations of the reciprocating compressor can transmit to and disturb the operation of the centrifugal compressor. Pulsation dampeners may not completely solve downstream resonance, but they will reduce the vibration amplitudes.

Several other ways to decrease noise and amplification caused by discharge pulsation are available. Surge chambers can be used to change the equivalent length of the piping and increase the pulse-absorbing volume of the pipe. A surge chamber can be as simple as an increased diameter of discharge piping near the compressor discharge. An orifice plate or plates may be installed in conjunction with surge chambers to change the acoustical resonant frequency of the piping system. Piping support is also important at the compressor. They must not only be supported from top or bottom but also have lateral support. When piping is large, provide spring-loaded two-way lateral supports to absorb vibration.

Controls

Compressor control systems generally include one or more controlling devices, such as safety controls, speed controls, and capacity controls. Such devices function in the system to regulate the output of the compressor as it meets the demand for compressed air.

On some small compressors the simple Bourdon tube-type pressure switch serves as a controller by actuating the prime mover on and off over a predetermined pressure range. More complex compressors require control systems that load and unload the compressor as air demands change. The CONSTANT-SPEED type of controller used with many compressors decreases or increases compressor capacity in one or more steps by the use of unloading devices, while allowing the prime mover speed to remain constant. Another type, referred to as the DUAL-CONTROL, is a combination of the constant-speed and an automatic start-stop control. It permits constant speeds when demands are continuous and an automatic stop or start when demands are light. There is still another system that enables the prime mover to idle and compressor suction valves to remain open when air pressure reaches a set maximum. As the pressure drops below a set minimum, the prime mover speed is increased, suction valves are closed, and air is compressed.

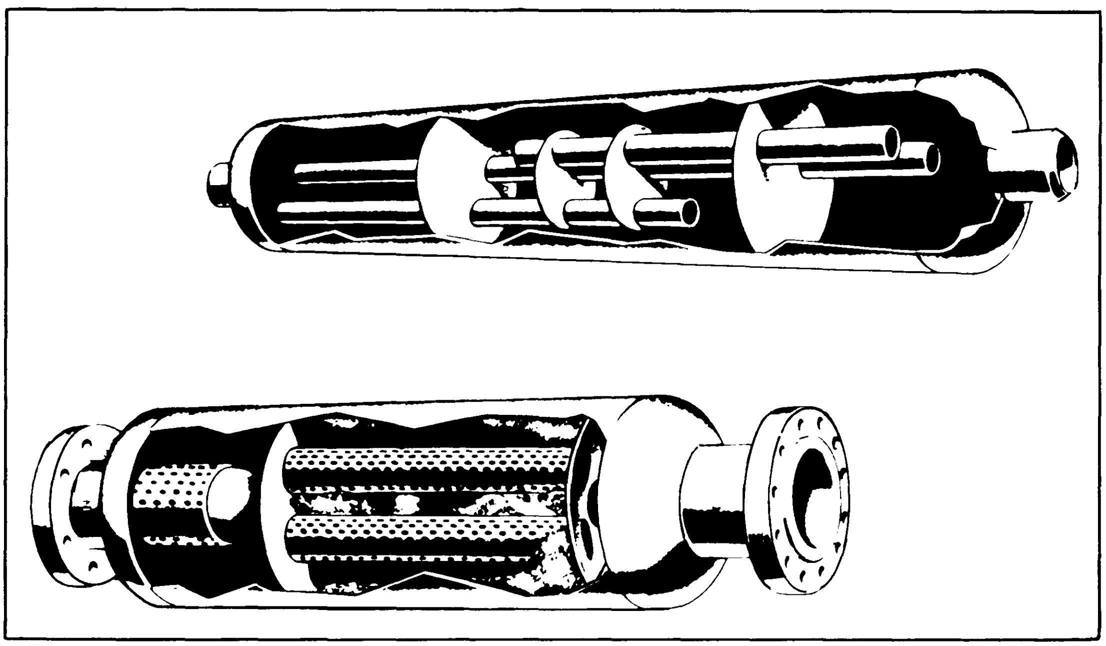

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Figure 11-19.—Pulsation dampeners.

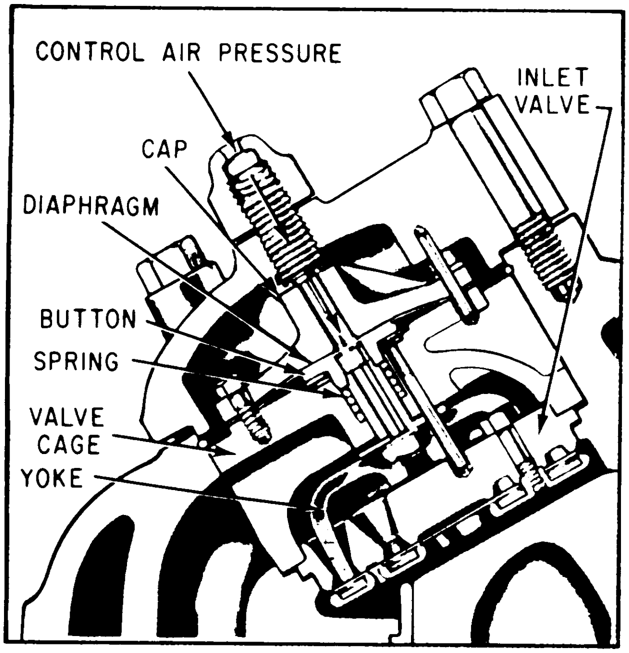

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Figure 11-20.—Inlet valve unloader.

Generally, control systems include unloading devices that function to remove all but the friction loads on compressors. Thus starting is unaffected by compression loads. Various types of unloading devices are discussed below.

The inlet-valve-type unloader holds the inlet valve open mechanically during both the suction and compression strokes, thereby preventing compression. Figure 11-20 illustrates a common inlet valve unloader. The unloader is positioned above the inlet valve. When air pressure rises to the preset unloading pressure, a pressure switch operates a solenoid unloader valve, which opens and allows receiver pressure to the inlet valve unloader. The pressure from the receiver, acting on the diaphragm of the inlet valve unloader, forces the yoke fingers against the inlet valve, holding it open. The intake air is pushed back out the inlet valve on the compression stroke so no compression takes place.

Figure 11-21 illustrates the thin plate, low-lift type of compressor valve. Most compressors use this type of valve.

The use of an unloader valve on each cylinder and a pressure switch with a solenoid unloader valve provides a step or sequenced capacity control. Figure 11-22 illustrates a flow diagram of a

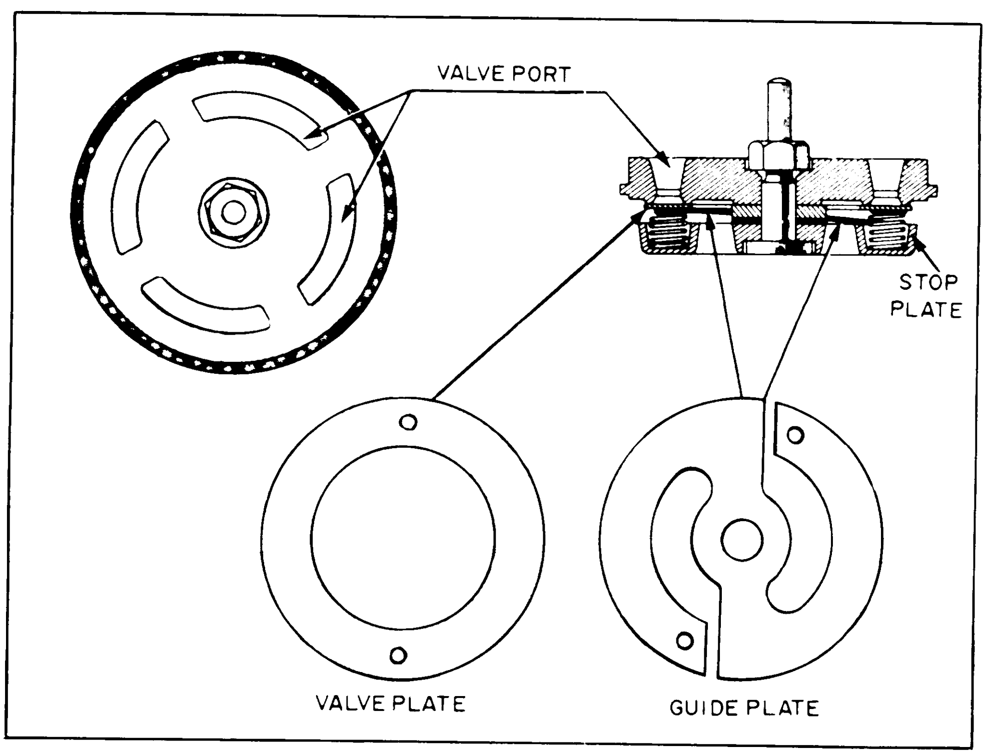

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Figure 11-21.—Thin plate, low-lift, compressor valve assembly.

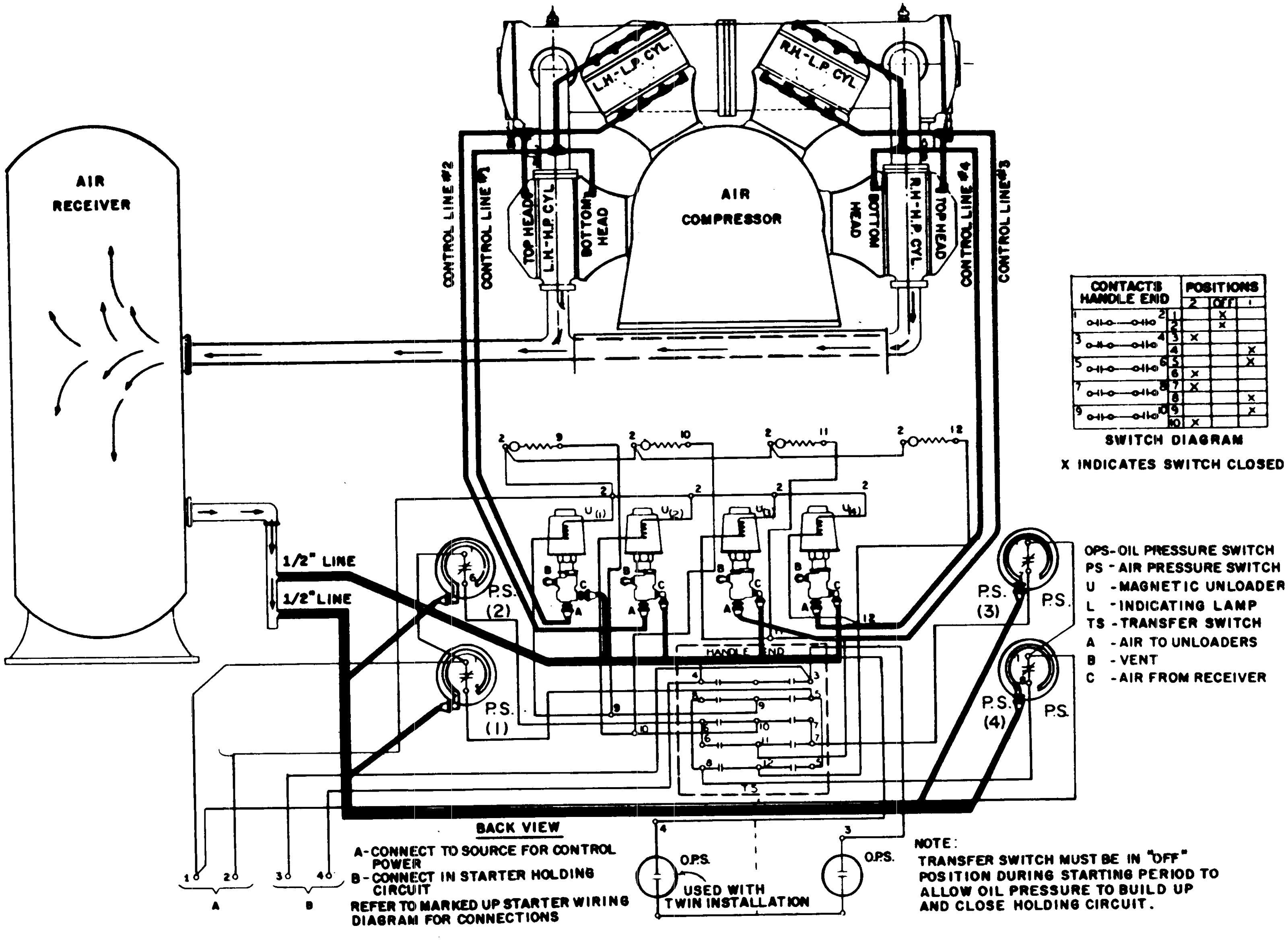

Figure 11-22.—Five-step capacity control.

five-step capacity control system applied to a two-stage, four-cylinder, double-acting, reciprocating compressor. Assuming that the compressor in the figure is required to maintain a pressure of 92 to 100 psi, the pressure switches should be set to load and unload as follows: switch 1, load at 93 psi and unload at 97 psi; switch 2, load at 94 psi and unload at 98 psi; switch 3, load at 95 psi and unload at 99 psi; and switch 4, load at 96 psi and unload at 100 psi. As the receiver pressure reaches the high limit of each pressure switch, 25 percent of the compressor capacity will unload. As receiver pressure falls to the low setting of each switch, 25 percent of the compressor capacity will load. Pressure switch 1 will therefore unload 25 percent of the compressor capacity at 97 psi and will load 25 percent at 93 psi, and so forth. As receiver pressure fluctuates between 93 and 100 psi, the compressor capacity varies in five steps; full, 75 percent, 50 percent, 25 percent, and zero capacity.

The compressor illustrated in figure 11-22 operates on the following principle: When it is started, air pressure switches are closed and the solenoids in the unloader valves become energized so that receiver pressure cannot enter the unloading lines, and compression is permitted. As the receiver pressure builds up and reaches 97 psi, pressure switch 1 breaks contact, de-energizing unloader 1, and allowing 97 psi receiver air to enter control line 1, actuating the inlet valve unloader. Twenty-five percent of the compressor has become unloaded and compression has reduced from full to 75-percent capacity. Control lines 2, 3, and 4 will operate in the same way as receiver pressure increases. At 100 psi, all cylinders will be unloaded. Air compression ceases, but the compressor continues to run under no load. As air is drawn off from the receiver, the pressure begins to drop. When the pressure falls to 96 psi, pressure switch 4 makes contact and energizes unloading valve 4, which cuts off receiver pressure from the inlet unloader and vents the unloader pressure to the atmosphere. The inlet valve unloader releases the inlet valve and normal compression takes place, loading the compressor to 25-percent capacity. If the demand for air increases and receiver pressure continues to decrease, control lines 3, 2, and 1 will load in sequence.

Another method of unloading a compressor is by the use of clearance pockets built into the cylinders. Normal clearance is the volume at the end of the piston and under the valves when the piston is at the end of the COMPRESSION stroke. Figure 11-23 shows an air cylinder with clearance pockets and clearance valves used with a five-step clearance control. Each end of the cylinder is fitted with two clearance pockets that are connected with or cut off from the cylinder by air-operated clearance valves. A regulated device, not shown, which is operated by receiver pressure, uses pilot valves to open and close the clearance pocket valve in the proper sequence. Each clearance pocket can hold one-quarter of the air compressed by the cylinder in one stroke. When both pockets at the end of the cylinder are open, no air is taken into that end of the cylinder. Figure 11-24 illustrates the operation of clearance pockets under five-step clearance control.

Prime Movers

Prime movers for compressors can be electrical, gasoline, or diesel driven. This section will address electrical prime movers only. Gasoline and diesel-driven prime movers are normally the responsibility of the Construction Mechanic. Several types of electric motors can be used to drive compressors: induction, synchronous-wound motor, and direct current (dc) motors.

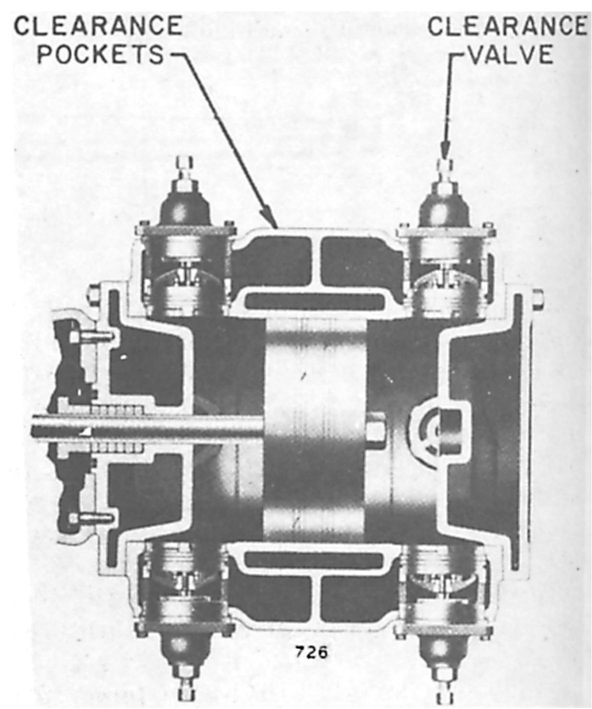

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Figure 11-23.—Air cylinder showing clearance pockets and clearance valves

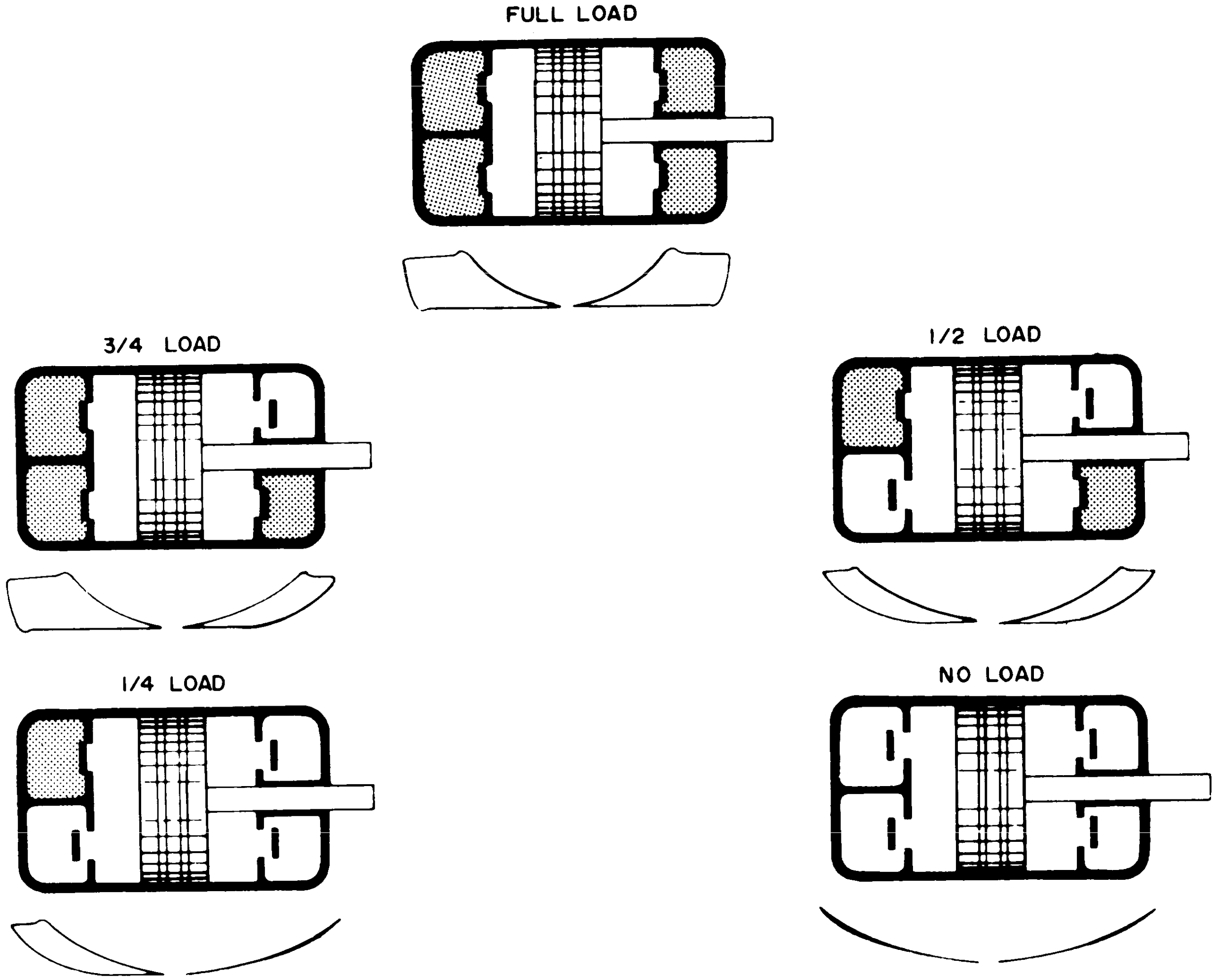

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Figure 11-24.—Five-step clearance control.

Although electric motor drive is available for compressors of almost any capacity, certain types of machines are best driven by an induction motor; others may be driven by a synchronous motor. Generally, cost will rule out synchronous motors except in unusual cases. Direct current motors are seldom used.

Motor-driven compressors may be further identified by the type of connection that is used between the motor and compressor. Any one of the following types of drives may be used: belt, direct-connected, or speed reduction gears.

Induction motors can be used to power single-acting reciprocating compressors ranging from fractional horsepower up to approximately 300 horsepower at a speed of 1,800 rpm. Speeds of 1,200 and 900 rpm and lower are sometimes used in higher horsepower applications. When sizing a motor, you must allow for belt or drive losses of power.

Caution must be exercised when large belted motors are used; manufacturer's recommendations should be applied. Most motors that are belted to compressors are rated as normal starting torque, low-starting current motors. Belt selection should be based on a continuous operation rating of at least 125 percent of motor size with 150 percent preferred. Other compressors that start under load may require motors rated as high-start torque, low-starting current. Consideration should be given to compressor inertia and load to avoid lengthy acceleration time. Whenever possible, it is best

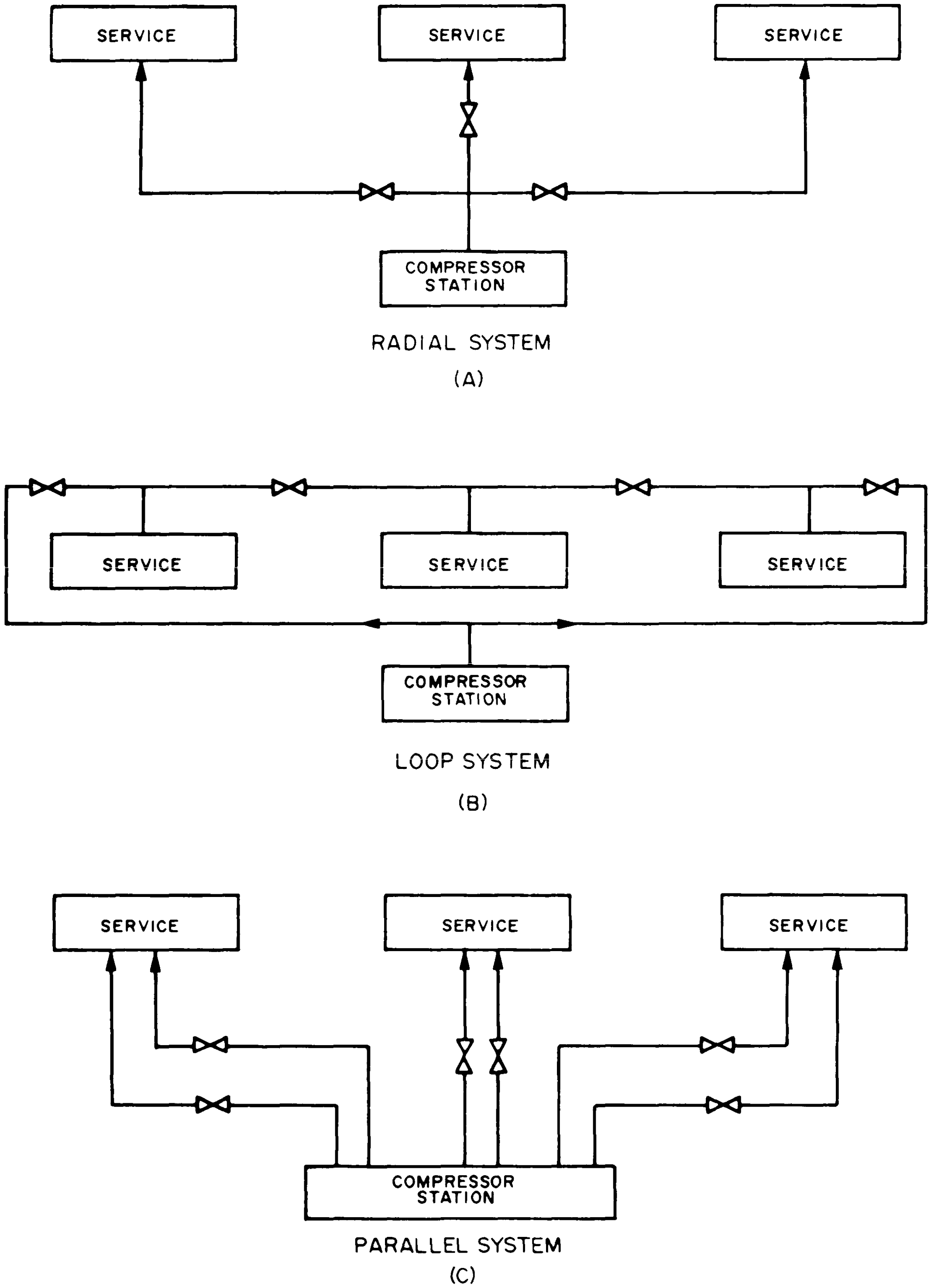

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Figure 11-25.—Types of air distribution systems.

to arrange the compressor to be unloaded during start-up.

A reciprocating compressor maybe driven by an induction motor with a speed reduction gear placed between the motor and compressor. This permits the use of a higher speed with a less costly motor. Gear-driven compressors should have flywheel or inertia effect carefully checked. Couplings should have enough elasticity and dampening to allow for torque and current pulsations. Without this consideration, changes in torque caused by load variations or loading and unloading of a compressor could result in drive and motor damage.

DISTRIBUTION SYSTEMS

The development of a distribution system is dependent upon a combination of factors, such as location and size of each service, time rate demand of larger services, and concurrence or demand factor of larger services.

TYPES OF AIR DISTRIBUTION PIPING SYSTEMS

The more common types of distribution systems or patterns (fig. 11-25) and their prime advantages are as follows:

- Radial, one-way system—used for isolated or individual service or where special requirements dictate a single path.

- Loop system—used for a closed route such as throughout a building. The two-directional flow capacity represents an economical way to provide constant pressure to all services and permits selective isolation when necessary.

- Parallel system—used to provide dual service source to ensure at least one source will be available at all times.

SIZING DISTRIBUTION SYSTEMS

Compressed air distribution systems are sized mainly by calculating the friction loss to be expected from piping, fittings, and valves as well as various accessories you may install.

Pipe diameters are determined from commercially available products, such as copper, stainless steel tubing, or steel piping. As contained pressure increases, the pipe wall thickness must increase and interior diameters decrease. This affects friction pressure loss; it should not exceed 15-percent pressure loss.

When you are determining total friction loss for a distribution system, the total length of the system piping plus the equivalent length of each fitting, valve, or device is summed to produce an equivalent hydraulic length. The equivalent lengths of fittings, valves, and other devices can be determined from table 11-2. Friction loss in air hoses may be taken from table 11-3.

LAYOUT DETAILS

When installing compressed air systems, you must follow seven basic guidelines just as you must consider basic guidelines when installing any other type of piping or drainage system.

Compressed air lines should be installed as level as practical with a slight pitch in the direction of airflow. This pitch is generally placed at 3 inches per 100 feet of piping. In cases when pipes must be pitched upward causing condensate to flow against the flow of air, the pitch upward must be 6 inches or greater per 100 feet, and the piping size should be increased one pipe diameter.

The layout of the piping systems should always allow for the removal of dirt, water, oil, or other foreign material, which can accumulate over long periods of time. Because of this, pockets should be avoided and, where necessary, low points should be provided with driplegs. In addition to providing low points to drain foreign material from the system, the prevention of carry-over of this material into branch lines is necessary. Carry-over into branch lines can be prevented by making connections from the top of the distribution mains.

Piping must be placed with sufficient flexibility to prevent excessive strain or distortion caused by thermal expansion or sudden changes in pressure. By properly placing pipe supports,

Table 11-2.—Representative Equivalent Length in Pipe Diameters (L/D) of Various Valves and Fittings

Description of Product				Equivalent Length in Pipe Diameters (L/D)
Globe Valves	Stem Perpendicular to Run	With no obstruction in flat, bevel, or plug-type seat	Fully open	340
		With wing or pin guided disk	Fully open	450
	Y-Pattern	(No obstruction in flat, bevel, or plug type seat) —With stem 60 degrees from run of pipe line	Fully open	175
		—With stem 45 degrees from run of pipe line	Fully open	145
Angle Valves		With no obstruction in flat, bevel, or plug type seat	Fully open	145
		With wing or pin guided disk	Fully open	200
Gate Valves	Wedge, Disk, Double Disk, or Plug Disk		Fully open	13
			Three-quarters open	35
			One-half open	160
			One-quarter open	900
	Pulp Stock		Fully open	17
			Three-quarters open	50
			One-half open	260
			One-quarter open	1,200
Conduit Pipe Line Gate, Ball, and Plug Valves			Fully open	3**
Check Valves	Conventional Swing		0.5† . . .Fully open	135
	Clearway Swing		0.5† . . .Fully open	50
	Globe Lift or Stop; Stem Perpendicular to Run or Y-Pattern		2.0† . . .Fully open	Same as Globe
	Angle Lift or Stop		2.0† . . .Fully open	Same as Angle
	In-Line Ball		2.5 vertical and 0.25 horizontal† . . .Fully open	150
Foot Valves with Strainer		With poppet lift-type disk	0.3† . . .Fully open	420
		With leather-hinged disk	0.4† . . .Fully open	75
Butterfly Valves (8-inch and larger)			Fully open	40
Cocks	Straight-Through	Rectangular plug port area equal to 100% of pipe area	Fully open	18
	Three-Way	Rectangular plug port are equal to 80% of pipe area (fully open)	Flow straight through	44
			Flow through branch	140
Fittings	90-Degree Standard Elbow			30
	45-Degree Standard Elbow			16
	90-Degree Long Radius Elbow			20
	90-Degree Street Elbow			50
	45-Degree Street Elbow			26
	Square Corner Elbow			57
	Standard Tee	With flow through run		20
		With flow through branch		60
	Close Pattern Return Bend			50

**Exact equivalent length is equal to the length between flange faces or welding ends.

†Minimum calculated pressure drop (psi) across valve to provide sufficient flow to lift disk fully.

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Table 11-3.—Loss of Air Pressure in Hose Caused by Friction

Pulsating flow															
Size of hose, coupled at each end (in.)	Gage pressure at line (lb)	Free air (cfm)													
		20	30	40	50	60	70	80	90	100	110	120	130	140	150
		Loss of pressure (psi) in 50 ft. lengths of hose													
1/2	50	1.8	5.0	10.1	18.1										
	60	1.3	4.0	8.4	14.8	23.4									
	70	1.0	3.4	7.0	12.4	20.0	28.4								
	80	0.9	2.8	6.0	10.8	17.4	25.2	34.6							
	90	0.8	2.4	5.4	9.5	14.8	22.0	30.5	41.0						
	100	0.7	2.3	4.8	8.4	13.3	19.3	27.2	36.6						
	110	0.6	2.0	4.3	7.6	12.0	17.6	24.6	33.3	44.5					
3/4	50	0.4	0.8	1.5	2.4	3.5	4.4	6.5	8.5	11.4	14.2				
	60	0.3	0.6	1.2	1.9	2.8	3.8	5.2	6.8	8.6	11.2				
	70	0.2	0.5	0.9	1.5	2.3	3.2	4.2	5.5	7.0	8.8	11.0			
	80	0.2	0.5	0.8	1.3	1.9	2.8	3.6	4.7	5.8	7.2	8.8	10.6		
	90	0.2	0.4	0.7	1.1	1.6	2.3	3.1	4.0	5.0	6.2	7.5	9.0		
	100	0.2	0.4	0.5	1.0	1.4	2.0	2.7	3.5	4.4	5.4	6.6	7.9	9.4	11.1
	110	0.1	0.3	0.4	0.9	1.3	1.8	2.4	3.1	3.9	4.9	5.9	7.1	8.4	9.9
1	50	0.1	0.2	0.3	0.5	0.8	1.1	1.5	2.0	2.6	3.5	4.9	7.0	...	...
	60	0.1	0.2	0.3	0.4	0.6	0.8	1.2	1.5	2.0	2.6	3.3	4.2	5.5	7.2
	70	...	0.1	0.2	0.4	0.5	0.7	1.0	1.3	1.6	2.0	2.5	3.1	3.8	4.7
	80	...	0.1	0.2	0.3	0.5	0.7	0.8	1.1	1.4	1.7	2.0	2.4	2.7	3.5
	90	...	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.2	1.4	1.7	2.0	2.4	2.8
	100	...	0.1	0.2	0.2	0.4	0.5	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4
	110	...	0.1	0.2	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.8	2.1
1-1/4	50	...	...	0.1	0.2	0.2	0.3	0.4	0.5	0.7	1.1	...	...	...	...
	60	...	...	...	0.1	0.2	0.3	0.3	0.5	0.6	0.8	1.0	1.2	1.5	...
	70	...	...	...	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.7	0.8	1.0	1.3
	80	...	...	...	...	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0
	90	...	...	...	...	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8
	100	...	...	...	...	...	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7
	110	...	...	...	...	...	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6
1-1/2	50	...	...	...	...	...	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.6
	60	...	...	...	...	...	...	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5
	70	...	...	...	...	...	...	...	0.1	0.2	0.2	0.2	0.3	0.3	0.4
	80	...	...	...	...	...	...	...	...	0.1	0.2	0.2	0.2	0.3	0.4
	90	...	...	...	...	...	...	...	...	...	0.1	0.2	0.2	0.2	0.3
	100	...	...	...	...	...	...	...	...	...	...	0.1	0.2	0.2	0.2
	110	...	...	...	...	...	...	...	...	...	...	0.1	0.2	0.2	0.2

(1 inch = 25.4 mm, 1 CFM = 0.0283 mm^3/min, 1 psi = 6.90 kPa, 50 feet = 15.2 m)

87.414

as shown in table 11-4, movement of pipe can be accounted for. In addition, piping should be supported at all changes in direction and load concentrations, such as heavy valves.

There are many other considerations in the layout of compressed air systems, which are beyond the scope of this manual. Refer to NAVFAC DM 3-5, *Compressed Air and Vacuum Systems,* for further information.

TEST PROCEDURES

After installation, the compressed air system must undergo testing. Generally, all piping and pressurized components should be tested at 150 percent of maximum working pressure. When testing, use clean, dry air or nitrogen. The system should be held at test pressure without loss for at least 4 hours.

MAINTENANCE REQUIREMENTS

As with any system, preventive maintenance conducted on a scheduled basis is an important factor in providing reliable service. Breakdown maintenance causes interruption in services that

Table 11-4.—Maximum Span for Pipe

DIAMETER INCHES	STD. WT. STEEL PIPE 40 S	COPPER TUBE TYPE K
1/2	5'-0"	3'-9"
3/4	5'-9"	4'-3"
1	6'-6"	5'-0"
1-1/2	7'-6"	5'-9"
2	8'-6"	6'-6"
2-1/2	9'-3"	7'-3"
3	10'-3"	7'-9"
3-1/2	11'-0"	8'-3"
4	11'-6"	9'-0"
5	12'-9"	10'-0"
6	13'-9"	10'-9"
8	15'-6"	
10	17'-0"	
12	18'-3"	

(1 inch = 25.4 mm, 1 foot = 0.3048 m)

87.415

prove costly to the Navy. It also requires more extensive repair to system components. As a senior Utilitiesman, you must be able to coordinate maintenance efforts. An understanding of the maintenance required for each component will assist you in carrying out this type of duty.

PRIME MOVER MAINTENANCE

Air compressors can be driven by diesel, gasoline, and electrical prime movers. These power-producing items of equipment require the same maintenance as any prime mover used to drive other equipment encountered by the Utilitiesman.

Establish a definite lubrication schedule. Normal oil levels in engines must be maintained at all times, using lubricants recommended by the manufacturer. The frequency of oil changes depends on the severity of service, atmospheric dust, and dirt. These factors also affect the filter and in the case of electrical motors, the need for regular lubrication of bearings.

Daily operator maintenance prevents most breakdownsm Following the suggested maintenance requirements of the manufacturer helps to reduce downtime caused by prime mover failure.

AIR COMPRESSOR MAINTENANCE

Taking into consideration the many types of air compressors the Utilitiesman may encounter in the field, it is impossible to cover all the maintenance requirements of air compressors in this section. Several common factors do apply to all compressors.

The establishment of a lubrication schedule is at the top of the list for ensuring trouble-free operation of compressors. A definite schedule and assignment of responsibility for maintenance personnel to follow are required. The manufacturer's manual establishes minimum requirements that should be followed.

Bearings, packing, seals, and clearances between moving parts must be within the manufacturer's specifications and be included on the maintenance schedule. Many compressors allow for adjustment while others require overhaul when clearances are exceeded.

Visual inspections for dust, dirt, or leaks provide early detection of possible maintenance requirements. Operator maintenance, when conducted properly, can help you catch and correct potential problems early. Ensure all of your operators know how to operate the equipment. In all cases, you should use the manufacturer's manual when making repairs or adjustments.

AUXILIARY EQUIPMENT MAINTENANCE

All auxiliary equipment that services the air compressor or is serviced by the compressor requires periodic scheduled maintenance. Air filters should be checked and cleaned at least once a month. Silencers should be checked twice a year for corrosion, paint, and gasket damage. Intercoolers and aftercoolers must be inspected for scale buildup in hub leaks and so forth. In general, all auxiliary equipment must be placed on a schedule for inspection and periodic maintenance.

DISTRIBUTION SYSTEM MAINTENANCE

Distribution systems require a minimum of maintenance. Checking valve operation, hose connecters, draining condensation (manual or automatic), protecting piping from damage, and repairing leaks are the most common considerations in a maintenance plan.

Procedures applicable to the preventive maintenance inspections for compressed air plants can be found in NAVFAC MO 209, *Steam, Hot Water, and Compressed Air* and NAVFAC P-717, *Preventive/Recurring Maintenance Handbook*. For more involved technical maintenance, such as overhauls, make sure competent personnel are trained before they are needed. Again, follow the manufacturer's manual to repair any air compressor component.

CHAPTER 12

BOILERS

The most common type of boiler in the NCF is the scotch marine. "Scotch marine" is a generic term that identifies a boiler with a furnace, which forms an integral part of the boiler assembly. This configuration allows for compact construction requiring only a small space for the capacity produced. Scotch marine boilers are package units consisting of a pressure vessel, burner, controls, draft fan, and other components assembled into a fully factory fire-tested unit. This provides an engineered unit equipped for quick installation and connection to services. As a first class petty officer, you will supervise personnel in the installation, operation, and maintenance of boilers. As a chief petty officer, you will be responsible for the general management of these plants. This chapter provides insight into many skills that you must develop to be a proficient supervisor/manager of a boiler plant.

INSTALLATION OF BOILERS

When you are preparing to install a boiler, consider three basic factors-site location, accessories, and fittings. This section discusses each of these items. Proper installation of a boiler helps to ensure succesful operation. Always refer to the manufacturer's manuals, and follow your prints and specifications closely. By being thorough in your planning and execution of plans, you can prevent many future problems for operators and maintenance personnel.

SITE LOCATION

Give careful consideration to site location for the construction of a boiler plant. Primarily, the cost in materials, manpower, and equipment is the most important factor effecting this selection. These costs can usually be reduced by locating the plant site as close as possible to the largest load demand facility, such as a galley or laundry.

Location

When selecting a site for boiler installation, you must consider the availability of the following:

- Water
- Electricity
- Fuel
- Natural site drainage

Attempt to avoid high pedestrian and vehicle traffic areas for safety reasons. Another item to consider is noise level. Noise pollution may cause discomfort for personnel, especially if the site being considered is adjacent to a berthing area.

These are factors you must consider when you become involved in selecting a boiler plant site. Each situation may include all, part, or more than these factors. You must look at each installation and evaluate the needs of that job.

Boiler Foundation

Constructing the foundation or platform a boiler sits on requires skilled engineering and development. Follow the manufacturer's specifications. Boilers may vary in wet weight from 1.5 tons to more than 20 tons. A substantial foundation that can withstand the weight and absorb vibration is essential.

Reinforced concrete slabs with runners provide for placing and anchoring the boiler. The runners should provide a level, uniform support and be of sufficient height to allow for maintenance and the installation of piping under the boiler. A raised platform also provides easier access for boiler room cleanup.

Generally, a sump in the slab between the runners provides a catchment area for boiler blowdown or draining of the boiler. This sump drains from the building to a suitable dispersal point.

Boiler Room

When considering the requirements of sheltering a boiler, you must ensure there is enough room for the boiler and all of the accessory equipment. This accessory equipment may include condensate tanks and pumps, chemical feeders, water makeup tanks and feeders, and blowdown tanks.

The boiler room must also be large enough to allow for boiler maintenance, for retubing, and for removing and replacing the boiler. The tube length of a boiler maybe from 2 feet 6 inches to at least 10 feet, and possibly longer. To simplify the removal of the tubes, ensure the boiler room is long enough or have a door located behind the boiler. The most important thing to check is the manufacturer's specifications, which provides the proper dimensions for locating the boiler.

Fresh air inlets and louvers allow fresh air to enter and move across the boiler area. This fresh air entering the boiler room removes excess heat and provides adequate makeup air for combustion.

When planning for boiler room construction, you must always consider boiler requirements, maintenance requirements, and manufacturer's recommendations.

ACCESSORIES

As you review table 12-1, open the fold out figure 12-1 on page 12-5 for identification of the boiler accessory equipment.

Table 12-1.—Boiler Accessories

	ACCESSORY	LOCATION	PURPOSE	SPECIAL REQUIREMENTS
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	Must be outside yoke rising spindle type if it is over 2". This allows the operator to distinguish the position of the valve by sight
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	When two or more boilers are connected to a common header, the steam connection from a boiler with a manhole opening must be fitted with a main steam-stop and a guard 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	When both the main steam-stop and guard valves are required, install a daylight drain valve

Table 12-1 (Continued).—Boiler Accessories

	ACCESSORY	LOCATION	PURPOSE	SPECIAL REQUIREMENTS
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	Pitch horizontal piping 1/4" per 10'. Do not use galvanized piping
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)	Normally of gate-valve design, fully opened or closed
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 chests, 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	Install traps with unions on both sides for easy replacement. Inlet and outlet piping of trap needs to be equal or larger than trap connections
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	Place at intervals of not over 200' for horizontally pitched pipe and at intervals of not over 300' for buried or inaccessible piping
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	When the valve throttles to a partially closed position, the pressure in the equipment can easily go into a vacuum. This is caused by condensing steam and it holds condensate in the equipment. Use a vacuum breaker to solve the problem
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 elements. 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 components by trapping foreign matter, such as rust, scale, and dirt	

Table 12-1 (Continued).—Boiler Accessories

	ACCESSORY	LOCATION	PURPOSE	SPECIAL REQUIREMENTS
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	Pitch lines toward boiler 1/4" per 10'. Do not use galvanized piping
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 shell or steam drum	Pump must be capable of pumping higher pressures than that of the boiler pressure
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	Place relief valve, check valve, and stop valve in the feedwater pipe
17	Relief valve	Between the feed pump and the nearest shutoff valve in the external feed line	Relieve excessive pressure should the external feedline 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	Relief valve opens gradually at a set pressure. Safety valves open fully at a set pressure. Do not use a relief valve in place of a safety 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	Ensure installation of valve is set in the roper direction for its intended purpose
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	If a globe valve is used, you must install the valve so as to enter (pass through) the valve under its disk

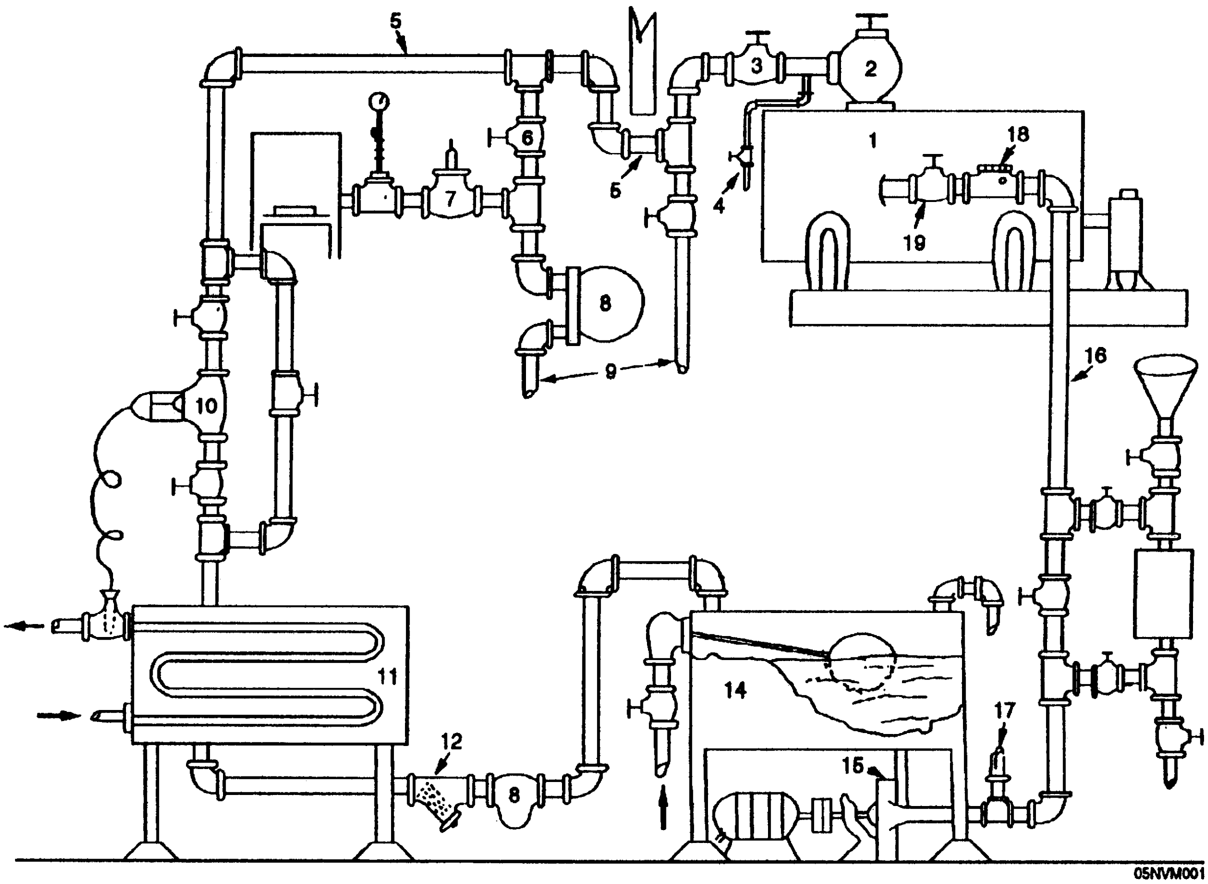

Figure 12-1.—Boiler accessary equipment.

FITTINGS

Before reading table 12-1(A), open the fold out on page 12-9(A) and refer to figure 12-2 and 12-3.

Table 12-1(A).—Description of Boiler Fittings

	FITTING	LOCATION	PURPOSE	ASME CODE REQUIREMENTS
1	Air cock	Installed in the upper-most steam space connected to the boiler shell or steam drum	Permit air to escape when filling boiler with water during the initial building of steam. It allows air to enter the boiler when being drained	Open valve when a boiler is initially filling with water during steam buildup and when emptying a boiler
2	Water column	Installed either on a boiler shell or steam drum adjacent to the steaming water level	Steady the water level in the gauge glass and serve as a sedimentation chamber to minimize obstruction of the small diameter gauge glass connections	Column must be connected to the steam and water space with a minimum size pipe and fittings of 1 inch and that each right angle turn be made with a cross to aid in inspection and cleaning. See figure 12-3
3	Water column blowdown line and valve	From the bottom of the lower cross on the water column to either a bilge, tank, or blowdown pit. Valve is installed just below the column in the blowdown line	The line and valve permit removal of scale and sediment from the water column	Minimum permissible size for the blowdown piping and valve is 3/4"
4	Gauge glass	Located at the steaming water level. Attached to steam drum, water column, or boiler shell	Visual means of checking the water level being maintained within a vessel	Minimal size of gauge glass is 1/2". Boilers operating at 400 psi of pressure or greater require two gauge glasses and the lowest visible portion of the gauge glass must be at least 2" above the lowest permissible water level
5	Gauge glass shutoff valves	Installed on the upper and lower ends of a gauge glass	Permit an indirect connection of the glass to the water column, boiler shell, or steam drum. The valves also serve as a means for isolating the gauge glass from the steam and water for repairs	Gauge glass shutoff valves have a minimal size of 1/2". Some valves may be fitted with an automatic shutoff device, usually consisting of a nonferrous ball that functions to secure or prevent the escape of steam or hot water should the gauge glass break
6	Glass blowdown line and valve	The line from the bottom of the gauge glass to the blowdown pit, bilge, or tank	Permit the operator to detect a partial gauge-glass blockage manually	When under pressure and gauge glass blowdown line is opened and then closed, the water level should return promptly. If level returns slowly, a partial blockage may be present

Table 12-1(A) (Continued).—Description of Boiler Fittings

	FITTING	LOCATION	PURPOSE	ASME CODE REQUIREMENTS
7	Try cocks	Located on water column, boiler shell, or steam drum. If only two cocks are used, they are slightly above and below the steaming water level. If three are used, they are above, below, and at approximate steaming level	Prove the water level in a vessel and check the accuracy of a gauge glass	Boilers not exceeding a diameter of 36" or heating surface of 100 square feet need only two try cocks and one gauge glass. Boilers that exceed the above require three try cocks regardless of the number of gauge glasses
8	Pressure gauge	Installed in a well-lighted area and connected to some boilers uppermost steam space	Indicate the amount of pressure within a vessel	Dial on gauge is graduated so it reads approximately twice the pressure at which the safety valve is set to open. Test every 6 months or whenever you doubt the accuracy of the gauge
9	Fusible plugs	Fire-actuated and steam-actuated plugs are located at the lowest permissible water level. Normally screwed into rear tube sheet above highest row of tubes	Operator warning device of low-water condition. At 450°F the tin is melted out of the plug and the steam escaping causes a whistling sound	Must be replaced every year
10	Bottom blowdown piping	Piping connected to the bottom of the boiler and extending to a bilge, tank, or blowdown pit	Remove sediment, sludge, excessive chemicals, and water from the boiler	Minimum size blowdown and fittings for boilers having 100 square feet or less of heating surface require 3/4" pipe and fittings. If boiler is in excess of 100 square feet, 1" is the minimum and 2 1/2" is the maximum
11	Bottom blowdown valves	Located in the bottom blowdown line. If a quick closing valve is installed, it will always be installed as the first valve in the line coming from the boiler	Remove water, sludge, sediments, and chemicals from the boiler. May have two valves in-line	Every boiler must have one slow opening valve. A slow opening valve requires at least five complete 360° turns between fully opened and closed positions. Boilers exceeding 100 psi must provide two bottom blowdown valves. One may be of the quick closing type. When using the blowdown line, remember to always open the quick closing valve first and secure it last
12	Safety valve	Installed in the uppermost steam space of a boiler	Prevent pressure within the boiler from increasing beyond the safe operating limit	No other valve is permitted to be between the safety valve and the boiler. Every boiler must have at least one. If heating surface is over 500 square feet, two safety valves are required. Lift valves monthly to blow away dirt and prevent disk from sticking. Ensure boiler pressure is at 75% of valve pop setting for removal of debris, and ensure the valve will re-seat
13	Handhole plates	Elliptical- or round-shaped plates located at various locations on a boiler, depending on design	Provide visual hand-arm inspection for waterside maintenance, inspection, and repair work	

Table 12-1(A) (Continued).—Description of Boiler Fittings

	FITTING	LOCATION	PURPOSE	ASME CODE REQUIREMENTS
14	Manhole plates	Eliptical-or round-shaped plates that are 5 to 6 times as large as handholes plates	Provide for body entrance into boiler watersides for , inspection, maintenance, and repair work	
15	Access door	Located near the combustion chamber. Some are located on the bottom of the combustion chamber	Provide access to the combustion chamber and firesides of a boiler for inspection, maintenance, and repair work	
16	Breaching	Located at a point where the combustion gases leave the boiler and extend to where the stack begins	Allow for expansion and contraction	
17	Stacks	Located at the end of the breaching and extends to the atmosphere	Remove products of combustion from the combustion chamber to the atmosphere. Also stacks provide draft which aids combustion	Stacks are required to be high enough to comply with health requirements

INSPECTING AND TESTING RESPONSIBILITY

The commanding officer of the cognizant activity ensures that the boilers and unfired pressure vessels installed at their facility are certified. Inspection and testing of boilers and unfired pressure vessels are done by a boiler inspector certified by NAVFACENGCOM and/or licensed by the cognizant NAVFACENGCOM Engineering Field Division (EFD). This inspector is on the rolls, except for the following:

- Inspection responsibility has been assigned to the commanding officer of a Public Works Center.

- The commanding officer of a major or lead activity is responsible for doing the maintenance of public works and public utilities at adjacent activities.

- It is impractical to use qualified personnel for such inspections because of the limited work load. In such situations, assistance for inspection services should be obtained by an EFD inspector or an activity inspector located near the requested activity which has qualified personnel or by contract. When assistance is required by the EFD, such assistance is on a reimbursable basis. The requesting activity is responsible for providing the finds to accomplish the inspections

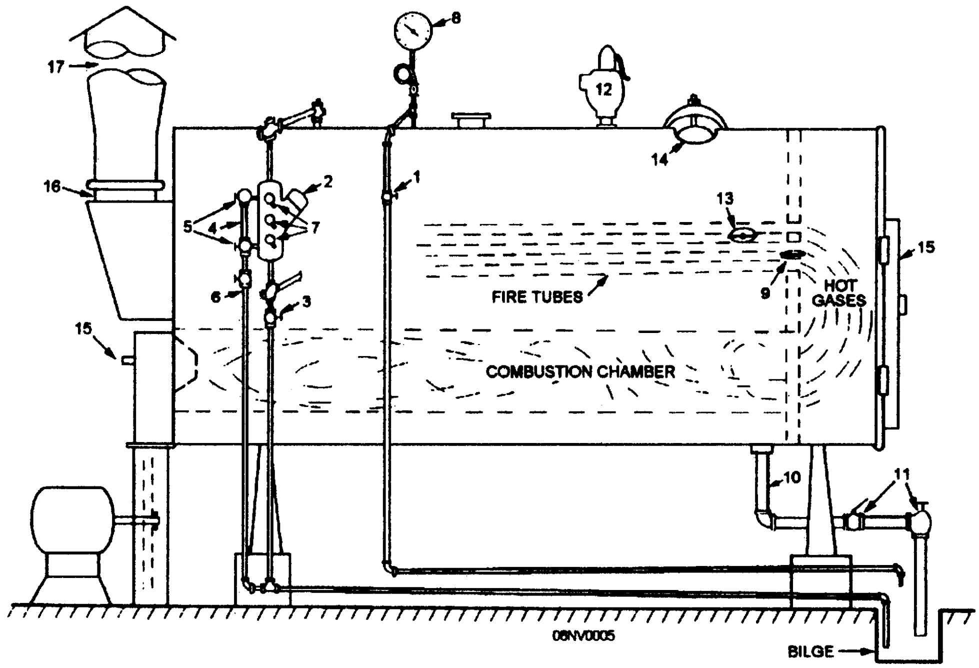

Figure 12-2.—Boiler fittings.

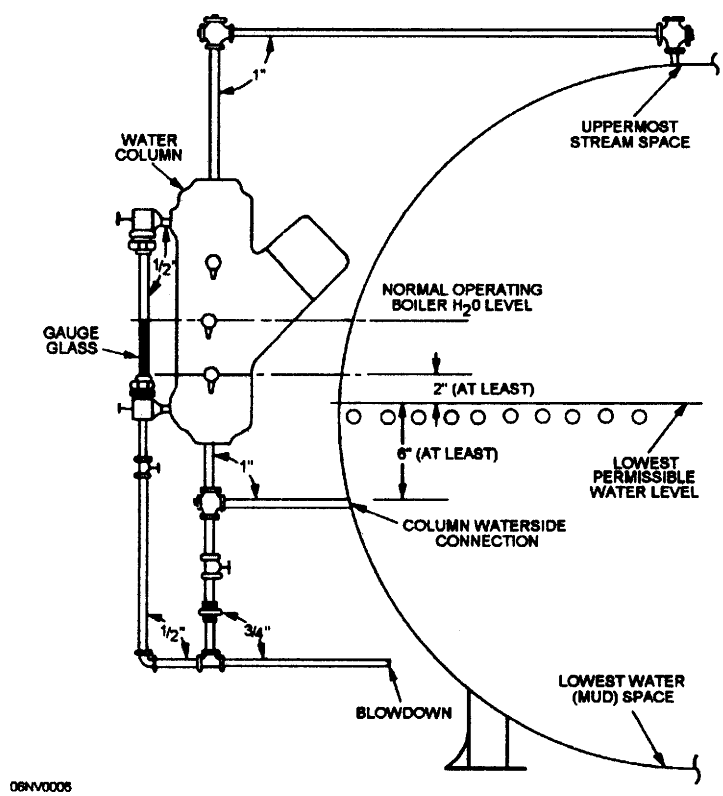

Figure12-3.—Water column.

FREQUENCY OF INSPECTION AND TESTS

The following chart lists different types of equipment and the frequency of boiler testing requirements. For frequency and testing requirements concerning unfired pressure vessels, refer to NAVFAC MO-324.

Table 12-1(B).—Boiler Inspection and Test Frequencies

ITEM	INTERNAL INSPECTION	EXTERNAL INSP. AND OPERATIONAL TESTS	HYDROSTATIC TESTS
Boilers; wet or dry lay-up	At least annually. At resumption of active service.	At least annually. At resumption of active service.	Tightness test at resumption of active service.
Boilers; heating and LTW LTW boilers within at least once every 3 years if output is less than 5 million Btuh	At least annually. After any repair or alteration of pressure parts.	At least annually. After any alteration or modification to boilers, control equipment, or auxiliaries.	Strength test at least once every 6 years. Tightness test all other years. Strength test after repair or alteration of pressure parts. Additional times at the discretion of the inspector.
Boilers; power, high pressure, HTW, and MUSE	At least annually. After repair or alteration of pressure parts.	At least annually. After any alteration or modification to boilers, control equipment, or auxiliaries.	Strength test at least once every 3 years. Tightness test all other years. Strength test after repair or alteration. Additional times at the discretion of the inspector.

Notes:

1. Additionally, MUSE boilers and other portable boilers must be inspected externally and internally and certified each time they are moved from one place to another. A MUSE steam coil type of boiler is exempt from annual inspections while in dry or wet lay-up.

2. All manhole and handhole gaskets must be replaced after a strength test unless they are made of non-compressible steel.

PREPARING FOR INSPECTION

The activity that operates and maintains pressure vessels provides all of the material and labor required to prepare the vessels for inspection. You need to help the inspector during inspection. An inspection on pressure vessels located on a naval base in a foreign country must comply with NAVFAC MO-324, *Inspection and Certification of Boilers and Unfired Pressure Vessels.*

WATERSIDE INSPECTION OF BOILER TUBES

Regular waterside inspection of boiler tubes provides the information required to determine the effectiveness of water treatment, maintenance procedures, diagnoses of boiler operating troubles, and in general an overall condition of the boiler.

Tube failures generally occur in the outer half of the tube nest from external corrosion just above the water drum. When such failures have occurred, either in operation or under

hydrostatic test, or when the examination of tubes in the exploring block shows that the tube thickness is less than half the original thickness, complete renewal must be made of all tubes from the center row to the outer row (inclusive) over a fore-and-aft length of the tube bank sufficient to completely cover the affected area. This renewal must be made regardless of the condition of the tubes that were not included in the exploring block.

The existence of slight, scattered pitting does not necessarily require the complete retubing of the boiler, even if the thickness of the tubes at some of the pits is less than 50% of the original tube thickness. When pitting is observed, tubes should be split and examined to see whether the pitting is (1) moderately heavy, and (2) general throughout the boiler.

Internal pitting resulting from improper treatment of boiler water is most likely to occur in tubes that receive the most heat (screen tubes, fire row tubes, and so forth) and in areas that are particularly subject to oxygen pitting. In general, oxygen pitting tends to occur most commonly in downcomers, in superheaters, and at the steam drum ends of generating tubes. If active oxygen pits (that is, pits that are still scabbed over, rather than clean) are found when the boiler is inspected, or if oxygen pitting is suspected because of the past operating history of the boiler, one or two tubes should be removed from the areas in which oxygen pitting is most likely to be found.

The tubes thus removed should be split and examined. If as many as 25% of the pits are deeper than 50% of the tube wall thickness, and if at least a few of the pits are deeper than 65% of the tube wall thickness, a sample of about 20 tubes from the screen and last rows of the generating bank should be cut. These tubes should be split and examined, and their condition should be evaluated on the same basis as before. If as many as 25% of the pits are deeper than 50% of the wail thickness, and if at least a few are deeper than 65%, the oxygen pitting is considered to be general throughout the boiler and moderately heavy. With these findings, complete tube renewal should certainly be considered. However, it is possible that complete tube renewal may be postponed in some cases if (1) the boiler can be successfully cleaned by a chemical cleaning, (2) the boiler can successfully withstand a 125% hydrostatic test, and (3) future boiler water treatment, use of blowdown, and laying-up procedures can be expected to be in strict accordance with NAVFAC requirements.

Before you make a detailed waterside inspection of boiler tubes, you should be familiar with some of the WATERSIDE CAVITIES and SCARS that can be recognized by visual examination.

LOCALIZED PITTING is the term used to describe scattered pits on the watersides. These pits are usually—though not always—caused by the presence of dissolved oxygen.

WATERSIDE GROOVES are similar to localized pits in some ways, but they are longer and broader than the pits. Waterside grooves tend to occur in the relatively hot bends of the tubes near the water drum; they may also occur on the external surfaces of desuperheater tubes. Some waterside grooves are clean, but most contain islands of heavy corrosion scabs. A typical example of waterside grooving is shown in figure 12-4.

CORROSION FATIGUE FISSURES are deep-walled, canyon-like voids. They have the appearance of being corroded, rather than fractured, and they may be filled with corrosion products. These fissures occur in metal that has been fatigued by repeated stressing, thus making it more subject to corrosion than it would other-wise be.

GENERAL WATERSIDE THINNING can occur if the boiler water alkalinity is too low over a long period of time, if the boiler water alkalinity is too high, or if acid residues are not completely removed from a boiler that has been chemically cleaned. The greatest loss of metal from general waterside thinning tends to occur along the side of the tube that is toward the flame. The entire length of the tube from steam drum to water

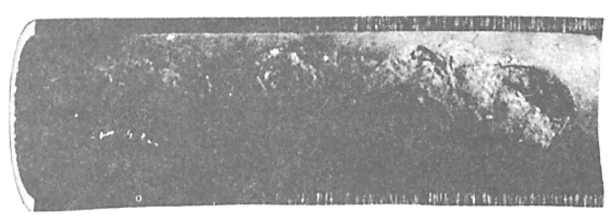

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Figure 12-4.—Waterside grooving in a generating tube.

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Figure 12-5.—General waterside thinning.

drum may be affected. Figure 12-5 shows general waterside thinning.

WATERSIDE BURNING may occur if the temperature exceeds about 750°F in plain carbon steel tubes or about 1,000°F in most alloy superheater tubes. The effect of waterside burn-ing is the oxidation of the tube metal to a shiny, black, magnetic iron oxide known as high-temperature oxide.

WATERSIDE ABRASION is the term used to describe waterside cavities that result from purely mechanical causes rather than from corrosion. For example, tube brushes or cutters may cause abrasion spots at sharp bends in economizer, superheater, and generating tubes. The surface markings of such abrasions indicate clearly that they result from mechanical abrasion rather than from corrosion.

DIE MARKS appear as remarkably straight and uniform longitudinal scratches or folds on the watersides of the tube. They are the result of faulty fabrication. Die marks, shown in figure 12-6, may extend for the full length of the tube. Localized corrosion occurs quite often along the die mark.

TUBE CORRUGATION is a peculiar type of heat blistering that occurs when the boiler water is contaminated with oil. Corrugation may consist of closely spaced, small-diameter, hemispherical bulges, as though the tube metal had been softened and then punched from the inside with a blunt instrument. It may also exist as a herring-bone or chevron pattern on the tube wall nearest the flame, as shown in figure 12-7. It is not known exactly why oil contamination of the boiler water tends to cause this patterned corrugation.

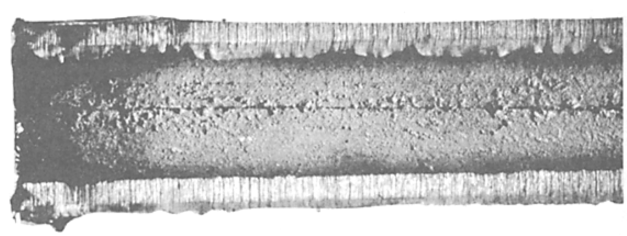

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Figure 12-6.—Die marks on the waterside of a tube.

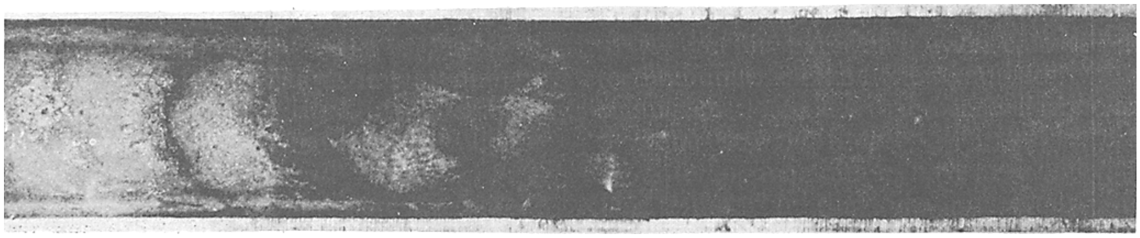

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Figure 12-7.—Tube corrugation resulting from oil on waterside.

Waterside Inspection of Drums and Headers

Whenever a boiler is opened for cleaning and overhaul, the internal surfaces of the drums and headers should be carefully inspected for evidence of cracking. Particular attention must be given to steam drum manhole knuckles, knuckles at corners of drum heads, corners of cross boxes and headers, superheater header vent nozzles, and handhole openings. Any defect found must be recorded in the boiler water treatment log and in the maintenance log. These defects should also be reported to the maintenance office so that appropriate repair action can be taken.

Hydrostatic Tests

Boilers are tested hydrostatically for several different purposes. In each case, it is important to understand why a test is being made and to use—but NOT to exceed—the test pressure specified for that particular purpose. In general, most hydrostatic tests are made at one of three test pressures: boiler design pressure, 125% of design pressure, or 150% of design pressure. Other test pressures may be authorized for certain purposes. For example, a test pressure of 150 psi is required for the hydrostatic test given before a boiler undergoes chemical cleaning.

The hydrostatic test at design pressure is required upon the completion of each general overhaul, cleaning, or repair that affects the boiler or its parts and at any other time when it is considered necessary to test the boiler for leakage. The purpose of the hydrostatic test at design pressure is to prove the tightness of all valves, gaskets, flanged joints, rolled joints, welded joints, and boiler fittings.

The test at 125% of design pressure is required after the renewal of pressure parts, after chemical cleaning of the boiler, after minor welding repairs to manhole and handhole seats, and after repairs to tube sheets, such as the correction of gouges and out-of-roundness. The “renewal of pressure parts” includes all tube renewals, rolled or welded, except downcomers and superheater support tubes.

The test at 150% of design pressure is required after welding repairs to headers and drums, including tube sheet cracks and nozzle repairs, after drain and vent nipple repairs, and after renewal or rewelding of superheater support tubes and downcomers. The hydrostatic test at 150% of design pressure is basically a test for strength. This test may be (but is not necessarily) required at the 5-year inspection and test.

Before making a hydrostatic test, rinse out the boiler with freshwater. Using at least 50-psi pressure, play the hose onto all surfaces of the steam drum, the tubes, the nipples, and the headers. Examine the boiler carefully for loose scale, dirt, and other deposits. Be SURE that no tools or other objects are left in the boiler. Remake all joints, being sure that the gaskets and the seating surfaces are clean. Replace the handhole and manhole plates and close up the boiler.

Gag all safety valves. Boiler safety valves must NEVER, under any circumstances, be lifted by hydrostatic pressure. When gagging the safety valves, do not set up on the gag too tightly or you may bend the valve stems. As a rule, the gags should be set up only handtight.

Close all connections on the boiler except to the air vents, the pressure gauges, and the valves of the line through which water is to be pumped to the boiler. Be sure the steam-stop valves are completely closed and that there will be no leakage of water through them.

After all preparations have been made, use the feed pump to fill the boiler completely. After all air has been expelled from the boiler, close the air vents and build up the hydrostatic pressure required for the particular test you are making. A hand boiler test pump can be used in building up the hydrostatic test pressure. If you do not have a hand test pump, buildup the required test pressure by continuing to run the feed pump after the boiler has been filled. In any case, be very careful that you do not exceed the specified test pressure. After the boiler is full, it takes very little additional pumping to build up pressure.

To avoid complications arising from changes in pressure caused by changes in temperature, you should use water that is approximately the same temperature as the boiler and the fireroom. In any case, the temperature of the water must be at least 70°F.

While the hydrostatic pressure is being built up, the boiler should be very carefully checked for signs of strain or deformation. If there is any indication of permanent deformation, stop the hydrostatic test and make the necessary repairs. If it is not possible to make the repairs right away, give a second hydrostatic test, progressing slowly up to 20 psi less than the pressure at which the first test was stopped. If the boiler passes this second test successfully, the new working pressure of the boiler must be two-thirds of the test pressure reached on the second test, and all safety valves must be set accordingly.

Do not make any attempt to set up on leaky handhole or manhole plates until the pressure has been pumped up to within 50 psi of the test pressure. After all manhole and handhole leakage has been remedied, pump the pressure on up to test pressure. Check the pressure drop over a period of time. If all valves have been baked off, the maximum acceptable pressure drop is 1.5% of the test pressure over a period of 4 hours. If connected valves are merely closed and left installed, a drop test will not indicate the true condition of the boiler. The pressure drop test is conducted at boiler design pressure.

A tube seat should not be considered tight unless it is bone dry at the test pressure. Any tube that cannot be made tight under a hydrostatic test should be renewed or rerolled.

If there is an excessive pressure drop when there is only a slight leakage at tube joints, handholes, and manholes, the loss of pressure is almost certainly caused by leakage through valves and fittings. Valves and fittings should be overhauled and made tight.

Five-Year Inspection and Test

At 5-year intervals, each boiler must be inspected for integrity of welds and nozzle connections. Lagging must be removed from drums and headers sufficiently to expose the welded joints and the nozzle connections. The welds and nozzle connections must be inspected visually from both inside and outside. If there is any doubt about the welds, they should be inspected by magnetic particle inspection or dye penetrant inspection. If any area, through examination (visual, magnetic particle, or dye penetrant) reveals that a 150-percent boiler design pressure hydrostatic test is warranted, and the area proves to be tight under test pressure, further investigation of the suspected area should be conducted. The investigation should continue until the true condition of the area is known, and if necessary, appropriate repairs are made.

INSPECTION OF FIRESIDES

Boiler firesides should be inspected for signs of damage to the refractory lining, tubes, protection plates, baffles, seal plates, support plates, and other metal parts. This type of inspection is usually conducted when the boiler is secured for fireside cleaning, but it should be conducted each time the boiler is secured.

Refractory Inspection

Frequent inspection of refractories, together with early repair of any weak or damaged places, can do a lot to prevent refractory failure and to postpone the need for complete renewal. It is a good maintenance practice to inspect the refractories every time the boiler is opened up. Such inspections should be very detailed if you have reason to think the boiler has been operated under severe service conditions—steaming at high rates, burning low-grade or contaminated fuel, or undergoing rapid fluctuations of temperature. Severe conditions cause rapid deterioration of refractories and, therefore, increase the need for frequent inspections.

To make a proper inspection of boiler refractories, you should have considerable knowledge of the causes of refractory deterioration. Also, you should know how to tell the difference between serious damage, which may require a complete renewal of brickwork, and less serious damage, which may be dealt with by patching.

Slagging and spalling are two of the main causes of refractory deterioration. Slag is formed when ash and other unburnable materials react with the brickwork. Although the ash content of fuel oil is low, there is always enough present to damage the refractories. The most damaging slag-forming materials are vanadium salts and sodium chloride.

If the slag that forms on the brickwork would remain in place, it would not cause any particular trouble; however, the slag does not remain in place. Instead, it peels off or melts and runs off, taking some refractory with it and exposing a fresh layer of refractory to further slag attack. When deterioration of the brickwork has progressed until only a 3-inch thickness of firebrick remains, the wall should be replaced. When sufficient slag has accumulated on the deck to cause striking with resultant deposits of carbon, the slag should be removed. If less than 1 1/2 inches of firebrick remain after the slag is removed, the entire deck must be replaced.

Another type of slag that results from using fuel oil that is contaminated is usually more damaging than peeling slag. This type of slag is very glassy in appearance, and when this slag melts, it usually covers the entire wall or deck.

Firebrick shrinkage is another cause of furnace deterioration. True shrinkage (permanent shrinkage) is quite rare in firebrick approved for naval use. However, this defect can occur even in approved firebrick. In any case, it is important to recognize the appearance of true firebrick shrinkage because of the extremely dangerous condition it could create if it should occur. When the firebrick shrinks, the hot-face dimensions of each brick become measurably smaller than the cold-face dimensions. This condition leaves an open space around each brick, and the entire wall or floor becomes loose. A wall or floor having this appearance is DANGEROUS and should be completely renewed as soon as possible.

Also, during your inspection, look for signs of unequal stresses that are caused by rapid raising of the furnace temperature while raising steam too rapidly. Emergencies may arise that require the rapid raising or lowering of furnace temperatures, but it is important to remember that the refractories cannot stand this treatment often. As a rule, you will find that raising the furnace temperature too rapidly causes the firebrick to break at the anchor bolts, and lowering the temperature too rapidly causes deep fractures in the firebrick.

Also, look for signs of mechanical strain caused by poor operation of the boiler. Continued panting or vibration of the boiler can cause a weakened section of the wall to be dislocated so that the bricks fall out onto the furnace floor. Improper oil-air ratio is the most common cause of boiler panting and vibration. Proper operation of the boiler, with particular attention to the correct use of the burners and forced draft blowers, generally prevents panting and vibration of the boiler.

Inspection should also be made of the lower side of the floor pan. Any overheating indicates a loss of insulation and excessive heat penetration. Under normal conditions, the brickwork in a boiler should last for a number of years without complete renewal.

Expansion joints should be inspected often for signs of incomplete closure. It is important to keep the joints free of grog, mortar, and refractory particles so that the joints can close properly when the boiler is fired. You can tell if an expansion joint is closing completely when it is heated by inspecting it when it is cold. If the inside of the expansion joint is light in color when the furnace is cold, the expansion joint is closing properly. If an expansion joint does not close properly when heated, the inside is dark and discolored.

The same method can be used to tell if cracks in refractory materials are closing properly when the furnace is fired. If the cracks are dark, showing that they do not close, they should be repaired.

Since the first firing of a plastic or castable burner front does more damage than any other single firing, the first inspection after installation is a very important one. The unfired burner front may appear to be in perfect condition while actually containing defects of material or workmanship that will show up immediately in the first firing.

After the boiler has steamed for several hours, slabs of plastic about 1/2- to 1-inch thick may separate from the burner's front surface and fall off. This is because the surface layer is more densely rammed during installation than the remainder of the material.

Radial cracks in the burner fronts may be found on the first inspection. These cracks are not harmful. They are caused by stresses resulting from the normal expansion and contraction of the refractory as it is heated and cooled. After the radial cracks occur, the stresses are relieved and there should be no further cracking of this type.

The cracks that eventually result in extensive damage run approximately parallel to the surface of the burner front, and they are called parallel cracks. Parallel cracks usually appear at or slightly behind the leading edge of the bladed cone. They are not dangerous until they actually loosen pieces of the burner front. Improper installation and boiler operation are usually the cause of parallel cracking.

A slanting crack in the narrow section between the burners sometimes joins a radial crack. When this occurs, pieces of plastic tend to break off. This type of damage can usually be repaired by a plastic patch.

If during your inspection you find that a castable burner front is breaking up after very little service, it is likely that too much water was used in mixing the material during installation. Sometimes the material is already partially set before installation; a common cause of this trouble is that the castable material, while in storage, reacted with moisture in the air and started to set. When castable material sets before it is used, it can never reach full strength.

Castable material is also subject to spalling after several hours of service. The peeling material, usually in 1/8-inch strips, should not be removed unless it is in the burner cone and is interfering with combustion.

If a castable front is chalky or crumbly, find out how deep the condition goes. If no more than the surface can be rubbed off, the burner front is not seriously damaged. Do not remove the crumbly material. The condition is serious only if the burner cone is affected or if the casing shows signs of overheating.

Burner tile should be inspected for loose segments and broken pieces that might cause improper cone angles. The broken or damaged segments can be repaired by patching with plastic fireclay refractory. In some cases a new segment of tile can be installed.

When you inspect boiler refractories, it is a good idea to keep in mind the possibility that damage may occur because of operational problems. Although boilers must occasionally be operated under very severe and damaging conditions, a lot of damage to refractories (and, in fact, to other boiler parts as well) is caused by poor operating procedures that are really not necessary under the circumstances. It may be helpful to show operating personnel any refractory damage that appears to be directly related to poor operation of the boiler.

Tube Inspection

When inspecting the exterior of boiler tubes, look for signs of warping, bulging, sagging, cracking, pitting, scaling, acid corrosion, and other damage. All tube sheets should be inspected for signs of leakage, especially the superheater tube sheet.

Inspection of boilers sometimes shows an unexpected condition in which adjacent boiler tubes are warped in such a way that they touch each other. When this condition exists, the tubes are said to be married. Tube marriages can result either from overheating of the tubes or from stresses developed in the tubes during installation. For the latter reason, newly erected boilers and boilers that have been retubed should always be inspected for tube alignment after the initial period of steaming.

When inspection reveals one or more tube marriages, the decision as to whether or not the married tubes should be renewed should be based on the following considerations:

1. If the tube marriage occurs in screen tubes 1 1/2 inches or larger, or if the furnace side wall or rear wall tubes are bowed, tube replacement is usually required.
2. If 1-inch or 1 1/4-inch tubes in the main bank of generating tubes are married, replacement is usually not required if the tube joints are tight under hydrostatic test.
3. Inspect the external surfaces of the tubes. If they show blistering or other signs of overheating, the tubes should be renewed.
4. Inspect the watersides. Where tube marriages exists, a poor waterside condition may indicate hard scale or oil within the affected tubes. If hard scale or oil does exist, the married tubes should be replaced, and all appropriate steps should be taken to remove the scale or oil from the rest of the boiler. If the condition of the tubes is uncertain, or if a large number of tube marriages have occurred, remove one or more sample tubes, split them, and examine them carefully.
5. Tube marriages may cause gas laning, and gas laning, in turn, may cause local overheating of the inner casing, the bottom part of the economizer, and other parts. Inspect the boiler carefully for signs of local overheating that might have been caused by gas laning resulting from the tube marriages. If the local overheating from this cause is found, renew the married tubes.

6. On single-furnace boilers, a lane more than 1 1/2 inches wide may allow overheating of the superheater and of the superheater supports. If a large lane (1 1/2 tubes wide or wider) exists near the superheater outlet header end of the boiler, the married tubes that caused such a large lane should be renewed.

To identify the cause of the tube failure by visual inspection, you will need to know something about the various ways in which tubes rupture, warp, blister, and otherwise show damage. Tube failures must be reported, and they must be reported in standard terminology. The following sections of this chapter deal with the inspection techniques required for determining the causes of tube failure and with the various ways in which boiler tube damage is classified and identified.

The inspection techniques required for determining the cause of tube failure must naturally vary according to the nature of the problem. For example, a rupture in a fire row tube can usually be described adequately on the basis of simple visual observation, but the cause of damage to a tube that is deep in the tube bank cannot usually be determined without removing the intervening tubes. When a blistered tube suggests a waterside deposit, the nature and extent of the deposit can be determined only by removing and splitting the tube so that the waterside can be examined.

Relatively simple equipment is required for the field inspection of damaged or fouled pressure parts. Equipment for this purpose should include the following: (1) devices for measuring tube diameters, depth of pits, and thickness of deposits; (2) instruments for separating deposits and corrosion products—a sharp knife, a chisel, a steel scribe, or a vise to crack deposits loose from the tube samples; (3) an approved type of portable light; (4) a supply of clean bottles for collecting samples of deposits; and (5) a mirror for viewing relatively inaccessible places.

Many of these items of equipment can be improvised if necessary. For example, a simple gauge for measuring the depth of waterside pits may be made by pushing a straight pin or a paper clip through a 3- by 5-inch card so that the point of the pin or clip projects beyond the card, at right angles to the card. Such an improvised depth gauge is shown in figure 12-8. A section of string can be wrapped around a deformed tube and then laid along a ruler to obtain a measure of tube enlargement or tube thinning. Of course, special tools such as calipers, depth gauges, and scale thickness indicators give more accurate results and should be used if they are available; but the improvised tools, if used with care, can also give good results.

The classification of boiler tube damage is considered here under four major classifications: (1) fireside cavities and scars, (2) waterside cavities and scars, (3) tube deformities and fractures, and (4) tube deposits.

FIRESIDE CAVITIES AND SCARS on the tube firesides often indicate the reasons for tube failure. The term *circumferential groove* is used to describe the metal loss that occurs in bands or stripes around the circumference of a tube. Fireside grooving of this type often occurs at the header ends of horizontal tubes such as superheater tubes. The most common cause of this damage is leakage from tube seats higher in the tube bank. The grooving occurs as the water runs

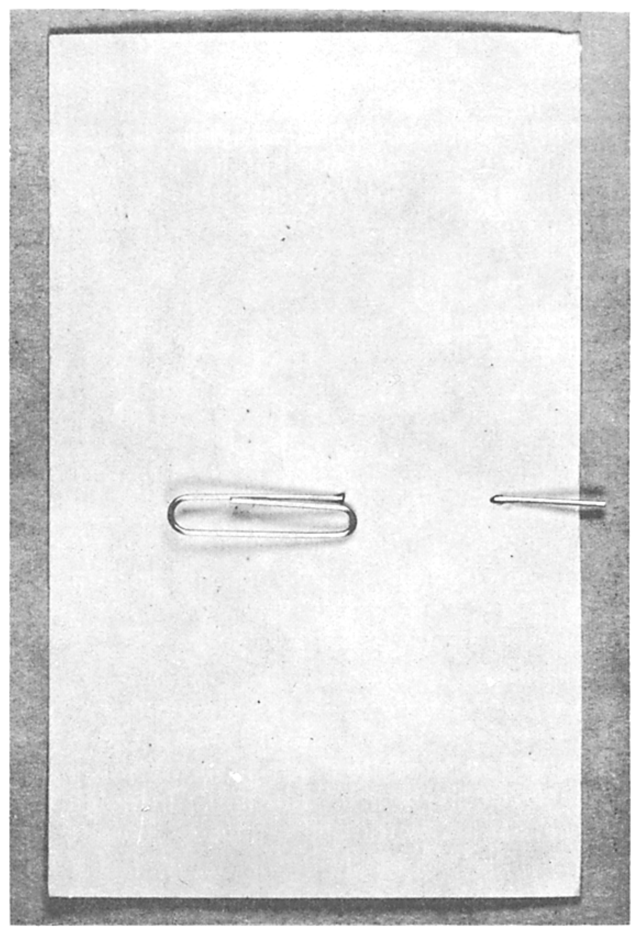

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Figure 12-8.—Improvised depth gauge.

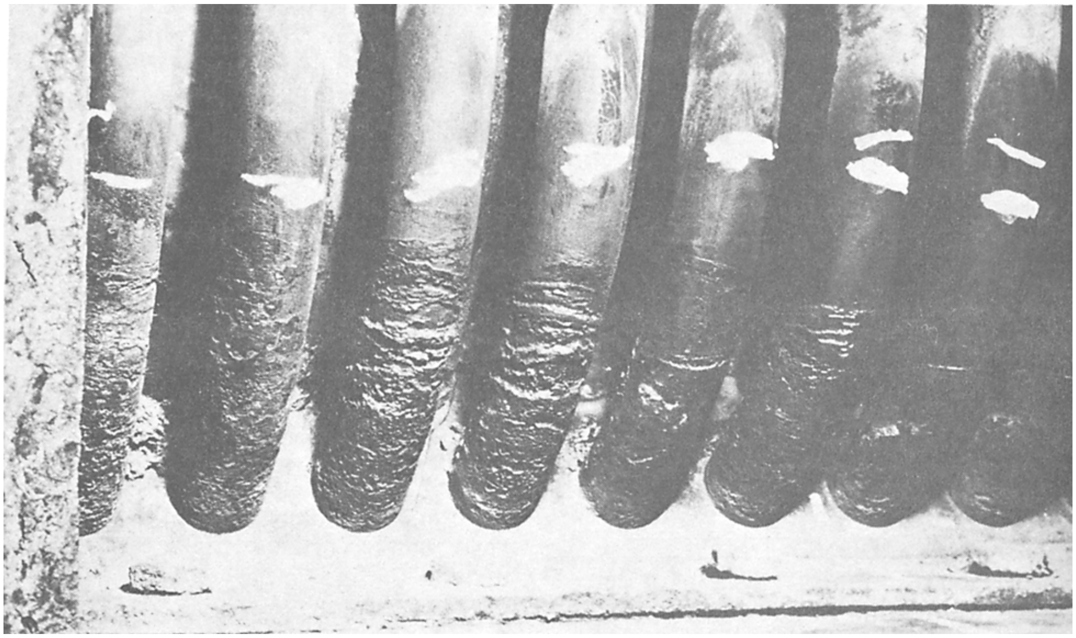

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Figure 12-9.—General fireside circumferential grooving.

down the header and onto the tube ends, or as it drips directly onto the tubes. This kind damage is greater on the top of the tube than on the underside, but the groove may extend the entire circumference.

Fireside circumferential grooving may also occur on vertical generating tubes as a result of thin, damp deposits of soot on horizontal drums or headers. In fact, this kind of grooving can occur in any part of the boiler where leakage provides a sufficient supply of water. Large quantities of water trapped between the water drum and the boiler casing—as, for example, from a serious economizer leak—can produce general fireside grooving around the bottom of the rear generating tubes. An example of this general fireside circumferential grooving is shown in figure 12-9.

CRATERS are deep, irregular, straight-walled cavities in the tube metal. WATER TRACKS are closely related to craters; the tracks consist of wandering, straight-walled, canyon-like cavities in the tube metal. Both cratering and water track-ing occur almost exclusively at the header ends of water wall tubes and division wall tubes that are surrounded by refractory; they are caused by water becoming trapped between the tube metal and the surrounding refractory. Water washing of boiler firesides, without proper drying out, is a frequent cause of cratering and water tracking; of however, any leak higher in the boiler can also cause this type of damage. The size of the leak around and the angle of the tube upon which the water leaks determine, to a large extent, whether the resulting damage will be circumferential groov-ing, cratering, or water tracking. Both cratering and water tracking are shown in figure 12-10. GENERAL FIRESIDE THINNING consists of a uniform loss of metal over a relatively large area on the outside of the tube. Soot corrosion is by far the most common cause of general fireside thinning. The parts that are particularly subject to this kind of damage are superheater

98.138

Figure 12-10.—Fireside catering and water tracking.

tube ends between the headers and the seal plates, water drum ends of generating tubes, and return bends in economizer tubes. General fireside thinning of a generating tube is shown in figure 12-11.

A rather unusual type of general fireside metal loss sometimes results from the combination of extremely high tube temperatures and the burn-ing of fuel oil that contains vanadium compounds. The vanadium compounds carried in the flame can cause rapid oxidation of metal at high temperatures. This type of damage is unusual in water-cooled parts of the boiler, since critical temperatures are not usually attained. Figure 12-12 shows a stainless steel superheater tube that has suffered this type of general thinning as a result of fuel ash damage.

FIRESIDE BURNING occurs when the rate of heat transfer through the tube wall is so reduced that the metal is overheated. Waterside deposits can cause fireside burning, but most serious fireside burning occurs when a tube becomes steam bound or dry. Figure 12-13 shows the coarse, brittle appearance of tube metal that has suffered fireside burning.

STEAM GOUGING occurs when steam jets out of a hole in an adjacent tube. Steam gouging can be identified by the extremely smooth surface of the cavity, together with the irregular shape of the

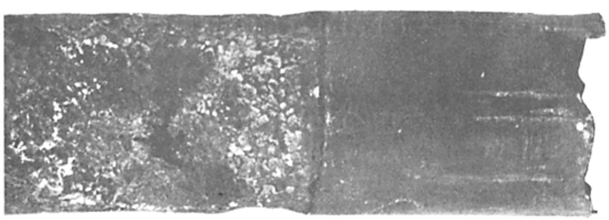

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Figure 12-11.—General fireside thinning of a generating tube.

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Figure 12-12.—General fireside thinning of a stainless steel superheater tube (results of fuel ash damage).

the cavity. As maybe seen in figure 12-14, a steam gouge looks as though the metal has been blasted away and the cavity polished.

TOOL MARKS, such as chisel cuts or hammer scars, can usually be identified without too much trouble. As shown in figure 12-15, tool marks do not resemble corrosion effects in any way.

TUBE DEFORMITIES AND FRACTURES comprise another category of boiler tube damage that covers abnormal bends, blisters, bulges, cracks, warps, sags, and other breaks or distortions. Like the cavities and scars previously discussed, tube deformities and fractures are fairly easy to distinguish by visual observation.

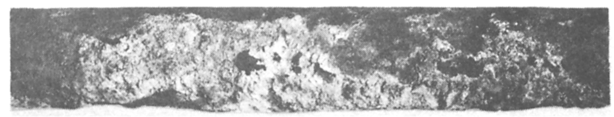

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Figure 12-13.—Fireside burning.

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Figure 12-14.—Fireside steam gauge.

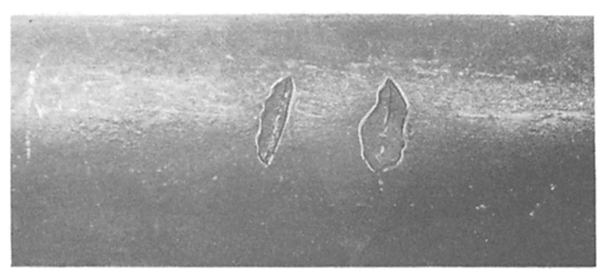

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Figure 12-15.—Fireside tool marks.

The THIN-LIPPED RUPTURE, shown in figure 12-16, is a fairly common tube deformity. The rupture resembles a burst bubble; the open lips are uniformly tapered to sharp, knifelike edges, with no evidence of cracking or irregular tearing of the metal. True thin-lipped ruptures occur in economizer tubes, in generating tubes, and, to a much lesser extent, in superheater tubes. Ruptures of this type indicate that the flow of steam or water was not adequate to absorb the heat to which the tube was exposed; consequently, the tube metal softened and flowed and then burst. Thin-lipped ruptures may be caused by a sudden drop in water level or by tube stoppage from plugs, tools, and so forth, that were accidentally left in the boiler.

Serious THICK-LIPPED RUPTURES resemble the thin-lipped ruptures except that the edges are thick and ragged rather than tapered and knifelike. Thick-lipped ruptures that occur in mild steel generating tubes indicate milder and more prolonged overheating than the overheating that leads to thin-lipped ruptures. Abnormal firing rates, momentary low water, flame impingement, gas laning, and many other causes can produce mild but prolonged overheating that can eventually lead to thick-lipped ruptures. A typical thick-lipped rupture in a generating tube is shown in figure 12-17.

PERFORATION is the term used to de-scribe any opening in a tube (other than a crack) that is NOT associated with tube enlargement. The most common kind of perforation

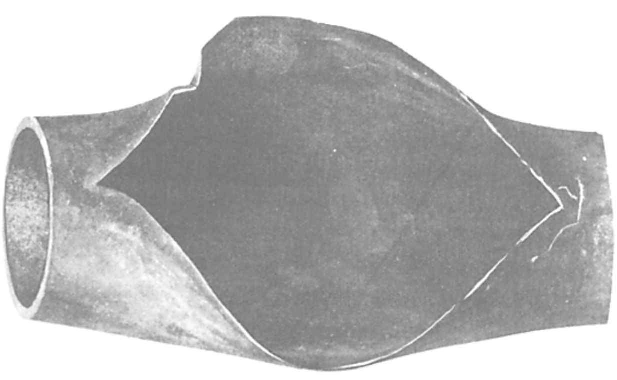

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Figure 12-16.—Thin-lipped rupture in a generating tube

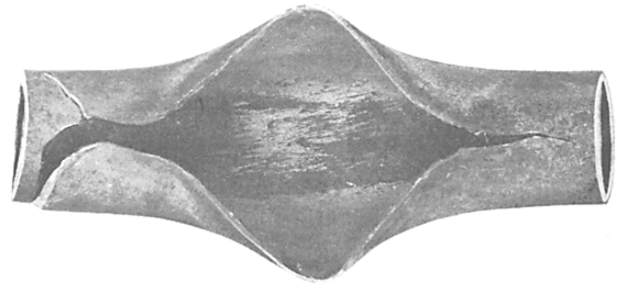

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Figure 12-17.—Thick-lipped rupture in a generating tube.

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Figure 12-18.—Thermal crack in a superheater tube.

is probably the pinhole leak. In many cases, the first evidence of tube failure is a pinhole leak.

THERMAL CRACKS, sometimes called CREEP CRACKS, result from prolonged, mild overheating or repeated short-time over-heating. Cracks of this type are found most often in alloy superheater tubes, but they can occur in mild steel tubes as well. The tube is not usually enlarged when a thermal crack exists; the cracked wall has normal thickness, and the break has a dark crystalline appearance. A typical example is shown in figure 12-18.

TUBE ENLARGEMENT of the type shown in figure 12-19 is relatively common in super-heater tubes but rare in generating tubes. This uniform enlargement of a portion of the tube is caused by milder overheating than that which produces cracks or ruptures. If an enlarged tube is continued in service, it will almost certainly crack or break.

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Figure 12-19.—Enlarged tube.

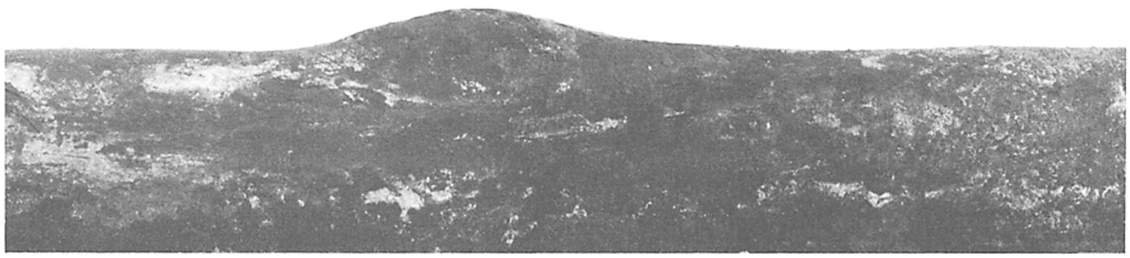

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Figure 12-20.—Heat blister on a fire row tube.

HEAT BLISTERS differ from tube enlargements in that they affect only one side of the tube, usually the side toward the fires. Blisters appear as egg-shaped lumps on the fireside. They indicate that the tube has been heated to the softening point and has blown out under boiler pressure. Heat blisters always indicate the presence of waterside deposits. If the deposit is brittle, as scale or baked sludge, blistering breaks the deposit and allows the boiler water to quench the hot metal before the tube bursts. Heat blisters are most commonly found on the fire row generating tubes; they are rarely found on superheater tubes or economizer tubes. A typical heat blister is shown in figure 12-20.

SAGGING is the term applied to tubes that appear to have dropped downward toward the furnace under their own weight. This type of deformation results from semiplastic flow of the tube metal, caused by extremely mild overheating. A momentary condition of low water is probably the most common cause of sagging. If the boiler has been cooled slowly, and if the distortion is not so severe as to interfere with the designed flow of combustion gases, sagged tubes may still be continued in service.

WARPING is similar to sagging except that the distortion is haphazard rather than in one direction. Warping usually occurs as a result of sudden cooling of the tubes after they have been overheated. Cooling a boiler too rapidly after a low-water casualty is a typical cause of warped tubes.

MELTING can occur as a result of a serious low-water casualty. If the tube temperature becomes high enough, the tube metal actually melts and runs down into the furnace. A cluster of fused tubes that resulted from melting is shown in figure 12-21. Melting of aluminum economizer parts can cause tremendous damage to a boiler. The molten aluminum from overheated economizer parts reacts so violently with the iron oxide coating on the steel tubes below that the heat of the chemical reaction may melt the steel tubes even though the furnace temperature is not high enough to melt them.

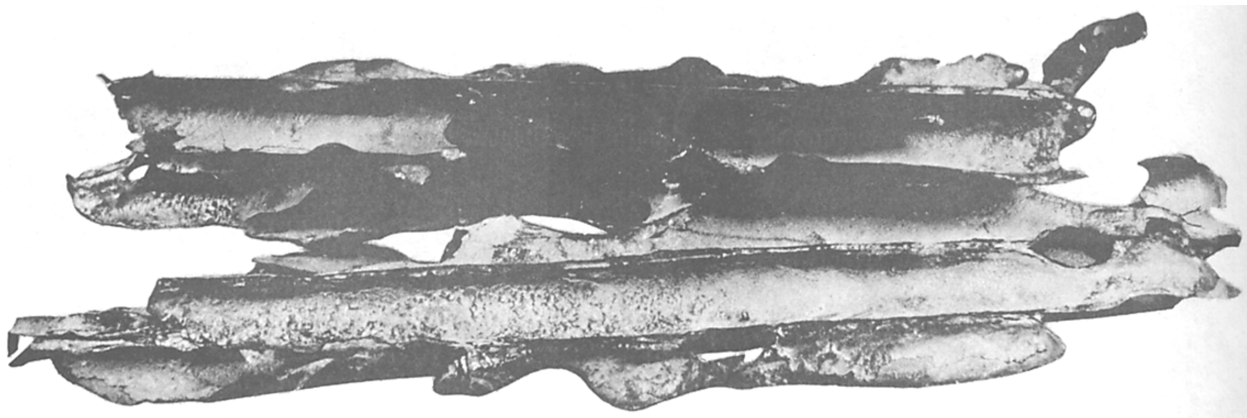

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Figure 12-21.—Melted cluster of tubes.

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Figure 12-22.—Lamination of a tube wall (fabrication detect).

MECHANICAL FATIGUE CRACKS occasionally occur in boiler tubes from such purely mechanical processes as flexing. Cracks of this type can usually be identified by a clean, bright break through a major portion of the metal thickness. These cracks begin on the outside circumference of the tube.

TUBE WALL LAMINATION is shown in figure 12-22. This lamination or layering occurs during the fabrication of the tube. It is the most common material defect found in boiler tubes.

FOLDED or UPSET TUBES are a result of defective fabrication. A folded tube is shown in figure 12-23. This defect resembles a heat blister in appearance, but the folded tube shows no wall thinning and has a depression on the side of the tube opposite the bulge.

STRETCHED or NECKED TUBES are also a result of defective fabrication. A stretched or necked tube is shown in figure 12-24.

FIRESIDE TUBE DEPOSITS can produce many of the scars and deformities just described. Basically, tube deposits cause tube failure because they lead to localized overheating of the tube

98.158

Figure 12-23.—Tube fold (fabrication defect).

98.159

Figure 12-24.—Stretched or necked tube (fabrication defect).

metal. The accurate identification of tube deposits is often a necessary part of determining the cause of tube failure.

FIRESIDE TUBE DEPOSITS include soot, slag, corrosion products, and high-temperature oxide.

SOOT is a broad term used to cover all of the ash products (other than slag) that result from combustion. These ash products include carbon, sand, salts such as sodium sulfate, and other materials. Soot deposits are usually powdery or ashy on the tube surfaces near the top of the boiler; but they tend to be packed solid on drums, headers, and the lower ends of the tubes.

SLAG is not a powdery or packed ashlike soot; rather, it is a saltlike material that is fused to the tube surfaces. Slag is objectionable on boiler tubes because it retards the transfer of heat to the tube metal and because it may cause gas channeling, with consequent local overheating of tube metal that is not covered by the slag. Most slags on boiler tubes are soluble enough to be controlled by periodic washing of firesides. The main way to prevent slag is to avoid burning fuel oil that is contaminated with seawater.

CORROSION DEPOSITS seldom form major fireside deposits. Occasionally, however, bulky deposits of ferrous sulfate may form as the result of the combination of soot and large amounts of water. These deposits have been known to travel away from their original location and adhere to remote rows of generating tubes. The deposits can usually be removed by water washing and mechanical cleaning. The source of the water leakage should be found and corrected. Also, the location of the original deposit should be found, and the area should be carefully inspected for signs of corrosion.

HIGH-TEMPERATURE OXIDE is the term applied to heavy fireside layers of mixed iron oxides formed by overheating of the tube metal. Low water is a frequent cause of high-temperature oxide on the tube firesides. The high-temperature oxide has a rather layered appearance; it resembles corrosion products and is often wrongly called scale.

Exterior Inspection of Drums and Headers

The exteriors of all boiler drums and headers should be inspected for signs of corrosion under the insulation. Rusty streaks or signs of corrosion on or around the edges of the covering, the drum pads, or the tubes indicate possible corrosion of the drum and should be investigated immediately. If machinery or piping is installed over the boiler, water may drip down on the boiler and work its way under the insulation. In such installations, the boiler drum coverings must be removed, and the exterior of the drum must be inspected carefully.

Inspection of Protection, Seal, and Support Plates

All corrosion-resisting steel plates such as baffle plates, seal plates, superheater support plates, steam drum protection plates, and so forth, must be carefully inspected whenever firesides are opened. These steel plates are subject to damage from overheating, particularly if clogged gas passages interfere with the designed flow of combustion gases and allow extremely hot gases to flow over the plates. Since failure of these parts could have extremely serious consequences, the plates should be inspected at every opportunity and should be renewed when necessary.

Inspection of Uptakes and Smoke Pipes

The uptakes and smoke pipes are examined according to a maintenance system. Check the uptake expansion joints to be sure they are not clogged with soot. Look for ruptures and for loose reinforcing ribs or Z-bar stiffeners. Check the rain gutters to see that they are not plugged with soot. Check the top of the economizer to see if it is clean.

OPERATIONAL INSPECTION AND TESTS

Following the hydrostatic test, the boiler should be fired and brought up to operating pressure and temperature. All automatically and manually operated control devices provided for control of steam and water pressure, hot-water temperature, combustion, and boiler water level should be inspected and caused to function under operating conditions. All associated valves and piping, pressure- and temperature-indicating devices, metering and recording devices, and all boiler auxiliaries should be inspected under operating conditions. All safety valves and water-pressure relief valves should be made to function from overpressure.

Inspections and tests may be made with the main steam or hot-water distribution valves closed or open as necessary to fire the boiler and operate it under normal operating conditions. Testing the function of automatically or manually controlled devices and apparatus that may interfere with distribution requirements should be one with main steam or hot-water distribution valves closed, as applicable.

The purpose of these inspections and tests is to discover any inefficient operation or maintenance of the boiler or its auxiliaries that may be evidenced under operating conditions. All deficiencies requiring adjustment, repair, or replacement, and all conditions indicating excessive operating costs and maintenance costs should be reported.

Firing Equipment

The operation of all firing equipment, including oil burners, gas burners, fuel injectors, fuel igniters, coal stokers and feeders, and other such equipment provided to introduce fuel into the boiler furnace and ignite the fuel, should be inspected for any deficiency that may be evidenced under operating conditions. In particular, igniters and burners should be checked to ensure that burner protrusion, angle, setting, and so forth, is such that light off and operation are as effective as possible.

Controls

Inspect the operation of combustion controls, steam pressure controls, water temperature controls, and feedwater controls. Assure that the ability of the combustion control and steam pressure control to maintain proper steam pressure (or water temperature in high-temperature water installations) and air-fuel ratio is demonstrated throughout the capacity range of the boiler. Air-fuel ratio should be checked by CO_2 or O_2 measuring devices. On smaller boilers the appearance of the fire may be used as a guide for inspection of air-fuel ratio. Check fully automatic boiler controls for proper programming sequence and timing with respect to prepurge, ignition, pilot proving, flame proving, and postpurge periods, Check the operation of flame failure and combustion air failure devices to assure that they properly shutoff the supply of fuel; do this by simulating a flame failure (manually shutting off the fuel or by other means) and observing the operating of the controls, solenoid valves, and diaphragm-operated valves that are to operate during a flame failure. Inspect feedwater controls and check the ability of the controls to maintain proper water level throughout the range of capacity with first load swings. Check the operation of low-water fuel cutoff and automatic water-feeding devices by draining the float bowl, lowering the boiler water level, or by performing other necessary steps to cause these devices to function, to assure they operate properly. The low-flow cutout on high-temperature water boilers should be tested by reducing the flow until cutout occurs. For additional information on the inspection of the operating conditions of the controls, refer to the section of this RTM that deals with WATER COLUMNS AND GAUGE GLASSES.

Steam and Water Piping

While the boiler is operating, examine all steam and water piping—including connections to the columns—for leaks. If any leaks are found, determine if they are the result of excessive strains caused by expansion and contraction or other causes. Listen for water hammer; if found, determine the cause. Look for undue vibration, particularly in piping connections to the boiler. Where excessive vibration of piping is found, examine connections and parts for crystallization.

Water Columns and Gauge Glasses

With steam on the boiler, blow down the water columns and gauge glasses and observe the action of the water in the glass to determine if the connection to the boiler or the blowoff piping is restricted or not properly free. This will help you determine the true condition of high- and low-water alarms and of the automatic combustion equipment.

Devices

While the boiler is operating, cause the individual mechanisms of LOW-WATER FUEL CUTOFF and/or WATER-FEEDING DEVICES to operate to assure they function properly.

Where a float-operated, low-water cutoff or water-feeding device or a combination low-water fuel cutoff and water-feeding device is provided, its operation should be tested by opening the drain to the float bowl and draining the bowl to the low-water level of the boiler. When the low-water point is reached, the mechanism of the low-water fuel cutoff should function and shut off the fuel supply to the boiler until boiler water is added to the proper level. Also, at the low-water point, the mechanism controlling the feedwater supply should function to start the feedwater.

Where there is a low-water fuel cutoff device controlled by excess temperature generated in a temperature element located inside the boiler, its operation may be tested by blowing off the boiler to its allowable low-water level. On or before the low-water level is reached, the device should function to shut off the boiler fuel supply until boiler water is added to the proper level.

On high-temperature water boilers, the flow through the boiler should be restricted to the minimum allowed, as shown by the manufacturer's operating data. The point at which fuel cutoff takes place should be noted and adjustments made as required.

With steam on the boiler, observe the STEAM GAUGE pointer for sticking or restriction of its movement. Blow down the pipe leading to the gauge to assure that it is free. Attach an approved test gauge to the pipe nipple provided for this purpose, and compare the accuracy of each steam gauge on the boiler with that of the test gauge. When inaccuracy of any gauge is evidenced or suspected, it should be removed and calibrated by means of a deadweight gauge tester or other device designed for this purpose. When several boilers are in service and connected to a common steam main, compare the readings of the separate gauges. All TEMPERATURE-INDICATING DEVICES should be observed for indications of excessive temperature, particularly during and immediately after the time high-load demands are made on the boiler. While the boiler is operating under normal conditions, observe the operation of all METERING AND RECORDING DEVICES. When there is evidence that any such device is not functioning properly, it should be adjusted, repaired, or replaced as necessary.

Blowoff Valves

Test the freedom of each blowoff valve and its connections by opening the valve and blowing off the boiler for a few seconds. Determine if the valve is excessively worn or otherwise defective, and if there is evidence of restrictions in the valve or connected piping preventing proper blowoff of the boiler.

Stop and Check Valves

While the boiler is operating, inspect the operating condition of each stop and check valve where possible. Serious defects of externally controlled stop valves may be detected by operating the valve when it is under pressure. Similarly, defects in check valves maybe detected by listening to the operation of the valve or observing any excessive vibration of the valve as it operates under pressure.

Pressure-Reducing Valves

While there is pressure on the system, open and then close the bypass valve as safety and operating conditions permit. Also, observe the fluctuation of the pressure gauge pointer as an aid in determining possible defects in the operation of the pressure-reducing valve or the pressure gauge. Look for any evidence that may indicate improper condition of the relief or safety valves provided for the pressure-reducing valves.

Boiler Safety and Water-Pressure Relief Valves

Test the blowoff setting of each safety valve for steam boilers and each water-pressure relief valve for hot-water boilers by raising the boiler pressure slowly to the blowoff point. In turn, test the releasing pressure of each valve, gagging all other safety or relief valves except the one being tested. Observe the operation of each valve as blowoff pressure is reached. Compare the blowoff setting with setting requirements specified in paragraph 1 or 2 of this section, as applicable, and make adjustments where necessary. When the steam discharge capacity of a safety valve is questionable, it should be tested by one of the methods given in paragraph 3 of this section. When the pressure-relieving capacity of a pressure-relief valve is questionable, it should be tested according to the procedures given in paragraph 4 of this section.

1. SAFETY VALVES—SETTING REQUIREMENTS. Note this word of caution: Before adjusting safety valves on electric steam generators, be sure that the electric power circuit to the generator is open. The generator may be under steam pressure, but the power line should be open while the necessary adjustments are being made. At least one safety valve should be set to release at no more than the maximum allowable working pressure of the steam boiler. Safety valves are factory set and sealed. When a safety valve requires adjustment, the seal should be broken, adjustments made, and the valve resealed by qualified personnel only. When more than one safety valve is provided, the remaining valve or valves may be set within a range of 3% above the maximum allowable working pressure. However, the range of the setting of all the safety valves on the boiler should not exceed 10% of the highest pressure to which any valve is set. Each safety valve should reseat tightly with a blowdown of not more than 2 psig or 4% of the valve setting, whichever is greater.

In those cases where the boiler is supplied with feedwater directly from the pressure main without the use of feeding apparatus (not including return traps), no safety valve should be set at a pressure greater than 94% of the lowest pressure obtained in the supply main feeding the boiler.

2. PRESSURE-RELIEF VALVE—SETTING REQUIREMENTS. At least one pressure-relief valve should be set to release at not more than the maximum allowable working pressure of the hot-water boiler. When more than one relief valve is provided on either hot-water heating or hot-water supply boilers, the additional valve (or valves) may be set within a range not to exceed 20% of the lowest pressure to which any valve is set. Each pressure-relief valve should reseat tightly with a blowdown of not more than 25% of the valve setting.

3. SAFETY VALVE—CAPACITY TEST. When the relieving capacity of any safety valve for steam boilers is questioned, it may be tested by one of the three following methods:

a. By the accumulation test, which consists of shutting off all other steam-discharge outlets from the boiler and forcing the fires to the maximum. The safety valve capacity should be sufficient to prevent a pressure in excess of 6% above the maximum allowable working pressure.

This method should not be used on a boiler with a superheater or reheater.

b. By measuring the maximum amount of fuel that can be burned and computing the corresponding evaporative capacity (steam-generating capacity) upon the basis of the heating value of this fuel. These computations should be made as outlined in the code.

c. By determining the maximum evaporative capacity by measuring the feedwater.

When either of the methods outlined in (b) or (c) above is employed, the sum of the safety valve capacity should be equal to, or greater than, the maximum evaporative capacity (maximum steam-generating capacity) of the boiler.

If you discover that the relieving capacity is inadequate because of deficiencies in the valve, the valve should be repaired or replaced. If the relieving capacity of the valve is found to be satisfactory within the proper relieving range of the valve but inefficient for the steam-generating capacity of the boiler, additional safety valve capacity should be provided.

4. PRESSURE-RELIEF VALVE—CAPACITY TEST. When the relieving capacity of any pressure-relief valve for hot-water boilers is questioned, the capacity can be tested by turning the adjustment screw until the pressure-relief valve is adjusted to the fully open position. The pressure should not rise excessively. When the test is completed, reset the pressure-relief valve to the required setting. This test is made with all water discharge openings closed except the pressure-relief valve being tested. When the discharge is led through a pipe, determine at the time the valve is operating if the drain opening in the discharge pipe is not properly free, or if there is evidence of obstruction elsewhere inside the pipe. If deemed necessary to determine the freedom of discharge from the valve, the discharge connection should be removed. After completing tests and adjustments, the inspector should seal the safety adjustment to prevent tampering.

Boiler Auxiliaries

While the boiler is operating under normal conditions, observe the operation of all boiler auxiliaries for any defects that may prevent proper functioning of the boiler or indicate a lack of proper maintenance of auxiliary equipment. The unnecessary use of multiple auxiliaries or the use of a large auxiliary during a light-load period (when a smaller auxiliary could be substituted) should be discouraged. The maximum use of steam-driven auxiliaries short of atmospheric exhaust should be encouraged. Steam leaks, wastage to atmosphere, and so forth, should be called to the attention of operating personnel. Particular attention should be given to deaerator venting practice. Venting should be held to the minimum required to preclude oxygen entrainment in the feedwater.

When intermittently operating condensate pumps are used, look for any tendency toward creation of a vacuum when a pump starts. If this happens, recommend installation of a small, continuously operating, float-throttled, condensate pump (in parallel with intermittently operating pumps) to assure a condensate flow at all times. If there are a number of intermittently operating condensate pumps, it may be possible to convert one of them (if of small enough capacity) to continuous throttled operation.

PLANT OPERATION

To operate boilers or be a plant supervisor, you need to know all the mechanical details of the boiler you are operating and its associated auxiliaries. However, just knowing this information is not enough. To be a professional boiler operator or plant supervisor, you must develop a keen eye for trouble, a finely tuned ear, and an overall sense of awareness concerning boiler plant operation at all times.

As an operator and/or supervisor of a boiler plant, you must learn to tell the difference between normal and abnormal operating conditions. By training yourself to notice and analyze strange noises, unusual vibrations, abnormal temperatures and pressures, and other indications of trouble, you will be better able to prevent any impending trouble or casualty to the plant.

OPERATORS

Boiler plant operators must maintain accurate records. Logs provide a means of recording continuous data on boiler plant performance and analysis of operation. Logs are arranged for use over a 24-hour period, consisting of three 8-hour shifts. Log entries should be carefully made in columns.

Logs

Information of importance in the operation of boilers must be recorded. This section provides information concerning the type of data that should be recorded in logs.

1. Steam pressures. Steam pressure is recorded by the operator from steam gauges and shows performance of automatic or 'manual control.

2. Steam flow. Actual output of the plant is recorded by the operator in pounds per hour to obtain steam flow. This record determines the number of boilers to operate for greatest efficiency.

3. Feedwater heater. Feedwater-heater pressure indicates whether 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.

4. Feed-pump pressure. Feed-pump pressure indicates effectiveness of the boiler feed pumps. If feedwater supply fails, the pressure reading enables the operator to determine whether or not the difficulty is in the feed pumps. The pumps are defective when the feed-pump pressure reading is below normal.

5. Forced draft. Forced draft is an indication of thickness of the fuel bed. The most satisfactory value varies with different installations and fuels and is determined by actual trial.

6. Furnace draft. Furnace draft, when used in connection with forced draft, should be slightly less than atmospheric pressure to prevent smoke from leaking into the boiler room and overheating the furnace lining. If only an induced or natural draft is used, furnace draft must be sufficient to cause the quantity of air required for combustion to flow into the furnace. Operating with a furnace draft higher than actually required results in excessive air leakage into the setting with an accompanying loss in efficiency.

7. Last-pass draft. Last-pass draft shows actual draft produced by a stack or an induced-draft fan. Fireman should become familiar with last-pass draft at various ratings when the boiler is operating satisfactorily. A decrease in last-pass draft with other conditions constant indicates leaking baffles. An increase in last-pass draft shows that gas passes are becoming clogged.

8. Percent CO_2 flue gas. Percent CO_2 flue gas 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, rating, and like factors. In plants not equipped with CO_2 recording meters, this value is determined with a hand gas analyzer. With experience, you can determine the correct amount of air supplied for a furnace by checking the draft gauges and from personal observation. In all cases, you should check values by use of a hand gas analyzer.

9. Flue-gas temperature. Flue-gas temperature is an indication "of the portion of heat "leaving the boiler with the flue gases. This heat represents a direct energy loss in fuel. Abnormally high flue-gas temperatures at a given boiler rating are caused by dirty heating surfaces or leakage of baffles. If the heating surface has a coating of soot and ash, heat that cannot escape is discharged to the stack. Leakage through baffles allows the gases to take a shorter path than intended and reduces contact of gases with the entire heating surface. Excessive fouling of the boiler's firesides increases the draft loss while leaking baffles decreases the draft loss. Either condition raises the temperature of flue gases above normal.

10. Fuel. Always determine the quality of fuel being used as this represents a major operating cost.

a. Pounds of coal. Procedures for determining the quantity of coal burned depends upon the means available. You may use scales that automatically dump weighed quantities of coal into the stoker or pulverizer hoppers. A register indicates the number of "dumps" that, multiplied by the weight of coal discharged per dump, gives the total. Another weighing method uses traveling larries equipped with scales so that the weight of each load can be recorded before it is dumped into the boiler hopper. In the absence of a weighing device, the quantity of coal consumed can be determined by filling and leveling bunkers at given intervals and recording the coal used from the report of coal received during a given interval. Methods for approximating coal burned by counting stoker revolutions are only estimates and are subject to considerable error when the size of coal changes.

b. Cubic feet of gas. The quantity of gas used is indicated on a meter. The readings can be direct or they may necessitate calculation by use of a meter factor.

c. Gallons of oil. Fuel oil quantities are determined by use of a measuring stick. Tables supplied with a given tank are then used to determine quantity from level of fuel. Tanks may also be supplied with gauges that can be read directly.

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

12. Makeup water. The quantity of makeup water used should be recorded. This enables the operator to note an abnormal increase in makeup water before a dangerous condition develops. Return all possible condensate to the boiler plant; this will save on water and chemicals being used to treat the water.

13. Water Pressure. Feedwater is most important to the safe operation of the boiler plant. The hot-water supply temperature should be recorded. Insufficiently heated water can cause scaling or deposits in a boiler.

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

15. Water softeners. Where softeners are employed, you should keep a meter record to inform the shift operator of the time when the units must be regenerated. A decrease in the time of runs between regeneration is an indicator of either an increase in hardness of incoming water or of deterioration of the softening material. The note columns are for recording total water softened and pounds of salt added.

16. Totals and averages. Space is provided for recording total and average quantities per shift.

17. Steam flow. To find the quantity of steam generated, subtract the steam flowmeter integrator reading at the start of shift from the reading at the end of the shift, then multiply the remainder by the meter constant. Dividing steam generated by fuel burned (pounds of coal, cubic feet of gas, or gallons of oil) yields a quantity that indicates the overall economy obtained. If the plant does not have a steam flowmeter, pumps can be calibrated for flow and a record kept of their operating time, or the condensate and makeup water can be metered.

18. Boiler feed pump in service. A record of the boiler feed pump in service makes it possible to determine appropriate operating hours and to see that the various pumps are used for equal lengths of service.

19. Soot blown time and blowdown. A record of blown time and blowdown is valuable to the relieving shift operator because it is an indicator of plant conditions, and it will show irregularities if any exist.

20. Phosphate, caustic soda, and tannin added. A record of phosphate, caustic soda, and tannin used is valuable in keeping correct boiler water analysis and in determining the total amount of chemicals used.

21. Remarks. The remarks column is in the upper right area of the log sheet. List all the equipment that is to be checked each day according to the schedule listed in TM 5-651. Annotate all the irregularities that are found in connection with these inspections. List the dates when the boilers are drained and washed and at other intervals, as determined by local water conditions. Indicate the degree of internal cleanliness.

22. Using personnel. Names of personnel responsible for these data must be entered in the appropriate area on the bottom of the log sheet.

Turnover/Watch Relief

When an operator comes on duty, he should make an operational inspection to ensure that everything is operating normally. The points to be checked are as follows:

1. Check the water level in the gauge glass on each boiler by opening and closing the try cocks.
2. Check the low-water cutoffs and the boiler feed equipment by blowing down the water columns on each boiler.
3. Check the steam pressure and compare it with the steam pressure that the plant should deliver.
4. Check the boilers for leaks or other conditions that can affect plant operation.
5. Check for proper operation of the boiler room accessories.
6. Check the fuel supply and the firing equipment.
7. Check the condition of the fires to determine if they are clean.
8. Check the general appearance of the boiler room, fixtures, piping, and insulation.
9. Check the boiler room record sheets to determine if any troubles were encountered by the previous shift operator.
10. Question the operator being relieved about plant operation and the troubles encountered.
11. Check for any verbal or written orders with which you are to comply.

Table 12-2.—Effects of Inadequate or Improper Water Conditioning

EFFECT	CONSTITUENT	REMARKS
Scale........	Silica..........	Forms a hard, glassy coating on internal surfaces of boiler. Vaporizes in high-pressure boilers and deposits on turbine blades.
	Hardness......	$CaSO_4$, $MgSO_3$, $CaCO_3$ and $MgCO_3$ form scale on boiler tubes.
Corrosion.	Oxygen........	Causes pitting of metal in boilers, and steam and condensate piping.
	Carbon dioxide........	Major causes of deterioration of condensate return lines.
	O_2 - CO_2......	Combination is more corrosive than either by itself.
Carryover.	High boiler water concentrations.	Causes foaming and priming of boiler and carryover in steam, resulting in deposits on turbine blades and valve seats.
Caustic embrittlement.	High caustic concentration.	Causes intercrystalline cracking of boiler metal.
Economic losses.	Repair of boilers.	Repair pitted boilers and clean heavily scaled boilers.
	Outages.......	Reduce efficiency and capacity of plant.
	Reduced heat transfer.	High fuel bills.

PLANT SUPERVISOR

As a boiler plant supervisor, you are expected to organize and manage the overall operation of the boiler. Ensuring that daily logs are maintained by operators, submitting monthly operation reports and logs, checking maintenance requirements, training personnel, and so forth, are included in your duties and responsibilities. Each boiler plant has its unique requirements. Only through operating your specific plant and completely familiarizing yourself with it can you establish a comprehensive management program.

This chapter cannot cover all the aspects of supervising a boiler plant. You must refer to current Navy publications and manufacturer's manuals that pertain to your specific plant. When assigned as a boiler plant supervisor, -establish an on-site library of these publications and manuals, and keep them handy for immediate reference.

WATER CHEMISTRY

The effects of inadequate or improper water conditioning can cause major problems in the operation of boilers. Manufacturer's specifications must be strictly adhered to. Table 12-2 outlines the effects and results of poor water treatment of boiler water. By establishing an aggressive water-treatment program, you can greatly reduce inefficient boiler operation and high maintenance costs.

CHEMICAL MAKEUP OF WATER

Water is called the *universal solvent.* The purer the water, that is, the lower its dissolved solids content, the greater the tendency to dissolve its surroundings. Pure water, if stored in a stainless steel tank after a short contact time, has a very small amount of iron, chromium, and nickel from the tank dissolved in it. This dissolving of the tank does not continue indefinitely with the same water. The water, in a sense, has satisfied its appetite in a short time and does not dissolve any more metal. Pure water, if exposed to air, immediately absorbs air and has oxygen from the air dissolved in it. A glass of tap water at 68°F contains 9.0 ppm of oxygen. Tap water heated to 77°F contains 8.2 ppm of oxygen, and some oxygen is driven out of the water. The higher the temperature of the water, the less dissolved oxygen it can hold. Conversely, the higher the pressure imposed on the water, the greater the dissolved oxygen it can hold. Water, when boiled, produces steam. The steam contains some liquid water. There is never a perfect separation of pure steam from the boiling water. The steam above the boiling water always has entrained with it some boiling water. The foregoing three ideas: water is a universal solvent, water dissolves oxygen when in contact with air, and boiling water is always entrained with steam should help you understand the nature of feedwater.

The feedwater, as it enters the boiler steam drum, is now considered boiler water. Complete understanding of the nature of boiler water can be gained by temporarily making the assumption that no water treatment, chemical addition, or blowdown is applied to the boiler water. The character of the boiler water continually changes as the boiler steams. The dissolved and suspended solids, contained in the feedwater, concentrate in the boiler water at the rate of eightfold every hour if the boiler is producing steam at 50 percent of its normal capacity. Three damaging conditions arise in the boiler as the boiler water continues to steam wit bout treatment. *Scale formation* on the steam generating surfaces, *corrosion* of the boiler metal, and boiler water *carry-over* with the steam due to foaming are the three results of untreated boiler water.

To prevent scale formation on the internal water-contacted surfaces of a boiler and to prevent destruction of the boiler metal by corrosion, you must chemically treat feedwater and boiler water. This chemical treatment prolongs the useful life of the boiler and results in appreciable savings in fuel since maximum heat transfer is possible when no scale deposits occur.

CHEMICAL TREATMENT (EXTERNAL AND INTERNAL)

The method of using chemicals may take the form of external treatment, internal treatment, or a combination of both. The principal difference between these forms of treatment is that in external treatment the raw water is changed or adjusted by chemical treatment outside of the boiler so a different type of feedwater is formed. In internal treatment, the water is treated inside the boiler by feeding chemicals into the boiler water, usually through the feed lines. Again, in external treatment the main chemical action takes place outside the boiler, while in internal treatment the chemical action takes place within the boiler.

INTERNAL TREATMENT AND PREVENTION

At many Navy installations, the boilers are not large and do not operate at high pressure. When the makeup water is not too high in hardness or dissolved solids, good operation is possible with only internal treatment. Under this condition, external treating equipment is unnecessary. Chemical treatment covered in this chapter applies primarily to internal treatment.

Scale

When water evaporates in a boiler, the hard components that were in the water, such as calcium salts, magnesium salts, and other insoluble materials, form deposits on the tubes and other internal surfaces. These deposits are known as scale. Actually, the temperature of the water determines how well the different salts dissolve and how long they remain dissolved. Some salts are such that the hotter the water, the better they stay dissolved. Other salts stay dissolved while the water is at a relatively low temperature but form

Table 12-3.—Chemicals Used by NAVFAC for Internal Boiler Water Treatment in Shore-Based Boilers

CHEMICAL	PURPOSE	COMMENT
Sodium hydroxide NaOH (caustic soda).	increase alkalinity, raise pH, precipitate calcium sulfate as the carbonate.	Contains no carbonate, therefore doesn't promote CO_2 formation in steam.
Sodium carbonate Na_2CO_3 (Soda ash)	Increase alkalinity, raise pH, precipitate magnesium.	Lower cost, more easily handled than caustic soda. But some carbonate breaks down to release CO_2 with steam.
Soduim phosphates NaH_2PO_4, $NaHPO_4$, Na_3PO_4, $NaPO_3$.	Precipitate calcium as hydroxyapatite ($Ca_{10}(OH)_2(PO_4)_6$).	Alkalinity and resulting pH must be kept high enough for this reaction to take place (pH usually above 10.8).
Sodium aluminate $NaA1_2O_4$.	Precipitate calcium, magnesuim	Forms a flocculent sludge.
Soduim sulfite Na_2SO_3	Prevent oxygen corrosion.	Used to neutralize residual oxygen by forming sodium sulfate. At high temperatures and pressures, excess may form H_2S in steam.
Hydrazine hydrate $N_2H_4.H_2O$ (35%).	Prevent oxygen corrosion.	Remove residual oxygen to form nitrogen and water. One part of oxygen reacts with three parts of hydrazine (35% solution).
Filming amines; Octadecylamine, etc.	Control return-line corrosion by forming a protective film on the metal surfaces.	Protects against both oxygen and carbon dioxide attack. Small amounts of continuous feed will maintain the film. Do not use where steam contacts foods.
Neutral amines; morpholine, cyclo-hexylamine, ben-zylamine.	Control return-line corrosion by neutralizing CO_2 and adjusting pH of condensate.	About 2 ppm of amine is needed for each ppm of carbon dioxide in steam. Keep pH in range of 7.0 to 7.4 or higher.
Sodium nitrate $NaNO_3$	Inhibit caustic embrittle-merit	Used where the water may have embrittling characteristics.
Tannins, starches, glucose and lignin derivatives.	Prevent feed line deposits coat scale crystals to produce fluid sludge that won't adhere as readily to boiler heating surfaces.	These organics, often called protective colloids, are used with soda ash, phosphate. Also distort scale crystal growth, help inhibit caustic embrittlement.

Table 12-3.—Chemicals Used by NAVFAC for Internal Boiler Water Treatment in Shore-Based Boilers—Continued

CHEMICAL	PURPOSE	COMMENT
Seaweed derivatives; (Sodium alginate, Sodium mannuronate).	Provide a more fluid sludge and minimize carryover.	Organics often classed as reactive colloids since they react with calcium and magnesium and absorb scale crystals.
Antifoams; (polyamides, etc.).	Reduce foaming tendency of highly concentrated boiler water.	Usually added with other chemicals for scale control and sludge dispersion.
Proprietary compounds (of ball or brick type).	Do not use for water treatment	Boilers 125 psig and above, all power plant boilers, all boilers using intermittent blowdown.
	May be used for water treatment	Low makeup boilers (under 125 psig) for space heating.
		High makeup boilers (under 125 psig) with continuous blowdown and stable feedwater, if cost saving is effected.

solid crystals (scales) that come out in increasing amounts as the water gets closer to becoming steam.

The scale-forming salts stay dissolved in the water and in the cooler parts of the boiler, but when the water reaches the hot tubes, these salts start forming solid particles that come out of the water and stick to the hot metal parts as scale deposits. These deposits are highly objectionable because they are poor conductors of heat, actually reduce efficiency, and are frequently responsible for tube failures. Some of the principal scale-forming salts to be considered in most cases are listed as follows:

Calcium sulfate	$CaSO_4$
Calcium silicate	$CaSiO_3$
Magnesium silicate	$MgSiO_3$
Calcium hydroxide	$Ca(OH)_2$
Calcium carbonate	$CaCO_3$
Magnesium hydroxide	$Mg(OH)_2$

Scale is made up of three main parts: calcium sulfate, calcium carbonate, and silicates of calcium and magnesium. Scales that are principally calcium sulfate or chiefly of the aforementioned silicates are very hard; those scales that are principally calcium carbonate with little silicate are somewhat softer. A scale consisting chiefly of calcium carbonate may appear only as a thin, porous, soft scale that does not build up in thickness.

Scale can be prevented by the intelligent use of proper water treatment, and that is one of the objectives of the boiler water test and treatment program.

Prevention and Treatment for Scale Control

Scale-forming substances cannot always be prevented from entering the boiler, but they can be made to form a fluid sludge. The problem then is simply one of proper chemical treatment and blowdown.

The selection of chemicals for internal treatment is determined by many factors: the kind of feedwater hardness (whether carbonate or sulfate); the ability of feedwater to build up required causticity; the type of external treatment, if used; the pH and percentage of condensate returns; the location of chemical feed injection; and the cost and availability of chemicals.

The first two chemicals to be considered for boiler water treatment of shore-based boilers are caustic soda and sodium phosphate (table 12-3).

The caustic soda prepares the way by making the water definitely alkaline (high pH). The sodium phosphate can then attack the calcium magnesium and silica salts and convert them into a fluid sludge that can be removed by blowdown.

Caustic soda is used when the feedwater cannot build up the required causticity residual in the boiler water. Use of soda ash (Na_2CO_3) <u>is not authorized</u> in steaming boilers because it breaks down under heat to form undesired carbon dioxide (CO_2). This gas is corrosive to condensate return lines. The Navy boiler compound customarily used aboard ship <u>is not authorized</u> because it contains about 39% soda ash.

Sodium phosphate ($NaPO_4$) has a special affinity (attraction) for calcium, and in boiler water the phosphate joins with calcium to precipitate calcium phosphate ($CaPO_4$).

Phosphate prevents the formation of calcium scales, such as calcium sulfate, calcium carbonate, or calcium silicate. The precipitate of calcium phosphate develops as a finely divided fluid material that can readily be removed by blowdown. The sodium phosphate dosage should be regulated to maintain a residual reading of 30 ppm to 60 ppm.

Sludge

Another source of tube coating is BAKED SLUDGE. This sludge comes from dirt, oil, water-treatment chemicals, and so forth, that are suspended in dirty feedwater. The solids settle on tube surfaces and absorb the heat intended to be transferred to the water. The heat then cooks the sludge into a hard coating on the tube walls. These deposits are as hard or harder to remove than TRUE SCALE and should be recognized as a completely different problem. Methods of preventing and combating baked sludge are different from methods of preventing and combating scale.

Baked sludge is very hard to remove by mechanical means, and boiler compound has no effect on it at all. The best method found to combat sludge is to know where it comes from, make it gather by proper treatment, and blow it out before it cooks.

Prevention and Treatment for Sludge Control

When the proper causticity residual is maintained and phosphate is fed in correct amounts, the scale-forming impurities in boiler water sludges out and should be easy to blow out. Sometimes, however, the characteristics of the precipitated chemicals are such that the sludge formed does not go along with the water and leave the boiler with the blowdown. It has been discovered that additives called sludge conditioners cause the sludge to flow better. Most sludge conditioners are organic substances that act as dispersants. They keep the sludge in a fluid state by holding the precipitates as finely divided particles. As the precipitated chemicals settle, a loose fluid mass that is easy to blow out is formed. The only sludge dispersant approved by NAVFAC for use in shore-based boilers is QUEBRACHO TANNIN.

Generally, when quebracho tannin is used, sufficient quantities are fed to the boiler to give the boiler water a medium tea color. [f the causticity residual is high, a darker color should be maintained. This darker color for high causticity aids in preventing hardening of metal in the boiler. As the tannin particles become part of the sludge and are blown out, the brown color, given to the water by the initial dose of tannin, becomes a lighter color, and more tannin must be added.

Proper blowdown is important because some sludges are almost always in the boiler water. When only parts of the boiler are badly sludged, blowdown may not be complete or there are areas of poor circulation. The boiler design may be such that even good blowdowm does not clear all the parts. Another concern is that frequency, time, and the kind of blowdown being used may not be complete or correct to maintain optimum conditions.

A small amount of seawater in the feedwater causes heavy sludging. Where seawater is likely to contaminate feedwater or where evaporated seawater is used for feedwater, every precaution should be taken to prevent saltwater contamination of the feedwater. Regular daily boiler water tests will show up contaminated feedwater so that it car be corrected before serious harm is done.

Where makeup water is clean and not much sludge shows at bottom blowdown, tannin may not be necessary. Where there is a lot of sludge, the addition of tannin is a big help in keeping the boiler free and clean. Also, much less sludge-forming materials are required when the raw water makeup is upgraded by external treatment.

Corrosion

Corrosion is the deterioration of metal by Chemical action. When dissolved oxygen is present in the boiler water, corrosion begins and continues until all metal has been transformed into iron oxide or, commonly stated, rust. When rust forms in the boiler, it may drop out as sludge or cling to other metal surfaces. It is not economically possible to prevent at least some of the iron in the boiler from going into solution. All iron not protected by a coating or film of something that keeps out moisture and air is sooner or later going to become RUST. The idea is to slow down the process as much as possible by KEEPING OXYGEN OUT and by maintaining a proper causticity residual.

The pH level of boiler water is also a factor in corrosion. The active agent in the corrosion of the internal water surface of boilers is oxygen; however, the combined action of oxygen and the acid action of the water are required for the corrosion process. To suppress the acid action of the water, you can raise the pH value of the water by adding caustic soda. The lower the pH value, the stronger the acid concentration. The higher the pH value, the weaker the concentration. Economically, acid corrosion cannot be stopped completely, but it can be suppressed by keeping oxygen out of the boiler and by maintaining a proper pH value and causticity range.

Prevention and Treatment for Oxygen Corrosion

The chemical most commonly used in oxygen removal is sodium sulfite, and it is quite often referred to as an oxygen scavenger. It is an example of a chemical that actually reacts with the harmful constituent. It reacts with oxygen, forming a neutral compound—sodium sulfate.

When enough sodium sulfite is fed into a boiler so that a surplus of the chemical is maintained, any of the oxygen getting into the boiler water is taken up by the chemical, and the boiler water is kept virtually free of oxygen. By maintaining a suitable residual, little, if any, corrosion due to oxygen occurs. Common practice in feeding sodium sulfite is to maintain a surplus residual of about 20 ppm to 50 ppm in the boiler water. This is generally enough sodium sulfite to react with normal amounts of oxygen that might get into the boiler. Higher concentrations of sodium sulfite are unnecessary.

Sodium sulfite dissolves readily in water and must be fed at a point between the feed heater and the boiler so that it is used to take up only the oxygen that gets by the deaerator or heater. If the sodium sulfite is fed through the feed lines by continuous feeding, it is always present in the feed lines and takes up oxygen in the feedwater in addition to maintaining a surplus in the boilers.

Another advantage of using sodium sulfite is that if, for any reason, a feedwater heater or deaerator becomes inoperative or efficient operation is temporarily interrupted, the sodium sulfite residual present in the boiler water can take up the larger amounts of the oxygen getting in. At the same time, the concentration of sodium sulfite drops. This is shown by test analysis of the boiler feedwater. This test gives the operator ample warning of an existing malfunction within the boiler feedwater supply system. Immediate steps should be taken to correct this off-standard condition. Feedwater or makeup water tanks should be heated to a temperature of 180°F to 200°F. This heat alone helps to dispense of most of the dissolved oxygen before it can enter the boiler. It also allows for more economical use of sodium sulfite.

The prevention of corrosion in the boiler means regulating the alkalinity of the water, producing protective films, and removing dissolved oxygen. These preventive measures are accomplished by maintaining the proper chemical residuals in the boiler water and by proper deaeration.

Carryover—Foaming and Priming

The word *priming* is used rather loosely to express the action of the water and steam in a boiler when an unusual amount of water is being carried over with the steam. For a given boiler installation, a certain amount of water or moisture in the steam is tolerated. The amount depends upon the use of the steam, the boiler construction, and the facilities for removing the water from the steam. The mechanical causes include deficiency in boiler design, high water level, improper method of firing, overloading, and sudden load changes. A poorly designed boiler may have insufficient steam disengaging space. It is fairly obvious that the faster the steam is produced in a given vessel, such as a boiler, the more violent is the boiling effect. But when the steam space above the water level is large enough, the steam leaving the boiler does not show any evidence of carryover. The size of the steam header and the velocity of steam leaving the boiler are, therefore, important elements in boiler design. As the rate of steam production goes up, so does the tendency for steam contamination. The sudden opening of a steam valve or the cutting in of a boiler too quickly speeds up the production of steam, which can cause violent bubbling and carryover.

The primary chemical causes of carryover are high concentrations of totally dissolved and suspended solids in the boiler water, excessive alkalinity, and the presence of oil.

Foaming is the production of froth or unbroken bubbles on the surface of the boiler water. The froth may be thin, with few bubbles overlying each other, or it may build up throughout the steam space. Under such conditions it is difficult to free the steam of the liquid films, and the moisture content increases. When certain substances are dissolved in water, they concentrate somewhat more in the body of the liquid than on the surface; others concentrate more on the surface than in the body. In either case, the surface tension of the water is affected, and bubble film develops. The formation of froth depends upon the tenacity of the films of liquid that form the shells of the bubbles. A tough film can develop that refuses to break and release the steam. Apparently, finely divided solids in suspension increase the stability of the film so that the combination of salts in solution and finely divided solids cause foaming to develop more readily than when either one is present by itself. Soaps getting into the boiler from outside sources or formed within the boiler from oils or animal greases intensify the foaming action. Water can be carried over in the steam without formation of froth. When a pure water that does not foam is boiled, it frequently “bumps” as unstable steam bubbles are formed. These rapidly reach the surface of the water and instantaneously burst through. Parts of the water tend to become superheated and suddenly turn to steam. Fine solid particles released in water under these conditions cause the immediate production of much steam. This may occur in a boiler when particles of scale suddenly become loose.

When a boiler is foaming or priming, it is difficult and quite often impossible to read the true level of the boiler water on the gauge glass. The slugs of boiler water can wreck turbines or engines. The carryover of boiler water solids, usually caused by foaming and priming, disrupts operation of the equipment coming in contact with the steam, Deposits form in steam piping, valves, superheaters, engines, or turbines. These solids erode the turbine blades and frequently create out-of-balance conditions to the rotor. They often clog tubing, a pipe, and other apparatus following the boiler. When live steam is used for processing purposes or for cooking, the solids can seriously damage the final product. Remember also, any moisture carryover with the steam is an additional heat loss through the steam line.

Prevention and Treatment for Carryover—Foaming and Priming

There are two kinds of solids present in most boiler water—the dissolved solids, or substances that are in solution, and suspended solids. Suspended solids are finely divided solid particles floating around in the water. This is material left over after the scale-forming and corrosive salts have been changed into sludge by chemical treatment.

When a boiler is steaming, the feedwater continuously carries dissolved mineral matter into the boiler. However, the steam leaving the boiler carries very little mineral matter with it. The concentration of dissolved solids in the boiler water, therefore, keeps building up unless properly controlled by continuous or intermittent blowdown.

In water tube boilers, concentrations are generally highest at the place where (he mixture of steam and water from the tubes spills over into the steam drum. Where total concentrations are not reduced sufficiently by the bottom blow, another blowdown line should be installed to remove water from the drum at the point where TDS (total dissolved solids) concentrations are the highest. This blowdown is generally operated continuously when the boiler is in service and is called a continuous blowdown.

The best remedy for foaming and priming carryover is the proper blowdown of TDS. The continuous blowdown should be regulated to maintain the TDS at 3,000 to 4,000 ppm. The greater the TDS that can be carried without trouble, the less water, fuel, and chemicals required or wasted in the TDS blowdown.

CHEMICAL TREATMENT DETERMINATION

Because raw water conditions vary so greatly with locale, it is impossible to recommend a single, specific water treatment. Whenever possible, a water treatment chemist should be consulted and his or her recommendations for the chemical treatment of boiler water should be followed. The degree of success of any water treatment program depends upon how well the recommendations for treatment are monitored. When the services of a qualified water treatment chemist are obtained, his or her recommendations should include the following:

- The treatment formula
- The treatment ingredients
- Instructions to the boiler operator in the use of the treatment
- Periodic visits to the plant to check on the results of the treatment plan

When the operator follows instructions and uses the proper blowdown procedure, scale and sludge in the boiler are reduced to a minimum. Blowdown limits the amount of dissolved and suspended solids in the boiler water.

Consulting a chemist is an ideal situation. Seabees seldom operate under ideal situations, particularly during contingency operations. How do you determine the initial chemical treatment for a boiler, and then, how do you establish an effective treatment program? Some general guidelines follow.

The first determination you have to make is the steaming rate of the boiler, expressed in pounds per hour. This is a fairly simple computation. You first determine the boiler horsepower (bhp); then multiply the result by 4.5 pounds. For example, if you have a 100 horsepower boiler operating at one-half fire, your steaming rate is 1,725 pounds of steam per hour.

1 BHP = 34.5 lb steam/hour
100 x 34.5 = 3,450 steam/hour at high fire
3,450 ÷ 1/2 =1 .725 lb steam/hour at one-half fire

To determine the initial chemical dosage, you must know the hardness of the raw water. A chemist can tell you this; however, in the field you must determine it by experimentation. The harder the water, the more phosphates you must add during treatment to obtain correct phosphate residuals. The example that follows assumes zero hardness of the raw water and uses a 1,725-pound steaming rate. 1. Mix the following chemicals in 28 gallons of water:

a. 1 1/4 pounds of sodium sulfate
b. 1/2 pound of trisodium phosphate
c. 1/2 pound of caustic soda

2. Adjust the chemical feed rate to 3 gallons per hour (allows for 8- to 10-hours of steaming).

The chemical dosage varies with the steaming rate of the boiler. To establish your water treatment program, use the following steps every hour of operation for the duration of your initial chemical batch.

1. Determine the hourly steaming rate
2. Test for phosphate residual (30-60 ppm)
3. Test for sulfite residual (25-50 ppm)
4. Test for pH (9.5 to 11.5)
5. Test for TDS (3,000 to 4,000 ppm)

You should make a log entry of these test results every hour. This establishes a history of the test results. At the completion of the initial chemical dosage, you can either add or subtract chemicals, based on your log. It may take several batches fed over an 8 to 10 hour period to get a consistent chemical requirement for boiler water treatment. Once the boiler has stabilized and treatment test results remain reasonably balanced, testing may be required only every 4 hours.

At this time you can chart your chemical requirements, based on load demand of the boiler. By establishing this history through experimentation, your operators are able to treat the boiler water with fairly accurate results. At this time note that boiler blowdown has a big effect on your treatment program. Proper blowdown practices cannot be overemphasized. Too little blowdown causes TDS readings to be high; too much blowdown causes a high demand for chemicals and results in lost efficiency of the boiler.

MAINTENANCE

The subject of boiler maintenance covers a wide range of topics.

Major repairs that involve welding of pressure parts of the boiler are done by Steelworkers in strict adherence to the procedures in section IX of the ASME (American Society of Mechanical Engineers), "Boiler and Pressure Vessel Code." This section is concerned with operator and preventive maintenance and major considerations for the maintenance and care of firesides and watersides. Procedures for laying up idle boilers are also discussed.

OPERATOR MAINTENANCE

Operator maintenance is the necessary, routine, recurring maintenance work performed by the operators to keep the equipment in such condition that it may be used continuously, at its original or designed capacity and efficiency for its intended purpose. The operator is actually the most important member of the maintenance team. A well-informed and responsible operator can do the following:

1. Keep equipment in service for maximum periods of time.

2. Detect any flaws so equipment can be removed from service in time to prevent serious damages.

3. Perform minor repairs on equipment removed from service to minimize outage time.

It is sometimes difficult to determine where operator duties end and maintenance crew work begins. However, the operator must realize that he or she has the keenest interest in the condition of the equipment. A well-kept plant not only reflects the operator's interest (and the desire to better his or her position) but it also is vital to the safety of equipment and personnel. It is essential for every person in the operating aisle to perform the following duties:

1. Clean. Dirt is the principal cause of equipment failure. Whether it is fly ash in the switch gear, oil on the deck, cloth lint, or dust, it causes trouble. No matter the form in which dirt appears, it should be removed immediately by the operator.

2. Lubricate. Any two surfaces brought together develop friction. If not properly lubricated, these surfaces wear one another down, change clearances, and cause equipment breakdowns. A well-placed drop of oil or a thin layer of grease can go a long way toward keeping a much-used piece of equipment in good condition.

3. Cool. Every piece of equipment has an operating temperature range. The operator should be informed on this matter. An unusual change in temperature that the operator cannot correct should be reported immediately to the plant supervisor. When the temperature of a piece of equipment rises rapidly, an immediate shutdown is recommended,

4. Tighten. Vibration is another major source of equipment failure. A simple step taken in time, such as tightening of bolts, can prevent a serious failure. Equipment that is not secured properly, vibrates, causes an unbalance, vibrates further, and compounds a cycle that can only lead to further trouble. In making rounds, the operator should put his hand on the bearings, touch the fan housing, and feel the motor casing. When any unusual sound is heard, vibration felt, or motion seen, the proper steps should be taken by the operator to correct the condition.

PREVENTIVE MAINTENANCE

Preventive maintenance inspection (PMI) is a system of routine inspections of equipment recorded for future reference on some type of inspection record. The purpose of PMI is to anticipate and prevent possible equipment failures by making periodic inspections and minor repairs in advance of major operating difficulties. Preventive maintenance directed specifically toward maintaining boiler efficiency is the exception, rather than the rule. Rising fuel costs have placed an increasing emphasis on conscientious maintenance because it results in higher boiler operating efficiency. Preventive maintenance practices are easily justified from an economical and safety standpoint. Tables 12-4 and 12-5 reflect NAVFACENGCOM recommendations for PMI.

Table 12-4.—PMI Checklist for Steam Boilers 350,000 Btuh or Less

STEP	IF	THEN	WHEN
Observe condition of flame	Flame is smokey, flame impinges on furnace walls or burner starts with a puff	Make appropriate repairs or adjustments	Weekly
Test low water and fuel cutoff	Boiler does not secure during tests	Locate problem and repair	Weekly
Test water column or gauge glass	Gauge glass is dirty, has an obstruction, or leaks are present including gauge cocks	Clean, remove obstructions or repair leaks, or replace	Weekly
Observe operation of condensate of vacuum pumps	Pump is defective or leaking	Repair or replace pump	Weekly
Check operation of chemical feed pots and pumps	Leaks or improper operation exists	Repair or replace defective equipment	Weekly
Test flame detection devices and associated automatic fuel cutoff valves	Loss of flame does not shut off fuel to burner	Repair or replace valves or defective equipment	Monthly
Inspect steam supply and condensate return piping	Problems with valves, radiators, trap leaks, or excessive rust	Repair or replace defective equipment	Monthly
Inspect fuel supply systems and piping. Include adjustment of oil pressure and ensure both oil supply and return lines have a fusible in-line valve	Discrepancies are leaks, or insulation is missing	Repair or replace for corrective action	Monthly
Check condition of safety valves	Valves are obstructed to flow, inoperative, or fail to meet code requirements	Repair or correct the problem	Monthly
Check boiler room drains	Drains are not operating properly	Repair	Monthly
Inspect burner assembly	Evidence of improper fuel nozzle wear, plugging, or carbon buildup exists	Replace nozzle and adjust equipment after new nozzle is installed	Monthly

Table 12-4(Continued).—Checklist for Steam Boilers 350,000 Btuh or Less

STEP	IF	THEN	WHEN
Inspect burner assembly, replace fuel filters and nozzle on oil burning equipment, clean and adjust electrodes			Annually
Internal and external inspection of heating surfaces after cleaning			Annually
Inspect gas piping valves for proper support and tightness	Leaks are present	Secure piping to the boiler and contact the gas company	Annually
Check transformer	Transformer is replaced for any reason	Do not interchange transformers of different capacities	Annually
Remove trash			Annually
Check draft, manifold pressure, and combustion. Overfire draft should be .02" water gauged for oil burners	Deficiencies are noted	Repair, adjust, or replace defective mechanism	Annually
Inspect control equipment for proper sequence and operation	Covers are missing, controls are dirty, or electrical contacts are fouled	Replace, clean, or repair	Annually
Calibrate and check operation of gauges and meters	Gauges are defective, cracked, have broken glass, or bent pointers	Have gauges calibrated, repaired, or replaced	Annually
Check shell for cleanliness, excessive rust, corrosion streaks, deformations, and cracks			Annually
Check stack and breaching for integrity and tightness			Annually

Table 12-5.—PMI Checklist for Hot-Water Boilers

STEP	WHEN
Observe condition of flame	Weekly
Check fuel supply and note oil level	Weekly
Observe operation of circulating pumps. Lubricate pump motor bearing assembly and flex coupling	Weekly
Test flame detection devices and associated automatic fuel cutoff valves	Monthly
Inspect fuel supply systems and piping in boilers for leaks and loss of insulation	Monthly
Check boiler room drains for proper functioning	Monthly
Check condition of safety relief valves	Monthly
Inspect burner assembly	Monthly
Internal and external inspection of heating surfaces after cleaning	Annually
Inspect gas piping and valves regularly for proper support and tightness	Annually
Check transformer	Annually
Inspect area around boiler for cleanliness	Annually
Inspect hot-water supply and return piping and valves	Annually
Check draft, manifold pressure, and combustion. Conduct combustion efficiency tests and adjust burner for safe and efficient operation	Annually
Check expansion tank and air eliminator equipment	Annually
Check control equipment for proper sequence and operation	Annually
Calibrate and check operation of gauges and meters	Annually

Table 12-5(Continued).—PMI Checklist for Hot-Water Boilers

Check breaching and stack for integrity and tightness	Annually
Check shell for cleanliness, excessive rust, corrosion streaks, deformations, and cracks	Annually

EFFICIENCY MAINTENANCE

Efficiency-related boiler maintenance is directed at correcting any condition that increases the amount of fuel required to generate a given quantity of steam. Thus, at a specified boiler load, any condition that leads to an increase in flu-gas temperature; flue-gas flow; combustible content of flue gas or ash; convection or radiation losses from the boiler exterior, ductwork, or pipe; or blowdown rates is considered an efficiency-related maintenance item. Generally, attention to items can eliminate more serious consequences, such as damage to equipment and/or injury to personnel.

The boiler tune-up is the best method of improving efficiency. The primary objective of a tune-up is to achieve efficient combustion with a controlled amount of excess air, thus reducing the dry gas loss and the power consumption of forced- and induced-draft fans.

CARE OF BOILER FIRESIDES

The boiler firesides must be kept clean. The burning of any petroleum product tends to be incomplete, thus leaving soot and carbon deposits on the boiler firesides. These deposits seriously reduce the efficiency of the boiler. Slag contributes greatly to failure of such parts as superheater support plates, baffles, protection plates, and soot blowers. Deposits also act as insulation and prevent the transfer of heat to the water or steam in the tubes.

Soot and slag accumulations that block the gas passages through the tube banks require the use of high air pressures to force the combustion gases through the boiler, thus reducing fireroom efficiency. Accumulations that block the gas passages also interfere with the designed flow of combustion gases and cause extremely hot gases to pass over protection plates, baffles, seal plates, and other parts that are not designed for such high-temperature gases; in some cases, early failure of these parts can be blamed directly on blocked gas passages and the resulting overheating of the parts.

When soot is allowed to remain on the boiler firesides for any length of time, the sulfur in the soot combines with moisture and forms sulfuric acid. This acid attacks tubes, drums, and headers. The extent of the damage caused by acid attack depends upon the length of time the soot remains on the tubes and upon the amount of moisture present during this interval. Moisture may be present as a result of high atmospheric humidity; rain or snow coming down the stack; leaky boiler tubes; and steam or water leakage through the boiler casing joints, particularly from machinery and piping installed above the boiler.

One indication of soot corrosion is the development of pinhole leaks at the point where the tubes enter the water drums and headers and at other points where it is difficult to clean the tubes properly. When soot corrosion is allowed to proceed unchecked, extensive deterioration of the boiler metals results.

You will find that keeping the firesides clean actually saves work, as well as saving the boiler. Clean tubes do not collect deposits as readily as dirty tubes do. It is a good deal easier to clean the firesides several times when they are only slightly dirty than to clean them once when they are heavily coated with soot and carbon.

Local instructions usually specify steaming intervals after which the boiler firesides must be cleaned. In addition to this upkeep, the firesides are normally cleaned just before to the annual internal inspection.

Although there are a number of cleaning methods available (such as hot-water washing, wet-steam lancing, and so forth), mechanical cleaning should be considered the basic and preferred method of cleaning firesides. The other methods are generally used only when mechanical cleaning cannot adequately remove the fireside deposit.

Mechanical cleaning is accomplished within the boiler, in the furnace, and from outside the boiler through access doors by using various types of scrapers, probes, and wire brushes to remove soot and other deposits. In most instances, these cleaning tools can be obtained from the boiler manufacturer.

In addition to scrubbing and cleaning the firesides of the generating tubes, other areas of the firesides should receive scrupulous cleaning as well. Particular care should be given to those more or less inaccessible portions of the firesides that are not cleansed by the soot blowers. Any encrusted soot should be removed from burner impeller plates, bladed cones, and drip pans. The furnace refractory must also be cleaned. This operation is perhaps best done last to remove not only original deposits from the brickwork but also soot and dust deposited after other parts of the boiler were cleaned. It is important to keep the brickwork clean for two reasons: First, soot and foreign matter lodged in expansion joints can obviously prevent proper expansion of refractories when hot, and can ultimately cause serious cracking of the brickwork; second, soot and other deposits left on the brickwork will lower the melting point of the refractories.

CARE OF BOILER WATERSIDES

Failure to keep boiler watersides clean reduces the efficiency of the boiler and contributes to overheating, thus leading to serious damage. Experience has shown that tube failures resulting from defective materials or poor fabrication are rare. The majority of all tube failures, other than those associated with water-level casualties, are caused by waterside deposits or accumulations. Some tube failures are caused by waterside deposits of hard scale. More frequently, however, tube failures occur as the result of an accumulation of relatively soft materials such as metal oxides, the residue of chemicals used for boiler water treatment, the solids formed as a result of the reactions between scale-forming salts or other impurities and the chemicals used for boiler water treatment.

As in the case of fireside cleaning, waterside cleaning is usually accomplished after specified steaming intervals and also before the annual internal inspection.

The need for cleaning watersides or firesides is often signaled by a gradual rise in the stack gas temperature. In other words, deposits on either the firesides or watersides of generating tubes reduce heat transfer from the furnace to the water. A good part of the nontransferred heat is, as you know, retained by the fireside or waterside deposit. However, some of the heat not properly carried away by the water and not absorbed by the deposits remains with the combustion gases. Therefore, [he temperature of the stack gas rises.

When working in the watersides of a boiler, you should take all possible precautions to keep tools, nuts, bolts, cigarette lighters, and other small objects from sliding down into the tubes. Some required precautions are as follows:

1. Remove all small objects from your pockets before entering the boiler.

2. Keep an inventory of all the tools and equipment you take into the boiler. Ensure that you remove each item and check it off the inventory before closing up the boiler.

3. Do NOT set tools or other articles down in places where you are likely to forget them. For example, you must not leave tools on top of the steam separators or in other places that are easy to reach but hard to see.

4. When an article is lost in the boiler watersides, you must NOT close up or operate the boiler until the article has been located and removed. Even a very small article can interfere with boiler circulation and cause tube ruptures.

Additional precautions for waterside work include the following:

1. Close, wire, and tag all steam, water, and air valves that could possibly admit fluid to the boiler. Disconnect (or otherwise render inoperative) the remote operating valves as well.

2. Be sure that adequate ventilation is provided before entering the waterside of a boiler.

3. Be sure that all portable extension lights are of the watertight globe type, with the globe encased in a rubberized, metal cage. Be sure all lights are grounded and wires are not broken. Examine the wires from end to end to be sure that the insulation is not broken or cracked, exposing the bare wire.

4. Station a person outside the drum whose ONLY duty is to act as tender and to assist personnel working in the drum.

Boiling out is a special waterside cleaning technique. There are two approved methods for boiling out boilers—the sodium metasilicate pentahydrate method and the trisodium phosphate method. The method used depends upon the purpose of the boiling out. The sodium metasilicate pentahydrate method is used to remove rust-preventive compounds and other preservatives; consequently, this method is used for boiling out (1) newly erected boilers, (2) reactivated boilers, and (3) boilers that have had major tube renewals. The trisodium phosphate method is used when you are boiling out for the removal of oil and for scale softening in preparation for mechanical cleaning.

LAYING UP IDLE BOILERS

Many operators faithfully and carefully follow all the procedures and regulations concerning boiler water treatment only to find that the watersides, nevertheless, experience corrosion and pitting. It should come as no great surprise that the fault is not with the treatment methods, but rather the manner in which the boiler is permitted to stand idle. After the pressure drops within an idle boiler, air gradually seeps into the boiler, carrying oxygen with it. The air also contains carbon dioxide that combines with the boiler water to form carbonic acid, which, in turn, lowers the residual causticity of the boiler water. Gradual inleakage of feedwater can dilute and lower the causticity of the boiler water even further. In addition, condensation within the boiler, on both waterside and firesides, can produce water droplets that are saturated with oxygen and contain no causticity. Conditions within the boiler are now ideal for active and rapid corrosion. The need for protecting boilers that are left idle for any length of time should be obvious.

Laying Up a Boiler by the Wet Method

A wet lay-up is done after a thorough cleaning of both firesides and watersides. The feedwater used to fill the boiler is deaerated as much as possible. While the boiler is being filled, add caustic soda in sufficient quantities to maintain a pH reading of 9.5 to 11. Additionally, add approximately 0.03-0.06 pounds of sodium sulfite per 1,000 gallons of boiler holding capacity to maintain 30-60 ppm. When equipment is installed in a plant and used in acid treatment of feedwater, it should never be used to fill a boiler for idle standby; this results in a low pH in the boiler, as concentration by boiling is taking place. To ensure the boiler is filled completely, you should add water until it overflows at the top of the boiler through any convenient outlet, and then close the outlet. When there is a superheater on the boiler, add water to fill it completely. If appreciable air is dissolved in the water, you should boil the water to vent out any air after the boiler is nearly filled.

When the chemical feeding system installed is not suitable for continuous feeding and it is necessary to slug feed the chemical while the boiler is being filled, the boiler water must be mixed to obtain uniform distribution of the chemical throughout the boiler. This can be achieved by using a circulating pump to pump water from one section of the boiler to another. When such a pump is not available, mixing can be accomplished by heating the boiler just enough under low fire to set up natural circulation.

After a boiler has been filled for standby, it must be kept filled as long as it is idle with no water flowing in or out. Leakage out, as through a leaky blowdown valve, can admit air and form a waterline in the boiler. A method sometimes used for keeping a boiler completely full consists of using a small tank placed above the boiler with a line connected to any outlet of the boiler or the superheater header. This method also shows when any leakage occurs into or out of the boiler. The small tank is provided with a vent and a water column. When the boiler is filled, water is added up into the tank. Then, if water leaks out of the boiler, water from the tank flows in, keeping the boiler full. When the level in the tank rises, it shows that water is leaking into the boiler, either through the feed line or the steam line.

Water in an idle boiler should be sampled and analyzed weekly. When the causticity or the concentration of sulfite drops considerably, you should ensure additional chemical is fed and the boiler water circulated to distribute the chemical uniformly.

One disadvantage of using the wet method is that when the temperature of the water in the boiler is lower than the outside temperature, condensation or moisture occurs on the outside of a metal boiler, causing corrosion. Some engineers coat the outside of a metal boiler with light oil to help protect it from corrosion.

Laying Up a Boiler by the Dry Method

Dry lay-up should be used when a boiler is scheduled to be out of service for a long period of time or when a boiler is in danger of freezing. The first step is to clean both firesides and watersides of the boiler thoroughly. After cleaning the boiler, the watersides must be completely dried, because any moisture remaining on the surface will cause corrosion. Take precautions to preclude entry of moisture in any form from steam lines, feed lines, or surrounding air.

Place a moisture-absorbing material, such as quicklime, in the boiler at a rate of 2 pounds, or silica gel at the rate of 5 pounds, for 30 cubic feet of boiler volume. Place the chemical-absorbing material in trays and insert it in the drums or manholes. Air carries moisture; ensure that you close all of the manholes and handholes. This method requires checking the moisture-absorbing material every 3 months.

One method of dry lay-up for a large utility type of boiler is to simply feed nitrogen through the boiler vents while draining the boiler. With this method, maintain nitrogen pressure at 5 psig during the storage period.

CHAPTER 13

DUCT AND VENTILATION SYSTEMS

As a Utilitiesman, you can expect to become involved in the installation of duct and/or ventilation systems designed to provide conditioned air or to remove less desirable air from a given space or facility. When sheet metal is to be fabricated into system components, the Steelworker provides the expertise. When duct board is used, fabrication and installation may be tasked to the Utilitiesman exclusively.

This chapter provides some key knowledge to aid you in the identification of types of duct and ventilation systems, their installation, and factors you must be aware of in determining the sizes required to meet specified building requirements. Keep in mind that the term *air conditioned* refers to air that has been cooled, heated, dehumidified or humidified, or any combination of these.

DUCT SYSTEMS

To deliver air to the conditioned space, you need air carriers. These carriers are called ducts. They are made of sheet metal or some structural material that does not bum (noncombustible).

Duct systems are also classified as high--pressure or high-velocity ductwork and low--pressure or low-velocity ductwork. The term *high-pressure* or *high-velocity* ductwork includes ductwork systems and plenums from the fan discharge to the final high-velocity mixing boxes, or other final pressure-reducing devices or any air supply system served by a fan operating with a static pressure range of 3 inches to 7 inches of water column (WC).

High-velocity or high-pressure systems with fan static pressures of 3 inches WC or greater are defined as high pressure. Usually the static pressure is limited to a maximum of 7 inches WC, and duct velocities are limited to 4,000 feet per minute (fpm). Systems requiring pressures more than 7 inches WC are normally unwarranted and could result in very high operating costs. Systems with velocities more than 4,000 fpm peforms satisfactorily when all duct fittings are carefully designed and installed. However, velocity pressure losses are excessive and velocities more than 4,000 fpm are not recommended.

A high-velocity double-duct system begins with a high-pressure fan of class II or III design any conveys air through sound-treated high-velocity ductwork connected to sound and pressure-attenuating mixing units. Connections to the outlets of the reduction units are treated as low velocity.

Smaller sized ductwork, using higher velocities, permits conveyance of air to areas limited by construction and reduces floor-to-floor height. Round ductwork generally provides the greatest strength, tightness, and economy. However, oval and rectangular ducts can be used when large risers are involved.

A necessary component of the high-pressure system is the mixing box or unit. Its function is to blend air at two different temperatures for proper delivery to the rooms. This requires special pressure-reducing air valves at both hot and cold inlets, mixing baffles to prevent stratification of air, and sound attenuation treatment to absorb noise generated by the air valves.

Table 13-1.—Outlet Velocities for Optimum Performance of Fans

STATIC PRESSURE INCHES OF WATER	CENTRIFUGAL FANS OUTLET VELOCITY fpm	TUBEAXIAL AND VANEAXIAL FANS OUTLET VELOCITY AT WHEEL DIA. fpm
1/4	400- 100	950-1,500
1/2	550-1,450	1,350-1,900
3/4	700-1,750	1,650-2,350
1	800-2,000	1,900-2,700
1 1/2	1,000-2,500	2,350-3,300
2	1,150-2,800	2,700-3,800
2 1/2	1,250-3,200	3,000-4,300
3	1,400-3,500	3,300-4,700
4	1,600-4,050	
6	2,000-4,950	
8	2,300-5,700	
10	2,500-6,400	

The term *low-pressure* or *low-velocity* ductwork applies to systems with fan static pressures less than 3 inches WC. Generally, duct velocities are less than 2,000 feet per minute.

The choice between the use of low versus high-velocity systems requires architectural, mechanical, and structural considerations. Installation cost, temperature control, and operating cost should also be studied.

Low-velocity double duct systems are many years old. It was not until after World War II that their use became extensive. Space for the installation of the double ducts is a main consideration for this system and must be provided during initial planning. Difficulties in providing for this space in modern structures with low floor-to-floor heights and flush ceilings, together with the need for developing a compact distribution system for existing buildings, has brought about the development of high-velocity double duct systems. High velocity saves ceiling space and duct shaft space, but requires greater attention in the selection of fans and equipment with regard to sound levels. Also, higher duct velocities require increased fan static pressures; therefore, increased operating costs. On the other hand, high-velocity systems are easy to balance and control and have much greater flexibility for partition changes and so forth.

Generally, high-velocity systems are applicable to large multistory buildings; primarily because the advantage of saving in duct shafts and floor-to-floor heights is more substantial. Small two- and three-story buildings are normally low velocity; however, both systems should be analyzed for each building. Table 13-1 shows outlet velocities for the range of optimum performance of typical ventilation fans.

Ducts are made of many types of materials. Pressure in the ducts is small, so materials with a great deal of strength are not needed. Originally, hot air ducts were thin, tinned sheet steel. Later, galvanized sheet steel, aluminum sheet, and

TABLE 13-2.—Materials for Ductwork

Application	Material
Normal system handling dry air 1. Air conditioning 2. Ventilating	Galvanized steel Fiberboard
Systems handling air at very high temperature 1. Kitchen exhaust	Black steel
System handling partially saturated air 1. Outside air intake ductwork 2. Exhaust ductwork near discharge outlet 3. Ductwork exposed to weather elements	Aluminum
Systems handling completely saturated air 1. Shower exhaust 2. Dishwasher exhaust 3. Ductwork exposed to salty atmosphere	Copper

finally. insulated ducts made from materials, such as asbestos and fiberboard, were developed. Passageways, formed by studs or joists, are sometimes used for return air when a fire hazard does not exist.

Ducts made of asbestos are no longer legal. If discovered, asbestos in any form must be removed and disposed of according to the laws and regulations discussed in chapter 16 of this manual.

The material used for the construction of ductwork depends on the application of the duct. Use table 13-2 as a guide in the selection of duct material. The thickness of the material depends primarily on the pressure developed within the duct, the length of the individual sections, and the cross-sectional area of the duct. The developed length of a section for a particular gauge can be increased by installing angle bracing around the duct. It is beyond the scope of this manual to include the technical details necessary for the selection of proper metal thickness and section length for different pressures and for different cross-sectional areas of duct material. However when repairs are made, the same thickness of metal that was originally included in the system must be installed. Where the original ductwork was destroyed by pressure, repairs may include increasing metal thickness or adding of angle bracing.

Ducts are either round or rectangular in cross section. Although rectangular ducts usually have the advantage of saving room space and being easier to install in walls, round ducts provide less resistance to air flow and should be used whenever possible.

Additionally, round ducts require less material to construct; thus, by using round ducts, you can save both money and material during installation.

Initially, an air-handling duct is usually sized for round ducts. Then, if rectangular ducts are wanted or required, duct sizes can be selected to provide flow rates equivalent to those of the round ducts originally selected.

Table 13-3 is a ready reference to determine the size of a rectangular duct that equals the carrying capacity of a predetermined round duct. To use this chart, convert a rectangular duct with sides of 17 inches by 16 inches, respectively. First, come down the left-hand column until you reach 17 inches; then trace the line horizontally across the columns until you reach the column headed by 16 inches. At the center of these intersecting lines is 18.0 inches. This is the round duct size equivalent. In the second example, following the same procedure, it is clearly shown that a 22-inch by 17-inch rectangular duct has a 21-inch round duct equivalent.

TYPES OF DUCT SYSTEMS

In this section, the advantages and disadvantages of a double-duct system are discussed. Since there are many possibilities for an adequate duct system, one such system is modified to fit the needs of two different residential configurations.

Table 13.3.—Duct Capacity Conversions

The dimensions in this chart are in inches

Side Rectangular duct	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
3.0	3.8	4.0	4.2	4.4	4.6	4.8	4.9	5.1	5.2	5.5	5.7	6.0	6.2	6.4	6.6	6.8	7.0
3.5	4.1	4.3	4.6	4.8	5.0	5.2	5.3	5.5	5.7	6.0	6.3	6.5	6.8	7.0	7.2	7.4	7.6
4.0	4.4	4.6	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.4	6.8	7.1	7.3	7.6	7.8	8.1	8.3
4.5	4.6	4.9	5.2	5.4	5.6	5.9	6.1	6.3	6.5	6.9	7.2	7.5	7.8	8.1	8.4	8.6	8.9
5.0	4.9	5.2	5.5	5.7	6.0	6.2	6.4	6.7	6.9	7.3	7.6	8.0	8.3	8.6	8.9	9.1	9.4
5.5	5.1	5.4	5.7	6.0	6.3	6.5	6.8	7.0	7.2	7.6	8.0	8.4	8.7	9.0	9.4	9.6	9.8

Side Rectangular duct	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30
6	6.6																			
7	7.1	7.7																		
8	7.5	8.2	8.8																	
9	8	8.6	9.3	9.9																
10	8.4	9.1	9.8	10.4	10.9															
11	8.8	9.5	10.2	10.8	11.4	12														
12	9.1	9.9	10.7	11.3	11.9	12.5	13.1													
13	9.5	10.3	11.1	11.8	12.4	13	13.6	14.2												
14	9.8	10.7	10.5	12.2	12.9	13.5	14.2	14.7	15.3											
15	10.1	11	11.8	12.6	13.3	14	14.6	15.3	15.8	16.4										
16	10.4	11.4	12.2	13	13.7	14.4	15.1	15.7	16.3	16.9	17.5									
17	10.7	11.7	12.5	13.4	14.1	14.9	15.5	16.1	16.8	17.4	18.0	18.6								
18	11	11.9	12.9	13.7	14.5	15.3	16	16.6	17.3	17.9	18.5	19.1	19.7							
19	11.2	12.2	13.2	14.1	14.9	15.6	16.4	17.1	17.8	18.4	19	19.6	20.2	20.8						
20	11.5	12.5	13.5	14.4	15.2	15.9	16.8	17.5	18.2	18.8	19.5	20.1	20.7	21.3	21.9					
22	12	13.1	14.1	15	15.9	16.7	17.6	18.3	19.1	19.7	20.4	21	21.7	22.3	22.9	24.1				
24	12.4	13.6	14.6	15.6	16.6	17.5	18.3	19.1	19.8	20.6	21.3	21.9	22.6	23.2	23.9	25.1	26.2			
26	12.8	14.1	15.2	16.2	17.2	18.1	19	19.8	20.6	21.4	22.1	22.8	23.5	24.1	24.8	26.1	27.2	28.4		
28	13.2	14.5	15.6	16.7	17.7	19	18.7	19.6	20.5	21.3	22.1	22.9	23.6	24.4	25	25.7	27.1	28.2	29.5	30.6
30	13.6	14.9	16.1	17.2	18.3	19.3	20.2	21.1	22	22.9	23.7	24.4	25.2	25.9	26.7	28	29.3	30.5	31.6	32.8
32	14	15.3	16.5	17.7	18.8	29.8	20.8	21.8	22.7	23.6	24.4	25.2	26	26.7	27.5	28.9	31	32.3	33.6	33.8
34	14.4	15.7	17	18.2	19.3	20.4	21.4	22.4	23.3	24.2	25.1	25.9	26.7	27.5	28.3	29.7	32.3	33.6	33.8	34.8
36	14.7	16.1	17.4	18.6	19.8	20.9	21.9	23	23.9	24.8	25.8	26.6	27.4	28.3	29	30.5	32	33	34.6	35.8

This chart depicts sizes of rectangular duct that are equal in carrying capacity to round ducts. To use this chart find the diameter of round duct in the chart. Then find one side of rectangular duct by reading up. Find the other side by reading left to the first row of numbers representing the other side of the rectangular duct.

A double duct system generally consists of a blowthrough fan unit discharging filtered air through stacked or adjacent heating and cooling coils into separate plenums and ductwork with thermostatically controlled mixing dampers at various room locations.

The inherent advantage of a double duct system is that individual room conditions can be maintained from a central system, within the limitations of supply air temperatures. This is done by the blending of hot and cool air through automatically controlled mixing devices. Another important credit is flexibility. In this regard, individually controlled rooms can be easily incorporated, at modest cost, after the building is completed.

In modern buildings of multiple exposures designed for variable functions and changing occupancy, individual room control is essential and a double duct system should be seriously considered.

Double duct systems for low pressure are usually tiered hot and cold ducts within the furred space. They are generally located above corridors. The manner of distributing proper temperature air to the room is through right angle, interlinked mixing dampers operated by motors controlled through thermostats. In general, this type of system uses the same corridor plenum area around the ducts for conveyance of return or exhaust air. The residual volume of space left for this purpose is too often neglected. Inevitably, this results in insufficient relief for the rooms.

The main disadvantage of a double duct system is lack of stability of air quantities supplied to areas (rooms) because of varying duct static pressures.

All duct elbows, including supply, exhaust, and return, should be made with a center line radius of 1.5 times the duct width, parallel to the radius wherever possible. In no case should the center line radius be less than the width of the duct parallel to the radius. Where space does not permit the above radius, or where square elbows are indicated on plans, turning vanes of an approved type should be used.

Additionally, there are numerous adaptations and modifications of duct systems. Figure 13-1 shows a residential duct system with the furnace and central air unit located in the basement.

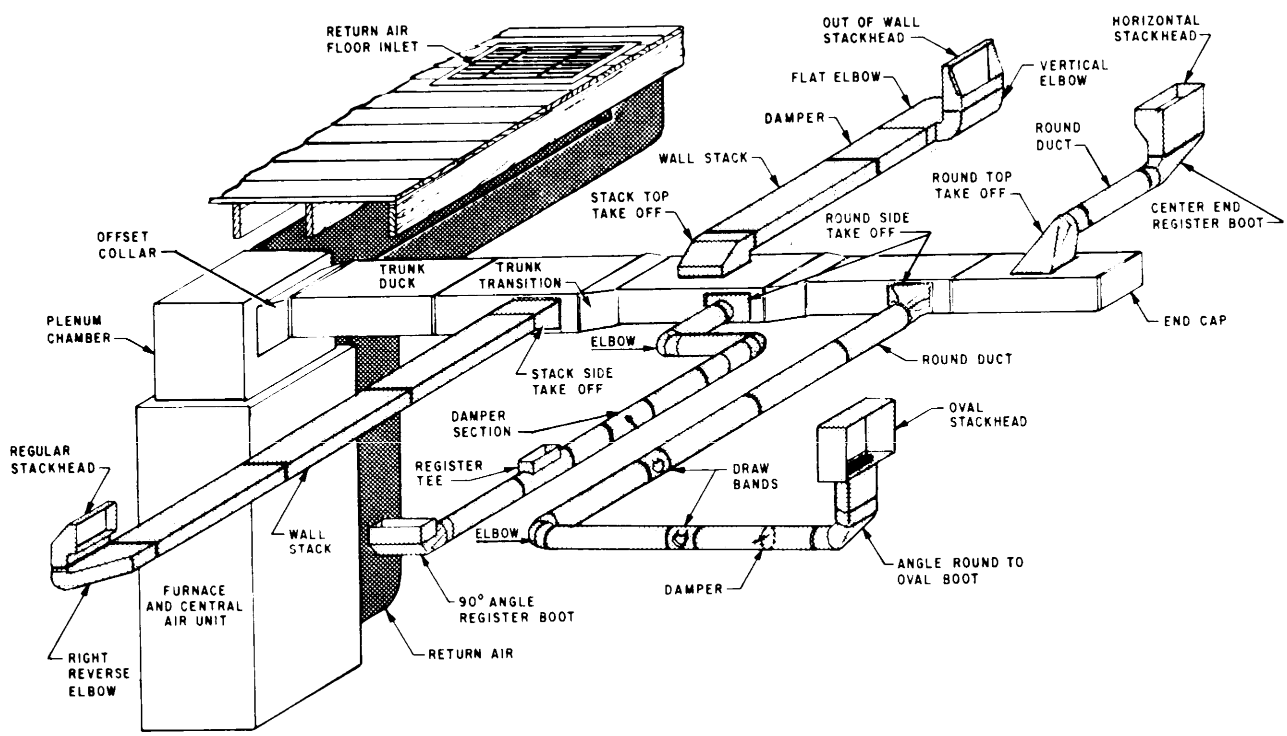


Figure 13-1.—Residential duct system.

In figure 13-2, the same basic system is shown in a single-story house. The duct system is located in the overhead and the return air enters through the bottom of the central air-handling unit. When the duct system is located in a crawl space, basement, or attic, it should be insulated to maintain the existing temperature.

DUCT CONSTRUCTION

In this section, basic sheet metal ducts, both round and rectangular, are discussed. Emphasis is placed on layout and pattern requirements. Then fiberboard duct construction and its use are discussed.

Round Duct

Straight sections of round duct are usually formed from sheets rolled to a proper radius and assembled with a longitudinal grooved seam Each end of a round section is swaged and assembled with the larger end of the adjoining section butting against the swage. Sections are held together by rivets, by sheet metal screws, or by solder. Where solder is not used, duct tape or liquid rubber (duct sealer) should be used as a covering at all joints. Rectangular ducts are generally constructed by bending corners and by grooving along the longitudinal seam.

The duct system should be constructed in a way that avoids abrupt changes in size,

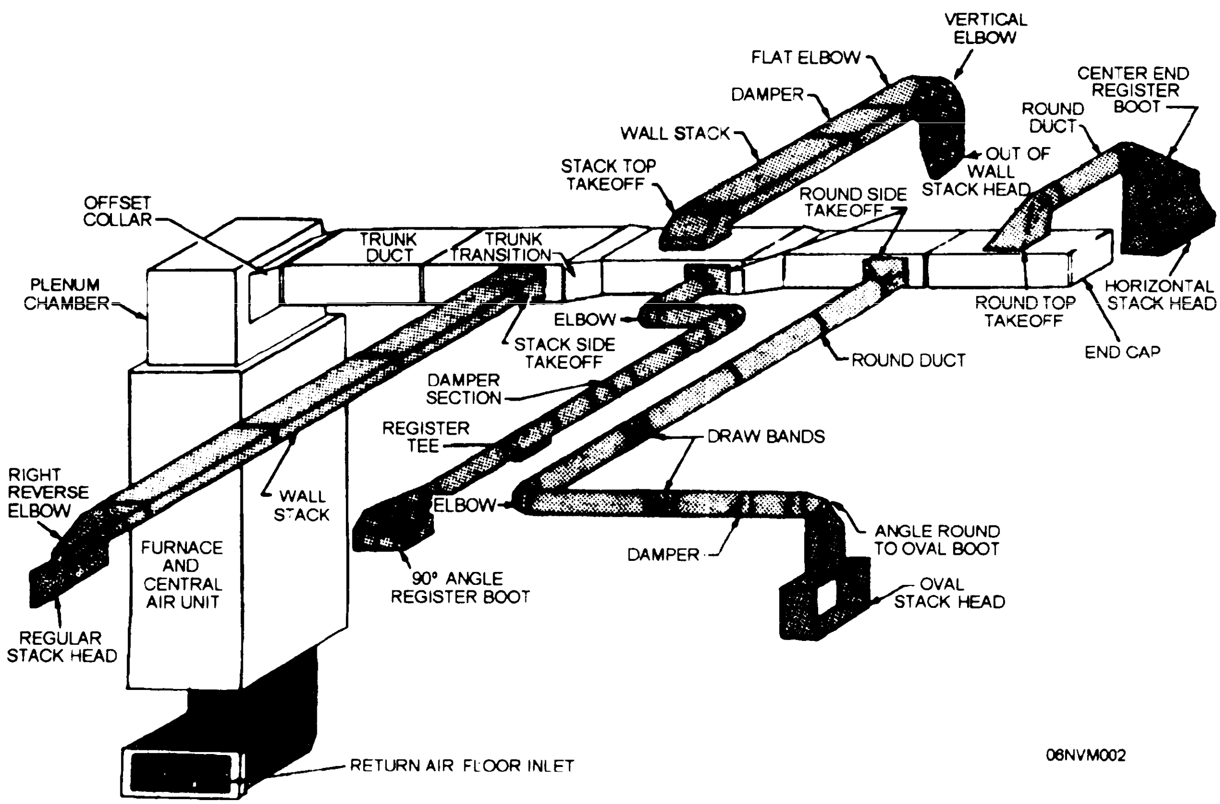


Figure 13-2.—Residential duct system.

direction, or other resistance conditions that can create unnecessary noise and reduce the air volume. The normal noise level of air flowing through a duct depends on the velocity of the air moving through the duct. This can be further reduced by lining or covering the duct with sound-absorbing material. The exterior of ducts that carry conditioned air can be covered with heat insulation materials to prevent heat transfer between ducts and the surrounding air. All materials used for duct lining and coverings must be noncombustible.

Ducts should be constructed for easy maintenance. They should have access plates or doors included to facilitate cleaning and inspection. It is important that the correct size duct (as specified on the prints or drawings) be used for the construction of the duct system. The amount of air to be carried depends on the size of the duct. This determines the pressure loss in the system—the larger the quantity of air moving through a duct of a given cross-sectional area, the greater the friction loss. Similarly, with a given quantity of air to be delivered, the friction loss increases in inverse proportion to the sizes of ducts provided to carry the air. Therefore, the power required at the fan for delivering a given quantity of air increases rapidly as the duct size is decreased. It is important to bear these facts in mind when it is necessary to replace or to change sections of ducts. The same size new duct should be used unless proper design provisions are made for a change in size.

Rectangular Duct

Straight sections of rectangular duct are normally formed by personnel in the Steelworker rating. This is normally accomplished on bending-brake type of equipment. Then the rectangular ductwork is joined together as mentioned earlier.

Straight sections of ducts can usually be laid out without a pattern. However, elbows, transitions, jump fittings, and so forth, require a pattern. While Steelworkers perform the task, you, as a planner, need to be aware of the time required to draw and fabricate the required patterns. Also bear in mind that if this is a one-time job, you can make the pattern of paper or cardboard. When there are large numbers of the same size and dimension fittings to be constructed, you should make the pattern of sheet metal.

Fiber Glass Duct

A fiber glass duct is constructed of molded glass fibers covered with a thin film coating. This coating is usually of aluminum, but vinyl or other plastic coatings are sometimes used. Since they are made of glass fibers, the ducts are inherently insulated. Also, they are primarily used where insulation is a factor. Fiber glass meets military specifications for a flame spread rating of less than 25 and a smoke development rating of less than 50 for insulating material. The thickness of fiber glass ducts allowed for use in Navy installations must range between 3/4 inch to 2 inches, depending upon the size of the duct.

The nature of a fiber glass duct requires that it be supported with 1-inch by 1/16-inch galvanized steel strap hangers shaped to fit the duct. For round ducts, these supports must be on not less than 6-foot centers. Rectangular and square ducts up to 24-inch spans may be supported on 8-foot centers. Ducts larger than 24 inches require support on 4-foot centers.

The applicability of fiber glass ducts on heating systems is sometimes limited by the adhesive used on the protective outer covering to cause it to adhere to the fiber glass material. Unless aluminum surface duct is used, the specification of the duct should be checked carefully to ensure that it does not fail when heated over 250°F.

Fiber glass ducts can be molded into a variety of shapes for special uses. Round ducts and reducers are available from manufacturers' stock. For most purposes, however, the duct is supplied flat in the form of a board, with V-grooves cut into the inner surface to allow folding to make a rectangular section. The ends of the boards are molded so that when the rectangular duct is formed, two sections of the same size fit together in a shiplap joint to ensure a tight joint in positive alignment. It is important to exercise care in selecting a board of adequate size to complete the desired duct before beginning cutting and grooving operation. In all cases, the inside diameter of the duct is the determining factor for board size. To determine board size see table 13-4.

To form a rectangular duct, the flat duct board is measured accurately and grooves are cut at the proper locations. The board is then folded into a rectangular shape. When the board is cut, an overlapping tab is left and this is then pulled tight and stapled. Tape is applied and the joint is heat sealed. Joints between sections are made by pulling the shiplap end sections together. The joint is then completed by stapling, taping, and heat sealing the junction as shown in figure 13-3.

Sheet metal ducts expand as they become hot and contract as they become cold. The degree to which expansion and contraction becomes an installation factor depends upon the temperature of the air surrounding the ducts and the temperature of the air moving through the ducts. Fabric joints are often used to absorb this duct movement. Additionally, fan noise and furnace or air-conditioner noise tends to travel along the

Table 13-4.—Duct Board Length Selection Chart

	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
6	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76
7	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78
8	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80
9	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
10	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84
11	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86
12	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88
13	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90
14	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92
15	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94
16	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96
17	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98
18	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100
19	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102
20	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104
21	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106
22	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108
23	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
24	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112
25	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114
26	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116
27	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118
28	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
29	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	
30	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120		
31	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120			
32	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120				
33	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120					
34	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120						
35	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120							
36	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120								
37	94	96	98	100	102	104	106	108	110	112	114	116	118	120									
38	96	98	100	102	104	106	108	110	112	114	116	118	120										
39	98	100	102	104	106	108	110	112	114	116	118	120											
40	100	102	104	106	108	110	112	114	116	118	120												
41	102	104	106	108	110	112	114	116	118	120													
42	104	106	108	110	112	114	116	118	120														
43	106	108	110	112	114	116	118	120															
44	108	110	112	114	116	118	120																
45	110	112	114	116	118	120																	
46	112	114	116	118	120																		
47	114	116	118	120																			
48	116	118	120																				
49	118	120																					
50	120																						

*For 1½-inch board—ADD 4 INCHES to these dimensions.

°For 2-inch board--ADD 8 INCHES to these dimensions.

87.422

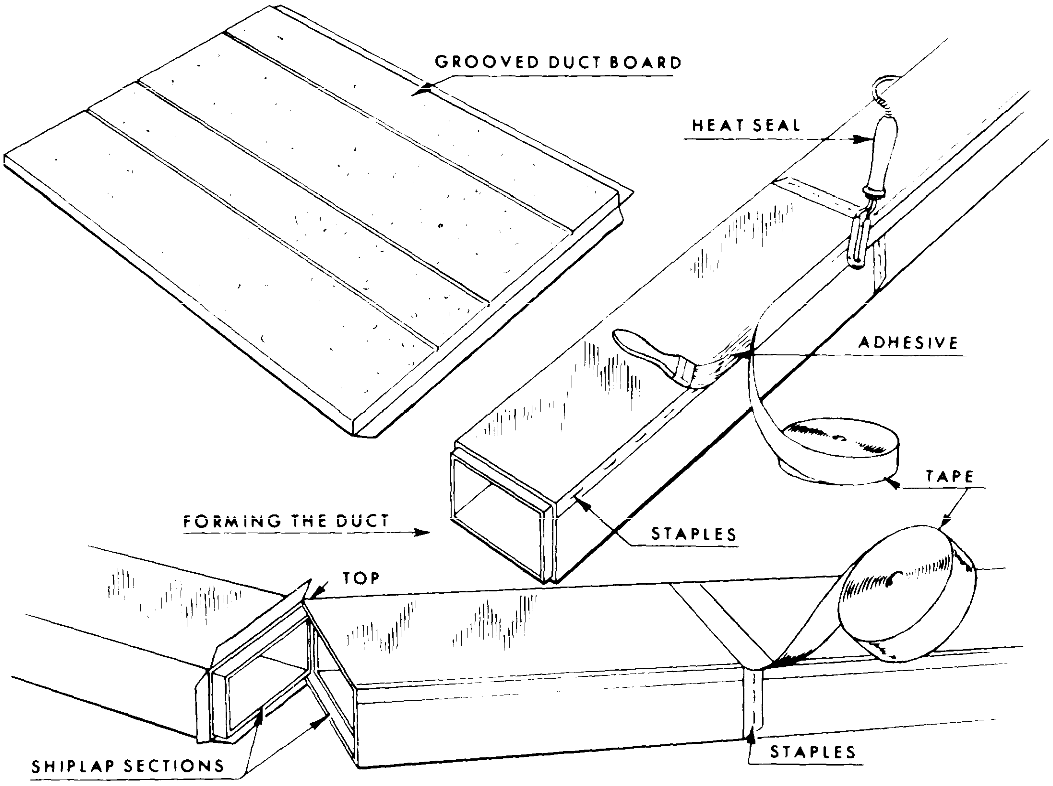


Figure 13-3.—Forming rectangular fiber glass ducts from duct board.

metal ducts. Therefore, fabric joints (usually constructed of heavy canvas) are used to join the branch ducts to the plenum.

SIZING DUCT SYSTEMS

There are numerous factors to be considered when sizing duct systems. These factors cause you to make modifications and adjustments throughout the planning and installation process to develop an efficient working system. First, you must calculate the air volume required for heating and for cooling the required space. This will assist you in determining the necessary duct size, fan size, fan speed, and so forth, that is needed to circulate the conditioned air. While determining the heating and the cooling factors, you should think in terms of air circulation throughout the building and in each individual room or space. Remember, air movement is determined by the type of return airflow that you use.

Four other important duct system components are diffusers, grilles, registers, and dampers. Each of these components has a direct correlation between functional design, amount of air accommodated, and the air movement pattern.

The elbows within the duct system are a major source of airflow restriction. Whenever possible, you can gain efficiency by installing long sweeping elbows. Short 90-degree elbows should be used sparingly on long duct runs. However, they can be used very effectively with a minimum of air turbulence and airflow restriction when installed just before diffusers, grilles, and registers.

Your final duct calculations involve taking unit pressure drops and total pressure drops throughout the system. Some of the major contributing factors to these pressure drops are as follows:

- Length of duct
- Duct material and interior finish
- Changes in duct size
- Number of elbows

Normally, you will be installing a duct system according to preestablished blueprints and drawings. Occasionally you may need to refer to other sources and review trade association standards. The *ASHRAE Handbook of Fundamentals* has three chapters dedicated to methods and procedures for selecting proper duct sizes. You should become familiar with the contents of these three chapters; particularly, if you are involved in the design phase of an air-conditioning system.

BALANCING DUCT SYSTEMS

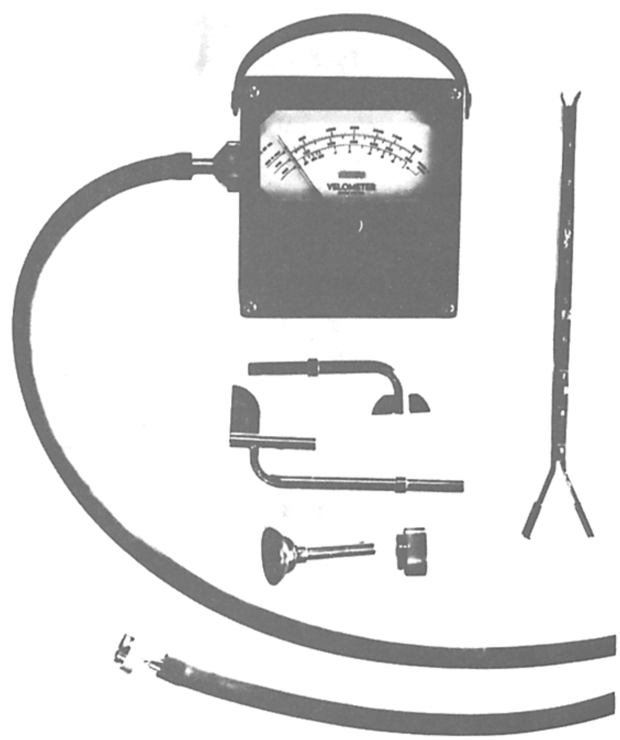
A duct system is always installed to fulfill specific requirement features related in some way to the health and welfare of human beings. Equally important is the fact that a properly balanced operating system results in lower operating costs and significant utilities conservation. Consequently, it is important that these systems, regardless of the function, operate properly. When a duct system is initially installed, the required pressures and performance data are available from the construction drawings and the manufacturer's instructions. After installation, pressures and performance requirements should be measured to ensure proper airflow at different locations. Once the proper airflows are established, little change should take place within the system. Maintenance personnel must ensure that the system is operating correctly by conducting certain periodic tests. Tests are used for the initial and subsequent setting of grilles, diffusers, dampers, and registers to obtain the necessary airflow required by specifications, codes, regulations, or trade association standards.

It is important to understand the pressure in a duct carrying a moving stream of air. Certain changes in an existing duct system are often necessary and you should be able to accomplish these changes. In addition, malfunctioning duct systems require immediate attention, and an understanding of the basic elements of the system is required before troubleshooting and corrective action can be undertaken. Furthermore, before a duct system can be properly balanced, certain essential knowledge of airflow is required.

Static pressure is a measure of the outward push of air on the walls of a duct. When air is not moving within a duct because a damper at the outlet is closed, the static pressure can be measured by means of a pressure gauge installed in the wall of the duct. If the damper in the duct is then opened and the air is flowing, static pressure continues to be present. It will be reduced when the damper is opened, but the static pressure can still be read on the gauge.

When air is flowing in a duct, there is another pressure—in addition to the static pressure—that can be measured. This is the pressure exerted by the moving airstream. This pressure acts in a plane perpendicular to the direction of airflow. To illustrate, imagine a horizontal duct without any air flowing in it. When a thin, flat piece of metal is suspended with a movable hinge from the top of the duct, it will hang straight down when air is not moving. When air flows, the hinged piece of metal swings upward toward the top of the duct. The velocity pressure is the force that causes the deflection of the hinged vane (obviously, the greater the air velocity, the greater the pressure acting on the hinged vane and the greater its deflection from the perpendicular).

The velocity pressure cannot be measured as easily as the static pressure. When a hollow tube is inserted in the moving airstream, and a gauge is connected to the end of the tube, the gauge registers a certain pressure. This pressure is larger than the static pressure because the gauge indicates the sum of the static and the velocity pressure. This sum is known as the total pressure. Since



87.177

Figure 13-4.—Velometer set.

87.257

Figure 13-5.—Pitot probe.

total and static pressure can be easily measured, the velocity pressure can be found by subtracting static from total pressure. In most problems concerning duct systems, air pressure is expressed in terms of inches of water (1 pound per square inch = 27.74 inches of water.)

At the time of initial installation of a duct system, the design data should be recorded. After initial start-up, the system should be balanced so that each air outlet is adjusted to the design rate of flow. During the initial balancing procedure, the actual design rate of flow is sometimes not achieved, but the flow is within the range of acceptable standards. When such conditions exist, they should be noted on the design data sheet where they may be considered by maintenance personnel during repairs or the rebalancing of the system. After the system is balanced and proper operation is assured, static pressure measurements are taken throughout the system. Also, the total pressure difference across the fan (the difference between the suction total pressure and the discharge total pressure) is noted. Although these initial measurements can be used for checking the design of the system, their main function is to serve as reference data for future tests. If the system fails to function properly at any time, another set of measurements should be taken and compared to the original set.

AIR BALANCING INSTRUMENTS

Numerous instruments designed for air balancing requirements are available from different manufacturers. Those that are most commonly used are discussed in this section.

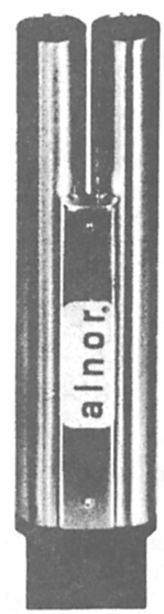
Velometer

This instrument is particularly adaptable to maintenance work because of its portability, wide scale range, and instantaneous reading features. Its accuracy is suitable for most air velocity and static pressure readings. Since velometers are made by several manufacturers, the instruction sheets for any instrument should be thoroughly understood before attempting to use it. A functional velometer set consists of the basic meter with hoses and accessories as shown in figure 13-4.

MEASURING DEVICES.— There are four measuring devices used with the basic meter for determining air velocities and pressures. They are the pitot probe, low flow probe, diffuser probe, and static pressure probe.

The pitot probe (fig. 13-5) is a stainless steel measuring probe with a standard length of 12 inches and a diameter of 1/2 inch. It is suitable for measuring velocities at supply openings and at return openings. Its primary purpose is to measure velocities within ducts. It is not recommended for velocity ranges below 300 fpm.

The low flow probe (fig. 13-6) is used for measuring velocities in open spaces. It connects directly to the meter and permits measurement of air by placing the instrument directly in the air currents. It is useful for measuring drafts in rooms and air velocities at ventilation hoods and spray

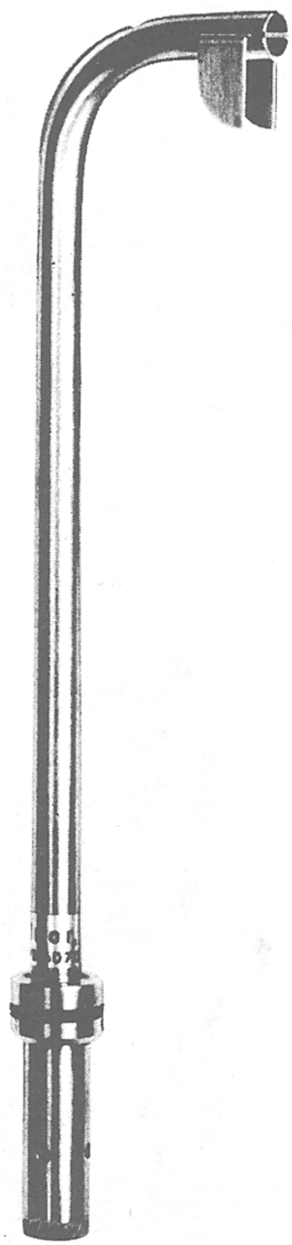


87.258

Figure 13-6.—Low flow probe.

booths. Only velocity ranges from 0 to 300 fpm are applicable to this device.

The diffuser probe (fig. 13-7) is used for measuring air output at duct supply diffusers. It can also be used with some meters on return air diffusers. The meter reading and the K factor established by the diffuser manufacturer can be used to determine air volume outputs.



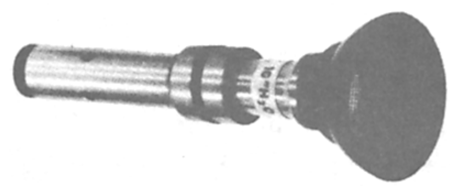
87.259
Figure 13-7.—Diffuser probe.

The static pressure probe (fig. 13-8) is used for measuring drops across blowers or fans in duct systems. The probe is carefully placed over an opening in the wall of a duct so as to form a positive seal. The hole should not be less than one-quarter inch in diameter.

RANGE SELECTORS.— These are devices (fig. 13-9) that permit a rapid change of measuring ranges without the need for shifting to separate jets for each range. They are provided with connections that accept the various probes. These probes can also be connected to the meter. With the exception of the low flow probe, measurements may require a range selector.

Manometer

A manometer is an instrument that indicates air pressure by employing the principle of



87.260
Figure 13-8.—Static pressure probe.

87.261
Figure 13-9.—Range selector.

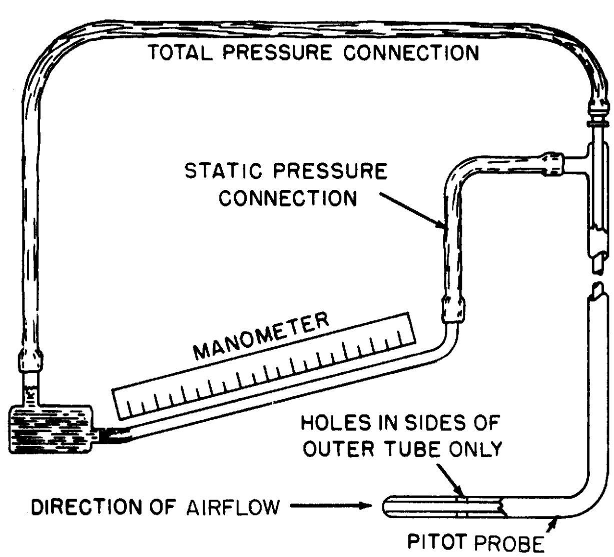
balancing a column of liquid of known weight against air pressure. The units of measure used are pounds per square inch, inches of mercury using mercury as the fluid, and inches of water using water as the fluid.

The simplest form of manometer is the basic U-tube type. Several variations of the basic type are presently used in air movement applications, for example, the inclined type (draft gauge) and the combination inclined and vertical type. An inclined manometer with a pitot probe is shown in figure 13-10. Many commercially installed central duct systems have permanently mounted manometers connected to duct interiors with static pressure tips.

Rotating Vane Anemometer

The rotating vane anemometer (fig. 13-11) consists of a propeller or revolving vane connected through a gear train to a set of recording dials that indicate the number of linear feet of air passing in a measured length of time. It requires correction factors and frequent calibrations, and it is not as accurate as the velometer.

The primary application for a rotating vane anemometer is the measurement of grille velocities on heating, cooling, and ventilating installations; however, it may not be suitable for exhaust measurements or for measurements on very small grilles.



87.179
Figure 13-10.—Inclined manometer with pitot probe.

Miscellaneous Instruments

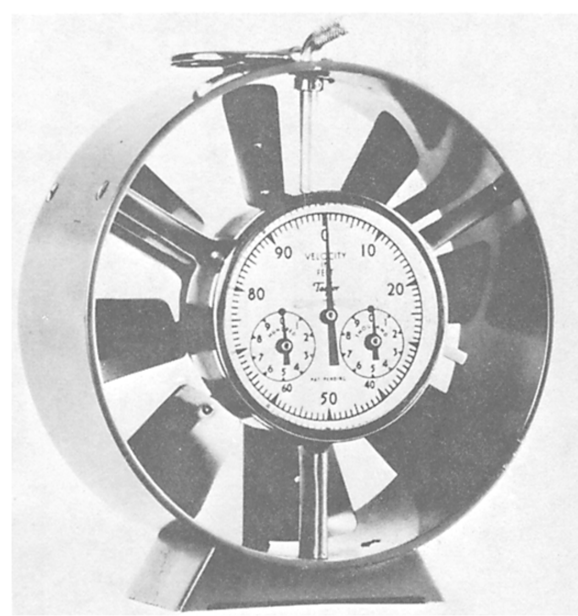
In addition to the air balancing instruments, there are other miscellaneous devices required. Thermometers are necessary for making temperature measurements at various duct and room locations; a tachometer is needed to determine fan speeds; and a multimeter is needed to check fan motors for proper operation.

PREPARATION FOR BALANCING

The following preliminary procedure is necessary before proper balancing can begin. These steps are general in nature and should apply to most situations.

1. Review applicable mechanical drawings and job specifications. This review will provide necessary data on the ducts, air handlers, and outlets. Information pertaining to design airflow can also be taken from these drawings.

2. Prepare a simple working sketch of the entire duct system showing dimensions, airflow volumes and velocities, and the location of all components such as dampers, fans, coils, and filters. Duct outlets should be numbered on the sketch starting at the farthest one from the fan



87.178
Figure 13-11.—Rotating vane anemometer.

and working back toward the fan. (See fig. 13-12.) The type of diffuser and the air delivery design of each outlet should be noted.

3. Obtain data pertinent to motors, fans, diffusers, and grilles that are not given on drawings. This can usually be taken from the manufacturer's identification plate located on the component. This information is useful during the balancing process for comparing measured results with design conditions.

4. Make a visual check of the system to ascertain that all fans are rotating correctly. Also, that air filters are clean and properly installed.

5. Place all dampers in the open position. This includes volume balancing dampers, splitter dampers, outlet dampers, and fire dampers.

6. Check all necessary instruments *prior* to starting the balancing procedure. Always follow the manufacturer's recommendations for checking the calibration of instruments.

PROCEDURES FOR BALANCING

The procedures required for balancing most systems are similar. Balancing is a rigorous technique that, if properly done, yields excellent results. As with any set of procedures, each operation is necessary and must be performed in the correct sequence. The following procedures are general in nature and apply to most systems.

Determine Fan Performance

The first step of the procedure is to determine fan performance. The purpose for this is to ensure that there is sufficient static pressure and air volume being handled at the fan before balancing is started. The fan's revolutions per minute (rpm), the voltage and amperage of the fan motor, the fan static pressure, and the system's total airflow are indications of fan performance.

The fan rpm can be measured by a tachometer as shown in figure 13-13. You should take several readings to ensure an accurate reading. The results can be compared with the design conditions to determine performance.

You should use a multimeter to determine if the operating voltage and amperage of the fan motor are within the range of rated voltage and amperage indicated on the motor nameplate. The measured results can either be compared or used to calculate the brake horsepower. Use the manufacturer's recommended calculation to determine the brake horsepower.

You can determine the fan static pressure by attaching a velometer and static pressure probe to test tap holes located on the inlet and discharge duct of the fan, as shown in figure 13-14. Fan static pressure is the static pressure at the outlet minus the total pressure in the fan inlet. This

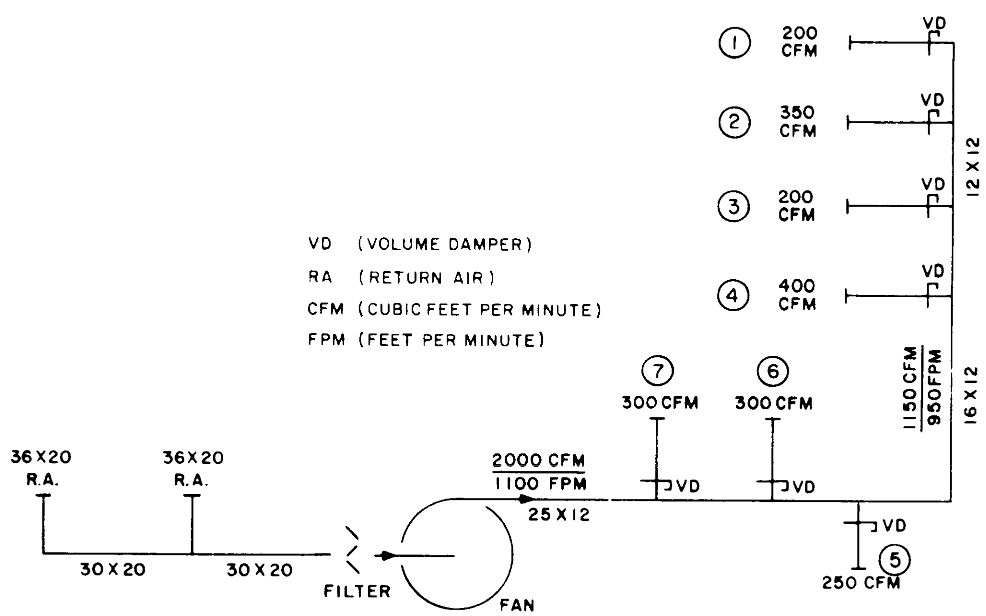


Figure 13-12.—Duct system working sketch.

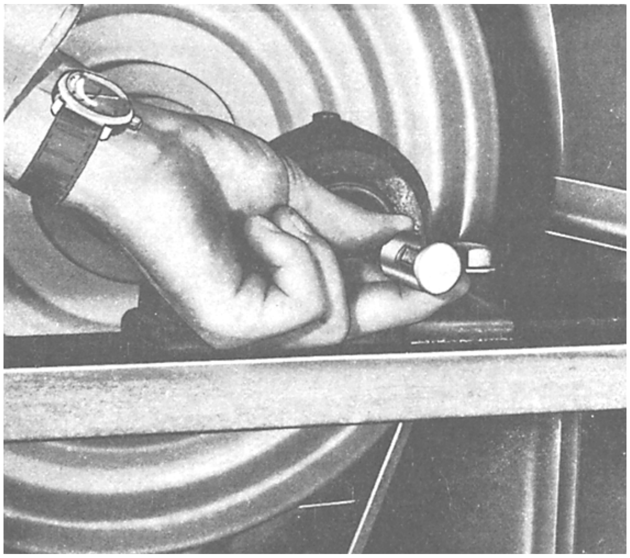


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Figure 13-13.—Measuring fan rpm.

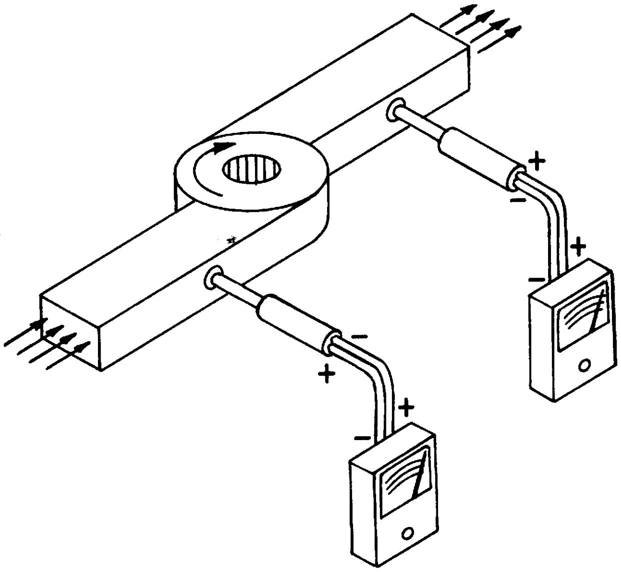

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Figure 13-14.—Fan static pressure measurement.

test may not be necessary in the field; however, if it is, the results can be compared with the manufacturer's fan curve and system specifications to determine fan performance.

You can quickly locate problems caused by blockages in duct systems by performing static pressure readings. The total air volume in cubic feet per minute (cfm) for a fan can be determined by the following procedures:

1. Downstream of the air handler, establish a point along the duct that has the longest straight run and drill test holes into the duct. Holes should be far enough downstream from any elbows or from the fan discharge to minimize the effect of turbulence. The holes must be closed and sealed after the test is completed.
2. Take velocity pressure readings using a pitot probe and manometer or velometer. For rectangular ducts, velocity readings are taken at the center of equally divided areas. On round ducts, readings are taken across each of two diameters on lines at right angles to each other. (See fig. 13-15.)
3. Calculate the cubic feet of air per minute by multiplying the average velocity pressure in feet per minute found in the above reading by the cross-sectional area of the duct in square feet. Total airflow in cfm = Average velocity in fpm x duct cross-sectional area in square feet.

The results are compared with design conditions to determine performance. Measured cfm should be approximately equal to design cfm plus 10 percent to allow for leakage.

In the event that fan performance is not consistent with design conditions, the necessary adjustments or repairs should be made at this point in the balancing procedure. For example,

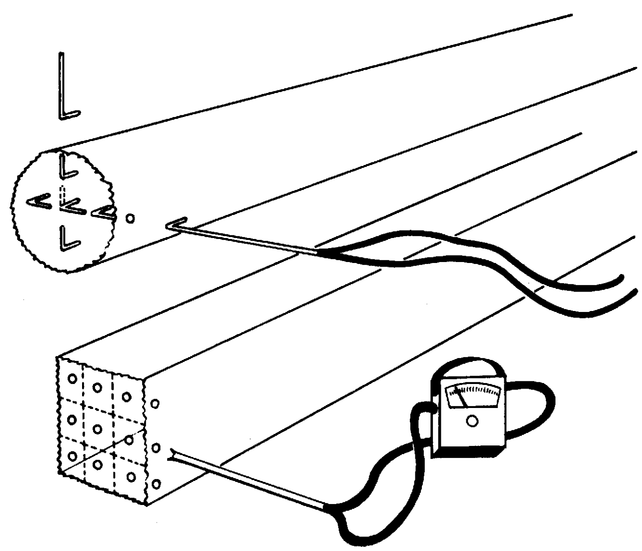

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Figure 13-15.—Velocity pressure measurement.

the fan speed can be changed by adjusting the variable diameter motor pulley. Be careful to avoid operating the fan at a speed that overloads the motor. After adjustments or repairs, tests should be repeated to verify that the design conditions have been attained. Total air volume measurements should be repeated for all air-handling units on branch, return, and exhaust duct systems.

Duct and Outlet Adjustments

You should use the same procedure for measuring total air volume to set the main splitter dampers on systems containing branch ducts. When main ducts, zone ducts, and branches are set for design air, the tests necessary for adjusting individual outlets can begin. When available, always follow the manufacturer's recommended procedure.

The final balancing procedure involves the adjustment of individual outlets to correspond with the manufacturer's design flow and system specifications. Begin with the last outlet on the branch farthest from the fan discharge and measure the velocity (or cfm). You can use either a velometer with the diffuser probe or an anemometer. If the cfm is below design, leave the damper open and proceed to the next outlet. If the cfm is greater than design, close the damper to obtain the desired results. In the same branch go to the next closest outlet, repeat the procedure, then continue the process with each outlet until you reach the main duct.

If applicable, you should complete the same procedure on the remaining branch ducts. Finally, total cfm of all outlets should agree with total cfm of all branches, and this grand total should agree with the air volume for the fan or fans. These figures should be within 3 to 7 percent of design conditions. You should check fan outputs and motor amperages to ensure that the motor is not in an overloaded condition. At this point, fan speed and horsepower, fan total air by velocity measurement, and total air by outlet volume measurements have been established for the specific operating condition of the system during the procedure. The system should be balanced for those conditions.

VENTILATION SYSTEMS

Normally air contains about 21 percent oxygen. A ventilation system serving human beings requires that a certain oxygen content be contained in the air to maintain life and to ensure comfort.

If a room is tightly sealed, any human in that room would slowly consume the oxygen and increase the amounts of carbon dioxide, water vapor, and various impurities. This could cause drowsiness or even death.

You must remember that space for human living must have air with a good oxygen content and that this air must be kept at a reasonable temperature. It is of utmost importance that fresh air be admitted to provide the oxygen.

In the past, this fresh air entered the space by infiltration (leakage) from the outside at door and window openings and through cracks in the structure. However, modern construction is reducing this air leakage. Air-conditioning apparatus, then, must furnish fresh air. Modern units have a controlled fresh-air intake. This fresh air is conditioned and mixed with the recirculated air before it reaches the room.

Some conditioned air leaves a building through doors, windows, and other construction joints. Some also leaves by exfiltration. (This means leaking out or being blown out by mechanical means.) Any kind of exhaust fan removes conditioned air. Some of this air is replaced by infiltration on those sides of the building exposed to wind pressure.

It is best to bring in replacement fresh air through a makeup air system. When this is done

- the makeup air can be cleaned.
- the makeup air can be cooled or heated.
- a positive pressure can be maintained in the building to keep out airborne dirt, dust, and pollen. (A negative pressure reduces the efficiency of exhaust fans and fuel-fired furnaces.)
- a definite amount of fresh air is brought into the building for health purposes (oxygen content).

Certain areas of a building should have a slightly less positive pressure (5 to 10 percent) than the rest of the building to reduce the spread of odors. Such areas would include the kitchen, lavatories, and where certain industrial operations produce fumes.

The amount of fresh air required depends on the use of the space and the amount of fresh air admitted by infiltration. One basic rule is to provide at least 4 cfm of fresh air per person to provide enough oxygen and to remove carbon dioxide. If six people occupy a 1,000-square-foot space with a 10-foot ceiling, there is 10,000 ÷ 6, or 1, 667 cubic feet per hour for each person, or 1,667 ÷ 60 = 27.7 cfm (.78m^3 /min). This meets or exceeds ventilating code requirements.

One must remember that the air can be handled either to produce positive pressure (higher than atmospheric pressure) in a building or negative pressure (below atmospheric pressure). A positive pressure eliminates infiltration of air from the outside or from other spaces. Positive pressure is produced by using special air intakes to the blowers. A positive pressure assures that all air entering a building can be filtered and cleaned before reaching the occupied space. Hospitals use positive air pressure and require a 100- percent fresh air intake.

Negative pressure increases the infiltration at windows and doors. This air is untreated and may be dirty. If the amount of impurities in the inside air-such as odor, smoke, and bacteria—is great enough to require air cleaning, the remedy may be either more ventilation (using fresh air) or improved air cleaning.

Ventilation is usually based on air changes per hour for the conditioned space. If the space is 10,000 cubic feet, for example, three changes per hour would mean 3,000 cubic feet per hour or 50 cmf. Three changes every hour is the minimum for a residence during the heating season. As high as 12 changes an hour (in the above case, 200 cfm) are recommended for cooling.

It is a good practice to keep the air blowers running all the time to provide good ventilation to all parts of the building. Variable speed blowers are sometimes used. They provide more air movement when the heating or cooling systems are off.

An adequate air supply is the best way to control comfort. Body comfort is controlled by evaporation, convection, radiation, and respiration. You must, therefore, control the temperature of the walls, floors, or ceilings to make sure they are not too warm or too cold (radiation). You must also supply enough air to promote good respiration, evaporation, and convection. If the specified conditions are not known, it is best to design for 2 cubic feet per minute per square foot and/or 12 changes of air per hour. It is also very important to remember that people occupying a closed space give off considerable heat. A sleeping person gives off about 200 Btu/hr; a person doing heavy work gives off up to 2,400 Btu/hr.

Another way to determine ventilation requirements is to design for 4 cfm to 6 cfm of fresh air per person and for about 25 cfm to 40 cfm of recirculated air per person. This means the system should handle a total of 29 cfm to 46 cfm per person. (1 cfm = 0.0283 cu m/min.)

NATURAL VENTILATION

Natural ventilation, or gravity ventilation, uses the natural forces of wind, stack effect, and breathing of structures caused by the interior-exterior temperature difference to induce air circulation and removal. Generally, air enters through openings at or near the floor level in a building and escapes through openings high in the walls or ventilators on the roof.

Natural ventilation is used only where the necessary quantity of ventilation can be induced by natural forces. Applications that require a continuous supply of outdoor air for human comfort, or the safe use of space (or process), should not be designed for natural ventilation. In such cases, natural ventilation is not reliable because of wide variations in the natural forces, such as wind velocity and direction and the inside-outside temperature difference.

For an installation using natural ventilation, you should consider the location and control of ventilation openings. Locate the air inlet openings on the side of the building facing directly into the prevailing winds. Locate the air outlets where prevailing winds movements would create low-pressure areas; that is, on the side directly opposite the prevailing wind direction. Outlets may also be placed on a roof in the form of individual gravity ventilators or ridge ventilators. Calculate the ventilation rate due to wind velocity and the stack effect as detailed in criteria established by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE). When natural ventilation is provided for temperature control, you should provide a means for closing the openings during the heating season.

The use of gravity ventilators is another method. A roof-mounted gravity ventilator may be a stationary, a pivoting wind-directional, or a rotating-turbine type of ventilator. You should select gravity ventilators based on the rating tables for the mounting height involved and a wind velocity of 4 miles per hour.

Natural ventilation has limited uses. In general, natural ventilation is inadequate for the following examples:

- Offices having an open window area less than 5 percent of the floor area
- Offices over 24 feet deep and without cross ventilation
- Offices having cross ventilation but having occupied space more than 35 feet from a window or an air inlet
- Dining rooms having a window area less than 6 percent of the floor area

In using natural ventilation, you should consider local building and safety codes and the minimum requirements of the Occupational Safety and Health Act (OSHA), part 1910.

MECHANICAL VENTILATION

Mechanical ventilation uses mechanical forces to induce air circulation within buildings or spaces. Air movement is created by fans or by fans combined with a supply air and/or exhaust air duct system.

You should provide mechanical ventilation equipment when the necessary quantity of outside air cannot be supplied continuously by natural forces. The quantity of air supplied should be kept to an acceptable minimum. You should install mechanical ventilation equipment in the following cases:

- For a supply of outside air and the removal of bad air or air contaminated by smoke, body odors, and so forth, in areas having a high occupancy level (auditoriums, assembly halls, and cafeterias).
- For processes giving off noxious or hazardous fumes, dust, or vapor, resulting in unsafe or unhygienic conditions (paint spray booths, electroplating plants, welding booths, and other similar applications).
- For limited comfort of operators as in laundries, projection booths, and kitchens.
- For spaces containing fumes and vapor with specific gravity higher than air, such as garages and some refrigeration rooms. In these cases, provide exhaust intakes at floor level.
- For electronic or electric equipment installed in confined spaces where the operating temperatures of the equipment may exceed the safe limit.
- For spaces having explosive vapors or dust, use explosionproof ventilation equipment regardless of the concentration of explosive substances.
- For odor removal in bathrooms.

CHAPTER 14

AIR CONDITIONING AND REFRIGERATION

A Utilitiesman is expected to know technical informaiton about the air conditioning of buildings and the refrigeration of perishable products. This chapter covers the aspects of selecting and installing air-conditioning and refrigeration equipment. The individual components required in an air-conditioning system and a refrigeration system are also discussed. Finally, the fundamental electrical knowledge you actually need to install, maintain, and repair air-conditioning and refrigeration equipment is discussed.

SELECTION AND INSTALLATION OF AIR-CONDITIONING SYSTEMS

There are two types of air-conditioning systems that must be considered before selection and installation of equipment. The first system discussed is forced air. Then, in turn, the hot and chilled water system is discussed.

FORCED AIR

Forced air units are used when the areas to be air-conditioned are close to each other, are being used for similar purposes, or have the same humidity and comfort zone requirements. A few examples are office spaces, single-dwelling homes, and single-purpose shops. Some characteristics of the system that must be taken into consideration during the planning phase are the following: to keep units centrally located, to ensure return air is drawn from the area being cooled, and to ensure that one thermostat controls the system. See figure 14-1 for two examples of a forced air unit with accompanying ductwork.

HOT AND CHILLED WATER

Hot and chilled water units should be used when the areas to be air-conditioned are dispersed, have a wide range of different uses, or have different humidity and comfort zone requirements. Some examples are a barracks, a galley, or a hospital. Some characteristics of these air-conditioning units that must be taken into consideration regarding this system are location (mechanical room), use or non-use of return air (hospital operating room), humidity and temperature controls, individual room temperature requirements, and amount of installation space for piping and ductwork. See figure 14-2 for a typical piping diagram of a year-round air-conditioning system.

If you are involved in designing an air-conditioning system or desire more information, refer to NAVFAC DM 3.3, *Heating Ventilating Air-Conditioning and Dehumidifying Systems.*

HEAT LOAD CALCULATIONS AND AIR MOVEMENT

Once the type of air-conditioning system has been chosen, the next step is to figure out its appropriate size. There are two primary factors that must be considered. The first factor is heat load calculation. Humidity comfort temperature, and psychometrics are the three primary considerations necessary for calculating heat load. The second factor is air movement. Velocity, pressure, and drafts are the three main factors that are important when you are designing and planning the size

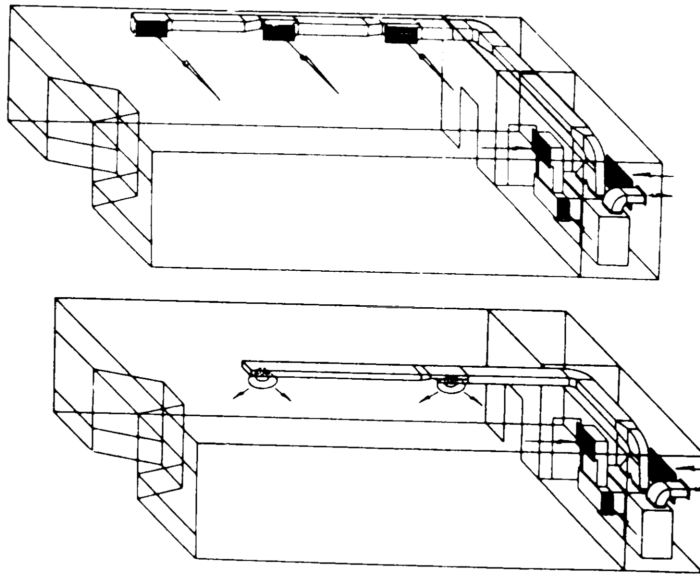

Figure 14-1.—Arrangements for package-type air-conditioning units and air ducts. 87.185

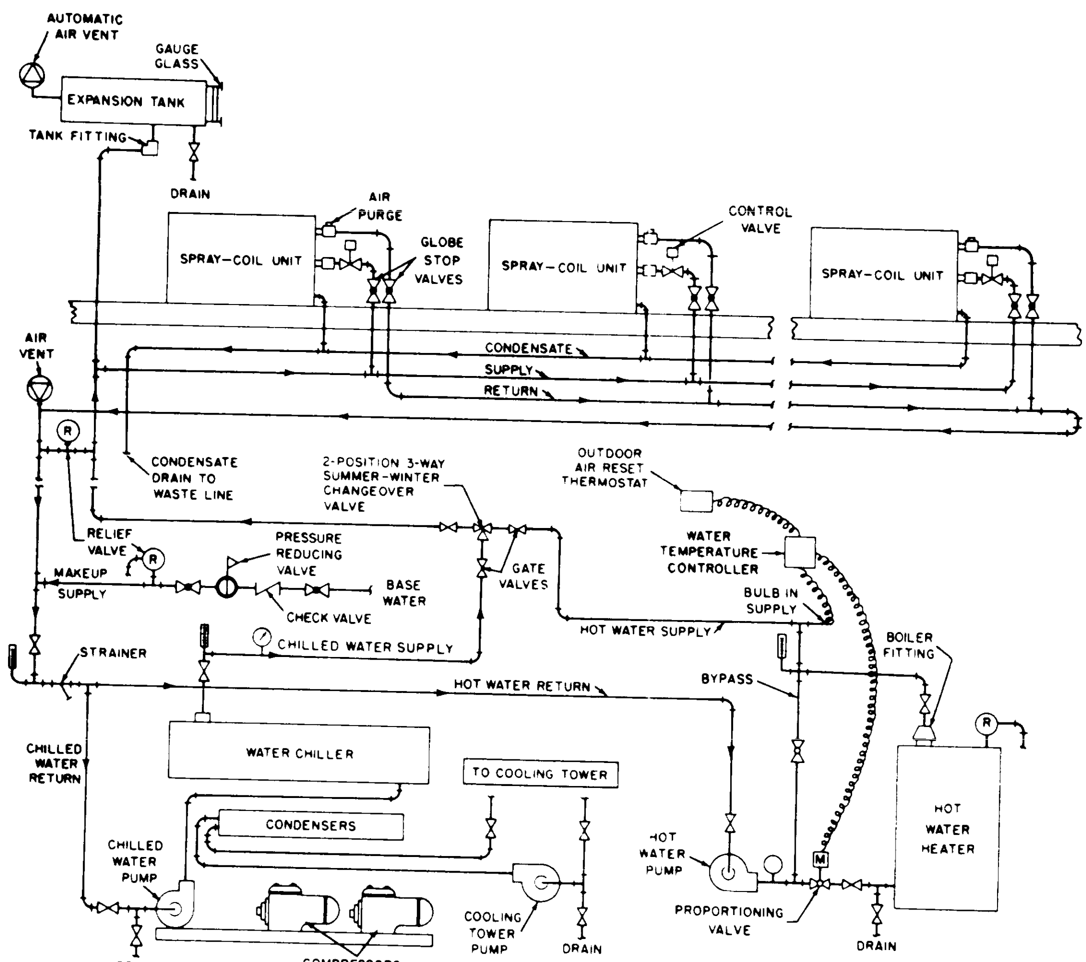

Figure 14-2.—Typical piping connections for a year-round air-conditioning system. 54.179

of an installation. Figure 14-3 shows the relationship between humidity, temperature and air movement.

SELECTION AND INSTALLATION OF RERIGERATION SYSTEMS

In a refrigeration system, the major consideration is the heat load calculation. There are five general factors that affect the refrigeration heat-load estimate required for a particular application.

Heat transmission load. This leakage occurs through walls, doors, ceilings, and floor space into the space being refrigerated.

Insulation factor. This is the rate of heat transfer that occurs through insulating material.

Air change load. This factor is determined by the frequency with which a door is opened and closed and the length of time a door is left open.

Product load factor. This is determined by the types of products being stored and product temperature at time of storage.

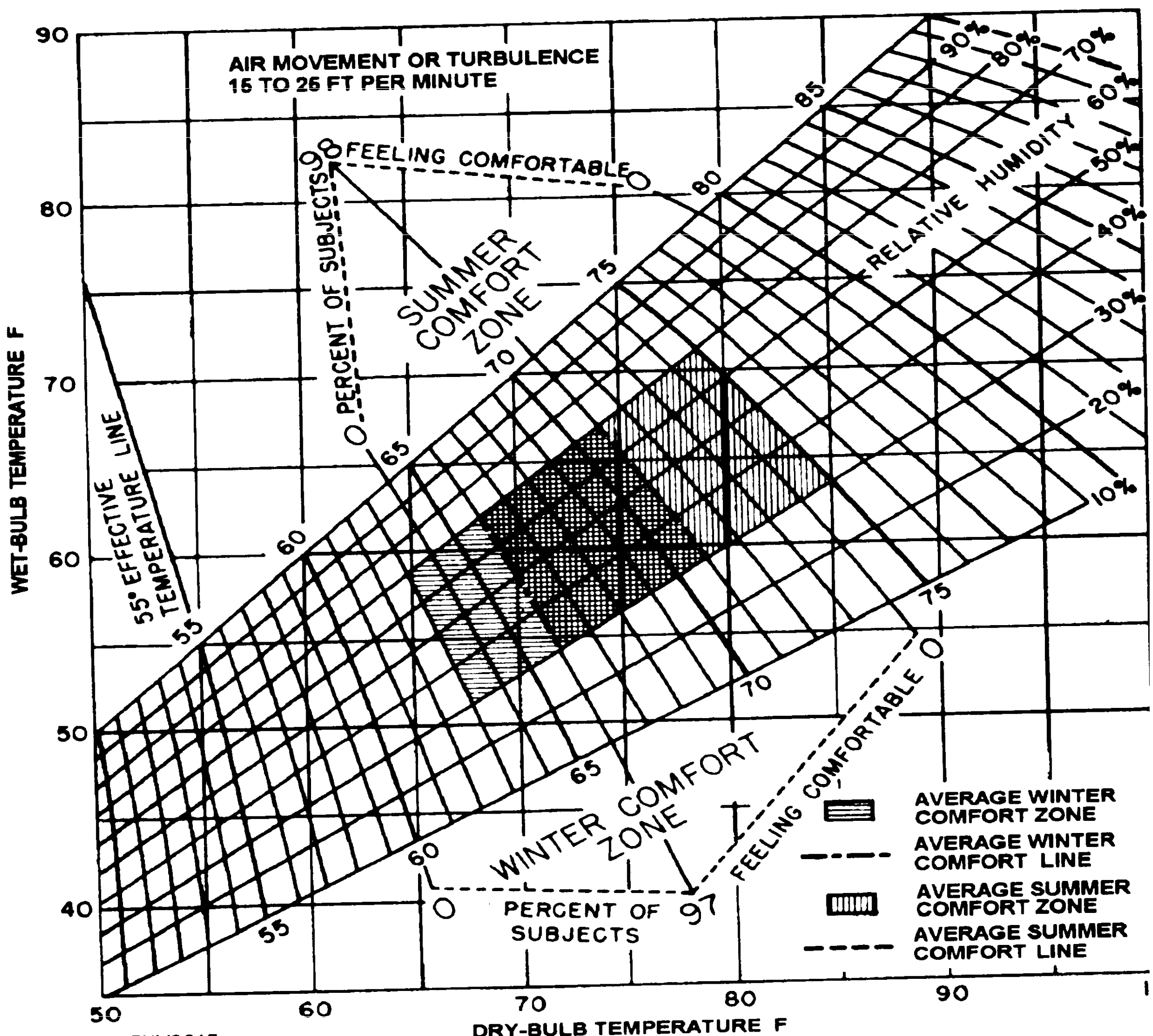

Figure 14-3.—Comfort zone chart.

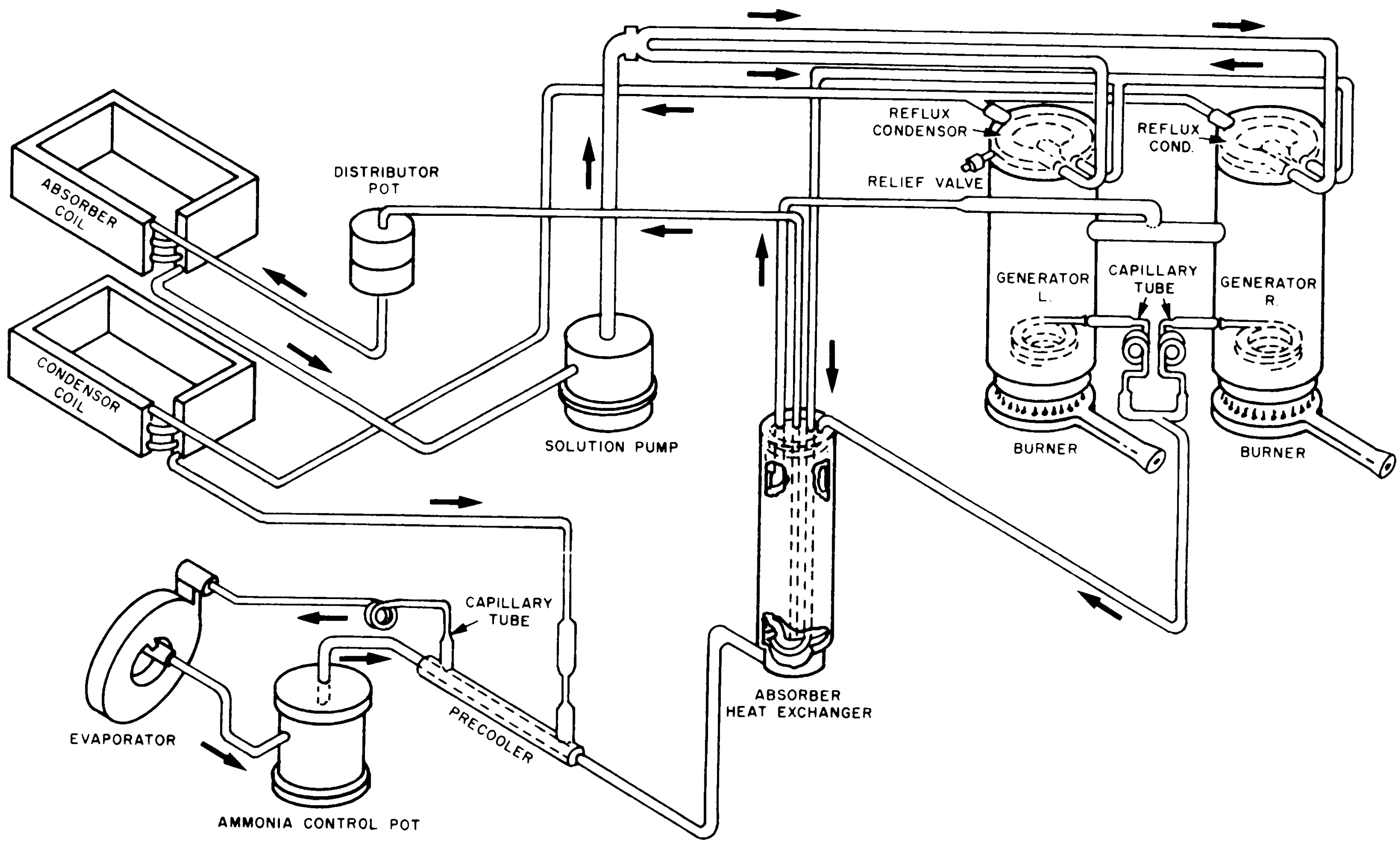

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Figure 14-4.—Absorption refrigeration cycle.

- Miscellaneous factor. This includes such factors as exposure to direct sunlight and ambient temperature surrounding the system.

There are several charts and graphs available that depict the relationship between the factors listed above. To do the job right, you must take into consideration the total effect of the factors before selecting a particular refrigeration system.

SPECIAL TYPES OF REFRIGERATION SYSTEMS

There are certain applications where an electrically powered refrigeration system cannot be used. This requires knowledge of special applications and selection of a refrigeration system that will work effective . The absorption and the expendable refrigeration systems are discussed in this section.

ABSORPTION REFRIGERATION SYSTEM

An absorption system uses either water, ammonia, or lithium bromide as the refrigerant. The system can range from very simple (small refrigerator) to complex (commercial freezer). This type of system is used in domestic and industrial refrigeration and air-conditioning applications. The absorption system is also used in recreational vehicles. Normally, these systems are identified by the type of heat source being used to power them, such as kerosene, natural gas, steam, or electricity. Because of the high pressure (400 psi), you should remember that welded steel tube construction must be used throughout the system. Also, because of the reaction between ammonia and copper or brass, you need a set of steel manifold gauges. Figure 14-4 shows an absorption.refrigeration cycle using ammonia as the refrigerant.

EXPENDABLE REFRIGERATION SYSTEM

An expendable refrigeration system. is for used in trucks, railroad cars, and shipping containers that transport perishable items. The three types of refrigerants presently being used in an expendable system are liquid nitrogen, carbon dioxide, and liquid helium. The evaporator system and the spray system are two types of expendable systems commonly used in the Navy, and they are discussed in this section

Evaporator Systems

In the expendable evaporator system, liquid refrigerant is stored in large metal insulated cylinders. These cylinders are normally located in the front of the cargo vehicle. Each cylinder is equipped with a temperature control to provide a temperature range of –20°F to 60°F.

The temperature control is connected to a temperature sensor. As the temperature rises, the switch operating the control valve opens and liquid refrigerant flows into the evaporator. The evaporator can be blower coils, plates, or eutectic plates. As it passes through the evaporator, the refrigerant vaporizes. This vapor is pushed through the evaporator by the pressure difference between the cylinder and the vent. When the selected temperature is attained, the refrigerant valve closes. The vapor that has been used is then discharged from the evaporator at about the same temperature as the air in the cargo vehicle. With this system, the refrigerant does not mix with air in the vehicle space. An example of the expendable evaporator system is shown in figure 14-5. This example shows two nitrogen cylinders located inside a truck body that are connected by a manifold to regulators and to temperature control solenoid valves. The vaporizing liquid nitrogen flows into the vaporizers or cold plates to refrigerate the true box.

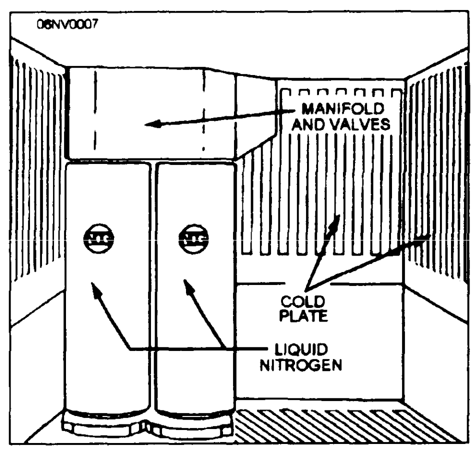

Figure 14-5.—Expendable evaporator refrigeration system.

Spray Systems

In the expendable refrigerant s ray system, liquid nitrogen or carbon dioxide is sprayed directly into the vehicle space that is to be cooled. This system. uses liquid containers, a control box, a fill box, spray headers. emergency switches. and safety vents.

The fill box is normally located on the front of the vehicle. It contains the valves, gauges, and connections that allow the liquid containers to be filled. The liquid containers are insulated cylinders similar to thermos bottles. The control box contains the valves, gauges, and thermostats that are necessary for safe release of the liquid to the spray headers. Once the liquid is received at the spray headers, the nozzles spray it into the vehicle. The remaining two components are primarily safety devices. These emergency interlock switches are attached to each door. Thus, whenever a door is opened, the system shuts down. The safety vent is a small trapdoor that vents air directly to the atmosphere whenever the air inside the truck box exceeds atmospheric pressure.

A benefit of this system is that liquid nitrogen or carbon dioxide replaces the oxygen inside the space being refrigerated. Therefore when fruits, vegetables, meats, and fish are being refrigerated, they are also preserved by the inert atmosphere.

A vehicle equipped with this type of system must display the following safety sign:

CAUTION: THE TEMPERATURE OF LIQUID NITROGEN, AS IT COMES FROM THE SPRAY NOZZLES, IS BELOW (0°F.

Liquid nitrogen will instantly freeze any part of the human body that it touches. Since liquid nitrogen can be dangerous, you should always inspect the refrigerated space before closing the doors. An expendable spray system for a refrigeration truck is shown in Figure 14-6. In this system, the liquid nitrogen is in an insulated container that is installed vertically inside the truck body. Another similar type of spray system with the refrigerant container mounted horizontal under the truck body is shown in figure 14-7.

THERMOELECTRIC REFRIGERATION SYSTEM

This type of system is used to move heat from one area to another by use of electrical energy. The electrical energy, rather than the refrigerant, serves as a "earner." The primary use of thermoelectric systems has been in portable refrigerators, water coolers, cooling of scientific apparatus used in space exploration, and in aircraft. The main advantage of this system is there are no moving parts. The system is compact, quiet, and requires little service.

MULTISTAGE REFRIGERATION SYSTEM

Multistage refrigeration systems are used where ultralow temperatures are required but cannot be obtained economical] through the use of a single-stage system. The reason for this is the compression ratios are too high to attain the temperatures required to evaporate and condense the vapor. There are two general types of -systems presently in use– cascade and multistage (compound.)

Cascade System

The cascade system has two separate refrigerant systems interconnected in such a way that the evaporator from the first unit cools the condenser of the second unit. This allows one of the units to be operated at a lower temperature and pessure than would otherwise be possible with the same type and size of single-stage system. It also allows two different refrigerants to be used, and it can produce temperatures as low as —250°F. Refer to figure 14-8. In this typical cascade system,

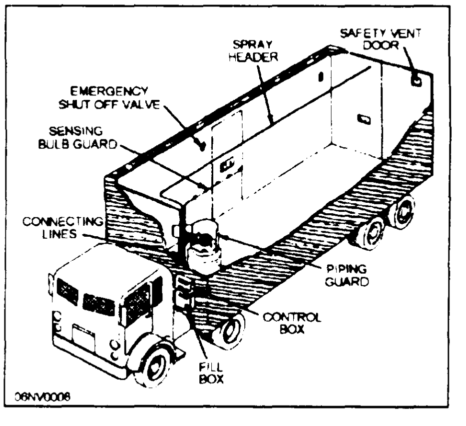

Figure 14-6.—An expandable spray System

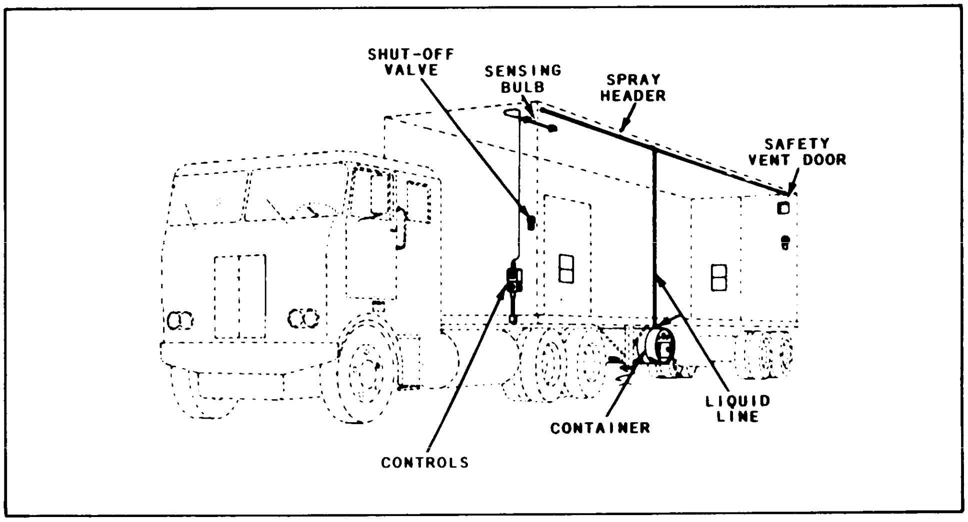

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Figure 14-7.—An expendable spray system.

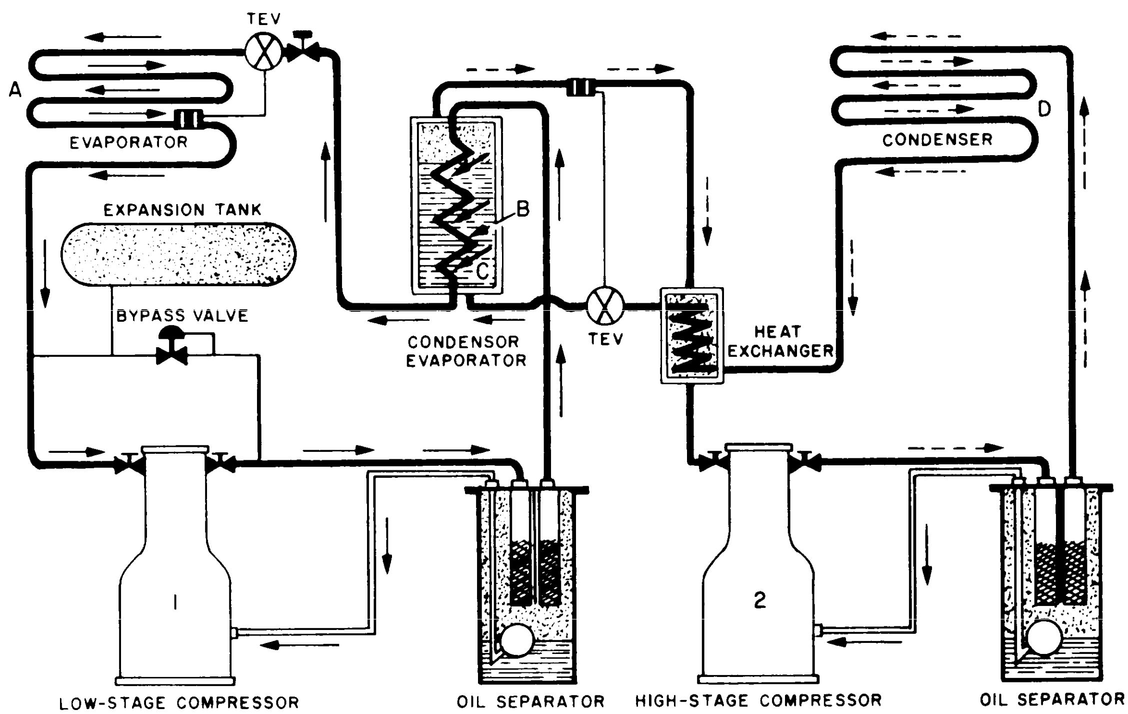

Figure 14-8.—Cascade refrigeration system.

condenser B of system 1 is being cooled by evaporator C of system 2. This arrangement enables ultralow temperatures in evaporator A of system 1. The condenser of system 2 is shown at point D in the figure. Two TEV refrigerant controls are also indicated in the figure. Notice the use of oil separators to minimize the circulation of oil.

Compound System

The compound system uses two or more compressers connected in series in the same refrigeration system. In this type of system the first stage compressor is the largest and for each succeeding stage the compressor gets smaller. This is because

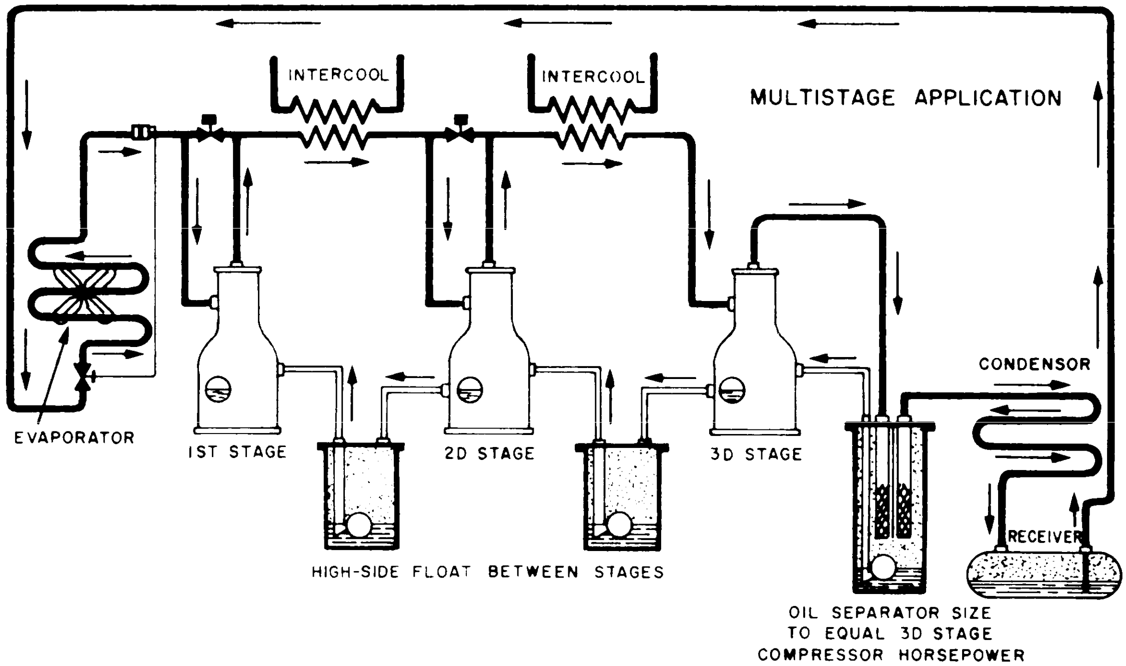

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Figure 14-9.—Multistage refrigerating system.

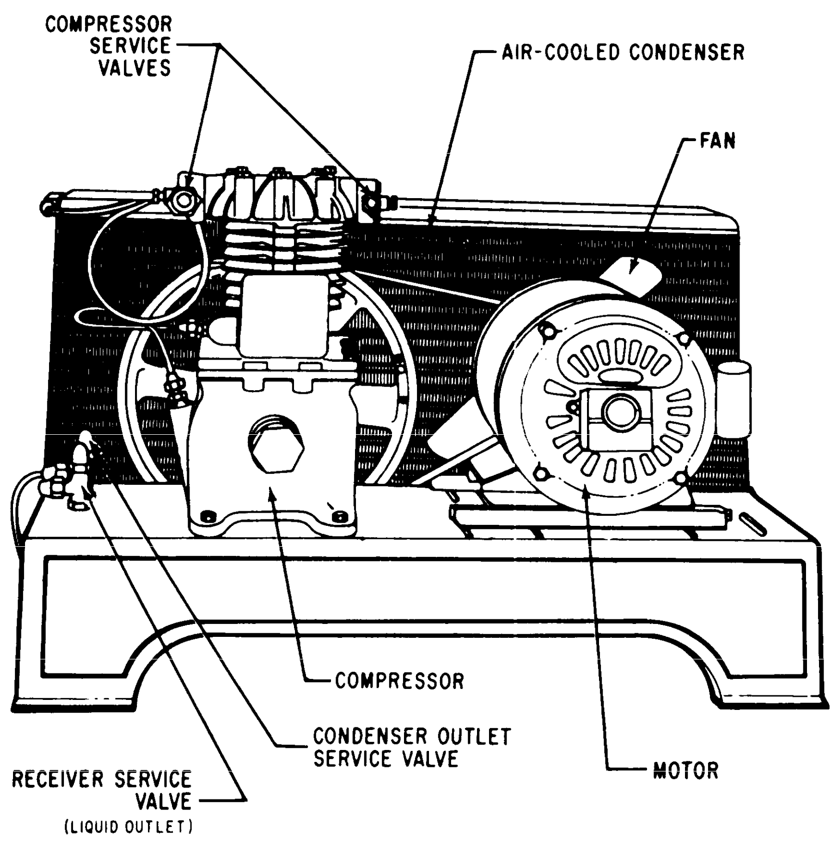

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Figure 14-10.—Air-cooled condenser mounted on a compressor unit.

as the refrigerant passes through each compressor, it becomes a more dense vapor. A two-stage compound system can attain a temperature of approximately –80°F. A three-stage system, like the one depicted in figure 14-9, can attain a temperature of –135°F efficiently. Compressor 1 pumps vapor into the intercooler and then into the intake of compressor 2. This operation is repeated between the second and third stages. In the third stage, the refrigerant vapor is further cooled and travels to the evaporator for specific cooling use.

MECHANICAL COMPONENT SELECTION

There are several mechanical components required in a refrigeration system. In this section, we discuss the four major components of a system and some equipment associated with the major components. These components include condensers, evaporators, compressors, refrigerant lines and piping, refrigerant capacity controls, receivers, and accumulators,

CONDENSERS

There are several condensers to be considered when making a selection for installation. They are air-cooled, water-cooled, shell and tube, shell and coil, tube within a tube, and evaporative condensers. Each type of condenser has its own unique application. Some determining factors include the size and the weight of the unit, weather conditions, location (city or rural), availability of electricity, and availability of water. For example, is electricity available in single phase or three phase? Is electricity economical or prohibitive? Water in some locations may be scarce, expensive, or contain chemicals that make it unsuitable for use. Local zoning laws should also be checked to ensure there are no restrictions as to use of electricity, water, or location of the unit. If you installed a unit on a roof, the roof load strength is very important. In some locations, the noise factor of an operating unit is an important consideration. With the rapid advances in technology, you should contact a manufacturer whenever possible to get the latest condenser design features available for a special-purpose installation. Figure 14-10 shows a typical installation of an air-cooled condenser mounted on a compressor unit. Figure 14-11 shows a cutaway view of a water-cooled condenser.

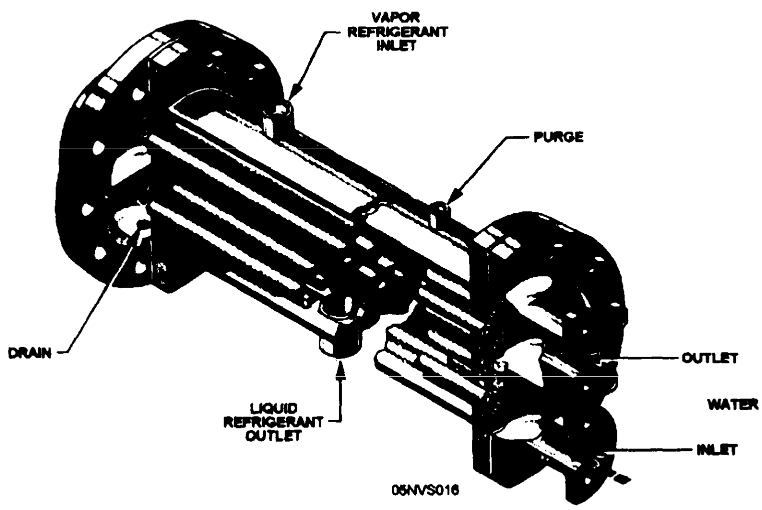

Figure 14-11.—Water-cooled condenser.

EVAPORATORS

There are almost as many different types of evaporators as there are applications. However, evaporators are divided into two general groups. The first group has evaporators that cool air that, in turn, cools the product. The second group has evaporators that cool a liquid such as brine solution that, in turn, cools the product. Normally, the proper evaporator comes with the unit (system) that you will be installing. However, there may be an occasion when you are designing a system. At this time, you will need to determine the requirements and select the proper evaporator from a manufacturer's catalog or manual. In figure 14-12 a blower-type evaporator is shown in a small space. The air enters the bottom of the evaporator, is cooled, and exits at the front of the unit. In figure 14-13, view A, a forced circulation evaporator is shown partially installed; view B shows the unit with the fan removed. A compact blower evaporator for use in low headroom fixtures is shown in figure 14-14. A vertical, flat-type blower evaporator designed for mounting behind either a window or a door frame is shown in figure 14-15. In the evaporator

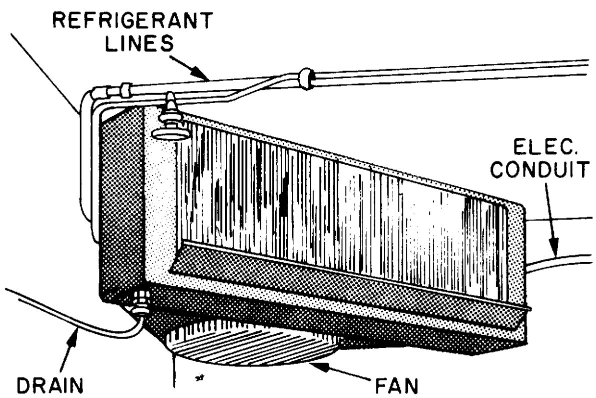

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Figure 14-12.—Blower-type evaporator.

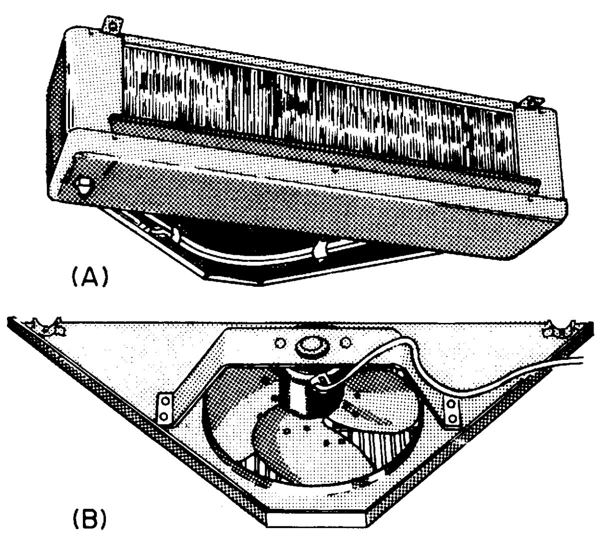

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Figure 14-13.—(A) Forced circulation evaporator partially installed; (B) fan unit removed.

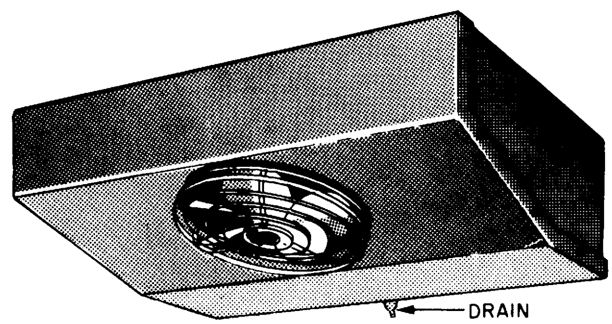

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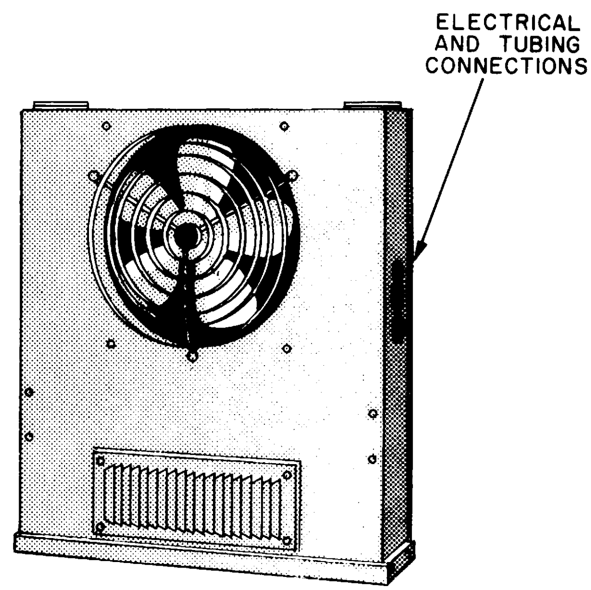
Figure 14-14.—Compact blower evaporator.



87.425

Figure14-15.—Vertical, flat-type blower evaporator.

unit shown in 14-16, the motor drives two propeller-type fans and the cool air exits at both ends of the evaporator. Figure 14-17 shows a low-velocity blower evaporator. In this type of evaporator, the air enters at the two fan grills and exits on both sides. Figure 14-18 shows a low-temperature blower evaporator. The low-temperature evaporator has two axial-flow fans and an electric defrost.

COMPRESSORS

With present technology, the newer air-conditioning and refrigeration systems use reciprocating, rotary, screw, centrifugal, swash plate, and scroll compressors. There are many designs and models available for all types of applications. A typical hermetic compressor is shown in figure 14-19. For more in-depth information about compressors, you can refer to sources, such as *Modern Refrigeration and Air Conditioning* by Althouse/Turnquist/Bracciano.

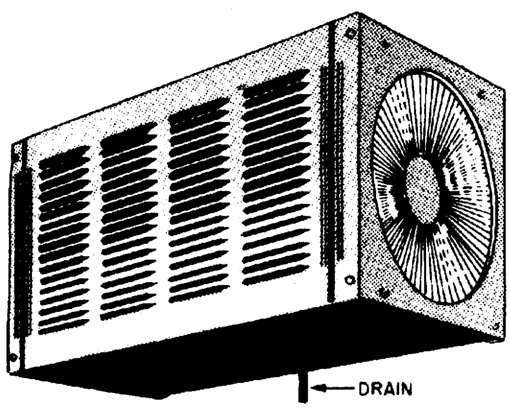


Figure 14-16.—Dual fan evaporator

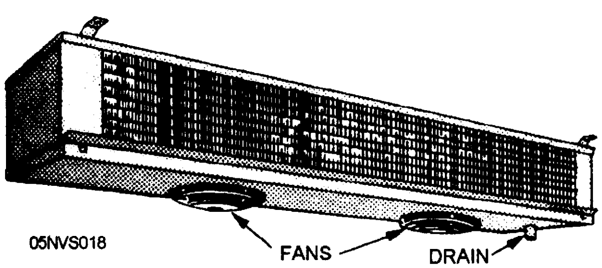


Figure 14-17.—Low-velocity blower evaporator.

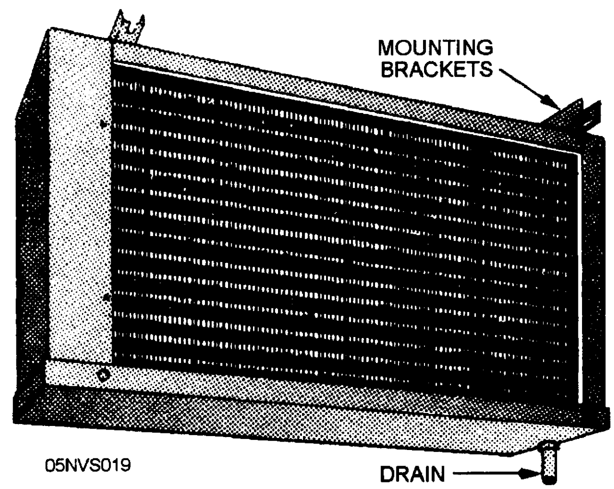


Figure 14-18.—Low-temperature blower evaporator.

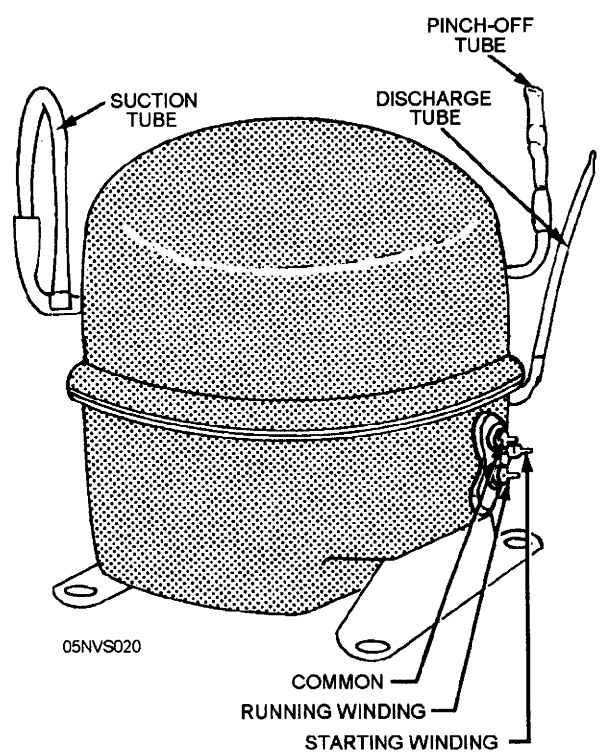


Figure 14-19.—Hermetic compressor.

THERMOSTATS

The thermostat is a control that responds to changes in temperature and directly or indirectly controls the temperature. There are many different designs of thermostats. Figure 14-20 shows a few of the common thermostats used in modem heating and cooling systems. Thermostats are of three types: heating, cooling, and dual (combined heating and cooling thermostat in one).

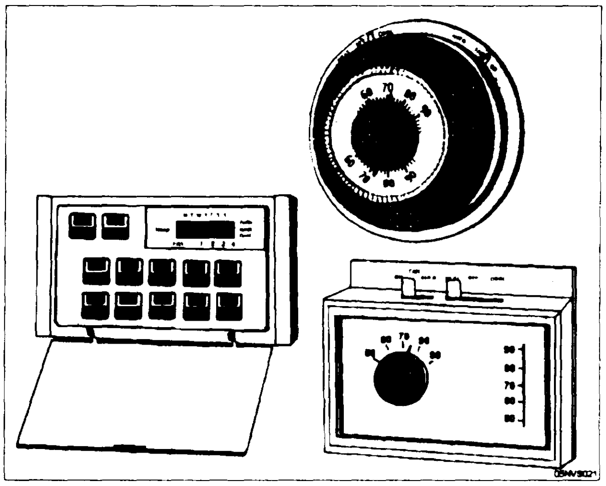


Figure 14-20.—Thermostats.

The common sensing element of a thermostat is bimetal. A bimetal sensing element simply uses two different types of metal, brass and invar, which have different expansion rates. Figure 14-20(A) depicts three common profiles of bimetals used in thermostats.

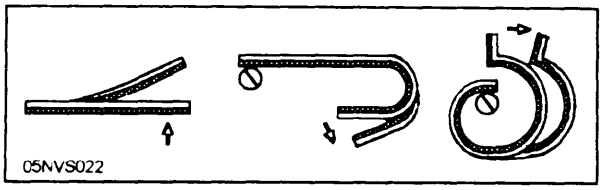


Figure 14-20(A).—Bimetal profiles.

The bimetal element in 14-20(B) has a set of contacts on one end. The top contact is fixed. When the temperature changes around the bimetal, the two contacts open or close.

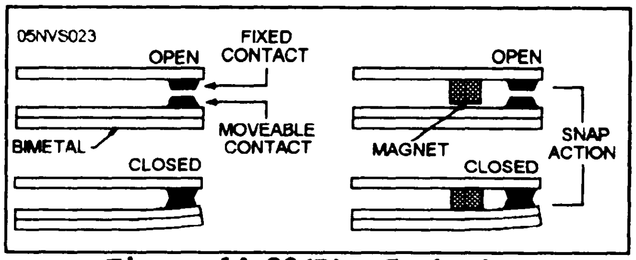


Figure 14-20(B).—Contacts.

When the contacts close, a path is created for current to flow. The snap action in the magnetic type makes the contacts close or open quickly. This eliminates any spark and extends the life of the contacts. Figure 14-20(C) shows enclosed contacts that use a bimetal element for movement and contacts or mercury for making contact between two electrodes.

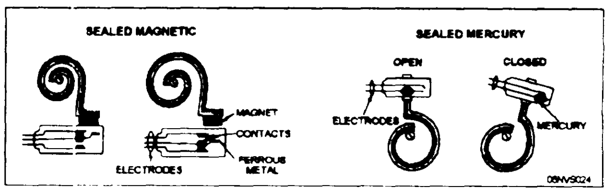


Figure 14-20(C).—Contacts.

The manufacturing engineers determine what type and design of thermostat should be installed in a particular system. Knowing and understanding the advantages and disadvantages of different types of thermostats will help you identify the type of thermostat being used in a system and enable you to troubleshoot an inoperative system efficiently.

Electrical room thermostats are in three categories: line voltage, low voltage, and millivoltage. Line-voltage thermostats are usually 115 volts. When line-voltage thermostats are installed, there is no need for lowering voltage with a transformer. However, line-voltage thermostats are dangerous for the users and the cost is higher. Normally line-voltage thermostats are located only in industrial commercial applications.

Low-voltage thermostats (24 volts) are not dangerous to the user. They are also more cost efficient than line-voltage models. The disadvantage of low-voltage thermostats is the extra requirements of wiring and additional components; they are less rugged than line-voltage thermostats.

The millivoltage thermostat operates at 750, 500, or 250 millivolts. This thermostat uses its own power source for operation and is not affected by power interruptions. The system requires only a small amount of wiring compared to other systems. However, this system is limited for use only in heating applications. The temperature control is less precise than other systems, wire length and size are critical, and the system requires a separate device to power a 24-volt control, or you must use a millivoltage control.

Anticipators

One component that enhances the operation of a thermostat is an anticipator. Anticipators are of two types-heating and cooling. The heating anticipator produces false heat in a thermostat to prevent extreme temperature changes within a space. The false heat created by resistance increases the thermostat rate of response. Basically, the thermostat receives false heat which shuts down the heating source before the thermostat reaches the desired temperature. This action reduces overshooting and is economically efficient. The heating source shuts off and the blower continues to run using the heat transferred from the surface of the furnace and ductwork. When adjusting a heating anticipator, you must set the anticipator resistance to match the current rating of the primary control.

The cooling anticipator adds false heat to the thermostat bimetal element the same way as a heating anticipator. Unlike the heating anticipator, cooling anticipators are not adjustable; they are sized by the manufacturer of the thermostat. The cooling anticipator is placed in parallel with the cooling contacts. By studying figure 14-20(D), you can see that the cooling anticipator is energized when the unit is in the OFF cycle (thermostat contacts open). The small amount of heat produced by the resistance heat closes the TC before the actual temperature in the space reaches the thermostat cut-in setting. This action allows the unit to start removing heat before the temperature in the space climbs above the desired temperature. When the cooling

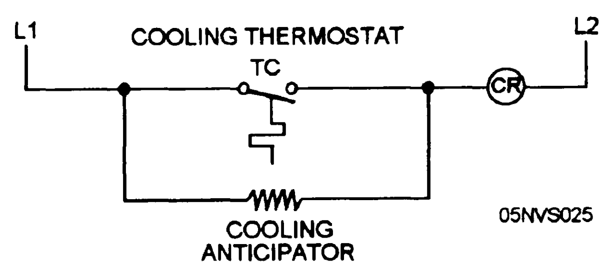


Figure 14-20(D).—Cooling anticipator.

thermostat contacts close, the current flow through the anticipator is insignificant because the contacts of the thermostat offer less resistance to current flow than the anticipator resistance, so the anticipator is de-energized.

REFRIGERANT LINES AND PIPING

Because of the progress made in this field, construction has become much simpler. Since precharged lines are in everyday use, the problems of installation are being eliminated. However, pay particular attention to neatness and cleanliness when you are installing support brackets (hangers) and insulation.

Figure 14-21 shows a schematic piping diagram of a typical commercial refrigeration system. This system has a roof-mounted air-cooled condenser and two motor compressors. Each motor compressor has a suction and a liquid header and is connected to six refrigerant lines. A detailed view of an oil separator installation is shown in figure 14-22.

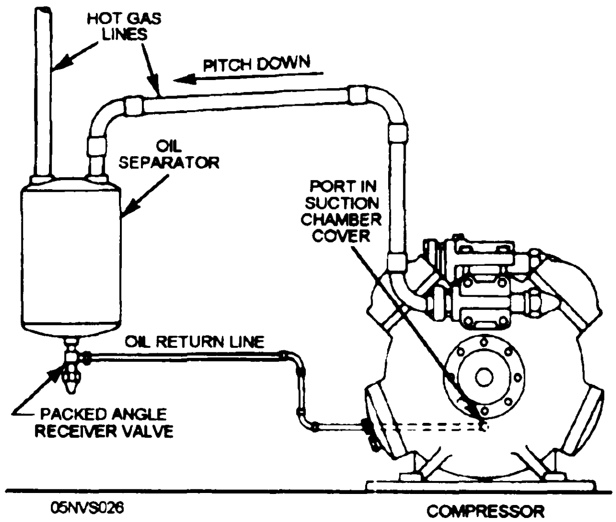
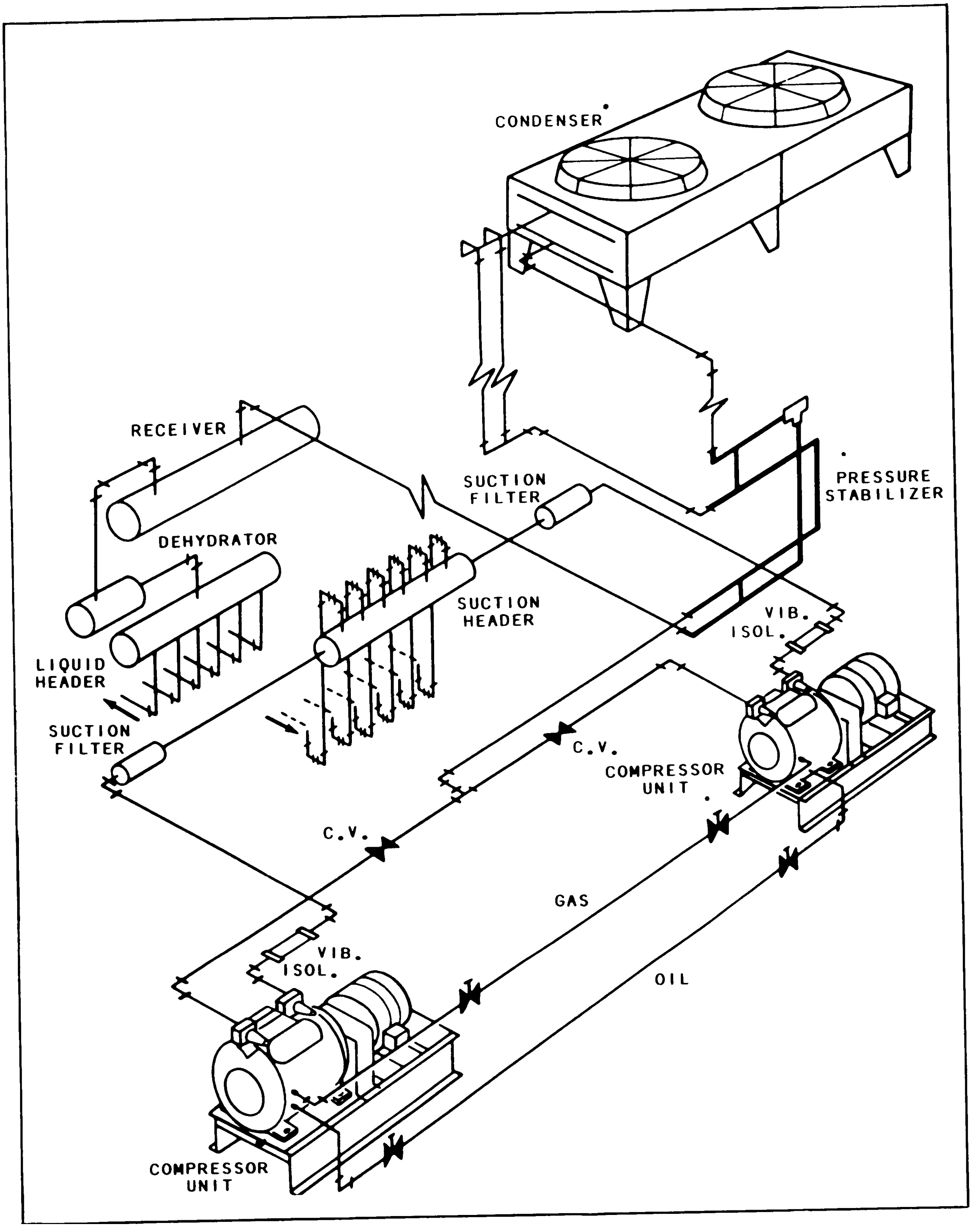


Figure 14-22.—Installation of an oil separator.



87.430

Figure 14-21.—Schematic piping diagram for a commercial refrigeration system.

In a single-stage installation, one evaporator, one condensing unit, and any one of the five types of refrigerant controls will work. However, in a multistage installation (fig. 14-9) with one condenser, only two types of controls can be used. There are very few lmw-side float systems in actual operation, but you should be aware that there are some units that still use this control. Thermostatic expansion valves are the most commonly used, and on large capacity units, they usually operate a pilot valve that, in turn, operates a larger valve.

The biggest problem associated with capacity controls is using one of the wrong size. When ordering replacements and when making repairs, you should always ensure that the control markings are appropriate for the intended system. Also, ensure the replacement part being ordered is compatible with the type of refrigerant being used in the system.

Automatic Expansion Valve

The automatic expansion valve (AEV) maintains a constant pressure inthe evaporator. Looking at figure 14-22(A), there are five pressures that affect the operation of the AEV. The pressures are p_1 (atmospheric pressure), p_2 (evaporator pressure), p_3 (liquid line pressure), S_1 (adjustable spring pressure), and S_2 (fixed spring pressure). To adjust the valve, turn the adjusting screw until the desired pressure is obtained in the evaporator.

Automatic expansion valves are installed on systems that have a relatively constant load. Primarily, the AEV is used on domestic refrigerators and small water coolers.

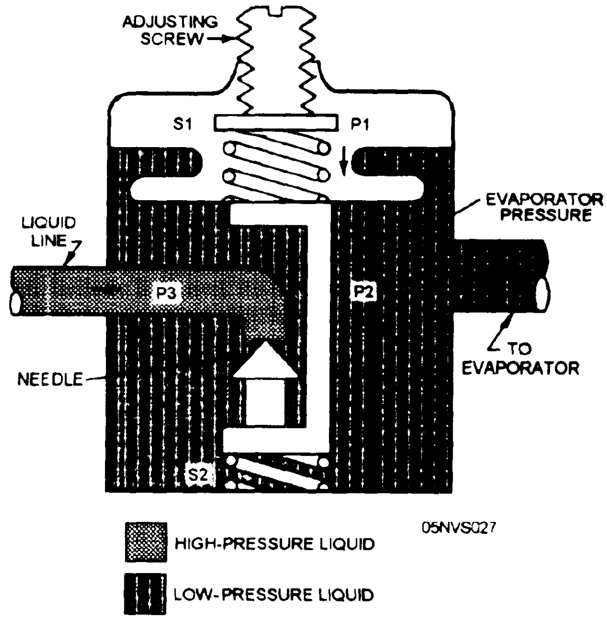


Figure 14-22(A).—Automatic expansion valve.

Thermal Expansion Valve

The thermal expansion valve (TEV) is the most widely used expansion device. The TEV controls the flow of refrigerant to maintain a constant superheat in the tail coil of an evaporator. Referring to figure 14-22(B), there are three pressures that affect the operation of this valve. They are p_1 (bulb pressure), p_2 (evaporator pressure), and p_3 (spring pressure).

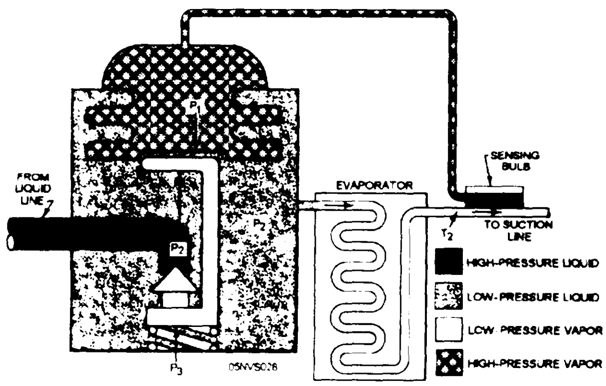


Figure 14-22(B).—Themal expansion valve.

When the pressure of p_1 is higher than the combined pressure of p_2 and p_3, the valve opens. This valve is equalized internally because the evaporator pressure is sensed through an intemal port in the valve. Figure 14-22(C) provides another view showing how a TEV is equalized internally. When a TEV is used on a large evaporator or an evaporator with a pressure drop of 6 to 7 pounds across the evaporator, the valve will prematurely cause hunting (valve fluctuates toward opening and closing). In the case of valve hunting, install a TEV equipped with an external equalizer line. Figure 14-22(D) shows the TEV installed with an external equalizer line. The external equalizer line compensates for a pressure drop from the inlet of the evaporator to the end of the tail coil and eliminates valve hunting. During installation of an equalizer line, ensure that it is located downstream from the sensing bulb.

Air-conditioning refrigeration units come equipped with a metering device that the manufacturer has engineered for the system. You should **never** change the recommended type of metering device for a system without consulting the manufacturer.

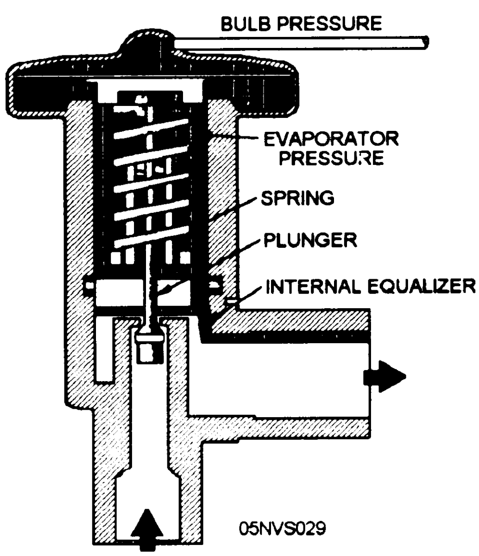


Figure 14-22(C).—Thermal expansion valve.

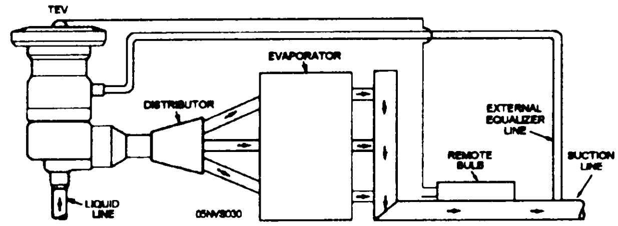


Figure 14-22(D).—Externally equalized TEV.

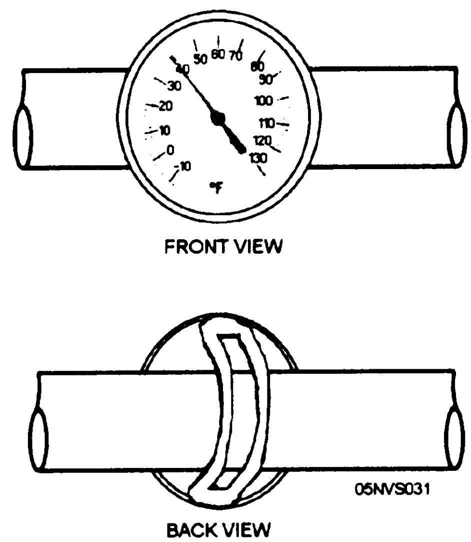


Figure 14-22(B).—Dial thermometer.

TEV Adjustment

Most TEVs are adjusted at a predetermined superheat setting and tested at the factory before they are shipped. If you need a different superheat setting, follow the steps in table 14-1(A).

Table 14-1(A).—Determining Superheat

STEP	ACTION
1.	Obtain the temperature of the suction line at the point where the TEV sensing bulb is attached. a. Take the temperature reading with a dial thermometer similar to the one shown in figure 14-20(E), or use some other temperature measuring device that senses surface temperatures accurately.
2.	Obtain the suction pressure inside the piping at the location of the remote sensing bulb. a. If the valve is externally equalized, you can place a gauge in the external equalizer line. This is the most accurate method. b. The alternate method is to read the manifold pressure gauges at the compressor and add the estimated pressure drop through the suction line between the bulb and compressor. The sum of the two pressures provides approximate pressure at the location of the remote bulb.
3.	Convert the pressure you received in step 2 into saturated evaporator pressure. a. Use a pressure temperature chart. When using the chart, ensure that you are looking at the proper refrigerant.
4.	Simply subtract the temperature in step 3 from the temperature in step 1. This is superheat.

Note: When adjusting the expansion valve, turn the adjusting stem no more than one full turn and wait approximately 15-30 minutes for the system to balance out. Once the system is balanced, recheck the superheat setting by following the steps in table 14-1(A).

RECEIVERS AND ACCUMULATORS

The receiver is a storage tank for liquid refrigerant. When a refrigeration system is equipped with a receiver, you can close the outlet valve (king valve) and pump refrigerant into the receiver. This enables you to store the refrigerant while you work on the unit. Additionally, when a unit is equipped with a receiver, the quantity of refrigerant in the system is less critical than a unit not so equipped. Figure 14-23 shows the location of a receiver installed in a system. This is a commercial system with an air-cooled condenser, a thermostatic expansion valve, and a V type of reciprocating compressor.

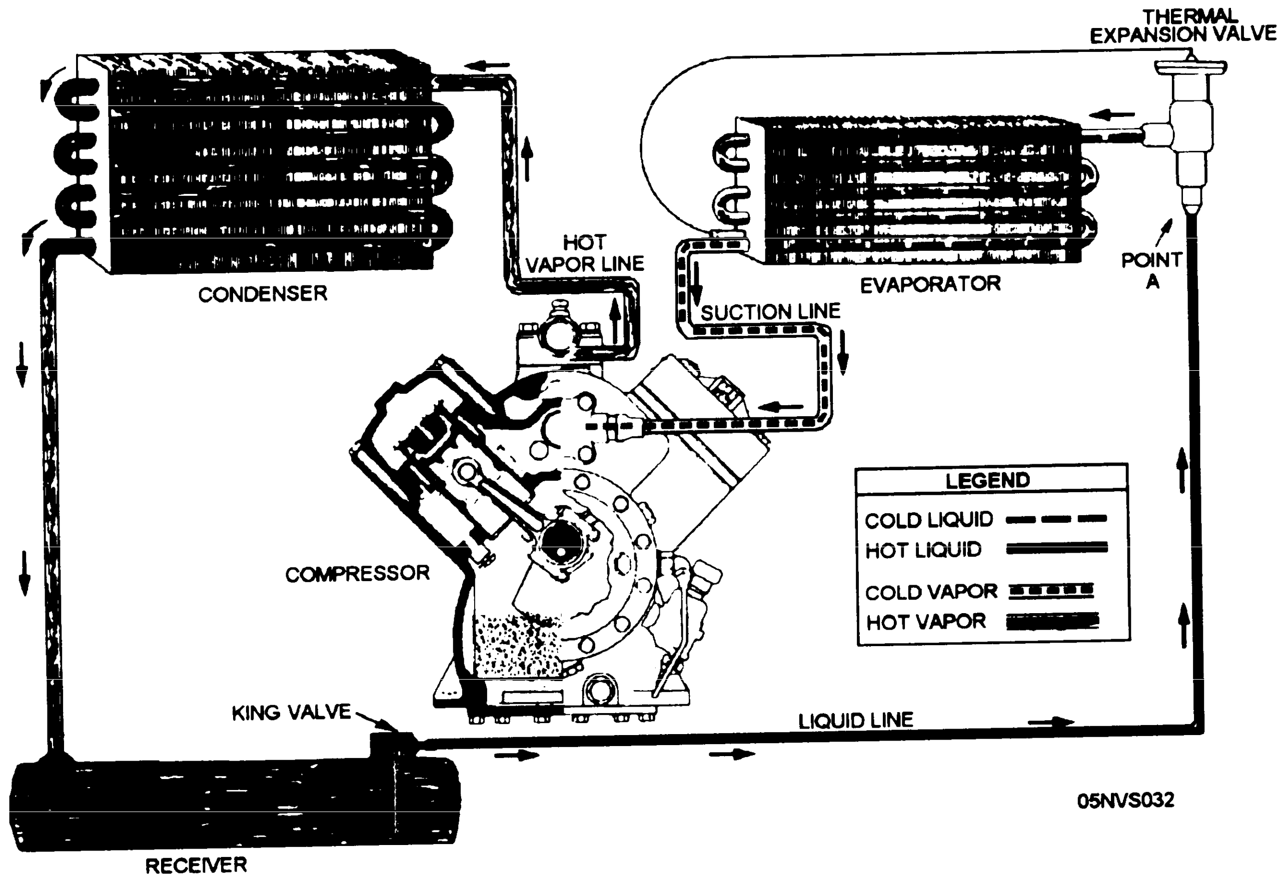


Figure 14-23.—Receiver in refrigeration cycle.

The accumulator is located inside the refrigeration cabinet and acts as a safety device. As a safety device it prevents the flow of liquid refrigerant into the suction line and the compressor. This is because liquid refrigerant causes considerable knocking and damage to the compressor. Figure 14-24 shows the location of an accumulator in a system.

SINGLE-PHASE HERMETIC MOTORS

Basically, there are four types of single-phase motors used in hermetic assemblies: the split-phase; the capacitor-start, induction-run; the capacitor-start, capacitor-run; and the permanent split-phase. Each motor is discussed in this section.

SPLIT-PHASE

The split-phase motor is used generally on condensing units of 1/10-, 1/6-, and 1/4-horsepower capillary tube systems. It has a low starting torque and contains both a starting winding and a running winding. A disconnect device is required for the starting winding when the motor reaches sufficient speed to operate on the running winding. Figure 14-25 is a schematic wiring diagram of a split-phase motor circuit.

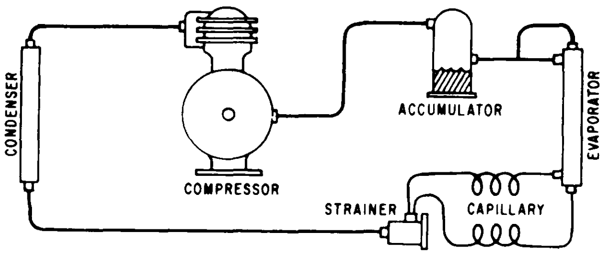


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Figure 14-24.—Accumulator location.

CAPACITOR-START, INDUCTION-RUN

This motor is similar to the split-phase type except that a starting capacitor is connected in series with the starting winding to provide higher starting torque. Figure 14-26 is a schematic diagram illustrating this type of motor. A device is also required to disconnect the starting winding when the motor reaches rated speed. This motor is commonly used on commercial systems up to three-fourths horsepower.

CAPACITOR-START, CAPACITOR-RUN

Two capacitors are used with the capacitor-start, capacitor-run motor: a starting capacitor and a running capacitor. The capacitors are in parallel with each other and in series with the starting winding. Figure 14-27 is a schematic diagram illustrating this type of motor circuit. The two capacitors turn the motor power surges into two-phase power when the motor is started. At approximately two-thirds rated speed, the starting capacitor part of the circuit is disconnected by a start relay device. Only the running capacitor remains in the circuit. This type of motor has a

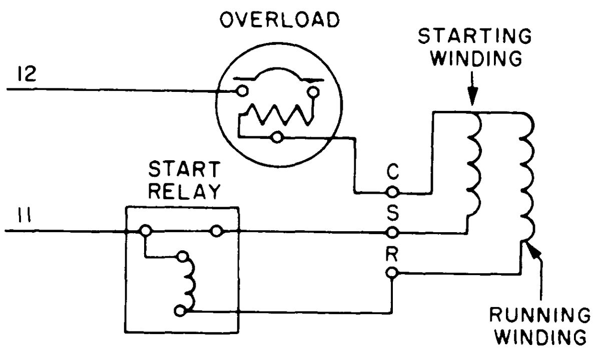

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Figure 14-25.—Schematic wiring diagram of a split-phase motor circuit.

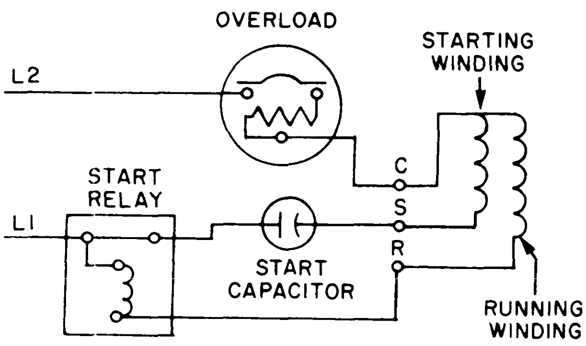

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Figure 14-26.—Schematic wiring diagram of a capacitor-start induction-run motor.

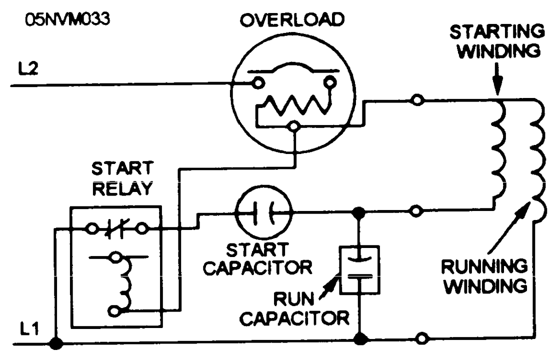


Figure 14-27.—Schematic wiring diagram of a capacitor-start capacitor-run motor.

high starting torque and is used with hermetic systems up to 5 horsepower.

PERMANENT SPLIT-PHASE

The permanent split-phase motor has limited starting torque and is used basically with capillary tube air-conditioning equipment, such as window units. Capillary systems permit high-side and low-side pressure equalization when the compressor is not operating. A run capacitor is wired in series with the starting winding. Both the starting winding and the run capacitor remain in the circuit during operation. No start relay or start capacitor is needed. Figure 14-28 is a schematic wiring diagram of the circuits used in this type of motor.

SPLIT-PHASE HERMETIC MOTOR WINDINGS AND TERMINALS

Split-phase motors used in hermetic refrigeration and air-conditioning applications are designed to start under load. These split-phase and capacitor motors use two sets of spiral windings: a starting winding and a running winding. The two sets of windings differ in their impedance and in their positions in the stator slots.

The starting winding has high resistance and small reactance, whereas the running winding has low resistance and high reactance. Reactance is the opposition to the flow of alternating current by inductance and capacitance. The running winding has many turns of large wire and is placed in the bottom of the stator slots. The starting winding is wound of small, high resistance wire and is placed on top of the running winding. Both windings are connected internally at one end to provide a common lead, and when starting, both are energized in parallel. The currents are out of phase with each other and their combined efforts produce a rotating field that starts the motor.

Figure 14-29 shows the starting and running windings of a two-pole motor in their 90-degree out-of-phase positions.

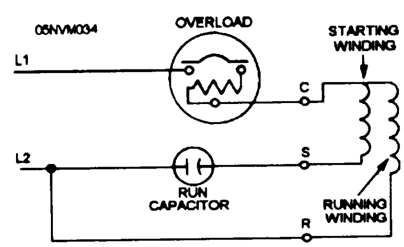


Figure 14-28.—Schematic wiring diagram of a permanent split-phase motor.

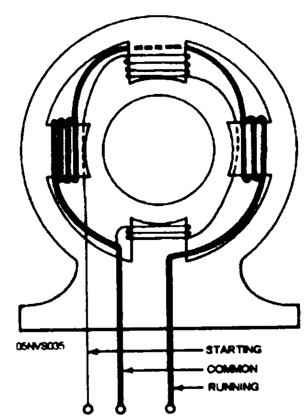


Figure 14-29.—View of a two-pole motor having starting and running windings.

Hermetic motors have three electrical terminals connected through an insulated seal to the motor windings inside the dome. Refer to figure 14-30. Troubleshooting procedures require that these terminals be identified with respect to the winding connected to each. The terminals must be identified as the START TERMINAL, the RUN TERMINAL, and the COMMON TERMINAL. Some manufacturers mark the S-, R-, and C-terminals for start, run, and common, respectively; other manufacturers use different designations.

The terminals can always be identified by using a low-range ohmmeter following the procedure below:

- Disconnect all power to the terminals, discharge capacitor where necessary, remove the wires connected to the terminals, and mark the wires so they can be reconnected properly.

- Clean terminals to provide a good connection.

- Using the ohmmeter, find the two terminals across which the greatest resistance occurs. The remaining terminal is the C-terminal. The resistance between the S- and R-terminals is highest because both are being measured in a series circuit.

- Identify the S-terminal by placing one meter lead on the C-terminal and then checking the other two terminals to determine which one has the greatest resistance. The S-terminal (starting winding) has windings with many turns of small wire, and therefore has the greatest resistance. The remaining terminal is the connection of the running winding.

- Always mark the terminals so they can be identified later.

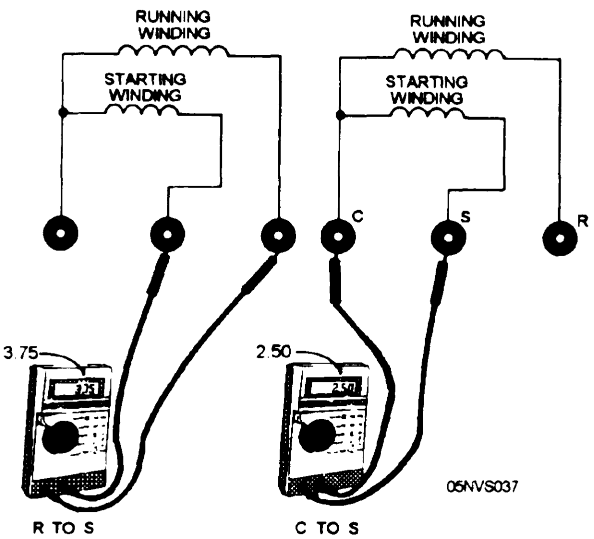


Figure 14-30. —Odentifying motor terminals using an ohmmeter.

TROUBLESHOOTING ELECTRICAL SYSTEMS

Electrical troubleshooting techniques are used on refrigeration and air-conditioning equipment. Electrical troubleshooting is done by a process of elimination. You should begin by checking the most obvious trouble and gradually progress to the more remote possibilities. As a Utilitiesman you cannot troubleshoot an electrical system for an air-conditioner or refrigeration unit unless you understand the function of each component in a system. When you can observe a unit operating and detect what is not functioning properly, you can identify the circuit or circuits that are having trouble. At this point you must be able to test each of the components within a circuit that is not functioning properly. Of course to do all of this. you must also be able to read and interpret electrical diagrams, understand loads, determine paths, and perform electrical testing procedures.

CIRCUITS

There are two basic types of circuits–load and control. The LOAD CIRCUIT consists of a circuit that contains a load and all of the wiring that provides line voltage directly to the load, such as compressor motor, fan motor, solenoid valves, lights, or any device that consumes current (other than the movement of an electrical switch). The second type of circuit is the CONTROL CIRCUIT. Simply stated, a control circuit contains controls that either open or close a path that operates a load device. Each load has a control circuit. Control circuits consist of thermostats, pressure switches, overload protectors, and all of the wiring in the control circuit.

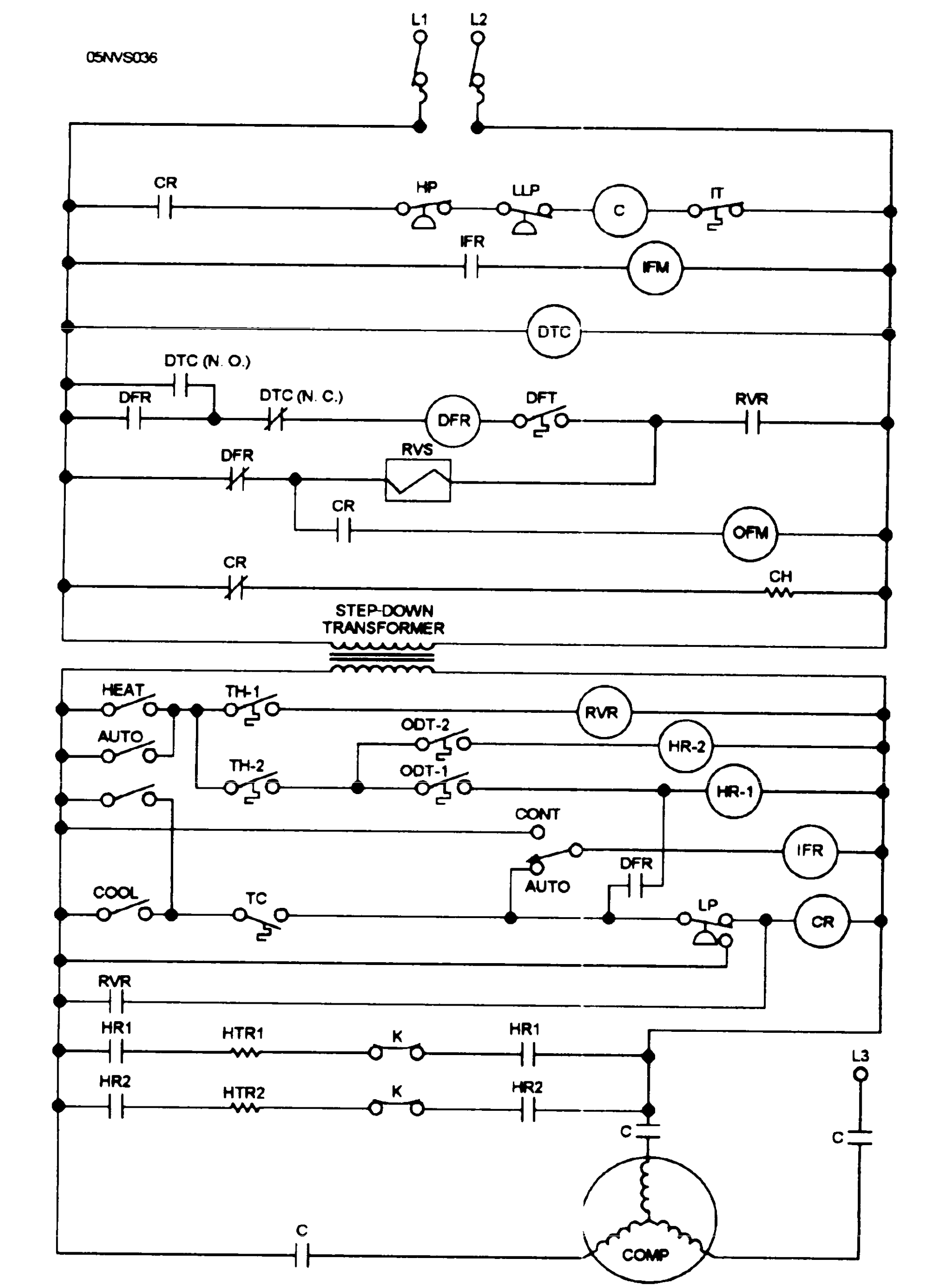
LOADS AND CONTROL CIRCUITS

Air-conditioning and refrigeration units normally have two fan motors and a compressor. Thesr components are considered load. A load is any device that consumes electrical energy. Most loads convert electrical energy into another type of energy to create some type of work. For example, electrical energy is converted to magnetism within a motor to make the motor run.

All loads have some type of control so they can be turned on, off, or regulated. These controls are located in a control circuit. The circuit is made up of controls and paths wiring. Controls and control circuits consume no electrical energy; they simply provide a path for electrical energy to flow, thus indirectly controlling the operation of various types of loads. Figure 14-29(A) shows an electrical schematic wiring diagram of a heat pump. At first glance the diagram appears complex, but after studying the diagram briefly and looking at one circuit at a time, the diagram becomes easy to follow and understand. An example is as follows: Look at the first circuit in figure 14-29(A). The circuit contains a control relay contact (CR), high-pressure switch (HP), liquid line pressure switch (LLP), compressor contactor (C), and an internal thermostat (IT). This is a complete circuit. The CR is simply a set of contacts and falls in the category of a path; the contacts are either open or closed. The HP and LLP are both pressure switches and are controls in this circuit; the pressure switches are either open or closed. The C is the compressor contactor. Actually this is a magnetic coil located within a contactor that simply closes all of the contacts in the diagram that are labeled C. The IT (internal thermostat) is located inside the compressor and opens when there is a temperature rise. The only load in this circuit is the compressor contactor because it is a current consuming device. Now, look at figure 14-29(A) and see if you can find the load in the second circuit. The load is the indoor fan motor (IFM) because it is a current consuming device. The IFR contact only provides a path for the current to energize the indoor fan motor.

TESTING CIRCUITS

To troubleshoot an inoperative or improperly operating unit electrically, you must be able to use a process of elimination systematically and use a multimeter effectively. Remembering and understanding a few simple rules will enable you to use a multimeter to locate a faulty electrical component or control. The first circuit in figure 14-29(A) is used as an insert to illustrate the different meter readings you will encounter when troubleshooting an electrical system. Refer to the insert next to the applicable troubleshooting procedure.



C — COMPRESSOR CONTACTOR
CR — CONTROL RELAY
HP — HIGH PRESSURE SWITCH
LLP — LIQUID LINE PRESSURE SWITCH
IT — INTERNAL THERMOSTAT
IFM — INDOOR FAN MOTOR
IFR — INDOOR FAN RELAY
OFM — OUTDOOR FAN MOTOR
DTC — DEFROST TIME CLOCK
DFR — DEFROST RELAY
DFT — DEFROST THERMOSTAT
RVS — REVERSING VALVE SOLENOID
TH — THERMOSTAT HEATING
ODT — OUTDOOR THERMOSTAT
RVR — REVERSING VALVE RELAY
HR — HEATING RELAY
TC — THERMOSTAT COOLING
LP — LOW PRESSURE SWITCH

Figure 14-29(A).—Heat pump schematic.

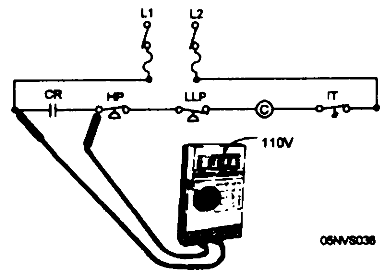
Voltage Readings

To begin, set your multimeter to voltage; ensure the power is on and all wires are connected to the component being tested. The four important troubleshooting procedures that apply to reading voltage are as follows:

1. Place the meter probes are on a path. If there is a voltage reading, the path is open.

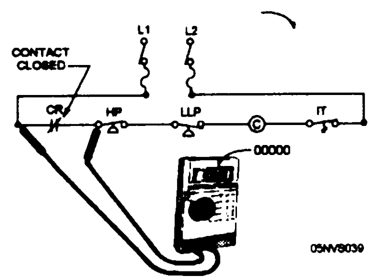
- Place one meter probe on the left side of the CR contact and the other probe on the left side of the HP switch.

If you obtain a voltage reading, this indicates that either the path is open or the contacts are open.



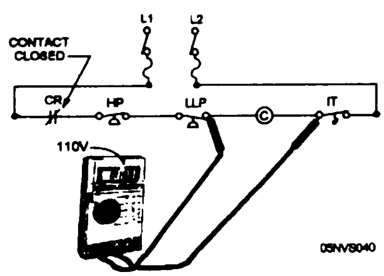
2. Place the meter probes on a path. If there is no-voltage reading, the path is closed.

- Place one meter probe on the left side of the CR contact and the other probe on the left side of the HP switch. If you obtain no voltage reading, the path is closed.



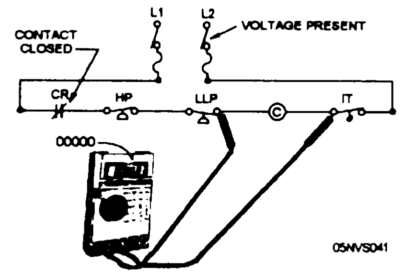
3. Place the meter probes across a load. If a voltage reading is obtained, the load is recieving current. When the load is NOT operating, you should check for a grounded winding and for winding resistance.

- Place one meter probe on the right side of the LLP switch and the other probe on the left side of IT. If you obtain a voltage reading, the compressor contactor is energized and the compressor should be running.



4. Place the meter probes across a load. If there is no-voltage reading, you have an inoperative load. Replace the load.

- Place one meter probe on the right side of the LLP switch and the other probe on the left side of the IT. If there is no voltage reading, replace the load.

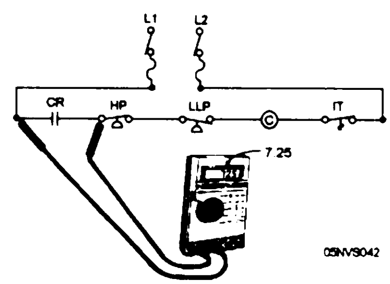


Continuity Readings

To perform an ohmmeter continuity test, set your multimeter to resistance; disconnect the power and remove the wires from the component being tested. Perform a continuity test as follows:

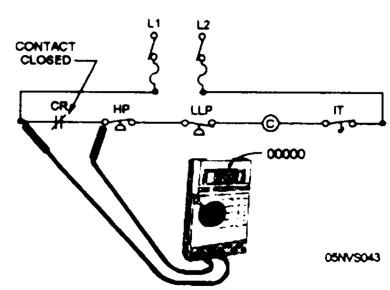
1. Place the meter probes across a path. If a reading is obtained, it indicates an open path.

- Place one meter probe on the left side of the CR contact and the other probe on the left side of the HP switch. If you obtain a reading, the path is open.



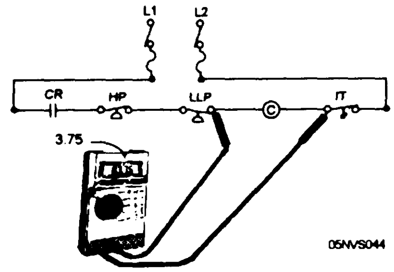
2. Place the meter probes across a path. If a zero reading is obtained, the path is closed.

- Place one meter probe on the left side of the CR contact and the other probe on the left side of the HP switch. With the CR contact closed, you should obtain a zero reading. This indicates the path is closed.



3. Place the meter probes across a load. You should obtain a reading.

- Place one meter probe on the right side of the LLP and the other probe on the left side of the IT. You should obtain a reading. If you obtain no reading, replace the load.



To further increase your understanding of electrical troubleshooting, review the rules you have just read using a different method. The flow charts in figure 14-30(A), and (B) review electrical troubleshooting with a digital multimeter. To use a multimeter effectively and troubleshoot an A/C & R unit electrically, you must not only know the information provided here but also practice by testing circuits. Always remember to respect electricity. Whenever possible, perform your electrical troubleshooting with the power OFF using continuity checks.

TESTING MOTOR WINDINGS

If, during the procedure for identifying motor terminals, the ohmmeter displays a blank readout during any test, there is probably a defective winding. A defective winding may be classified as an OPEN winding or a SHORTED winding. The display will be zero if the winding is GROUNDED. Test equipment and procedures applicable to faulty windings are discussed below.

OPEN WINDINGS

Open windings can occur in the starting winding, the running winding, or both. An open winding is the result of a burned-out or grounded fault or simply a break somewhere in the lead or winding that prevents the current from completing the circuit. A motor with an open winding does not start. If only one winding is open, the motor hums, but if both windings are open, no sound is emitted nor current consumed. Open windings can be checked by an ohmmeter, a voltmeter, or a test light.

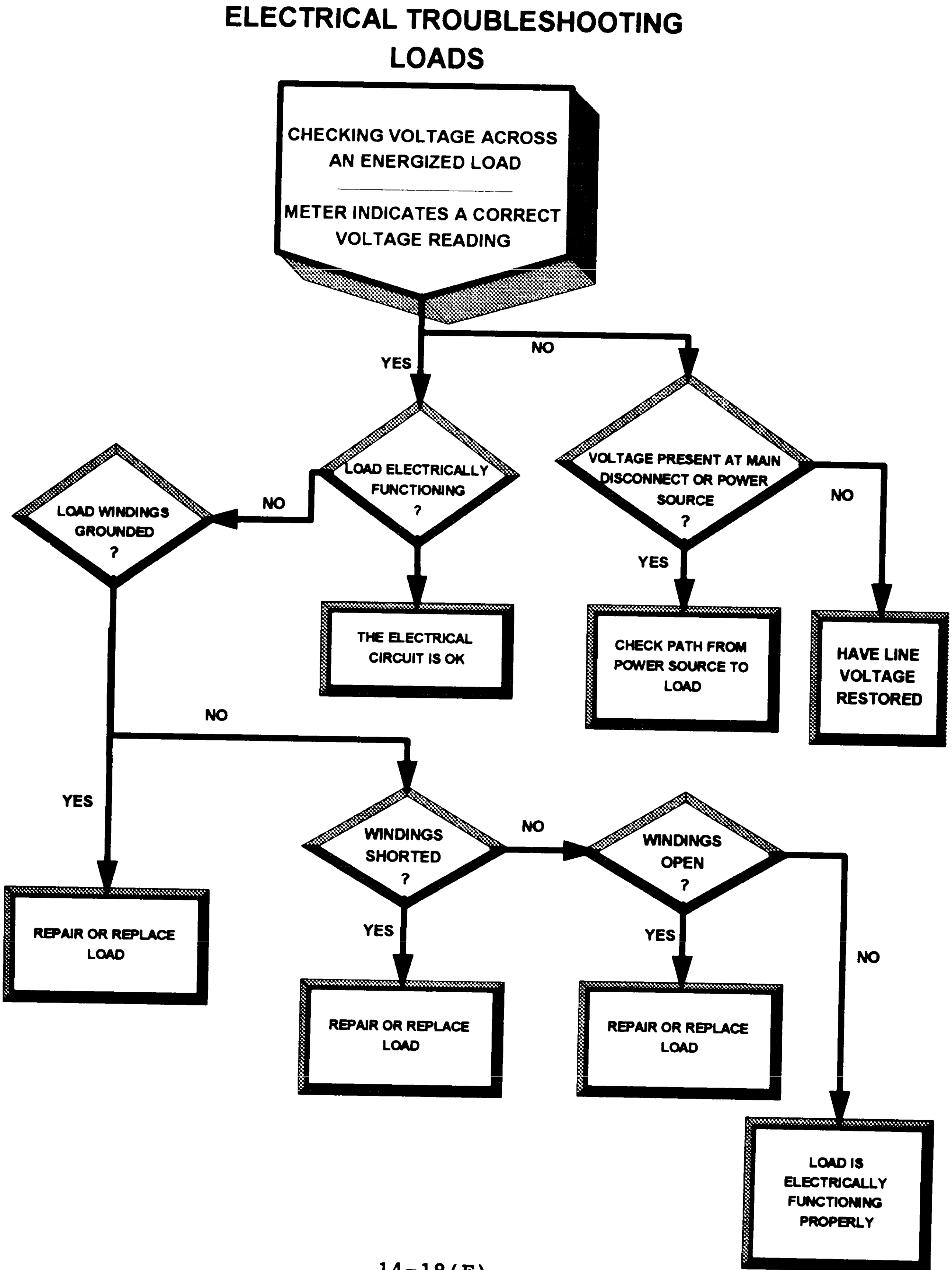
Ohmmeter Continuity Test Procedure

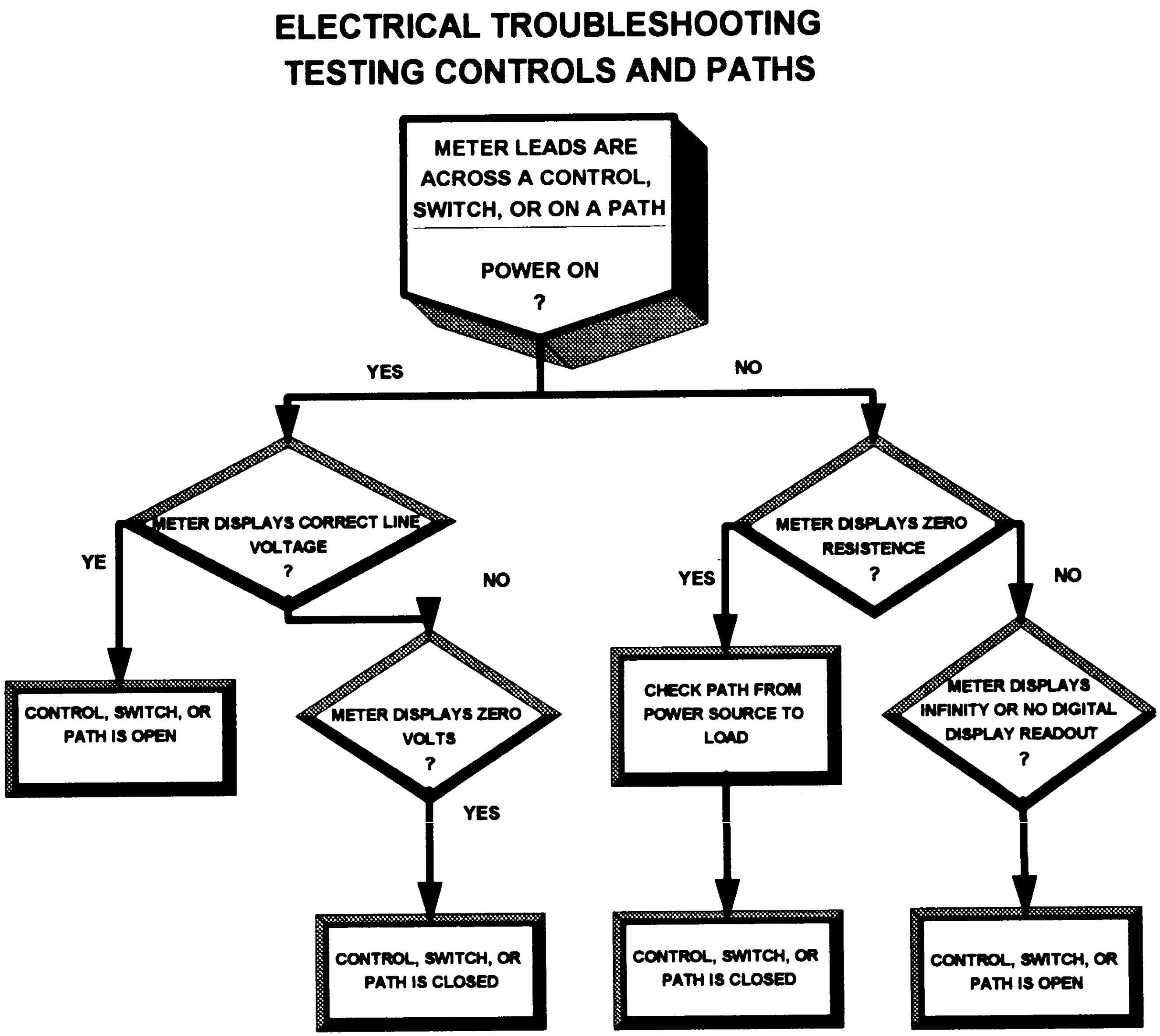
The procedure for making an ohmmeter continuity test is shown in figure 14-31 and outlined below.

- Turn the power OFF, discharge all capacitors, and remove the wires from the C-, S-, and R-terminals of the motor.

- With the ohmmeter set on the lowest scale, check the resistance from C to R, C to S, and R to S.

Table 14-30.—Electrical Troubleshooting Loads





TABLES 14-30(A) AND 14-30(B) DO NOT COVER EVERY ELECTRICAL TROUBLESHOOTING PROCEDURE YOU WILL INCUR. THE TABLES ARE PRESENTED TO HELP YOU UNDERSTAND ELECTRICAL TROUBLESHOOTING.

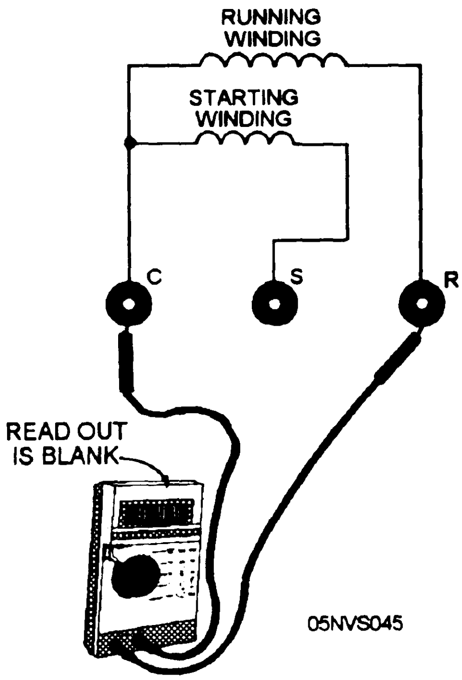


Figure 14-31.—Testing for an open winding with a ohmmeter.

- Watch the digital readout in the meter as the check is made. Each reading should appear to be approximately 0 ohms, since winding resistance is usually less than 10 ohms. If, during the check, the resistance digital display remains blank (infinity), an open or break exists.

Voltmeter Test Procedure

The procedure for carrying out a voltmeter test is as follows:

- Ensure the power is on and all wires are properly connected to motor terminals.
- With the voltmeter set on the proper scale, place the leads across the R- and C-terminals.
- Read the voltmeter.If the motor shows line voltage, the motor is energized and should be operating. The connections are similar to that shown in figure 14-31.

Test Lamp Continuity Check Procedure

The procedure for conducting a test lamp continuity check is as follows:

- A simple test lamp consisting of a power circuit plug, two flexible insulated wires with clip leads, and a 25-watt socket with a bulb is used. Figure 14-32 shows the test lamp procedure.
- Ensure the power is OFF, discharge all capacitors, and remove the motor terminal wires.
- Make a continuity test through both windings by attaching clips across the C-terminal, then do the other terminals one at a time. Now plug the test lamp into a receptacle. If the bulb fails to light, there is an open winding.

SHORTED WINDINGS

In an electric motor the winding turns lie side by side with only the insulating varnish separating one loop from another. When one loop of the copper wire contacts another, the

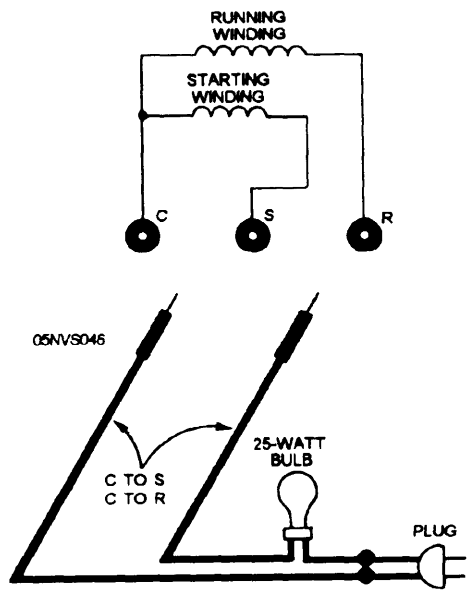


Figure 14-32.—Testing for an open winding with a test lamp.

winding is short. The pulling effect of the shorted portion of the winding is lost. This, in turn, places more load on the active winding, causing the motor to draw higher voltage and amperage with a concurrent increase in winding temperature. In this condition the motor either fails to start, or it starts and continues to run, finally causing the overload protector to open. The fuses may also blow. The result is likely to be a burnout where the insulating varnish deteriorates from excessive heat. Ultimately a ground or short occurs.

An ohmmeter can be used to check windings for shorts. For most applications a low-range meter with a scale graduated in tenths of ohms between 0 and 2 ohms is best. However, to check motors throughout the sizes normally encountered in hermetic motor-compressor units, a range of 0 to 25 ohms is necessary. The meter is used to measure resistance of the windings. The readings are compared with design resistances. A short is shown when measured resistance is less than design resistance. The ohmmeter connections are the same as those shown in figure 14-30.

Often manufacturer's data is not available and the design resistances are not known. Table 14-1 lists the approximate resistances for fractional horsepower single-phase motors. The following guidelines may also be helpful:

1. The starting winding of low-starting torque motors usually has a resistance of about seven to eight times that of the running winding.

2. The starting winding resistance of high- starting torque motors is usually three to four times that of the running winding.

GROUNDED WINDINGS

A ground is the result of an electrical conductor in contact, either directly or indirectly, with the motor frame or the metal shell of the unit. Either the starting winding, the running winding, or both can be affected. The ground is either one of low resistance or one of high resistance. A low-resistance ground is indicated when fuses blow repeatedly and the motor fails to start. A high-resistance ground is shown by an occasional blown fuse, but more often, by the opening of the overload protector.

Table 14-1.—Approximate Resistances for Fractional Horsepower Motor Windings

HP	Running Winding	Starting Winding
1/8	4.7Ω	18Ω
1/6	2.7Ω	17Ω
1/5	2.3Ω	14Ω
1/4	1.7Ω	17Ω

Three methods of testing windings for grounds are the ohmmeter continuity test, the test lamp continuity check, and the resistance measurement with a megohmmeter. The procedure to follow in making each of these tests is provided below.

Ohmmeter Continuity Test (Low-Resistance) Procedure

To perform an ohmmeter continuity test, proceed as follows:

- Disconnect the power and remove the wires from the motor terminals.
- Scrape off paint and clean a spot on the motor-compressor shell for testing.

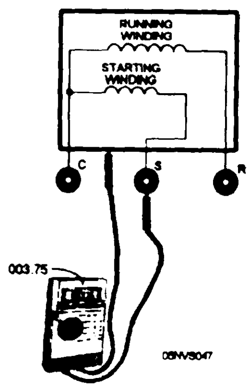


Figure 14-33.—Testing windings for ground with an ohmmeter.

● With the ohmmeter set on its highest scale, test for continuity between the terminals and the shell. This procedure is shown in figure 14-33. If continuity exists between the terminals and the shell, there is a ground.

Test Lamp Continuity Check (Low-Resistance) Procedure

The procedure for conducting a test lamp continuity check is as follows:

● Disconnect the power and remove the wires from the motor terminals.

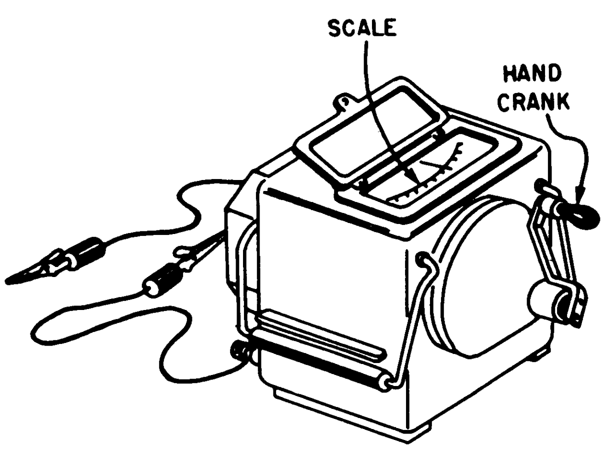
● Ensure the lamp is connected in the hot side of the line. Plug the test lamp into a receptacle.

● Connect the hot-line probe to a motor winding terminal.

● Touch the free probe to the cleaned spot on the shell. Ensure that a good connection is made. If the light illuminates, there is a grounded winding.

Megohmmeter (High-Resistance) Test Procedure

The megohmmeter (megger) consists of an indicating movement for which current is supplied by a small hand-driven generator. Figure 14-34 illustrates a typical megger used by the SEABEES.



236.261

Figure 14-34.—A typical megohmmeter (megger).

Two leads are supplied, one of which is marked Earth or Ground.

The procedure for making the megohmmeter (high-resistance) test is as follows:

● Disconnect power and remove the wires from the motor terminals.

● Place the megger probe marked Earth or Ground on the motor or compressor frame. Ensure there is a good metal-to-metal contact.

● Place the free probe on terminals C, S, and R in sequence. If any reading of low resistance is obtained, the motor is grounded.

You should always refer to the manufacturer's instructions when using a megger. It is also a good idea to request assistance from a Construction Electrician.

ELECTRICAL CIRCUIT COMPONENTS

Electrical components in hermetic motor compressor circuits that give trouble include starting relays, overload protectors, and capacitors. It is essential that a refrigeration and air-conditioning service member be able to identify these components and test them using the proper equipment and procedures.

STARTING RELAYS

Basically there are three types of starting relays in use. They are the current relay (magnetic type), the voltage relay (magnetic type), and the thermal relay (hot-wire type). In the hermetic motor control circuit, a starting relay allows electricity to flow through the starting winding until the motor reaches two-thirds to three-fourths of its rated speed. At this time, about 3 to 4 seconds after starting, it disconnects the starting circuit.

Current Relay

A current relay is an electromagnet, similar to a solenoid valve, that employs a weight and spring to hold the contacts open when the circuit is idle. In operation the instantaneous surge of starting current actuates the magnetic coil, causing the start winding contacts to close. This closure allows starting current to the winding;

after about 3 to 4 seconds, the motor reaches its rated speed and the current decreases, causing the relay contact to open and disconnect the winding. Current relays are ideal for use with split-phase, induction-run motors.

Figure 14-35 is a schematic diagram of a current relay motor starting circuit.

Voltage Relay

A voltage relay looks much like a current relay; however, it differs in operation. It operates on increased voltage as the motor reaches rated speed, and, unlike the current relay, the contacts remain closed during the off cycle. When the motor is first turned on, it draws heavy current and the voltage drop across the starting winding is low. As the motor picks up speed, there is less and less load; therefore, more and more voltage is induced into the winding. At about three-fourths rated speed the voltage is high enough to cause the relay coil to pull the contacts open and disconnect the winding. Voltage relays are used with capacitor-start motors. Figure 14-36 is a schematic diagram of voltage relay motor starting circuit.

Thermal Relay

A thermal relay is commonly known as a hot-wire relay. It is available in at least two different basic designs and is supplied by several manufacturers. All thermal relays operate on the theory that electrical energy can be turned into heat energy and that, when the temperature of a metal is increased, the metal expands. Thermal relays, like current and voltage relays, operate the starting winding circuit. In addition, the thermal relay controls the running winding circuit, if for any reason the circuit draws excessive current.

The device consists of a specially calibrated wire made from a material with high oxidation resistance and two sets of contacts, all of which are integrally attached to form the relay. Figure 14-37 illustrates a typical thermal relay motor starting circuit. The contacts are controlled by the hot wire, either through the use of heat-absorbing

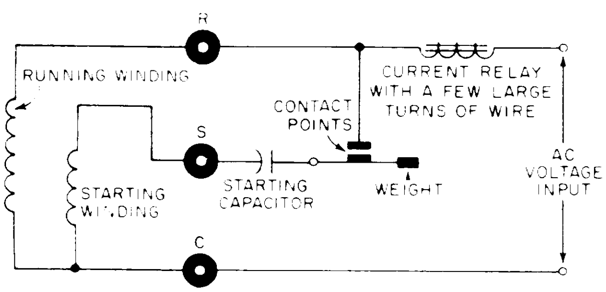


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Figure 14-35.—Schematic diagram of a current relay motor starting circuit.

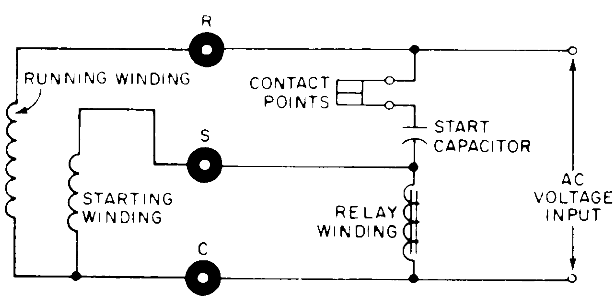

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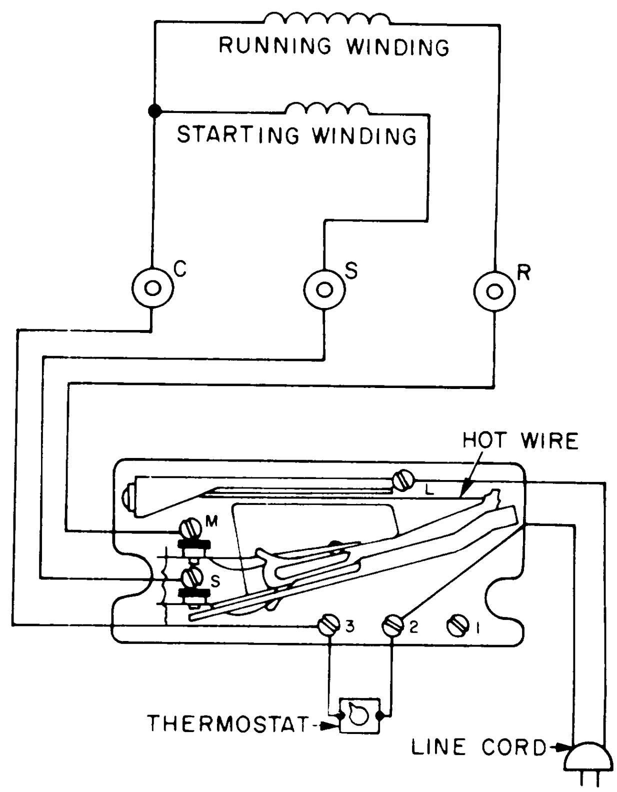
Figure 14-36.—Schematic diagram of a voltage relay motor starting circuit.



87.251

Figure 14-37.—A typical thermal relay motor starting circuit.

bimetallic metal strips, or by its expansion of the hot wire, depending on the design of the relay.

OVERLOAD PROTECTORS

Essentially, an overload protector is a heat sensitive device much like a circuit breaker. When current in the circuit increases above normal, the added current heats a bimetallic strip that bends and opens a pair of contacts. The opening of the contacts disconnects the motor-running circuit and the motor stops. This prevents damage to the compressor motor when troubles occur, such as a defective starting relay, an open starting capacitor, or high-head pressure. Figure 14-38 shows a typical bimetallic disk-type overload protector. This overload protector is connected in the common line and mounted on the compressor motor shell.

CAPACITORS

In hermetic refrigeration and air-conditioning work, capacitors are identified in two groups: start capacitors and run capacitors. These may be identified further as dry capacitors that are used for intermittent operations (start capacitors) and electrolytic capacitors that are used for continuous operation (run capacitors).

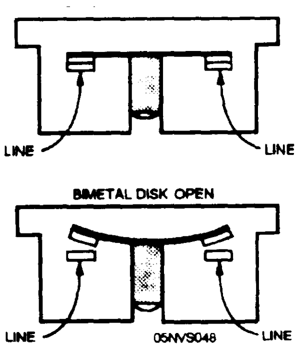


Figure 14-38.—Bimetal disk-type overload.

START CAPACITORS

Start capacitors are connected in series with starting windings. By looking at figure 14-39, you can see the location of the start capacitor in a circuit. Because a start capacitor is placed in series with one of the two stator windings, the current will lead, as compared to the current going directly to the connected stator winding. This, in turn raises the attraction of one stator winding over the other, allowing the motor to begin turning. Figure 14-39(A) shows that stator winding 2 is stronger than stator winding 1. Therefore, the motor begins to turn in the direction of the stronger attraction. Once the initial starting of the motor is completed, the start capacitor is removed from the circuit

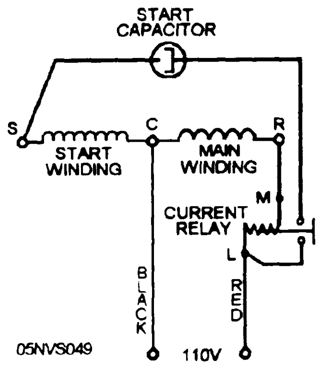


Figure 14-39.—Various types of capacitors.

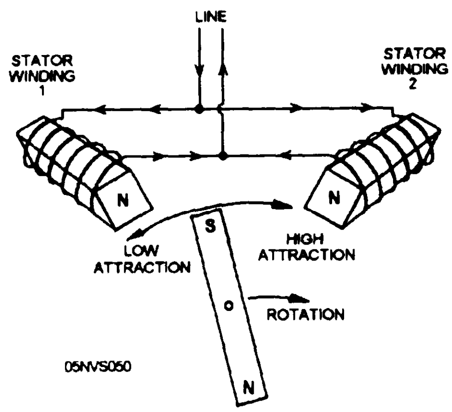
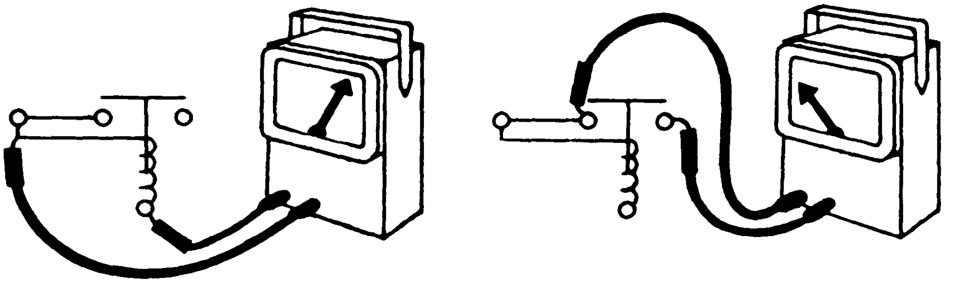


Figure 14-39.—Motor starting.

RUN CAPACITORS

Run capacitors are connected in the circuit between the line side of the starting and running windings. This type of capacitor serves to provide a smoother and quieter operating motor.



87.254

Figure 14-40.—Testing a starting relay with an ohmmeter.

EQUIPMENT AND TEST PROCEDURES FOR ELECTRICAL CIRCUIT COMPONENTS

The equipment and procedures for testing circuit components such as starting relays, overload protectors, and capacitors are discussed as follows.

STARTING RELAYS

Starting relays can be tested two ways with an ohmmeter. The meter can be used to check across the relay contacts, or it can be used to check across the relay coil. This does not apply to thermal relays. Figure 14-40 illustrates procedures for these tests.

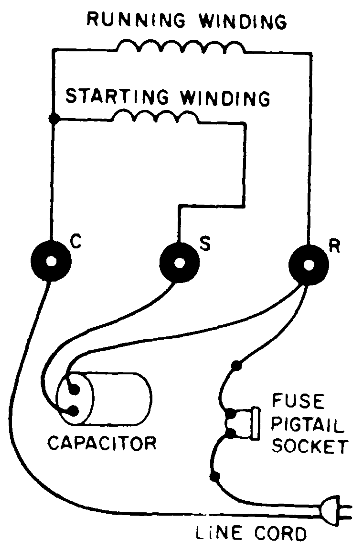
When you check the relay contacts, you must know if the contacts are normally open or normally closed. Voltage relay contacts and thermal relay contacts are normally closed, whereas current relay contacts are normally open. The meter reading should indicate continuity through voltage and thermal relays since the contacts are normally closed. On the other hand, if the meter indicates continuity through the normally open contacts of a current relay, the contacts are probably fused together.

Another method of checking starting relays is by using a test line cord and fuse combination to isolate the relay. Figure 14-41 illustrates the procedure used in making this test. Obtain a capacitor of the approximate size used with the compressor motor. Connect it from the hot side of the running winding to the hot side of the starting winding. Connect the test line to the motor terminals as illustrated in the figure and plug it in. If the compressor is good it should start running. After a short time, disconnect the capacitor. The compressor should continue to speed up and run normally. This procedure has accomplished manually what a properly functioning starting relay is supposed to accomplish. If the motor failed to start normally before the check, the relay is bad.

Voltage and current relay coils can also be tested for resistance with an ohmmeter. When the coil is burned out, the meter indicates no resistance or an open coil. Commercial starting relay testers are available from several manufacturers.

OVERLOAD PROTECTORS

Questionable Klixon external overload protectors should be replaced with new ones. If the



87.255

Figure 14-41.—Procedures for checking a starting relay with a test line.

motor then operates properly, the old Klixon (protector) should be destroyed. Klixons can also be checked with an ohmmeter. Since the contacts are closed at ambient temperature, the meter should show continuity. When the meter shows an open, the Klixon should be replaced and destroyed.

Internal current temperature overloads can be tested by making continuity checks. Continuity checks must be made across terminals C and S, C and R, and S and R. When both C and S and C and R are open and continuity is indicated across S and R, the protector is open. When the temperature is normal and the continuity test indicates the overload contacts are open, the motor compressor assembly must be replaced. When the operating temperature is normal, the internal current temperature overload contacts should be closed.

CAPACITOR TEST

The best test for a questionable motor capacitor is to try a new one of the correct size. If the motor operates properly, the old capacitor is defective and should be destroyed. Capacitors can also be tested with ohmmeter. First, the power must be turned OFF and the capacitor disconnected and discharged with a 2 watt 20,000 ohm resister. Set the meter on the 0 to 10,000 ohm scale and touch the meter probes to the capacitor terminals. If the digital display indicates 0 or low resistance and then climbs towards high resistance, the capacitor is good. If the display indicates 0 or low resistance and stays there, the capacitor is shorted. If the display stays blank, the capacitor is open. Figure 14-42 shows these procedures.

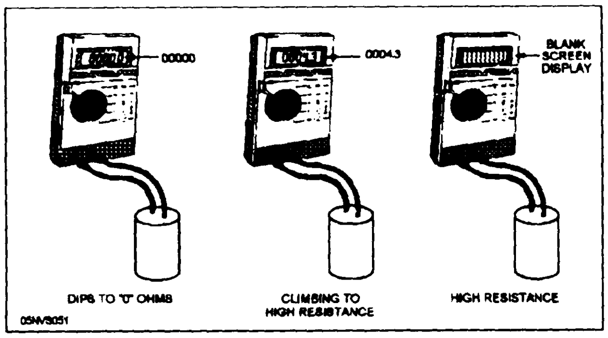


Figure 14-42.—Testing capacitors with an ohmmeter.

HERMETIC ELECTRICAL SCHEMATIC WIRING DIAGRAMS

All wiring circuits are built around four requirements: a source of electrons, a place for them to flow, a path for them to follow, and a load to make use of and control the flow. The schematic wiring diagram puts the symbol and line representation on paper in a manner that allows instant identification of all four requirements. It tells the service member how and why a unit works as it does.

In the schematic wiring diagram, the source of electrons is a line drawn on one side of the diagram and it is usually designated as L1. Any and all points on this line have a surplus of electrons. On the opposite side, a line is drawn representing a shortage of electrons and it is usually designated as L2. There is a potential for electron flow between the two wires represented by L1 and L2. When a load is inserted between L1 and L2, current flows and the load functions.

Figure 14-43 is a typical schematic diagram for a hermetic electrical system. Figure 14-44 is a wiring schematic and a wiring detail for a typical room air-conditioner.

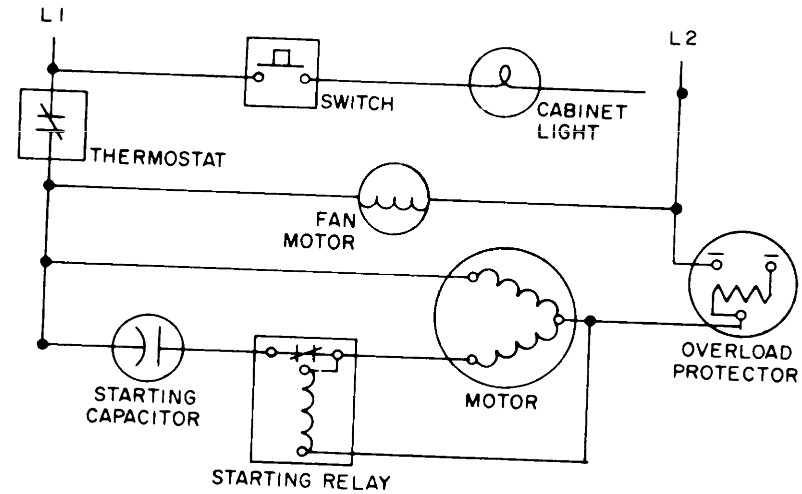


Figure 14-43.—Typical hermetic system schematic wiring diagram. 87.257

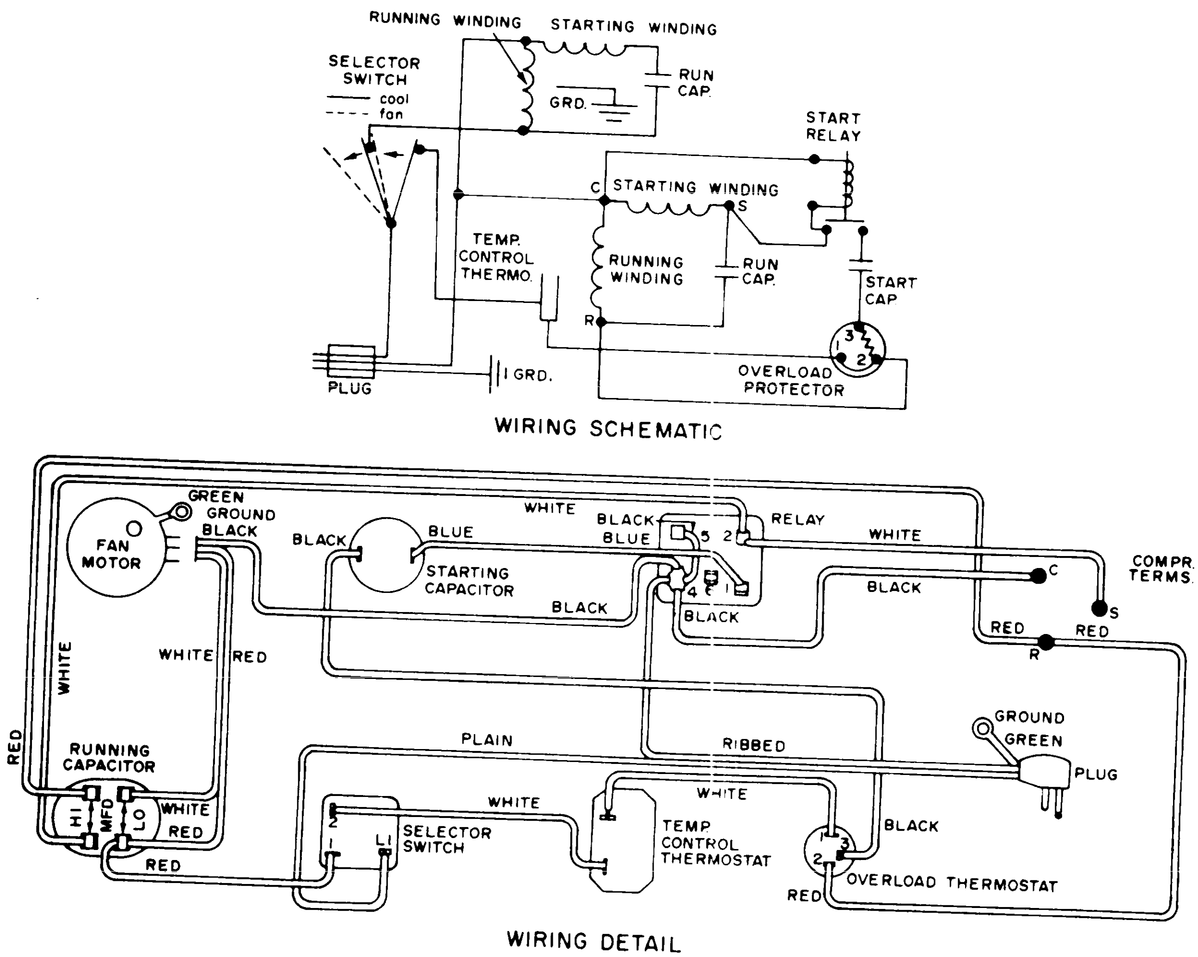


Figure 14-44.—Wiring schematic and detail for a typical room air-conditioner. 87.258

CHAPTER 15

SOLAR ENERGY

The energy that the earth receives from the sun is electromagnetic radiation. Most of the energy is received in the visible and infrared portions and a small amount is received as ultraviolet radiation. Energy from the sun travels approximately 90 million miles in just over 8 minutes to reach earth. If 100 percent of the solar constant were to be collected on an area the size of the United States, we could absorb enough energy in 32 minutes to supply the energy needs of the entire world for a year.

SOLAR RADIATION SYSTEMS

Solar insolation is the amount of solar energy per unit area per unit of time that strikes the surface of the earth. If measurements were made of the solar energy available in outer space, a fixed amount could be determined. This fixed amount of energy is called the solar constant. The solar constant is as follows: 428 Btu/hr-ft^2 or 2,453 watt S/m^2 to 1,940 Langleys/min. Langleys (L) is the most common measurement used. At most, 70 to 80 percent of this amount strikes the surface of the earth; the remainder is absorbed or reflected by the atmosphere. Those solar rays that hit the earth's surface on a clear day are, for the most part, parallel to each other. When there is haze, cloud cover, smog, or dust in the air, the parallel pattern is broken and the rays are deflected in many different directions by these particles of water or dust in the atmosphere. This is the reason why light and heat appear to come at us from all directions; the term used for this is diffuse radiation.

With the right solar collector, *diffuse radiation* can be useful. Because of the filtering effect, the average solar intensity on the ground is about 1,400 Btu per square foot per day. This is equal in a square mile to the productivity of a large hydroelectric power plant.

COLLECTING SOLAR ENERGY

Collection of solar energy is based on the high absorption of radiant energy by dull black surfaces and on the "greenhouse effect." The latter refers to the ability of glass to transmit visible radiation and to prevent the loss of heat from the collector plate that radiates at longer wavelengths (infrared frequencies). Glass (or plastic) cover plates are generally used over flat-absorber plates to reduce heat loss (fig. 15-1). The heated absorber plate has tubes that allow fluid to circulate through the plate and receive heat. The heated fluid heats potable water, closed spaces, or drives an absorption air-conditioner.

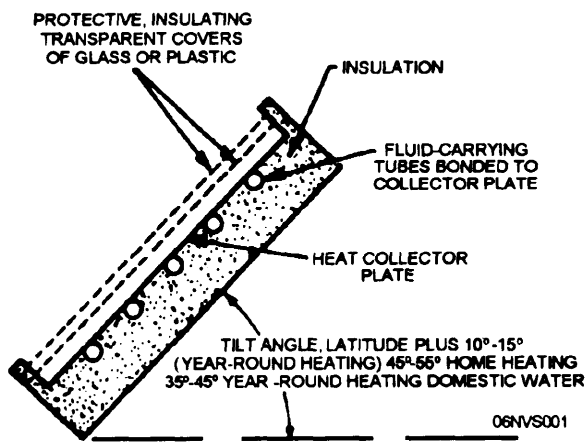


Figure 15-1.—Cross section of a typical solar heat collector with heavy back insulation and two cover sheets.

Table 15-1.—Advantages and Disadvantages of Air and Liquid Heating Systems

AIR	
ADVANTAGES	**DISADVANTAGES**
Moderate cost. No freezing problems. Minor leaks of little consequence. As air is used to heat the house, no temperature losses due to heat exchangers (devices which transfix heat from one fluid to another), when the system is used for space heat. No boiling or pressure problems.	Can only be used to heat homes; can not presently be economically adapted to cooling. Large air ducts needed. Larger storage space needed for rocks. Heat exchanger needed if system is to be used to heat water.
WATER OR LIQUID	
ADVANTAGES	**DISADVANTAGES**
Holds and transfers heat well. Water can be used as storage. Can be used to heat and cool homes. Compact storage and small conduits.	Leaking, freezing, and corrosion can be problems. Corrosion inhibitors needed with water when using steel or aluminum. There are liquids which are noncorrosive and nonelectrolytic; however, they are toxic and some of them are flammable. A separate collector loop using a nonfreezing fluid and a heat exchanger or, alternatively, a draining water or inhibited water system is required to prevent freezing. In warm regions, where freezing is infrequent, electric warmers or recirculation can be used.

The amount of solar energy collected by a solar collector depends on its efficiency. The construction, configuration, and the choice of material determines the efficiency of a solar collector.

SOLAR COLLECTOR ORIENTATION

Although solar collectors can collect heat from the diffuse component of solar radiation, solar systems are designed to use radiation. Direct radiation is in the form of parallel rays coming straight from the sun. To capture this energy, tilt the solar collector, as shown in figure 15-1, so it is nearly perpendicular to the solar rays.

In addition to choosing the best collector tilt angle, take into consideration the direction that the collector faces. Normally, true south is the best and most frequent choice, However, 10 degrees west of south maybe preferable in some locations if early morning haze or fog is a regular occurrence.

Equally important as collector location is keeping the collectors out of the shade, especially between 0900 and 1500 hours, when most of the useful energy collection occurs. In summary although many buildings do not have a “perfect” solar orientation, there are still many places with good solar energy potential.

COLLECTORS

The collector is the most important and most expensive part of a solar-heating system. Collectors for space and water heating are of two basic types: liquid and air. Liquids may be water, an antifreeze mixture, or various hydrocarbon and silicone heat transfer oils. An air type of collector uses air as the collector medium. For the advantages and disadvantages of air-and liquid-heating systems, see table 15-1. The absorber plate is that part of the collector that absorbs the solar energy and converts it to thermal energy. Some thermal energy is carried to the building or thermal storage unit by the medium that circulates through passages in the absorber plate. The absorber plates are made of metal, plastic, or rubber compounds. The metals commonly used in order of decreasing thermal conductivity are copper, aluminum, and steel. Plastic (polyolefin) and rubber (ethylene propylene compound) is inexpensive. However, because of their low thermal conductivity and their temperature limitations, they are suitable only for low-temperature applications, such as heating water in swimming pools or for use with water-source heat pumps. Figure 15-2 depicts typical cross sections of solar collectors.

Flat-plate collectors are most suitable for low-temperature applications, such as domestic water and space heating. They collect both direct and diffuse radiation. It is not required that they track the sun. Tubes should be 1/2 inch in diameter or greater for low-pressure drop and longer life. The better the attachment of tube-to-plate (such as by soldering), the better the heat transfers.

Liquid and air collectors each have some advantages. Liquid types are most suited to domestic hot water because the collector area is usually smaller.

The design procedures for air collectors differ however. Heat transfer oils used in liquid systems offer freeze protection and some corrosion protection, but they also require heat exchangers for heating domestic hot water, as do antifreeze-water mixtures.

Selective Surfaces

Collectors are black and gray in color and have a rough textured surface. The rough-surface absorbs solar rays better than a smooth surface. A smooth, shiny surface will reflect radiant energy away from the collector. Generally, surfaces are made of metal particles, rather than paint, because paint cracks and peels at high temperature.

Collector covers (glazes)

The transparent covers serve to admit solar radiation to the absorber while reducing convection and radiation heat losses from the collector. The covers also protect the absorber from dirt, rain, and other environmental contaminants.

The materials used as covers include glass or plastic sheets. Glass is most commonly used because of its superior optical properties and durability. Standard plate glass reflects about 8 percent and absorbs about 6 percent of normal incident solar radiation, resulting in a transmissivity of about 86 percent. Glass is subject to impact damage and is more expensive than plastic; however, it does not degrade in sunlight or at high collector temperatures and is more durable than plastic.

Although resistant to impact damage, plastic generally degrades in sunlight and is limited as to the temperatures they can sustain without undergoing serious deformation. In general, acrylic is the most ultraviolet-resistant, and polycarbonate offers good impact and high-temperature properties.

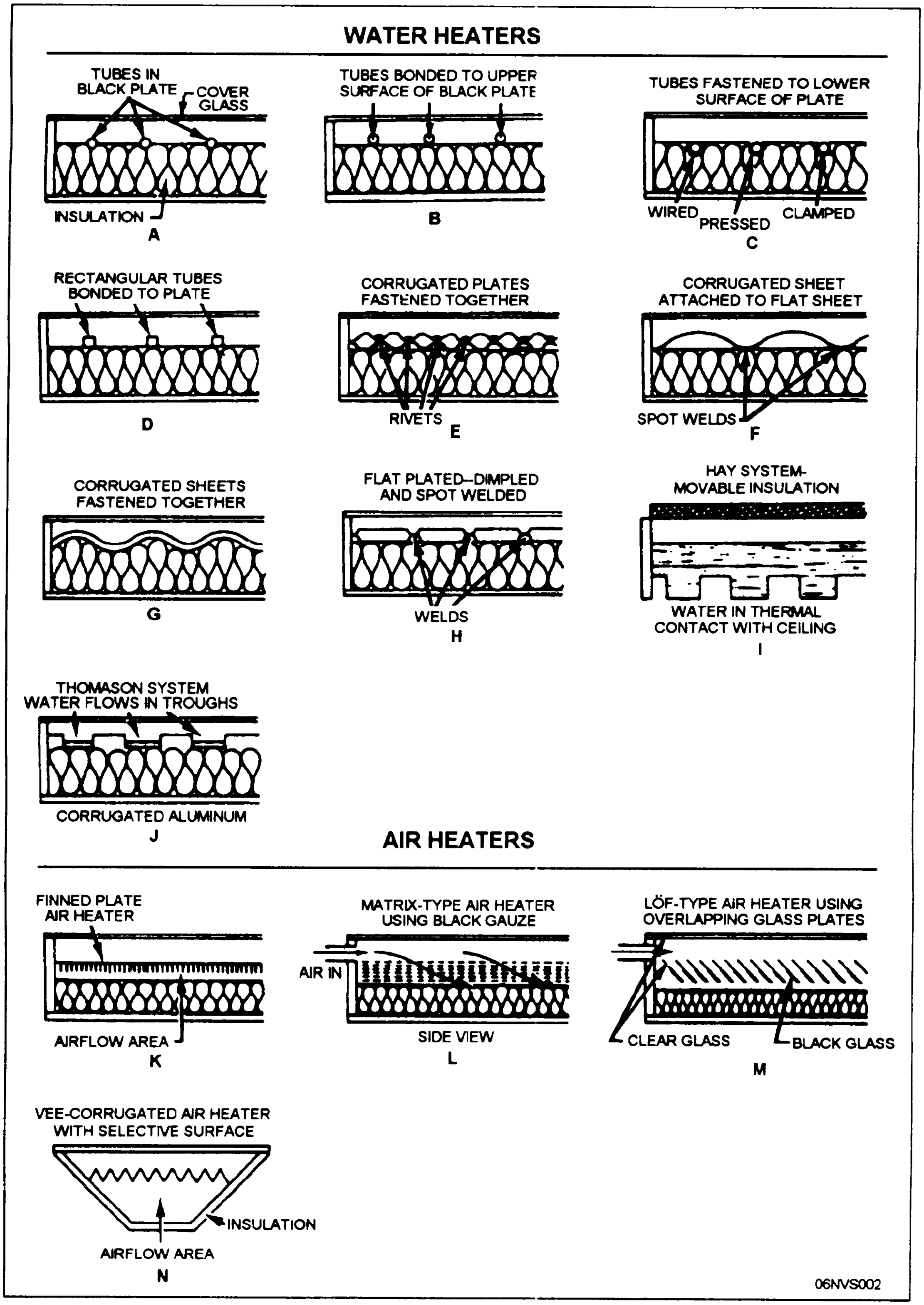


Figure 15-2.—Types of solar heat collectors.

Collector Gaskets and Sealants

Gaskets and sealants must be carefully selected if a collector is to have a long life. Generally, the housing and the glazing have different rates of thermal expansion. Gaskets and sealants form a flexible interface between the two components and seal out moisture and other contaminants. If they fail, moisture fogs the glazing and may damage the absorber coating and the insulation. These problems can drastically reduce the thermal performance of the collector.

Two suitable sealing methods are shown in figure 15-3. The gaskets provide flexible support and the primary weather sealant ensures against ,oisture leakage. Desiccants are sometimes placed between the two glazings to absorb any moisture that may remain after cover installation.

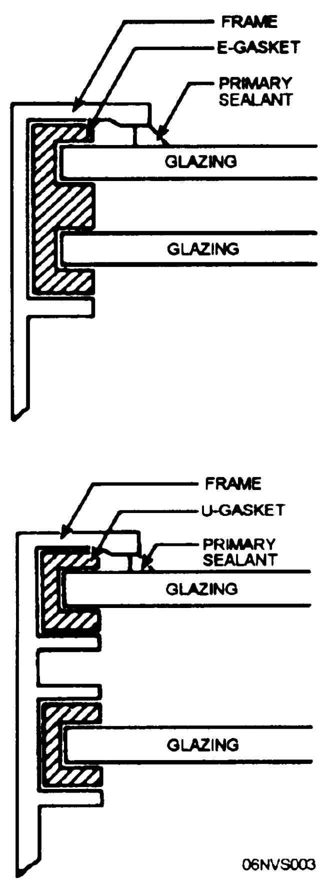


Figure 15-3.—Typical sealing methods for single or double glazing.

When you are selecting collector gaskets and sealants, certain material requirements must be kept in mind. The gaskets and seals must do the following:

1. Withstand significant expansion and contraction without destruction

2. Adhere effectively to all surfaces

3. Resist ultraviolet degradation

4. Resist outdoor weathering

5. Not harden or become brittle

6. Withstand temperature cycling from -30°F to 400°F

Silicone sealants have been found adequate for use as gasket material. Silicone sealants have exceptional weathering resistance and have received widespread use for many years.

Collector Fluid—Corrosion and Freeze Protection

The choice of collector fluid is important because this is the lifeblood of the system. The cheapest, most readily obtainable, and thermally efficient fluid to use is ordinary water. However, water suffers from two serious drawbacks: freezing and corrosion. Therefore, the choice of collector fluid depends on the type of solar system the choice of components, future maintenance, and several other factors.

Implicit in this discussion is the use of fluid in the collector. As explained in table 15-1, an air solar system does not suffer from corrosion or freezing. The low density and heat capacity of an air solar system requires the use of fans, large ducts, large storage volumes, and it is not suitable for domestic water heating.

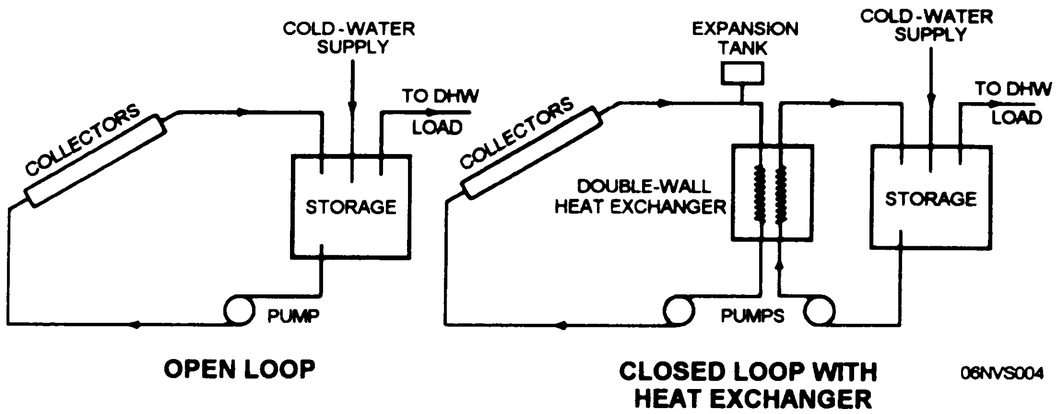


Figure 15-4.—Typical configuration for solar water-heating systems.

If there is no danger of freezing and the collector loop consists of all copper flow passages, then ordinary water should be the choice for collector fluid. When encountering freezing conditions, there are several designs to consider before deciding to use a heat transfer oil or antifreeze mixture. For the purposes of this discussion, these freeze protection schemes are summarized using figure 15-4 to explain the basic open-loop type of collector circuit.

DRAIN-DOWN METHOD.— When the water in the collector approaches freezing, the water drains into the storage tank. This scheme requires automatic valves to dump the water and purge the air from the system. Often a large pump is required to overcome the system head and reprime the collectors. A way to avoid automatic (solenoid) valves is to drain the collectors whenever the pump shuts off. This still requires a larger pump. You may require heat exchangers to separate potable water from nonpotable water.

HEAT TAPES.— Electrical-resistant heat tapes are thermostatically started to heat the water. This scheme requires extra energy and is not completely reliable. Inserting heat tapes into preconstructed collectors may be difficult.

RECIRCULATING METHOD.— The control system shown in figure 15-4 merely turns on the pump when it approaches freezing. In this way, warm water from storage circulates through the collectors until the freezing condition is over. The only extra component needed is a freeze sensor on the collector, which is a minimum cost item. However, by circulating heated water, the capacity of storage decreases and less is available the following day.

HEAT TRANSFER FLUID

When the preceding methods are not acceptable or the choice of water is unacceptable because of concern about corrosion, you should use a heat transfer fluid. Use a heat transfer fluid with a heat exchanger in a "closed-loop" configuration.

There are two categories of heat transfer fluids nonaqueous and aqueous. Silicones and hydrocarbon oils make up the nonaqueous group, while the aqueous heat transfer fluids include untreated potable (tap) water, or inhibited distilled water, and an inhibited glycol/water mixture. The potable tap water and inhibited distilled water do not offer freeze protection.

Silicone Fluids

Silicone heat transfer fluids have many favorable properties that make them prime candidates for collector fluids. They do not freeze, boil, degrade, or corrode common metals, including aluminum. They have excellent stability in solar systems stagnating under 400°F. Silicone fluids are also virtually nontoxic and have high flash and fire points. Current evidence suggests that silicone fluids should last the life of a closed-loop collector system with stagnation temperatures below 350°F to 400°F. The flash point is high, 450°F, but since HUD standards say that heat transfer fluids must not be used in systems whose maximum stagnation temperature is less than 100°F lower than the flash point of the fluid, this limits most silicone oils to systems with a maximum temperature of 350°F or less. Also, silicones do not form sludge or scale, so system performance does not decrease with time.

The main drawback of silicone fluids is their cost. The cost of the 20 to 30 gallons of collector fluid required for a typical 500 ft^2 collector system becomes considerable. As with hydrocarbon oils, the lower heat capacity and higher viscosity of silicone fluid requires larger diameter and more expensive piping. Because of the higher viscosity, larger pumps are required and subsequently, higher pumping costs. One other problem with silicone fluids is the seepage of fluid at pipe joints. This problem can be prevented by proper piping installation and by pressurizing the system with air to test for leaks. There have also been reports of seepage past the mechanical seals of circulating pumps.

Silicones have the advantage of lasting the life of the system with little maintenance. The high initial cost of silicone heat transfer fluid may be less than the savings that result from minimum maintenance and no replacement of collector fluid. The use of silicone fluid allows aluminum absorbers to be used without fear of corrosion. Hydrocarbon oils, like silicones, also have a long service life, but cost less. They are relatively noncorrosive, nonvolatile, environmentally safe, and most are nontoxic. They are designed for use in systems with lower operating temperatures, since some brands break down at higher temperature to form sludge and corrosive organic acids.

Distilled Water

Distilled water has been suggested for use in solar collectors, since it avoids some of the problems of untreated potable water. However, distilled water is still subject to freezing and boiling. Therefore, an antifieeze/antiboil agent, such as ethylene glycol, should be added.

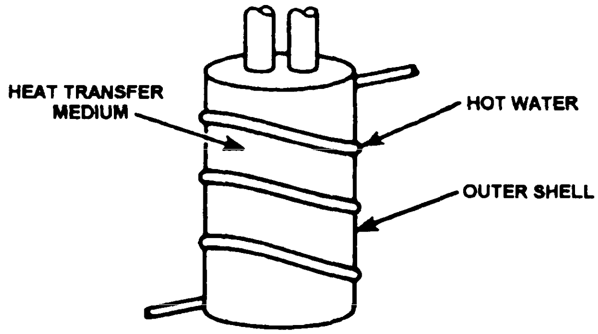
Water/Antifreeze

Nonfreezing liquids can also be used to provide freeze protection. These fluids are circulated in a closed loop with a double-wall heat exchanger between the collector loop and the storage tank (fig. 15-5.)

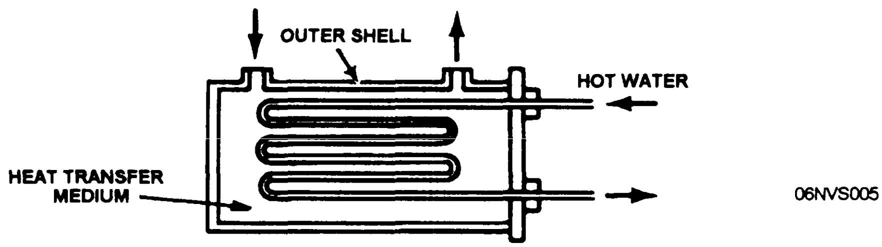
Water/antifreeze solutions are most commonly used. Ethylene glycol and propylene glycol are the two most commonly used antifreezes. A 50-50 water/glycol solution provides freeze protection down to about -30°F and also raises the boiling point to about 230°F.

OTHER TYPES OF SOLAR COLLECTORS

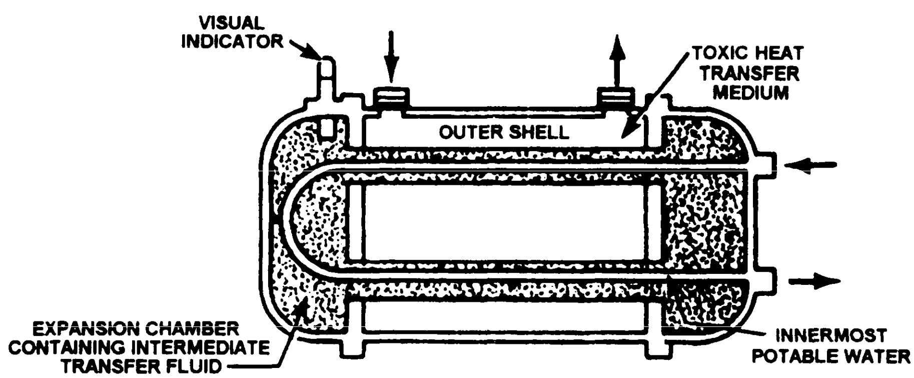
The three most common types of solar collectors are flat-plate collectors, evacuated tube collectors, and concentrating collectors. Because of certain cost and performance advantages, flat-plate collectors have been used extensively for domestic water heating and space heating. Evacuated tube and concentrating collectors are used mostly in solar applications requiring high temperatures. A brief description follows.



DOUBLE WALL. ANOTHER METHOD OF PROVIDING A DOUBLE SEPARATION BETWEEN THE TRANSFER MEDIUM AND THE POTABLE WATER SUPPLY CONSISTS OF TUBING OR A PLATE COIL WRAPPED AROUND AND BONDED TO A TANK. THE POTABLE WATER IS HEATED AS IT CIRCULATES THROUGH THE COIL OR THROUGH THE TANK. WHEN THIS METHOD IS USED, THE TUBING COIL MUST BE ADEQUATELY INSULATED TO REDUCE HEAT LOSSES.



SHELL AND TUBE. THIS TYPE OF HEAT EXCHANGER IS USED TO TRANSFER HEAT FROM A CIRCULATING TRANSFER MEDIUM TO ANOTHER MEDIUM USED IN STORAGE OR IN DISTRIBUTION. SHELL AND TUBE HEAT EXCHANGERS CONSIST OF AN OUTER CASING OR SHELL SURROUNDING A BUNDLE OF TUBES. THE WATER TO BE HEATED IS NORMALLY CIRCULATED IN THE TUBES, AND THE HOT LIQUID IS CIRCULATED IN THE SHELL. TUBES ARE USUALLY METAL, SUCH AS STEEL, COPPER, OR STAINLESS STEEL. A SINGLE SHELL AND TUBE HEAT EXCHANGER CANNOT BE USED FOR HEAT TRANSFER FROM A TOXIC LIQUID TO POTABLE WATER BECAUSE DOUBLE SEPARATION IS NOT PROVIDED AND THE TOXIC LIQUID MAY ENTER THE POTABLE WATER SUPPLY IN A CASE OF TUBE FAILURE.



SHELL AND DOUBLE TUBE. THIS TYPE OF HEAT EXCHANGER IS SIMILAR TO THE PREVIOUS ONE EXCEPT THAT A SECONDARY CHAMBER IS LOCATED WITHIN THE SHELL TO SURROUND THE POTABLE WATER TUBE. THE HEATED TOXIC LIQUID THEN CIRCULATES INSIDE THE SHELL BUT AROUND THIS SECOND TUBE. AN INTERMEDIARY NONTOXIC HEAT TRANSFER LIQUID IS THEN LOCATED BETWEEN THE TWO TUBE CIRCUITS. AS THE TOXIC HEAT TRANSFER MEDIUM CIRCULATES THROUGH THE SHELL, THE INTERMEDIARY LIQUID IS HEATED, WHICH, IN TURN, HEATS THE POTABLE WATER SUPPLY CIRCULATING THROUGH THE INNERMOST TUBE. THIS HEAT EXCHANGER CAN BE EQUIPPED WITH A SIGHT GLASS TO DETECT LEAKS BY A CHANGE IN COLOR (TOXIC LIQUID OFTEN CONTAINS A DYE) OR BY A CHANGE IN THE LIQUID LEVEL IN THE INTERMEDIARY CHAMBER, WHICH WOULD INDICATE A FAILURE IN EITHER THE OUTER SHELL OR INTERMEDIARY TUBE LINING.

Figure 15-5.—Heat exchangers for solar water-heating systems.

Flat-Plate Collectors

The flat-plate collectors are much simpler than the concentrating collectors. They do not need to face directly at the sun; they can absorb diffused light and almost anyone can make one. We know that dark surfaces absorb radiation, and lighter surfaces reflect it. A flat-plate collector is a black sheet of metal with fluid channels or conduits running over, under, or even through it.

A flat-plate collector works much like a greenhouse. Rays come through the glass, reflect off the walls and the floor of the greenhouse, but cannot escape back into the atmosphere. When rays of short wavelength hit the absorber plate, some of their energy is reradiated back toward the source, but their intensity is weakened—thus increasing the length of the waves. Because they cannot pass back through the glazing, they hit the absorber repeatedly, giving the plate several chances to absorb them.

Evacuated Tube Collectors

Figure 15-6 shows an evacuated tube collector. The vacuum tube collector has a vacuum between the absorber and the glass outer tube. This reduces convection and conduction heat losses.

Evacuated tube collectors operate essentially the same as flat-plate collectors. Solar radiation passes through the outer glass tube and the coated absorber receives the heat. The heat energy is transferred to the fluid flowing through the absorber. Most evacuated tube designs collect both direct and diffused radiation efficiently, but certain types are designed for more efficient collection of direct radiation. Although evacuated tube collectors are considerably more expensive than typical flat-plate collectors, they are much more efficient when high collection temperatures are needed for operating absorption chillers of for industrial processing.

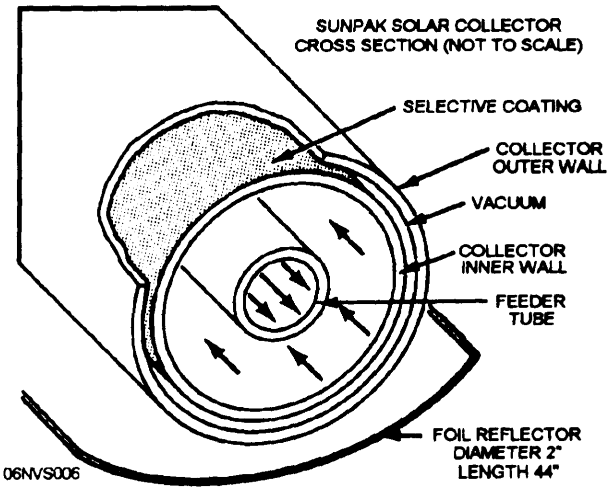


Figure 15-6.—Evacuated tube solar heat collector.

They may not be as efficient as flat-plate collectors at low temperatures, such as domestic water heating and space heating.

Concentrating Collectors

Concentrating, or focusing, collectors intercept direct radiation over a large area and focus it onto a small absorber area. These collectors can provide high temperatures more efficiently than flat-plate collectors, since the absorbtion surface area is much smaller. However, diffused sky radiation cannot be focused onto the absorber. Most concentrating collectors require mechanical equipment that constantly orients the collectors toward the sun and keeps the absorber at the point of focus.

There are many types of concentrating collectors. The most popular types are the parabolic trough, the linear-trough fresnel lens, and the compound parabolic mirror. Figure 15-7, view (A), shows a linear concentrating or parabolic-trough collector. It collects energy by reflecting direct solar radiation off a large curved mirror and onto a small absorber tube that contains a flowing heat transfer liquid. The absorber tube is encased in a glass or metal tube that may

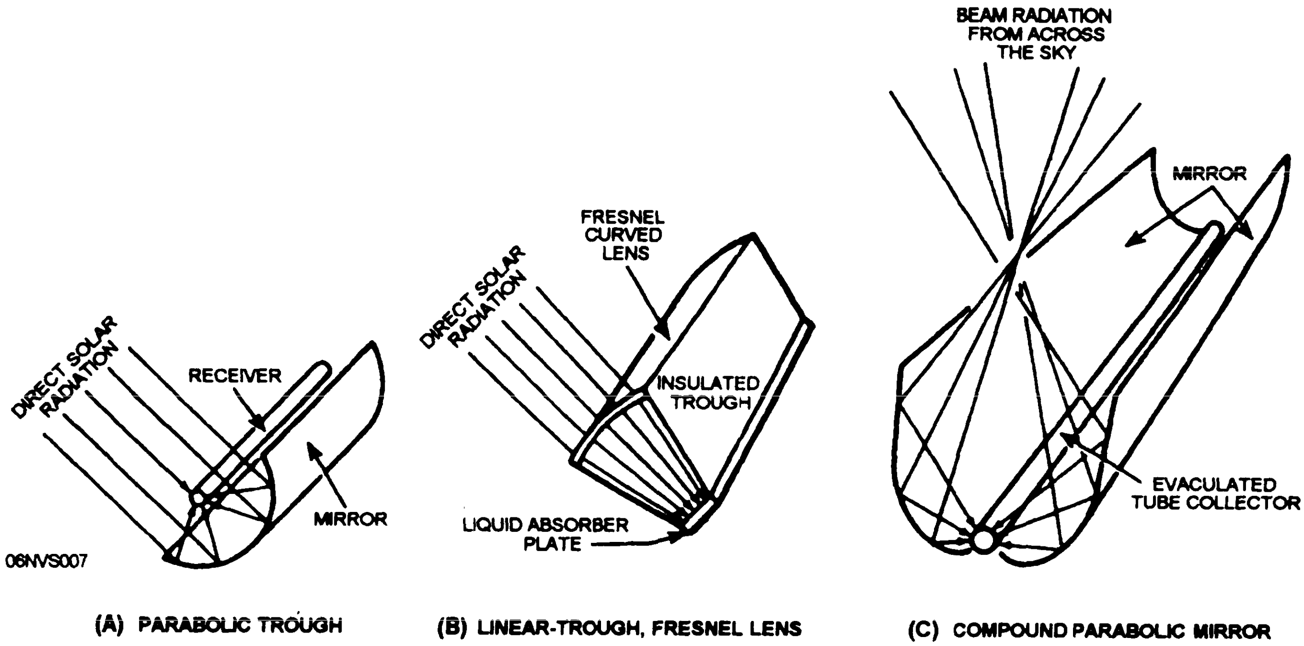


Figure 15-7.—Concentrating collectors for solar energy.

be evacuated. This type of collector must track the sun and can collect only direct radiation.

Figure 15-7, view (B), shows a linear-trough, fresnel lens collector. In this design, a curved lens is used to focus incoming rays onto a small absorber plate or tube through which the heat transfer liquid is circulated. This type of collector also requires a tracking mechanism and can collect only direct radiation.

Figure 15-7, view (C), shows a compound parabolic mirror collector. The design of the mirror allows the collector to collect and focus both direct and diffuse radiation without tracking the sun. Periodic changes in the tilt angle are the only adjustments necessary.

Direct radiation is intercepted by only a portion of the mirror at a time; thus this collector does not collect as much solar energy as a focusing collector that tracks the sun. It is, however, less expensive to install and maintain. The absorber tube is encased within an evacuated tube to reduce heat losses.

Many other types of concentrating collectors produce high temperatures at good efficiencies However, the high cost of installing and maintaining tracking collectors restricts their use to solar cooling and industrial applications where extremely high fluid temperatures are required. In addition, concentrating collectors must be used only in those locations where clear-sky direct radiation is abundant.

ENERGY STORAGE AND AUXILIARY HEAT

Since effective sunshine occurs only about 5 to 6 hours per day (in temperate latitudes) and

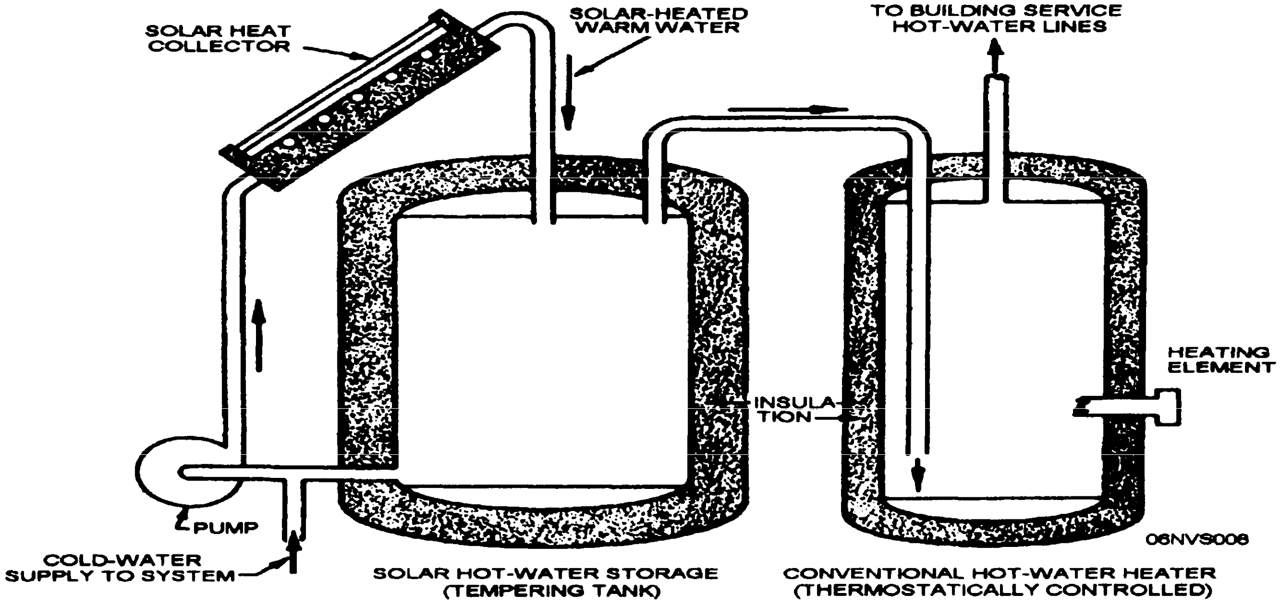


Figure 15-8.—Schematic of potable hot-water heating systems, using solar storage (tempering) tank ahead of the conventional fueled or electric service water heater.

since heating and hot-water loads occur up to 24 hours a day, some type of energy storage system is needed when using solar energy.

Practical experience in the industry, as well as computer simulations and experiments, has resulted in rules of thumb for storage sizing. These guidelines provide storage sizes for which the performance and cost of active solar systems are optimized and relatively insensitive to changes within the range indicated.

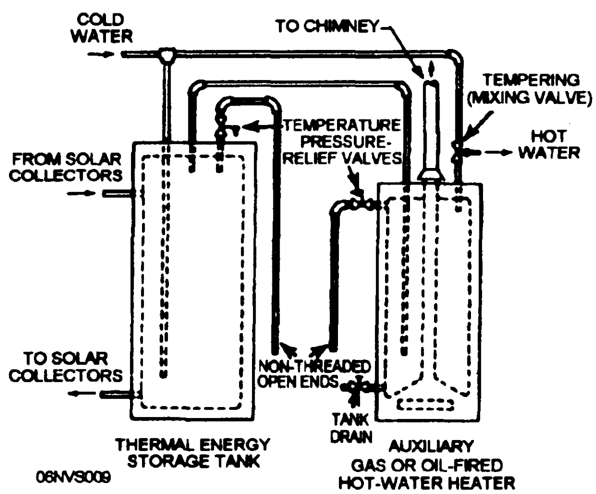


Figure 15-9.—Typical DHW installation.

Water Systems

Since water has a specific heat of 1 Btu/1b-°F, then 15 pounds of water storage is needed per square foot of collector or 1.8 gallons of storage is needed for each square foot of collector.

Air Systems

Since rock has a specific heat of 0.21 Btu/1b-°F and rock densities typically contain 20 to 40 percent voids, then the optimum storage size is 0.8 ft^3 per square foot of collector. Storage volumes in this range store the equivalent overnight of 1 full day of heating. A typical domestic hot-water system is shown in figure 15-8. The use of two tanks ensures that when hot water from the first (tempering) tank is available, the auxiliary heat does not come on; also less total fuel is used to bring the smaller second tank up to temperature. Single-tank arrangements are not recommended because they frequently activate the heating element every time there is a draw of water, rather than wait for the solar collectors to provide additional heated water. The two-tank arrangement (fig. 15-9) avoids this control problem. Two-tank arrangements are suited to retrofits since the second tank (the water heater) is already there. A variation would be to use a heat exchanger (copper coil) (fig. 15-10) in the tempering tank collector loop for freeze protection. The tempering tank then becomes an inexpensive unpressurized tank.

Another method of heat storage in air systems is latent heat storage. Latent heat is stored in a material as it changes state from a solid to a liquid. Materials that have melting points near the temperatures supplied by solar collectors store heat as they melt and release it as they resolidify. The two materials that have received the most attention are salt hydrates and paraffins.

Storage Tanks

Water may be stored in a variety of containers usually made of steel, concrete, plastic, fiber glass, or other suitable materials.

Steel tanks are commercially available and have been used for water storage. They are available in many sizes and are easy to install. However, steel tanks are susceptible to corrosion and should be lined or galvanized. Dissimilar metal at pipe connections should be separated by high-temperature rubber connections or galvanic corrosion will occur. Steel tanks must be well insulated to reduce heat losses.

Fiber glass and plastic tanks are corrosion-resistant and installed easily. They are available in many shapes and sizes. Although many commonly fabricated tanks begin to soften at temperatures above 140°F, there are more expensive, specially fabricated tanks available that can withstand temperatures up to 150°F. The types of plastics needed to store large quantities of water at high temperatures can be more expensive than steel. Buried tanks must be protected from groundwater and resist buoyant forces. The tank must be reasonably accessible for repairs. In mild or warm climates, an outdoor location may be feasible.

Domestic Hot-Water Systems (DHW)

Domestic hot-water systems (without space heating) may use lined, insulated, or pressurized tanks similar to the conventional water heater. Appropriate temperature-and pressure-relief valves must be used. Since it is possible for solar collectors to reach hot temperatures, a tempering or mixing valve should be used. A typical two-tank installation with proper valves and connections is shown in figure 15-9.

To size the collectors and storage tank, you must estimate the hot-water consumption of the facility or building. The hot water consumption rate for a typical family home is 20 gal/day/person. When the hot-water consumption rate is more than average, use 30 gal/day/person. So, 80 to 120 gal/day should serve a typical four-person family.

Thermosiphon Systems

A variation of the DHW system is the thermosiphon system. It uses the principle of natural convection of fluid between a collector and an elevated storage tank. The advantage is no pump or controller is needed. The bottom of the tank should be mounted about 2 feet higher than the highest point of the collector. This is the main disadvantage because structural requirements often prohibit the weight of a water tank on a high point of the structure. Also, since the thermosiphon system is connected directly to the potable water supply, it cannot be protected from freezing. A

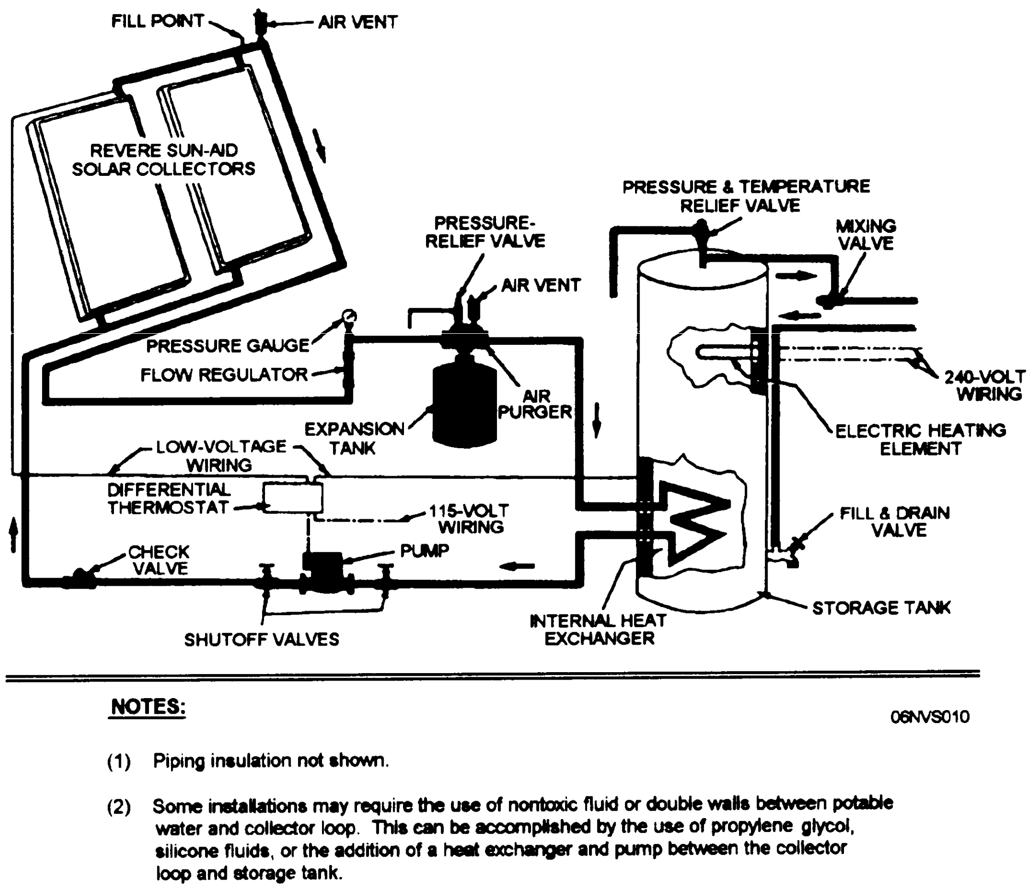


Figure 15-10.—A DHW system with heat exchanger in hot-water storage tanks.

heat exchanger cannot be used effectively in this system.

Space Heating and DHW Systems

Space heating systems are a simple extension of the domestic hot-water (DHW) systems (fig. 15-10). The collectors and storage tank need to be resized to provide greater loads. A heat delivery system is added and the auxiliary heater (or existing heater) is connected into the system as backup. The design of the space heating system, if a retrofit, depends on the existing system. Water-to-air heat exchangers may be placed in existing ductwork, in which case, an unpressurized, unlined tank may be used. This represents a minimum heating system, as shown in figures 15-11 and 15-12.

Domestic hot water could be added to the system shown in figure 10-33 by adding a preheat coil in the storage tank. Figure 10-31 has the potential to provide some cooling to the building by using the collector at night to radiate heat to the sky and store cool water for use during the day. A heat pump is another option that could be used to cool the building, reject the heat to the storage tank during the day, and then, as before, cool the tank at night through the solar collectors. Unglazed collectors are superior to glazed collectors for this application. There are many variations that can be used with the configurations shown.

Air types of space heating systems are receiving increased attention, and a typical system is shown in figure 15-14. (See table 15-1 for advantages of air versus liquid.) The heat storage tank is replaced by a rock bed (nominally 1 to 3 inches in diameter). Rock provides desirable temperature stratification. Designs should emphasize the minimum pressure drop through the rock bed. The rocks can be stored in a bin, which should be insulated, or beneath the building if this is feasible. Heat collected by the collectors is blown through the rock bed from top to bottom. Heat is delivered from storage to the building by circulating air in the reverse direction, bottom to top. Note that in contrast to water storage, heat cannot be added to and removed from the rocks at the same time.

During heat collection, the rocks at the top of the bin attain a temperature almost equal to that of the incoming solar-heated air, while the air leaving storage is delivered to the collectors at the minimum temperature of the rocks. The conduction between the rocks is small; thus, with no air circulation, the rock bed remains stratified with the top of the rock bed warmer than the bottom. Also, limited conduction and convection in the rock bed significantly reduce heat loss from the rock bed.

Heat is drawn from storage by circulating air from the building directly through the rock bed from bottom to top. The air is delivered to the building at a temperature near the maximum temperature of the collectors. If additional heat is required, supplementary heat is added downstream from the storage unit. This system allows the rock bed to deliver useful heat until all of the rocks are at room temperature.

A variation is a no-storage air heating system that circulates heated air when available. Performance is limited to daytime heating because of the lack of storage, but such systems are well suited to warehouses and factories with daytime operations.

Domestic hot water is provided by pumping the water in the preheat tank through an air-to-water heat exchanger placed in the return air duct from the collectors. This is not efficient and is one of the disadvantages of the air system.

Heat Distribution for Liquid Types of Solar Systems

The temperature requirements of a hydronic heating system depend on the amount of heat exchanger surface. Most baseboard heaters have comparatively small surface areas, so they require higher temperatures, typically about 180°F. If larger heat transfer areas are available, as in older or modified hot-water systems, temperatures of 120°F maybe sufficient. Temperatures of 100°F to 120°F are adequate for the system that uses entire floors, walls, and ceilings as radiator surfaces.

During the winter, typical liquid types of solar systems are seldom operated at delivery temperatures above 150°F. Clearly the use of

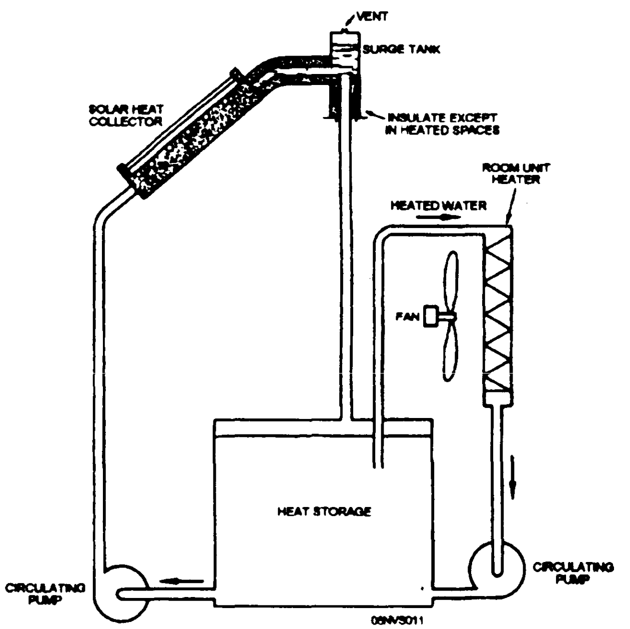


Figure 15-11.—Minimum heating system showing relationship of collector, storage, and room unit heater.

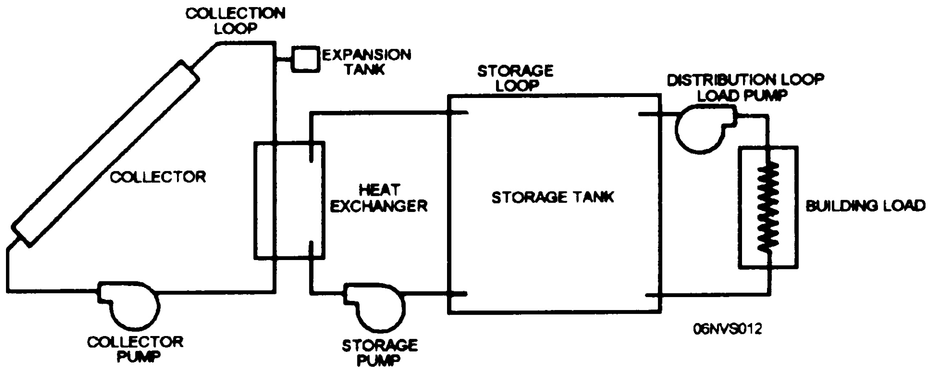


Figure 15-12.—Space heating system with a closed-loop collector.

solar-heated water in standard baseboard heaters is impractical. Only modified baseboard heaters of adequate size or radiant panels are suitable for use in hydronic systems that use solar-heated water.

One economical means of auxiliary heat supply and heat distribution for liquid types of solar systems involves the use of a warm-air system. A typical system is shown in figure 15-15. In this system, the warm-air furnace is located downstream from a liquid-to-air heat exchanger supplied with solar-heated water. The furnace can then serve to boost air temperature when insufficient heat is available from the solar-heated water, or it can meet the full heat load when no heat is available in solar storage. Auxiliary heat can be supplied by a gas, oil, or electric furnace, or by the condenser of an air-to-air heat pump.

Another method of heat distribution is to use a water-to-air heat pump that draws heat from the solar storage tank and pumps it to a condenser coil placed in a central air duct. The advantage of this system is that it can effectively use heat from solar storage at temperatures down to 45°F; thus more of the stored heat is available. Also, average storage temperatures are lower, resulting in significantly increased collector efficiency. Some manufacturers are combining solar systems with heat pumps to reduce auxiliary energy costs. When a heat pump and solar system are combined

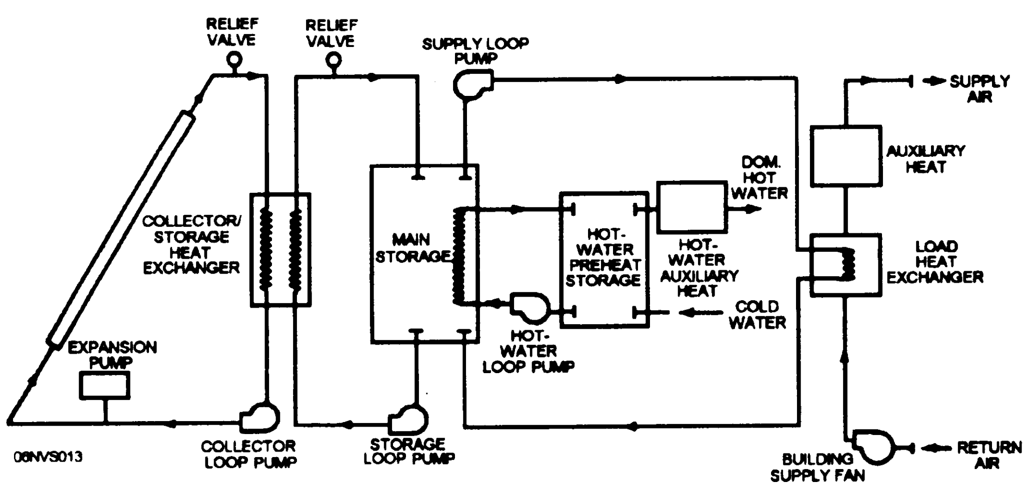


Figure 15-13.—Space heating and domestic hot-water systems.

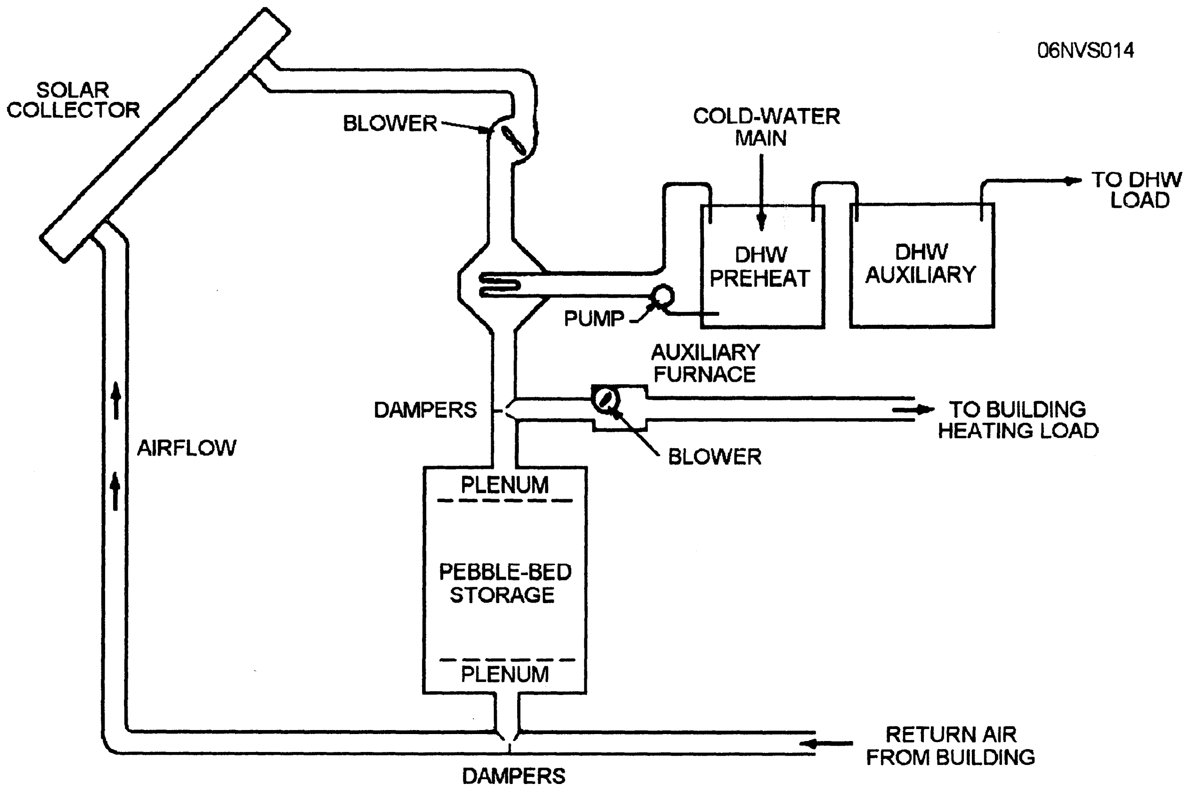


Figure 15-14.—Typical air types of space heating systems.

in this manner, the system is usually called a solar-assisted or solar-augmented heat pump (SAHP) system.

Solar-assisted heat pump systems are configured in many different ways. For example, the solar collectors can be either water or air types; the heat storage medium can be water or a solid material, such as rock or brick; and the heat pump can be of either the air-to-air design or the water-to-air design. But heat pumps have a characteristic that can limit their effectiveness: the efficiency and capacity of a heat pump decrease as the temperature of the heat source (usually outdoor air) decreases. This deficiency can be overcome, however, by using solar collectors to gather the energy of the sun to keep the heat source in the temperature range required for efficient heat pump operation.

Heat Distribution for Air Types of Solar Systems

The pipes and pumps of the liquid types of solar systems are replaced by air ducts and fans. The warm-air system is obviously the best heat distribution system for use with an air type of solar

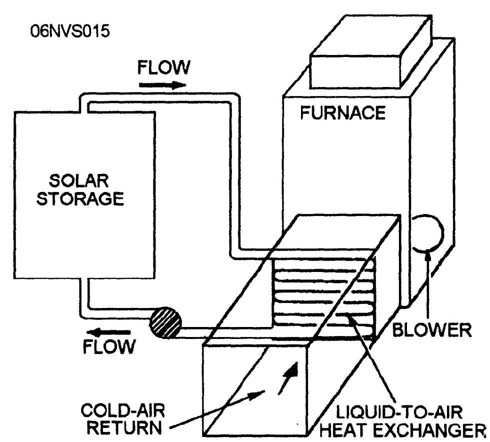


Figure 15-15.—A liquid-to-air heat delivery system.

system. The ability to circulate air to the building directly through the collectors is one of the major advantages of this system. The rock-bed storage also works best with a warm-air system.

Although warm air as low as 100°F can be used to heat an occupied building, most existing warm-air systems are sized assuming warm-air temperatures of 120°F to 150°F. Typical midday collection temperatures usually range from 130°F to 170°F. Maximum storage temperatures are typically around 140°F at the end of the collection period. Thus the heating load can be met by the temperature of the solar-heated air for a large portion of the day. When storage temperatures are insufficient to maintain the desired temperature of the building heat from an auxiliary source must be added to supplement the solar-heated air. The auxiliary furnace is located downstream from the rock bed, so the rock bed serves as a preheater for the furnace. This arrangement allows the rock bed to deliver useful heat until all of the rocks are at room temperature.

An air handler unit provides the dampers and blowers necessary to direct air circulation between the solar collectors, rock bed, and building. An air handler unit may be more expensive than the combined cost of individual dampers and blowers, but it is probably less expensive to install. It is also more compact.

CHAPTER 16

ENVIRONMENTAL POLLUTION CONTROL

Environmental pollution results from chemical, physical, or biological agents in the water, ground, or air that alter the natural environment. Pollution adversely affects human health, plant life, fish, and wildlife. Pollution can disintegrate nylon line, crumble masonry, corrode steel, and darken the skies. Most important is the damage to vegetation, human illness, and loss of productivity. Most pollution can be prevented, or slowed down, if people control the amount of foreign matter they put into the environment.

This chapter briefly covers ways to prevent water, ground, and air pollution on the jobsite. It also describes the means by which the Utilitiesman can help prevent, control, and clean up the pollution.

WATER AND GROUND POLLUTION

Other than creating a fire hazard, oil and other petroleum-related products pose many possible pollution threats when spilled in the water, dumped into the storm or sanitary sewer system, or spilled on the ground. Oil products on the ground infiltrate and contaminate surface water supplies with the groundwater runoff caused by rain. Oil products dumped or carried into a storm or sanitary sewer are also potential explosion hazards.

Oily wastewater from boiler rooms, banks of walk-in refrigeration units, and motor pool operations is caused by the following:

- improper handling and storage of new and waste oil,
- equipment and vehicle washing operations, and
- various other maintenance activities that generate liquid waste or wastewater that must be stored or treated.

An oil slick on the surface of the water blocks the flow of oxygen from the atmosphere into the water. This is harmful to fish, other aquatic life, and other sewage treatment facilities. If the fish do not die from the oil coating on their gills, or from eating the oil or oil-laden food, their flesh becomes tainted and is no longer fit for human consumption. Other than harming aquatic life, drinking water can become contaminated. Drinking water from wells and surface storage facilities are treated with chemicals to rid the water of harmful bacteria. However, no amount of treatment can rid a system of contamination from waste oil products. The system must be abandoned.

As a supervisor, your concern should be to prevent oil in the shop from draining into storm sewers and surface drainage systems. During pipe-threading operations, you should provide catch pans and absorbent material to soak up spilled oil. NEVER wash spilled oil or fuels down a drain or sewer unless an immediate fire hazard exists and an oil-water separator is connected to the discharge line. To clean up a spill, you should sprinkle absorbent material on the spill, sweep it up, and place it in an approved EPA container. Containers are disposed of through the Defense Reutilization Marketing Office

(DRMO). When this is not possible, the containers must be disposed of through a government-approved contractor or in a sanitary landfill approved by local government authorities.

Waste oils, filters, and contaminated fuel should be collected and disposed of properly. Most naval activities collect and dispose of waste oil periodically through a contractor who may burn it in a boiler plant or in a heating system. Naval supply fuel farms usually have the means to dispose of waste oils properly.

You will see contaminated water draining from the Equipment Operator's washrack every day. Work closely with the person in charge of the washrack to ensure that this wastewater is treated and not discharged into the storm sewer. Provisions must be made for pretreating or separating oil products and cleaning solvents used at the washrack.

Other than preventing oil pollution from vehicle and base equipment operation, Seabees are being considered for use in beach cleanup during major oil spill disasters. In case of a regional or national disaster from a major oil spill, this new manpower capability can be used very effectively by local commanders. A well-trained Seabee team can form the nucleus of a large-scale beach cleanup exercise team by using qualified personnel and heavy equipment.

AIR POLLUTION

You should be aware of the work conditions that cause air pollution and of the efforts required to reduce or correct the problem.

When incomplete combustion occurs in boilers, space heaters, and stoves, the unburned hydrocarbons and various other fuel components combine chemically to form by-products. Many of these by-products are harmful when emitted into the environment.

These by-products that affect the air are carbon monoxide, particulate matter, sulphur oxides, unburned hydrocarbons, nitrogen oxides, and lead. The most effective means of controlling air pollution from incomplete fuel combustion is to maintain the equipment properly and frequently. In this way, the equipment is operating at an optimal fuel and oxygen mixture. Another alternative, not always under your control, is to use only the best grade of fuel. This fuel contains low particulate matter, low water and sulphur content, and few contaminants.

ASBESTOS

Asbestos dust is another air pollutant that you must be knowledgeable of and concerned with in the installation, maintenance, and removal of asbestos material from a construction site.

Asbestos is a fibrous material that can be wooven like wool. Through a variety of processes, asbestos can be turned into thousands of construction products. Asbestos has been used by humans for over 2,500 years, It was not until the 1800s that asbestos was determined to be a health hazard. In the 1900s, asbestos was discovered to be the main cause of asbestosis (a generic term for a wide range of asbestos-related disorders) and mesothelioma. Mesothelioma at one time was a very rare form of lung cancer. It is presently occurring much more frequently among people exposed to asbestos dust particles.

There are three terms associated with asbestos dust particle size that you will encounter. These terms are *micron*, *nanometer*, and *angstrom*. To give you an idea of their size, in 1 meter there are 1 million microns, 1 billion nanometers, and 10 billion angstroms.

It was not until the advent of the transmission electron microscope and the scanning electron microscope in the latter part of the 1950s that the true size (200 to 250 angstroms) of an asbestos particle was discovered. Air that appears dust-free may contain millions of disease-producing asbestos dust particles. These minuscule' particles cannot be seen by the naked eye and can remain suspended in the air for months. In working to solve this problem, you must take air samples to ascertain the severity of the situation. The air must be scrubbed with a special air filtration machine to remove the particles.

Naval guidance for asbestos handling, demolition, and disposal are covered by OPNAVINST 5100.23. However, you should also learn the local laws and restrictions pertinent to the locale in which you work. These federal, state, and local laws are important. In an overseas location, the laws of the host country must be researched and clearly understood in the construction planning phase. It is inevitable that somewhere in the disposal cycle, transporting of this type of material to a disposal site will take place over roads not directly under Navy control.

Always research the laws governing asbestos. If you are continually involved with asbestos, you need to stay informed of current regulations and laws because they are constantly changing and being updated.

PESTICIDES

There are also many chemicals and pesticides that release harmful and deadly fumes into the air—for example, chlorine gas. It is important for you to become familiar with all of the materials used by shop personnel within your jurisdiction. Normally, toxic substances have warning labels attached to them. Once the chemicals being used are identified, you can obtain supplemental information from the unit environmental protection office or from the local safety office.

REFRIGERANTS

Scientists have determined that chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are linked to the depletion of the earth's ozone layer. In response to this environmental damaging threat, CFCs and HCFCs are being phased out of production. Additionally, the use and handling of refrigerants that contain CFCs and HCFCs must comply with the EPA Clean Air Act of 1990. Naval guidance may be found in OPNAVINST.5090.2, *Management of Ozone Depleting Substances*. This instruction provides policies, responsibilities, and guidance with respect to Navy actions for elimination of ozone-depleting substances. As a supervisor, ensure that shop personnel working with CFCs and HCFCs are **licensed, trained properly with the current techniques of using and handling refrigerants, and aware of EPA and Navy guidance on handling CFCs and HCFCs.**

APPENDIX I

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INDEX

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W

Assignment Questions

Information: The text pages that you are to study are provided at the beginning of the assignment questions.

ASSIGNMENT 1

Textbook Assignment: "Blueprint Reading and Technical Drawings." Pages 4-1 through 4-13. "Planning Plumbing Projects." Pages 7-1 through 7-18.

1-1. What factor is generally used to categorize a drawing?

1. Importance
2. Purpose
3. Methodology
4. Format

1-2. During what phase of a building project is the preliminary drawing prepared?

1. Design
2. Scheduling
3. Fabrication
4. Construction

1-3. What category of drawing is used to make material selections?

1. Construction
2. Secondary
3. Preliminary
4. Engineering

1-4. Shop and working drawings are developed at which of the following times?

1. Before developing secondary drawings
2. After receiving the engineering drawings
3. Before developing the preliminary drawings
4. After receiving approval for construction

1-5. Construction plans are developed from what type of drawing?

1. Architectural
2. Secondary
3. Preliminary
4. Engineering

1-6. Which of the following individuals designs the power and lighting system requirements for a project?

1. Engineer
2. Architect
3. Designer
4. Customer

1-7. As a supervisor, you should refer to what documents as the chief source(s) of information during a construction project?

1. Construction drawings
2. Project specifications
3. Bill of materials
4. Each of the above

1-8. Construction prints are used to express ideas easier and faster. They are also used by the supervisor for which of the following reasons?

1. To evaluate personnel
2. To monitor construction progress
3. To determine the necessary construction methods
4. To determine the electrical load of the building

1-9. The waterline stub outs, located on the right side of figure 4-1C, are supplying what fixture?

1. Tub
2. Water closet
3. Cleanout
4. Lavatory

1-10. What type of line is used to show the center of a line or fitting?

1. Stitch
2. Cutting
3. Center
4. Visible

IN ANSWERING QUESTIONS 1-11 THROUGH 1-15, SELECT FROM COLUMN B THE TYPE OF LINE THAT MATCHES THE DEFINITION IN COLUMN A. RESPONSES MAY BE USED MORE THAN ONCE.

	A. DEFINITIONS	B. TYPES OF LINES
1-11.	Indicates concealed edges	1. Extension
1-12.	Indicates distance measured	2. Dimension
1-13.	Indicates extent of a dimension	3. Hidden
1-14.	Indicates a part, dimension, or reference	4. Leader
1-15.	Indicates medium lines with short, evenly spaced dashes	

1-16. In the preparation of electrical drawings, engineers use symbols adopted by what authority?

1. National Association of Architects and Engineers
2. American Engineering Society
3. American National Standards Institute
4. National Institute of Construction Engineers

1-17. Blueprints have a symbol list or legend for which of the following reasons?

1. Because engineers modify existing symbols to fit their needs
2. Because standard electrical symbols cannot be used on military projects
3. Because it is required by labor unions
4. Because few symbols are recognized nationwide

1-18. What type of plan shows the spot where a building is to be placed on a piece of land?

1. Architectural
2. Plot
3. Foundation
4. Engineering

1-19. To determine the point where service taps should be connected, you should use which of the following plans?

1. Elevation
2. Floor
3. Foundation
4. Plot

1-20. Exterior elevation drawings help when you are installing which of the following components?

1. Lavatories
2. Rough-in piping
3. Hose bibs
4. Drains

1-21. You are installing a lavatory in a bathroom counter. Which of the following drawings indicates the water supply stub outs?

1. Framing
2. Site
3. Floor
4. Interior elevation

1-22. When the actual length of a pipe run is 80 feet, what is the length of its line on a blueprint with a scale of 1 /8 inch = 2 feet?

1. 5 inches
2. 7 inches
3. 3 inches
4. 10 inches

1-23. The distance between two fixtures drawn on a blueprint is 3 inches long. What is the actual distance between the fixtures if the print is drawn with a scale of 1/2 inch = 3 feet?

1. 6 feet
2. 9 feet
3. 18 feet
4. 24 feet

1-24. What is the bill of material for a project?

1. A listing of material by cost
2. A listing of project specifications
3. A statement of required material
4. A listing of defective requisition line items

TYPES OF ELECTRICAL DIAGRAMS
A. Connection
B. Wiring
C. Block
D. Schematic

Figure 1A

IN ANSWERING QUESTIONS 1-25 THROUGH 1-29, REFER TO FIGURE 1A.

1-25. Shows relationship of major components:

1. A
2. B
3. C
4. D

1-26. Shows the electrical operation:

1. A
2. B
3. C
4. D

1-27. Shows all internal and external connections:

1. D
2. C
3. B
4. A

1-28. Portrays a picturelike drawing:

1. D
2. C
3. B
4. A

1-29. Called an elementary or a single-line diagram:

1. A
2. B
3. C
4. D

1-30. To assist in the installation of a plumbing system, the Utilitiesman should draw what type of document?

1. A schematic
2. A working sketch
3. A block diagram
4. A single-line diagram

1-31. When drawing a working sketch, you should perform what step first?

1. Locate the main cable runs on the drawing
2. Draw the terminal connections
3. Locate the power supply on the drawing
4. Draw the symbols used for components

1-32. Specifications set what level of standards for a construction project?

1. Minimum
2. Maximum
3. American Engineering Society
4. National Institute of Construction Engineers

1-33. Project specifications provide which of the following information?

1. Size of materials
2. Quality of materials
3. Generic descriptions of materials
4. Relationship between different materials

1-34. Designer intentions about a project can be clarified in the specifications in which of the following ways?

1. By adding a detail or note to the drawings
2. By adding detailed, descriptive statements to the specifications
3. By ensuring the material is duplicated in the drawings
4. By using only general statements on construction methods and materials

1-35. Ensuring that the operations department receives a marked set of prints showing any construction deviations is the responsibility of what person?

1. The project engineer
2. The project supervisor
3. The project Engineering Aid
4. The quality control inspector

1-36. Record drawings are prepared from which of the following documents?

1. Original blueprints
2. Working sketches
3. As-built drawings
4. Project specifications

1-37. When maintenance on a structure requires a change to the record drawing, you should pass this information to which of the following departments?

1. Quality control
2. Operations only
3. Maintenance control only
4. Operations or maintenance control

1-38. What document is used to present notes and information in tabular form?

1. A schedule
2. A project specification
3. A material summary sheet
4. An overall project list

1-39. On a plumbing fixture schedule, a Utilitiesman can locate information concerning installation in what column?

1. Type
2. Remarks
3. Mounting
4. Installation

1-40. To provide expert advice to crew members, you should be thoroughly familiar with which of the following data?

1. Plumbing codes
2. Job plans and specifications
3. Technical references and manufacturers' manuals
4. Each of the above

1-41. What person is responsible for communicating requirements to other companies and departments?

1. The coordinator
2. The supervisor
3. The planner
4. The technical advisor

1-42. Which of the following factors determines the type of pipe that should be used in a sanitary system?

1. Building requirements
2. Waste matter conveyed
3. Pipe location
4. Each of the above

1-43. What is the minimum allowable horizontal distance between the underground water service and the building drain, in feet?

1. 8
2. 2
3. 6
4. 4

1-44. After installation, a building sewer should be pressure-treated with what minimum head of water?

1. 5 feet
2. 2 feet
3. 10 feet
4. 15 feet

1-45. So you can obtain the necessary fluid velocity in a sanitary drainage system, what is the minimum amount of slope, in inches per foot, for piping 3 inches or less in diameter?

1. 1/16
2. 1/8
3. 1/4
4. 1/2

1-46. Sewer mains installed with the proper grade provide a discharge velocity of not less than how many feet per second?

1. 8
2. 2
3. 6
4. 4

1-47. To create an efficient natural scouring action and still allow capacity for peak loads, what should be the flow depth in the optimum size of pipe under normal use?

1. One-fourth full
2. One-half full
3. Two-thirds full
4. Three-fourths full

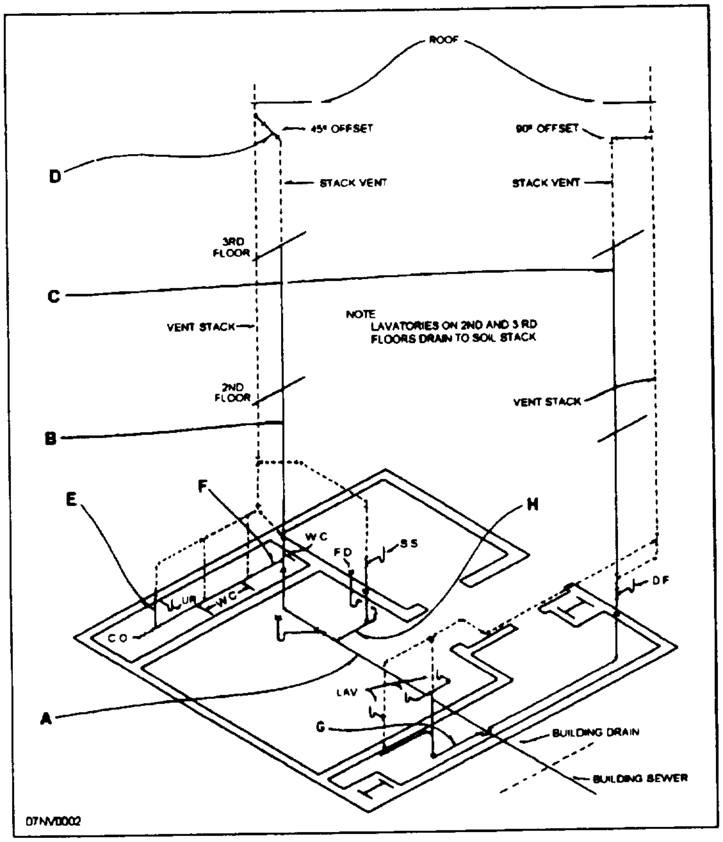

Figure 1 B

THE ANSWERS TO QUESTIONS 1-48 THROUGH 1-59 ARE DERIVED FROM FIGURE 1 B USING THE PROCEDURES DISCUSSED IN THE TEXT. FIGURE 1 B ILLUSTRATES A CAST-IRON DRAINAGE SYSTEM FOR A BUILDING WITH THREE IDENTICAL HEADS, ONE ON EACH OF THREE FLOORS LOCATED DIRECTLY ABOVE EACH OTHER. THE FOLLOWING TYPES OF FIXTURES ARE TO BE USED:

Valve-operated water closet
Siphon jet blowout pedestal urinal
Standard 1 1/4-inch-diameter waste lavatory
Standard 2-inch-diameter waste floor drain
Drinking fountain
Combination sink and tray with a 1 1/2-inch-diameter trap

1-48. What is the total number of drainage fixture units in the installation?

1. 101 1/2
2. 106 1/2
3. 107 1/2
4. 109 1/2

1-49. A pipe of what diameter, in inches, is required for the building drain at point A when installed at a 1 percent-grade?

1. 5
2. 2
3. 3
4. 4

1-50. A total of how many drainage fixture units could be added to the drainage system without requiring an increase in the size of the building drain?

1. 180
2. 93 1/2
3. 73 1/2
4. 60

1-51. A waste stack is indicated at what point?

1. B
2. C
3. D
4. E

1-52. A soil stack is indicated at what point?

1. B
2. C
3. D
4. F

1-53. What diameter of pipe, in inches, is required at point B?

1. 6
2. 2
3. 3
4. 4

1-54. What diameter of pipe, in inches, is required at point D?

1. 6
2. 2
3. 5
4. 4

1-55. A pipe of what diameter, in inches, is required at point C?

1. 1 1/4
2. 2
3. 1 1/2
4. 2 1/4

1-56. A pipe of what diameter, in inches, is required at point E?

1. 1 1/2
2. 2
3. 3
4. 3 1/2

1-57. What diameter of pipe, in inches, is required at point F?

1. 5
2. 2
3. 3
4. 4

1-58. A pipe of what diameter, in inches, is required at point G?

1. 1 1/4
2. 2
3. 1 1/2
4. 2 1/4

1-59. What diameter of pipe, in inches, is required at point H?

1. 1 1/2
2. 2
3. 31/2
4. 4

1-60. Which of the following fixtures requires the largest waste pipe?

1. Shower
2. Trap-to-floor slop sink
3. Lavatory with a copper tubing waste pipe
4. Scullery sink with a steel waste pipe

1-61. For planning purposes, the size of a sanitary collecting sewer in a residential area is based on which of the following information?

1. Full occupancy of all quarters served
2. Number of persons employed in an 8-hour period
3. Average number of contributing persons during a 24-hour period
4. Allowance for full capacity plus 25 percent

1-62. In the sizing of a typical sanitary collecting sewer, what figure is added to the extreme rate of flow to obtain the design flow?

1. The average rate of flow
2. The differential between average and peak flow
3. An amount equivalent to the low-flow ratio differential
4. An allowance for infiltration

1-63. Which of the following factors should be considered when you are determining the size of a sewer pipe?

1. Grade
2. Design flow
3. Pipe characteristic
4. Each of the above

1-64. Slope is an important part of sewer pipe installation and is, in part, dependent upon the inside diameter of the pipe. What is the minimum slope, in feet per 100 foot, for pipe with an 8-inch inside diameter?

1. 0.60
2. 0.40
3. 0.24
4. 0.14

1-65. Flow velocity is an important consideration in designing a sanitary collecting sewer for which of the following reasons?

1. Excessive velocity erodes the sewer pipes
2. Excessive velocity draws subsurface water into the sewer
3. Low velocity causes pipe erosion
4. Low velocity results in soil contamination around the pipes

1-66. Manholes for sanitary collecting sewers are normally placed at intervals of 300 to 500 feet. What condition can reduce the interval between two manholes to less than 300 feet?

1. A change in grade or direction
2. A junction of two or more sewer lines
3. A change in pipe size
4. Each of the above

1-67. When building storm drains, you should allow for what minimum slope?

1. 1 inch per foot
2. 1/8 inch per foot
3. 1/4 inch per foot
4. 1/2 inch per foot

1-68. You should use which of the following factors to determine the size of pipe in a cold-water supply system?

1. Maximum fixture demand
2. Type of flushing devices
3. Pressure of the water supply
4. Each of the above

1-69. The term “simultaneous use” as applied to a cold-water supply system and its fixtures has what meaning?

1. Probable percentage of fixtures in use at any given time
2. Probable percentage of fixtures in use at the same time within a 24-hour period
3. Approximate amount of water required to supply fixtures used simultaneously over a given period of time
4. Ratio of persons to fixtures

1-70. What is the minimum practical size of a water-service line?

1. 1 inch
2. 3/8 inch
3. 1/2 inch
4. 3/4 inch

1-71. Copper pipe is advantageous as a hot-water supply line for which of the following reasons?

1. It retains heat
2. It is an excellent insulator
3. It resists corrosion
4. It is an excellent conductor of heat

1-72. You should use a circulating hot-water supply system for which of the following reasons?

1. To conserve energy
2. To maintain a constant hot-water supply
3. To assist in heating a building
4. Each of the above

1-73. The corporation stop should be installed in what position?

1. On the water main where a tap is made
2. On the overhead-feed and gravity-return system
3. On the highest point of the distribution piping
4. On the water main in a convenient location

1-74. A stop and waste valve is used for what purpose?

1. To secure water to the boiler
2. To drain the building water system
3. To secure water at the main
4. To drain the hot-water heater

ASSIGNMENT 2

Textbook Assignment: "Planning Plumbing Projects" and "Fire Protection Systems." Pages 7-20 through 8-27.

2-1. Direct chemical attack over the surface of a metal is known by what term?

1. Galvanic action
2. Uniform corrosion
3. Dezincification
4. Embrittlement

2-2. A difference of potential between areas on a metallic surface in contact with an electrolyte causes what condition?

1. Compositional corrosion
2. Direct chemical attack
3. Local galvanic action
4. Uniform corrosion

2-3. Corrosion of underground pipelines, resulting from unlike soils and subsurface stray currents, is characterized by what type of deterioration?

1. Localized
2. Uniform
3. Nonelectrolytic
4. Synthetic

2-4. In underground pipelines, the mill scale embedded in the wall of iron pipe causes what type of corrosion?

1. Uniform
2. Localized
3. Compositional
4. Biological

2-5. Which of the following types of pipe is most susceptible to microbiological corrosive action?

1. Monel
2. Plastic
3. Steel
4. Asbestos

2-6. Dezincification, graphitization, and hydrogen embrittlement are what specific type of corrosion?

1. Localized
2. Compositional
3. Uniform
4. Biological

2-7. Sections of buried pipelines under stress are subject to localized electrolytic corrosion when adjoining unstressed sections become

1. cathodic
2. localized
3. anodic
4. sacrificial

2-8. Nonelectrolytic gases and vapors cause corrosion only when subjected to what condition?

1. Low temperatures
2. Negative potentials
3. High temperatures
4. Positive potentials

2-9. Internal deterioration is most likely to occur in metal piping and storage facilities containing impure nonelectrolytic fluids.

1. True
2. False

2-10. Rainwater is generally considered an electrolyte because it contains

1. dissolved atmospheric gases
2. suspended solids
3. minerals in solution
4. measurable resistivity

2-11. Which of the following corrosive reactions is often the result of an agent, such as salt, being present in the environment?

1. Hydrogen embrittlement
2. Localized galvanic action
3. Stray current electrolysis
4. Direct chemical attack

2-12. When you find it necessary to join copper and galvanized piping, the fitting should be equipped with which of the following materials?

1. An anode
2. A fiber-glass wrap
3. A dielectric bushing
4. A standard cross-connection

2-13. Which of the following coatings is best suited for use as a corrosion inhibitor on exposed steel pipelines suspended along piers?

1. Coal tar
2. Grease
3. Concrete
4. Asphalt

2-14. In the galvanic anode method of cathodic protection for steel structures, the structure is established as the cathode in a dissimilar metal galvanic cell by the use of what electrically connected component?

1. Copper anode
2. Sacrificial anode
3. Magnesium cathode
4. Controlled resistor

2-15. The impressed current method of cathodic protection is different from the galvanic anode method in which of the following ways?

1. An electrical source is not required
2. A direct current is applied from anode to cathode
3. An anode is unnecessary
4. A cathode may be used for the anode

TEST EQUIPMENT
A. Holiday Leak Detector
B. Resistivity Meter
C. Volt-Millivolt Meter
D. Ohmmeter

Figure 2A

IN ANSWERING QUESTIONS 2-16 THROUGH 2-20, REFER TO FIGURE 2A.

2-16. Locate imperfections in pipe coatings:

1. A
2. B
3. C
4. D

2-17. Measure the structure-to-soil potential of a given cathodic protection system:

1. D
2. C
3. B
4. A

2-18. Locate an area suitable for an anode bed:

1. A
2. B
3. C
4. D

2-19. Measure the corrosive susceptibility of a given soil:

1. D
2. C
3. B
4. A

2-20. Determine the variation in potential of galvanic anodes:

1. A
2. B
3. C
4. D

2-21. All automatic sprinkler systems have which of the following characteristics in common?

1. Water supply
2. Piping network
3. Sprinklers
4. Each of the above

2-22. What type of automatic sprinkler system is most commonly used?

1. Wet pipe
2. Semidry pipe
3. Low-differential dry pipe
4. Latched-clapper dry pipe

2-23. In a dry-pipe system, the pipes can contain air or what other element under pressure?

1. Argon
2. Nitrogen
3. Hydrogen
4. Xenon

2-24. In a differential dry-pipe valve system, the air must be maintained at least how many psi greater than the trip pressure?

1. 5
2. 10
3. 15
4. 20

2-25. When debris in the water is a problem, you should use what type of dry-pipe valve?

1. Low differential
2. High differential
3. Mechanical
4. Latched clapper

2-26. What type of automatic sprinkler system should you use in an aircraft hangar?

1. Wet pipe
2. Semidry pipe
3. Water-deluge
4. Semiwet pipe

2-27. Preprime plugs blow out of the sprinklers at approximately what water pressure?

1. 10 psi
2. 15 psi
3. 20 psi
4. 25 psi

2-28. Automatic sprinklers have orifices graduated in what size increments?

1. 1/16 inch
2. 1/8 inch
3. 1/4 inch
4. 1/2 inch

2-29. A fusible-link sprinkler is kept closed by a two-piece link fused together by what type of metal?

1. Copper
2. Aluminum
3. Solder
4. Steel

2-30. A dry-pendent sprinkler is used when the system is exposed to which of the following conditions?

1. High ambient temperatures
2. Freezing temperatures
3. Explosive elements
4. Unstable chemicals

2-31. A dry-pipe alarm system has which of the following characteristics?

1. It is slow acting
2. It is moderate acting only
3. It is fast acting only
4. It is moderate or fast acting

2-32. The retard switch connected to the alarm port of a wet sprinkler system alarm-check valve is normally set within what pressure range?

1. 10 to 20 psi
2. 8 to 15 psi
3. 6 to 15 psi
4. 4 t0 15 psi

2-33. A pressure pump/pressure drop type of water-flow detector is usually adjusted to maintain what system pressure above normal supply pressure?

1. 20 to 40 psi
2. 25 to 50 psi
3. 30 to 60 psi
4. 35 to 70 psi

2-34. In an electronic pressure-drop detector, an overpressure condition of what magnitude can cause a trouble signal?

1. 100 psi
2. 150 psi
3. 200 psi
4. 250 psi

2-35. To prevent freezing of water in a fire protection system, a Utilitiesman normally installs a supervisory device in a pipe or reservoir with what low water-temperature setting?

1. 0° F
2. 25° F
3. 32° F
4. 40° F

INSPECTION AND TEST PERIODS
A. Weekly
B. Monthly
C. Quarterly
D. Annually
E. Every 3 years

Figure 2B

IN ANSWERING QUESTIONS 2-36 THROUGH 2-43, REFER TO FIGURE 2B.

2-36. General condition of sprinkler heads and sprinkler systems:

1. B
2. C
3. D
4. E

2-37. Water-flow alarms:

1. A
2. B
3. C
4. D

2-38. Air and water pressure in dry-pipe systems:

1. D
2. C
3. B
4. A

2-39. High-speed suppression systems:

1. B
2. C
3. D
4. E

2-40. General condition of standpipe systems:

1. D
2. C
3. B
4. A

2-41. General condition of hydrants:

1. B
2. C
3. D
4. E

2-42. Water level in tanks:

1. A
2. B
3. C
4. D

2-43. Valves (to see if they are in the open position):

1. D
2. C
3. B
4. A

2-44. What minimum distance must be maintained beneath a sprinkler for proper water distribution?

1. 48 inches
2. 36 inches
3. 24 inches
4. 18 inches

2-45. What type of test should be performed quarterly to test the alarm-check valves?

1. 6-inch drain test
2. 2-inch drain test
3. 8-inch drain test
4. 4-inch drain test

2-46. In a dry-pipe sprinkler system, the entire system should be checked for tightness when air pressure losses exceed what value?

1. 5 psi
2. 10 psi
3. 15 psi
4. 20 psi

2-47. When testing a water-clapper valve designed to trip at a fixed pressure of 10 to 15 psi, you should maintain what minimum air pressure on this valve?

1. 15 psi
2. 30 psi
3. 45 psi
4. 60 psi

2-48. When performing a basic inspection of accelerators and exhausters, you should check what pressure?

1. Water
2. Air
3. Centrifugal
4. Atmospheric

2-49. When testing a dry-pipe valve, you should perform what action first?

1. Close the main control valve
2. Open the main control valve
3. Open the inspector test connection
4. Close the inspector test connection

2-50. Once the dry-pipe system has been tested and the dry-pipe valve reset, you should check the air pressure within what approximate time period?

1. 12 to 24 hours
2. 2 to 4 hours
3. 24 to 48 hours
4. 4 to 8 hours

2-51. When testing deluge and preaction valves, you should perform the 2-inch drain test at what time interval?

1. Weekly
2. Monthly
3. Quarterly
4. Annually

2-52. When performing a deluge valve dry trip-test in a flammable area, you should use what test in place of the electric test set?

1. Infrared light
2. Hot water only
3. Hot cloth only
4. Hot water or hot cloth

2-53. When performing the cathodic protection test with an ammeter, you notice a diminishing current flow. This is an indication of what type of problem?

1. Failing electrodes
2. Blown fuses
3. Frozen electrodes
4. Broken ground wires

2-54. Under normal circumstances, full operational testing of high-speed suppression systems should be conducted at intervals not to exceed how many years?

1. 1
2. 5
3. 3
4. 7

2-55. Gaseous extinguishing systems are normally located in which of the following areas?

1. Computer operation centers
2. Radio receiver buildings
3. Power generating facilities
4. Each of the above

2-56. A local application system would normally be found in which of the following locations?

1. Paint dip tank
2. Restaurant range hood
3. Special motor
4. Each of the above

2-57. What type of system, if any, should you install in a transformer vault that contains oil-filled equipment?

1. Local application
2. Total flooding
3. Hose line
4. None

2-58. What characteristic of carbon dioxide makes it desirable for use on electrical fires?

1. High-pressure application
2. Electrical conductivity
3. Electrical nonconductivity
4. Low-pressure application

2-59. What is the normal cylinder pressure in a high-pressure system?

1. 600 psi
2. 500 psi
3. 400 psi
4. 300 psi

2-60. Storage area ambient temperatures for carbon dioxide cylinders should be within what temperature range?

1. 0°F to 100°F
2. 32°F to 130°F
3. 40°F to 150°F
4. 50° F to 100°F

2-61. In a low-pressure system, the frangible disk is designed to burst at what pressure?

1. 200 psi
2. 400 psi
3. 600 psi
4. 800 psi

2-62. In a low-pressure system, liquid carbon dioxide should always be maintained at what constant (a) pressure and (b) temperature?

1. (a) 200 psi (b) 0°F
2. (a) 300 psi (b) 32°F
3. (a) 200 psi {b) 32°F
4. (a) 300 psi (b) 0°F

2-63. High-pressure systems require approximately how many pounds of equipment for every pound of carbon dioxide stored?

1. 1
2. 5
3. 3
4. 7

2-64. Pipe and fittings in a high-pressure system have what minimum bursting pressure?

1. 2,000 psi
2. 3,000 psi
3. 5,000 psi
4. 7,000 psi

2-65. Pipe and fittings in a low-pressure system have a minimum bursting pressure of how many psi?

1. 1,800
2. 2,000
3. 2,800
4. 3,000

2-66. Pressure-relief devices operate at what pressure on a low-pressure system?

1. 400 psi
2. 450 psi
3. 500 psi
4. 550 psi

2-67. What automatic device should be installed along with a total flooding system to conserve carbon dioxide?

1. Closing
2. Venting
3. Door closure
4. Electrical lockout

ASSIGNMENT 3

Textbook Assignment: "Fire protection systems" and "Water Treatment and Purification." Pages 8-29 through 9-13.

3-1. You are maintaining a halon fire protection system. You should consult a person in what organization for a system conversion?

1. NFPA
2. EPA
3. OSHA
4. Engineering

3-2. Installation of a new halon 1301 system is prohibited without special approval from whom?

1. NAVFACENGCOM
2. EPA
3. ROICC
4. Base fire chief

3-3. The production of halons will be eliminated by the year 2000?

1. True
2. False

3-4. What length of time delay, in seconds, is built into a halon system actuator?

1. 10 to 30
2. 10 to 45
3. 15 to 60
4. 20 to 45

3-5. Regardless of the method being used, what device must be attached to the releasing mechanism?

1. An auxiliary fan
2. A control valve
3. A light
4. An alarm

INSPECTION AND TEST PERIODS

A. Weekly

B. Monthly

C. Quarterly

D. Semiannually

E. Annually

Figure 3A

IN ANSWERING QUESTIONS 3-6 THROUGH 3-8, REFER TO FIGURE 3A.

3-6. Halon and carbon dioxide nozzles.

1. A
2. C
3. D
4. E

3-7. Weighing cylinders.

1. A
2. B
3. C
4. D

3-8. Leakage of devices and connections in a low-pressure carbon dioxide system.

1. A
2. B
3. D
4. E

3-9. You should perform a hydrostatic test on cylinders and hoses at what maximum time interval, in years?

1. 5
2. 7
3. 8
4. 12

3-10. At what maximum time interval should you replace the frangible disks on low-pressure storage tanks?

1. 5 years
2. 7 years
3. 8 years
4. 12 years

3-11. What type of system can be used with dry chemicals?

1. Total flooding
2. Local application
3. Hose line
4. Each of the above

3-12. What is the most widely used dry chemical?

1. Nitrogen
2. Sodium bicarbonate
3. Monoammonium phosphate
4. Potassium phosphate

3-13. Dry chemicals are used primarily on what type of fires?

1. Flammable liquid
2. Cellulose nitrate
3. Dry wood
4. Delicate electrical equipment

3-14. The term "saponification" refers to what reaction between a dry chemical and a fire source?

1. Chemical neutralization
2. Conversion of fatty grease to soap
3. Electronic equipment reaction
4. Heavy metal reaction

3-15. What type of gas is used as a propellent for a dry chemical system?

1. Hydrogen
2. Oxygen
3. Nitrogen
4. Carbon dioxide

3-16. Dry chemical distribution systems should be constructed of what schedule of steel pipe?

1. 10
2. 20
3. 30
4. 40

3-17. What term, if any, is used to describe the special problem of inertia that must overcome in nozzle installation?

1. Pressure drop
2. Saponification
3. Balancing
4. None

3-18. What term is used to describe a water source developed for military use?

1. Water source
2. Water point
3. Water well
4. Water outlet

3-19. A total of how many gallons per minute are flowing in a stream that is 10 feet wide and has an average depth of 3 feet when the water is flowing at a velocity of 15 feet per minute?

1. 960
2. 1,920
3. 2,880
4. 3,350

3-20. Compute the quantity of water in a lake that is 100 feet long, 20 feet wide, has an average depth of 6 feet, and no run off?

1. 30,000 gallons
2. 60,000 gallons
3. 90,000 gallons
4. 120,000 gallons

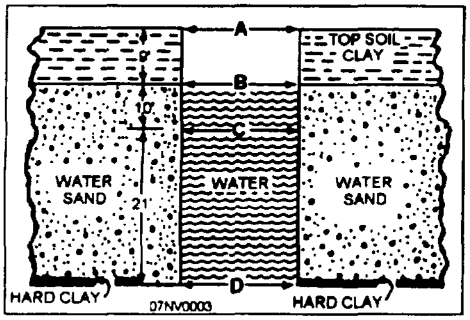

Figure 3B

IN ANSWERING QUESTIONS 3-21 THROUGH 3-23, REFER TO FIGURE 3B AND ASSUME THAT THE WATER STABILIZES AT POINT C AFTER CONTINUOUS PUMPING AT A CONSTANT RATE OF 50 GALLONS PER MINUTE.

3-21. The static level of the well is located at what point?

1. A
2. B
3. C
4. D

3-22. As measured from the ground surface, what is the dynamic water level of the well, in feet?

1. 9
2. 10
3. 19
4. 21

3-23. The amount of drawdown is equal to the distance between what points?

1. A and B
2. A and C
3. B and C
4. B and D

3-24. The yield of the well for a particular drawdown depends on which of the following factors?

1. Permeability of the topsoil and clay
2. Permeability of the water-bearing formation
3. Width or diameter and depth of the well
4. Depth from the surface to the static water level

3-25. Which of the following types of sand provides the greatest rate of flow during drawdown?

1. Fine sand with grains irregular in size
2. Fine sand with grains nearly uniform in size
3. Coarse sand with grains irregular in size
4. Coarse sand with grains nearly uniform in size

3-26. When determining the hydraulic characteristics of a well, you should not consider which of the following data?

1. Volume of water pumped per unit of time
2. Percolation rate per unit of time
3. Static water level before pumping
4. Pumping level at a constant pumping rate

3-27. The pump and power unit used for testing a well should be capable of continuous operation for a minimum of how many hours?

1. 24
2. 48
3. 72
4. 96

3-28. What should be the maximum operating rate of a pump for testing the yield of a well?

1. One that causes 50 percent of maximum possible drawdown
2. One that causes the maximum possible drawdown
3. Approximately 50 gpm
4. Approximately 100 gpm

3-29. The term “safe pumping yield” is defined as having what withdrawal rate?

1. A total of 50 percent of maximum drawdown without lowering the water table
2. A total of 75 percent of maximum drawdown without lowering the water table
3. An amount that allows for total recovery in 30 minutes or less
4. An amount that allows for total recovery in 1 hour or less

3-30. Relative to the initial development of a well, a complete test report includes the initial static water level, pumping rates, drawdown data, rate of recovery, and what other information?

1. Pump chart
2. Well chart
3. Bacteriological report
4. Water analysis report

3-31. In a temperate zone, what is the daily water consumption, in gallons, for one person marching in formation?

1. 1
2. 2
3. 1/2
4. 1 1/2

IN ANSWERING QUESTIONS 3-32 THROUGH 3-33, CONSIDER A GROUP OF 40 MEN IN A TEMPERATE ZONE WHERE THE TERRAIN IS LEVEL. YOU ARE EQUIPPED WITH FOUR LARGE TRUCKS AND TWO JEEPS.

3-32. When field rations are being used under combat conditions, what daily minimum individual water requirement should you consider appropriate?

1. 22 gallons
2. 42 gallons
3. 82 gallons
4. 102 gallons

3-33. Under peaceful conditions, you have set up a temporary camp with bathing facilities. What is the total daily water requirement?

1. 200 gallons
2. 401 gallons
3. 602 gallons
4. 1,200 gallons

3-34. What are the two classification of water impurities?

1. Suspended or bacteria
2. Suspended or dissolved
3. Dissolved or silt
4. Dissolved or bacteria

IN ANSWERING QUESTIONS 3-35 THROUGH 3-41, SELECT FROM COLUMN B THE EFFECT OF EACH WATER IMPURITY IN COLUMN A. RESPONSES MAY BE USED MORE THAN ONCE.

A. IMPURITIES	B. EFFECTS
3-35. Manganese	1. Alkalinity
3-36. Magnesium carbonate	2. Odor
3-37. Calcium bicarbonate	3. Brown water
3-38. Carbon dioxide	4. Corrosion of metal
3-39. Algae	
3-40. Calcium chloride	
3-41. Dissolved oxygen	

3-42. What data, if any, should you study to determine the variation in reliability that may be expected at a water source?

1. Geological
2. Hydrological
3. Bacteriological
4. None

3-43. At what level of government is the title to ground and surface water normally regulated within the United States?

1. Township
2. County
3. State
4. Federal

3-44. A temporary water source should not be converted into a permanent water source until after what activity has taken place?

1. A title search for water rights
2. An area search for a source requiring less development
3. An impurities examination by the medical officer
4. An inspection by the public works officer for additional free-flowing springs

3-45. The strainer on a suction hose should be placed a total of how many inches under the water level?

1. 6
2. 8
3. 3
4. 4

3-46. For a normal field water supply, what type of water source is the most accessible?

1. Well
2. Spring
3. Subsurface
4. Surface

3-47. In a swiftly flowing stream, what type of dam can be constructed to protect an intake screen without impounding the water?

1. Wing only
2. Baffle only
3. Wing or baffle
4. Ripple or wing

3-48. The quality of water from a muddy stream can be improved in which of the following ways?

1. By sinking shallow wells
2. By digging intake galleries
3. By filling unneeded trenches
4. By digging outtake galleries

3-49. Moisture is held beneath the surface of the earth in what total number of zones?

1. One
2. Two
3. Three
4. Four

3-50. Groundwater is the term used to describe underground water in what zone?

1. Filtration
2. Aeration
3. Saturation
4. Soil moisture

3-51. In a driven well, the sections of well pipe are delivered in lengths of what size?

1. 5 feet
2. 10 feet
3. 15 feet
4. 20 feet

3-52. When developed properly, springs yielding a minimum of how many gallons per minute can be used as a source of field water?

1. 5
2. 10
3. 15
4. 20

3-53. Refer to figure 9-6. What condition exists that requires the intake screen to be surrounded by coarse gravel?

1. The inlet hose is on a steep slope
2. The turbidity of the water is very high
3. The water source does not cover the screen by at least 4 inches
4. The water contains a large amount of suspended solids

3-54. Little or no consideration is given to the development of a thermal spring as a water source for which, if any, of the following reasons?

1. The high cost involved
2. The unreliability of such a spring
3. The likelihood of heavy mineral concentrations
4. None of the above

3-55. In the development of a spring, an impervious type of permanent structure should be used to protect the water source against

1. water from building drains only
2. surface water drainage only
3. rainwater only
4. water from all sources other than the spring

3-56. There is a total of how many classifications of wells?

1. Five
2. Seven
3. Three
4. Nine

3-57. A well that is dug is usually 3 feet in diameter or more and within what depth range?

1. 10 feet to 30 feet
2. 15 feet to 40 feet
3. 20 feet to 40 feet
4. 25 feet to 50 feet

3-58. A well can normally be bored within what maximum depth without fear of a cave-in?

1. 30 feet
2. 40 feet
3. 50 feet
4. 60 feet

3-59. When jetting a well, you turn the jet or frill slowly for what purpose?

1. To ensure the hole is straight
2. To assist in sinking the casing
3. To remove mud and sand
4. To extract muddy water

3-60. When a well is driven, the drive points are within what size range?

1. 1 inch to 3 inches
2. 2 1/4 inches to 3 inches
3. 3 inches to 4 inches
4. 1 1/4 inches to 2 inches

3-61. When a 2-inch well casing is used with a small self-priming centrifugal pump, water can be lifted from what maximum depth?

1. 24 feet
2. 48 feet
3. 72 feet
4. 96 feet

3-62. What is the purpose of a jar test?

1. To aid in the removal of turbidity
2. To indicate what chemical is necessary for coagulation
3. To determine whether the water is turbid
4. To provide sedimentation of the contents in the jar

3-63. To guard against subsurface contamination, you should locate rainwater catchment areas at what minimum distance from possible sources of contamination?

1. 25 feet
2. 50 feet
3. 75 feet
4. 100 feet

3-64. What minimum treatment is required for collected rainwater that is to be used as a water source?

1. Filtration only
2. Disinfection only
3. Filtration and disinfection
4. Aeration and filtration

3-65. A total of how many cubic feet of snow is required to produce 1 cubic foot of water?

1. 5
2. 7
3. 3
4. 9

ASSIGNMENT 4

Textbook Assignment: "Water Treatment and Purification" and "Sewage Treatment and Disposal." Pages 9-14 through 10-29.

4-1. Physical impurities in water are divided into what two classifications?

1. Color and turbidity
2. Suspended and dissolved
3. Mineral and bacteria
4. Silt and odor

4-2. Which of the following chemicals can be used to prevent the formation of algae in raw water supply points?

1. Chlorine
2. Copper sulfate
3. Activated carbon
4. Each of the above

4-3. What term accurately describes a muddy or unclear condition of water caused by sand, clay, or organic matter?

1. Suspension
2. Turbidity
3. Backwashing
4. Coagulation

4-4. To treat 1,000 gallons of water, you should use approximately how many ounces of activated carbon?

1. 1
2. 10
3. 100
4. 1,000

4-5. When you are using copper sulfate to treat a lake, concentrations of organisms should never exceed how may parts per million to protect the lives of fish?

1. 1
2. 2
3. 3
4. 5

4-6. You should reduce the water treatment rate when the outside temperature reaches what level?

1. 0°F
2. 20°F
3. 32°F
4. 45°F

4-7. The total concentration of manganese in potable water should not exceed how many parts per million?

1. 0.1
2. 0.3
3. 0.5
4. 0.7

4-8. The ion exchange unit removes which of the following undesirable properties of water?

1. Asbestos and chemicals
2. Chemicals and radioactive particles
3. Manganese and lead
4. Hexavalent chromium and fluoride

4-9. Dissolved gases can be removed from a water supply by what means?

1. Aeration
2. Chlorination
3. Coagulation
4. Ion exchange

4-10. You should NOT treat water with activated carbon that exceeds what maximum dosage?

1. 10 ppm
2. 15 ppm
3. 20 ppm
4. 25 ppm

4-11. A water source with a pH value less than what number is an indication of possible CBR contamination?

1. 1.5
2. 3.5
3. 5.0
4. 6.0

4-12. What water test kit does medical use to check a water source for chemical contamination?

1. M678
2. M474
3. M272
4. M222

4-13. The nuclear post-treatment cylinder used with the ROWPU removes which of the following agents?

1. Strontium
2. VX
3. BZ
4. All of the above

4-14. The rate of product water from the ROWPU is directly affected by the

1. turbidity of the water source
2. amount of contamination in the water source
3. operating pressure
4. temperature of the water source

4-15. What is the name of the process whereby latent heat is removed and steam becomes water?

1. Evaporation
2. Distillation
3. Vaporization
4. Condensation

4-16. The compressor in a thermal compression distillation unit raises the temperature of the steam from 212°F to what temperature?

1. 220°F
2. 222°F
3. 226°F
4. 229°F

4-17. Water produced by distillation equipment should NOT be used for what purpose?

1. Fire protection
2. Vehicle washing
3. Galley scrubbing
4. Personal cleanliness

4-18. To date, what type of filter is the most effective ever devised ?

1. Silica
2. Diatomite
3. Algae
4. Sand

4-19. You should use a slow sand filter under which of the following circumstances?

1. Coagulation is part of the process
2. High water output is desired
3. Low cost of operation is essential
4. Coagulation is not included in the process

4-20. The diatomite filter is classified as what type of filter?

1. Slow sand
2. Rapid sand
3. Pressure drop
4. Pressure

4-21. What type of treatment is used in residual disinfection as the final step in the water treatment process?

1. Coagulation
2. Chlorination
3. Activated carbon
4. Soda ash

4-22. What two extreme values retard disinfection?

1. High pH and low temperature
2. Low pH and high temperature
3. High pH and high temperature
4. Low pH and low temperature

4-23. What minimum amount of residual chlorine is considered significant?

1. 0.1 ppm
2. 0.2 ppm
3. 0.3 ppm
4. 0.4 ppm

4-24. What standard period of contact time is required for disinfection purposes to kill disease-producing organisms?

1. 10 minutes
2. 20 minutes
3. 30 minutes
4. 40 minutes

4-25. After using water sterilizing bags, you should add enough chlorine to the water so the residual chlorine after a total of 30 minutes has what minimum value?

1. 5 ppm
2. 7 ppm
3. 3 ppm
4. 9 ppm

4-26. What is the minimum amount of time you must boil water to kill disease-producing bacteria?

1. 60 seconds
2. 45 seconds
3. 30 seconds
4. 15 seconds

4-27. What term describes the process whereby more chlorine than needed for the chlorine residual essential to marginal chlorination is used?

1. Chlorination
2. Superchlorination
3. Dechlorination
4. Dissipation

4-28. When decay proceeds under anaerobic conditions, what is the ultimate result?

1. Offensive odors
2. Unsightly appearances
3. Offensive conditions
4. Each of the above

4-29. On a Navy installation that discharges liquid waste into controlled waters, you must maintain what standards?

1. Federal standards
2. State standards only
3. Local standards only
4. State and local standards

4-30. Which of the following types of industrial waste should NOT be dumped into a regular sewage collection system?

1. Dry-cleaning fluids
2. Radioactive isotopes
3. Metal plating residues
4. Flammable liquids

4-31. A heavy input of storm water into a sewage treatment plant results in what type of hydraulic problems?

1. Underloading
2. Bypassing
3. Overloading
4. Diverting

4-32. Within a 24-hour period, the lowest flow in a sewage treatment system is between what hours?

1. 0000-0500 hours
2. 0500-1000 hours
3. 1000-1500 hours
4. 1500-2000 hours

4-33. What is the normal color of wastewater containing dissolved oxygen?

1. Black
2. Brown
3. Gray
4. Green

4-34. Domestic sewage should have what noticeable odor?

1. Moldy
2. Sulphurous
3. Grainy
4. Musty

4-35. Wastewater is normally composed of what percentage of (a) water and (b) solids?

1. (a) 99.9 (b) 1.1
2. (a) 99.9 (b) 0.1
3. (a) 95.9 (b) 1.1
4. (a) 95.9 (b) 0.1

4-36. What term is used to describe suspended solids that are not dissolved in wastewater?

1. Floatable solids
2. Sludge
3. Colloidal particles
4. Sedimentation

4-37. Volatile solids either burn or evaporate within what temperature range?

1. 1500°C to 1600°C
2. 1200°C to 1300°C
3. 700°C to 800°C
4. 500°C to 600°C

4-38. The acid or base properties of a water solution is measured in

1. mg/1
2. ml/l
3. pH
4. DO

4-39. What term is used to describe wastewater that contains dissolved oxygen?

1. Anaerobic
2. Aerobic
3. Raw sewage
4. Treated sewage

4-40. What term accurately describes the amount of oxygen used by bacteria and other wastewater organisms as they feed upon the organic solids in wastewater?

1. Oxygen nutrients
2. Oxygen demand
3. Oxygen supply
4. Dissolved oxygen

4-41. What are the three biological organisms present in wastewater?

1. Bacteria, viruses, and pathogens
2. Viruses, parasites, and pathogens
3. Bacteria, parasites, and pathogens
4. Viruses, bacteria, and parasites

4-42. What type of bacteria requires dissolved oxygen to remain alive?

1. Facultative
2. Anaerobic
3. Aerobic
4. Parasitic

4-43. A grab sample normally covers what time span?

1. 15 minutes
2. 30 minutes
3. 45 minutes
4. 60 minutes

4-44. A composite sample normally covers what time span?

1. 16 hours
2. 2 hours
3. 8 hours
4. 4 hours

4-45. The flow proportional composite sample normally covers what time span?

1. 12 hours
2. 24 hours
3. 36 hours
4. 48 hours

4-46. Which of the following tests should be performed at the time of sample selection?

1. Dissolved oxygen
2. Sample temperature
3. pH
4. All of the above

4-47. For proper storage, you should maintain the sample within what temperature range?

1. -2°C to -10°C
2. 2°C to 10°C
3. 10°C to 18°C
4. 18°C to 26°C

4-48. At sea level, pure water at 20°C can hold a maximum of how many milligrams per liter of dissolved oxygen?

1. 0.917
2. 9.17
3. 91.7
4. 917.0

4-49. Treatment plant influent water should be between what pH values?

1. 6.5 to 8
2. 2 to 4
3. 8.5 to 10
4. 4 to 6

4-50. An Imhoff cone should be used to perform which of the following tests?

1. Dissolved oxygen
2. Activated sludge
3. Settleable solids
4. Hydrogen ion concentration

4-51. When performing the BOD_5 test, you should read one sample immediately and store the other at 20°C for exactly how many days?

1. 5
2. 2
3. 3
4. 7

4-52. In which of the following tests should the sample be allowed to sit for 30 minutes?

1. Dissolved oxygen
2. Activated sludge
3. Settleable solids
4. Hydrogen ion concentration

4-53. A COD test can be performed in a minimum of how many hours?

1. 1
2. 2
3. 3
4. 4

4-54. Which of the following tests should be used as a control test to help you decide whether to increase or decrease the rate of sludge return?

1. pH
2. MLSS
3. BOD_5
4. COD

4-55. Which of the following tests should be performed within 30 minutes of taking a sample?

1. Total suspended solids
2. Mixed liquor suspended solids
3. Chlorine residual
4. Fecal coliform

4-56. After a sample is chilled to 4°C, a fecal coliform test should be performed within how many hours?

1. 6
2. 9
3. 3
4. 12

4-57. Laboratory records can be used for which of the following reasons?

1. To locate suitable plant operating controls
2. To point out future plant requirements
3. To protect the government from lawsuits
4. Each of the above

4-58. Preventive maintenance should be scheduled so it can be performed at which of the following times?

1. During good weather only
2. During peak loads only
3. During good weather and low loads
4. During bad weather and peak loads

4-59. For a wastewater plant that discharges effluent to a body of water, what type of permit must be obtained from the EPA or designated state agency?

1. NPDES
2. Operating
3. Discharge
4. COD

4-60. What is the cheapest operating effluent discharge method?

1. Intermittent
2. Continuous
3. Direct discharge
4. Indirect discharge

4-61. What type of effluent discharge requires a place to store the effluent?

1. Intermittent
2. Continuous
3. Direct discharge
4. Indirect discharge

4-62. When effluent containing a toxic substance is accidentally discharged into receiving water used downstream as a drinking water supply for recreation or for livestock watering, the operator is required to notify which of the following constituents?

1. The regulating agency only
2. The water users downstream only
3. The regulating agency and the water users downstream
4. The plant manager and the regulating agency

4-63. Recycled wastewater is seldom used for what type of water supply?

1. Industrial
2. Recreational
3. Irrigation
4. Drinking

4-64. What type of soil has the best filtration and filtration characteristics?

1. Average loams only
2. Sandy loams only
3. Average and sandy loams
4. Clay and top soil

4-65. When the weather is sunny, hot, and dry with strong breezes, what percentage of applied water can evaporate during the process of irrigation?

1. 15%
2. 25%
3. 50%
4. 75%

4-66. Before being used on parks, golf courses, and other recreational areas, wastewater must be treated in which of the following ways?

1. Aerated
2. Disinfected
3. Clarified
4. Polished

4-67. Vegetation around evaporation and percolation basins should not be allowed to exceed what maximum height?

1. 10 inches
2. 15 inches
3. 20 inches
4. 24 inches

4-68. Trees should not be allowed to grow within how many feet of wastewater lagoons?

1. 150 feet
2. 200 feet
3. 450 feet
4. 500 feet

ASSIGNMENT 5

Textbook Assignment: "Sewage Treatment and Disposal," "Compressed Air Systems," and "Boilers." Pages 10-32 through 12-14.

5-1. What type of wastewater system eliminates the need for septic tanks, cesspools, or leaching fields?

1. Holding ponds
2. Polishing ponds
3. Common sewers
4. Storm sewers

5-2. What is the minimum desirable size of a septic tank?

1. 500 gallons
2. 1,000 gallons
3. 1,250 gallons
4. 2,000 gallons

5-3. When a septic tank discharges into a leaching field greater than 500 feet in length, you should incorporate what component(s) into the system ?

1. Dosing tank only
2. Siphon only
3. Dosing tank and siphon
4. Inlet and outlet filters

5-4. Regardless of size, a septic tank should be inspected at what standard intervals?

1. 6 months
2. 2 months
3. 12 months
4. 18 months

5-5. At what minimum distance from a septic tank should a (a) shallow well and (b) deep well be located?

1. (a) 200 feet (b) 50 feet
2. (a) 200 feet (b) 75 feet
3. (a) 100 feet (b) 50 feet
4. (a) 100 feet (b) 75 feet

5-6. Leaching cesspools should be located what minimum distance from each other?

1. 10 feet
2. 20 feet
3. 30 feet
4. 40 feet

5-7. Perforated pipe of what size should be used in leaching fields?

1. 10-inch diameter
2. 8-inch diameter
3. 6-inch diameter
4. 4-inch diameter

5-8. What is the maximum allowable length of a leaching field lateral?

1. 50 feet
2. 75 feet
3. 100 feet
4. 125 feet

5-9. When a leaching field becomes inoperable, you must consider what option?

1. Chemical cleaning
2. System replacement
3. Adding additional piping
4. Pumping the septic tank

5-10. Low-pressure systems provide compressed air at a maximum of how many pounds per square inch gauge (psig)?

1. 25
2. 75
3. 100
4. 125

5-11. Medium-pressure systems provide compressed air from 126 psig to what maximum pressure?

1. 299 psig
2. 325 psig
3. 399 psig
4. 425 psig

5-12. High-pressure systems provide compressed air within what pressure range?

1. 400 psig to 4,000 psig
2. 400 psig to 6,000 psig
3. 425 psig to 4,000 psig
4. 425 psig to 6,000 psig

5-13. What type of shop or laboratory requires up to 6,000 psig of compressed air?

1. Torpedo workshop
2. Testing laboratory
3. Wind tunnel
4. Ammunition depot

5-14. Air compressor filter systems should be able to remove particles in what micron size range?

1. 1 to 3
2. 2 to 5
3. 3 to 7
4. 4 to 9

5-15. Of the following grades of commercial compressed air, which one is the most pure?

1. B
2. D
3. F
4. H

5-16. A refrigerant dryer with a dew point at what maximum temperature should be used to remove moisture to meet air quality requirements for instrument and control air?

1. 20°F
2. 30°F
3. 35°F
4. 40°F

5-17. With pressure in excess of 400 psig, oil causes what compression phenomenon to occur?

1. Burnout
2. Blowout
3. Combustion
4. Recycling

5-18. In a reciprocating compressor, what are the three compression cycle phases?

1. Intake, multistage pressurization, discharge
2. Intake, impeller rotation, compression
3. Intake, single-stage pressurization, discharge
4. Intake, compression, discharge

5-19. In a W-type compressor, there are a total of how many cylinders in the (a) first and (b) second stages?

1. (a) One (b) one
2. (a) Two (b) two
3. (a) Two (b) one
4. (a) One (b) two

5-20. What type of compressor has two mating rotating screws, one locked and one grooved, to provide the driving force?

1. Rotary
2. Reciprocating
3. Helical
4. Centrifugal

5-21. When the load is reasonably constant, what type of compressor is intended for near-continuous industrial air service?

1. Rotary
2. Reciprocating
3. Helical
4. Centrifugal

5-22. When placed through a parapet roof, you should extend air intakes what approximate distance above the roof?

1. 6 to 8 feet
2. 8 to 10 feet
3. 10 to 12 feet
4. 12 to 14 feet

5-23. Of the following types of intake filters, which one(s) is/are best suited for use in locations where dust is prevalent in the atmosphere?

1. Oil bath only
2. Viscous impingement only
3. Oil bath and viscous impingement
4. Oil injected and centrifugal lubricated

5-24. The intercooler in a multistage compressor serves what purpose?

1. To lower the temperature of discharged air
2. To remove condensation and impurities from the air flow
3. To reduce the temperature of compressed air between each stage
4. To add cool air at the beginning of each cycle

5-25. Aftercoolers are used in compressor discharge lines for which of the following reasons?

1. To permit the use of larger discharge pipes
2. To lower the air discharge temperature only
3. To facilitate condensation and removal of moisture only
4. To lower the air discharge temperature and facilitate condensation and removal of moisture

5-26. Separators are used in conjunction with aftercoolers for what purpose?

1. To remove water and oil from the compressed air
2. To reduce working pressure in the distribution lines
3. To separate noncondensable gases from the compressed air
4. Each of the above

5-27. Compressor cylinder oil should have what minimum flash-point temperature?

1. 325°F
2. 350°F
3. 375°F
4. 400°F

5-28. Pulsation dampeners serve as pulsation and noise mufflers due to what feature within the dampener?

1. An injector
2. A vibration amplifier
3. An acoustical chamber
4. A sound resonator

5-29. The inlet valve unloading device functions mechanically to remove compression loads from the prime mover by

1. disengaging the drive clutch
2. holding the inlet valve open during the suction and compression strokes
3. opening the cylinder relief valve
4. holding the inlet valve closed during the compression stroke

IN ANSWERING QUESTIONS 5-30 AND 5-31, REFER TO FIGURE 11-22.

5-30. When the receiver pressure has dropped from 100 psi to 94 psi, U(2) causes the compressor to operate at what percentage of its total output capacity?

1. 25%
2. 50%
3. 75%
4. 100%

5-31. When the compressor is operating at 25 percent of capacity, the inlet unloader valves should be in what position?

1. U(4) energized; U(1), U(2), and U(3) de-energized
2. Each unloader valve energized
3. U(4) de-energized; U(1), U(2), and U(3) energized
4. Each unloader valve de-energized

5-32. The volume of air that can be released from a compressor cylinder into one clearance pocket is equal to what percentage of the cylinder volume?

1. 25%
2. 50%
3. 75%
4. 100%

5-33. When sizing a prime mover, you should take which of the following factors into consideration?

1. Availability of a dc power source
2. Availability of unleaded fuel
3. Compressor size in rpm
4. Belt or drive losses of power

5-34. Belt selection for a large motor should be based on what ideal percentage of motor size?

1. 100%
2. 125%
3. 150%
4. 175%

5-35. What type of air distribution system is used for isolated service or in situations where special requirements dictate a single path?

1. Parallel
2. Loop
3. Radial, one way
4. Radial, two way

5-36. What type of closed-route air distribution system can be used throughout a building?

1. Parallel
2. Loop
3. Radial, one way
4. Radial, two way

5-37. Normally, a compressed air distribution system is sized by calculating what factor?

1. Friction loss
2. Pipe size
3. Compressor size
4. Oil loss

5-38. In situations where compressed air pipes are pitched upward causing condensate to flow against the flow of air, e minimum pitch of how many inches per hundred feet should be allowed?

1. 10
2. 2
3. 6
4. 4

5-39. When testing e system with dry air or nitrogen, you should use what percentage of maximum working pressure for a minimum of 4 hours?

1. 75%
2. 100%
3. 125%
4. 150%

5-40. What maintenance program prevents most major prime-mover breakdowns?

1. Manufacturer
2. Operator
3. Equipmentman
4. Construction Mechanic

5-41. When a manufacturer’s recommended tolerance level between two moving parts is exceeded on a compressor, you must perform which, if any, of the following actions?

1. A component adjustment only
2. An equipment overhaul only
3. A component adjustment or an equipment overhaul
4. None of the above

5-42. Air filters should be checked and cleaned a minimum of how often?

1. Daily
2. Weekly
3. Monthly
4. Quarterly

5-43. For assistance in air system maintenance and inspection, you should refer to what NAVFAC publication?

1. P-320
2. P-322
3. P-324
4. P-330

5-44. When done properly, what is the most important single point in the successful operation of a boiler?

1. Installation
2. Selection of the site
3. Accessory procurement
4. Quality of replacement parts

5-45. A boiler should normally be installed in which of the following locations?

1. Close to the galley
2. Close to the laundry
3. Near the area of greatest load demand
4. Near the area of least load demand

5-46. When constructing a boiler foundation you must adhere to what specifications?

1. ASME
2. NAVFAC
3. Manufacturer
4. Organizational

5-47. The main steam stop valve must be a rising spindle type, if the valve is over what size?

1. 1 inch
2. 2 inches
3. 3 inches
4. 4 inches

5-48. What type of valve is located between the main steam stop valve and the guard valve?

1. Relief
2. Daylight
3. Pressure regulating
4. Temperature regulating

IN ANSWERING QUESTIONS 5-49 AND 5-50, REFER TO FIGURE 12-1.

5-49. What accessory is depicted by number 10?

1. Drip leg
2. Root valve
3. PRV
4. TRV

5-50. What accessory is located near number 15?

1. Feed pump
2. Condensate tank
3. Strainer
4. Relief valve

5-51. Refer to foldout figure 12-2. What fitting is depicted by number 8?

1. Gauge glass
2. Glass blowdown
3. Pressure gauge
4. Try cock

5-52. Boilers having a heating surface in excess of 100 square feet must be provided with blowdown piping and fittings in what size range?

1. 1 inch to 2 1/2 inches
2. 1 1/4 inches to 2 1/4 inches
3. 1 1/2 inches to 2 1/2 inches
4. 1 3/4 inches to 2 3/4 inches

5-53. You should manually lift each safety valve to clean it at what intervals?

1. Weekly
2. Biweekly
3. Monthly
4. Quarterly

5-54. Steam piping that is buried or inaccessible requires a drip leg at intervals of not over how many feet?

1. 400
2. 300
3. 200
4. 100

5-55. Normally, a root valve is what type of valve?

1. Butterfly
2. Altitude
3. Globe
4. Gate

5-56. The pressure gauge on a boiler should be tested at what intervals?

1. Annually
2. Semiannually
3. Quarterly
4. Monthly

5-57. As a minimum, high-pressure, HTW, and MUSE boilers require a hydrostatic test at what intervals, in years?

1. 1
2. 2
3. 3
4. 4

5-58. When chemically treating a boiler, you should maintain what recommended residual for phosphate?

1. 20 to 40 ppm
2. 25 to 50 ppm
3. 30 to 60 ppm
4. 35 to 70 ppm

5-59. Assume the original wall thickness of a tube is 0.225 inch anti an exploring block has been cut and examined. What wall thickness requires complete renewal of all tubes from front to rear of the boiler and from center row to outer row, inclusive?

1. 0.110 inch
2. 0.115 inch
3. 0.120 inch
4. 0.125 inch

5-60. Under what conditions can a boiler be steamed with tubes that are pitted to a depth of 50 to 65 percent of their wall thickness?

1. When the boiler has been chemically cleaned
2. When the boiler can withstand a hydrostatic test of 125 percent of design pressure
3. When future boiler water treatment, use of blowdown, and laying-up procedures conform to NAVFAC requirements
4. Each of the above

5-61. What type of tube defect has scattered pits caused by dissolved oxygen that are relatively short and narrow?

1. Waterside cavities
2. Waterside grooves
3. Localized pitting
4. Corrosion fatigue

5-62. At what temperature can waterside burning occur in plain carbon steel tubes?

1. 650°F
2. 750°F
3. 900°F
4. 1000°F

5-63. When defects are discovered during waterside inspection of drums and headers or other pressure parts of the boiler, you should take what action?

1. Report the defects to the maintenance officer
2. Record the defects in the maintenance log
3. Record the defects in the boiler water treatment log
4. Each of the above

5-64. A hydrostatic test of 125 percent of boiler design pressure is acquired at which of the following times?

1. After renewing downcomers
2. After rolling superheater support tubes
3. After renewal of pressure parts
4. After cleaning firesides

5-65. Before cleaning a boiler with an operating pressure of 600 psi, you should hydrostatically test it at what pressure?

1. 150 psi
2. 600 psi
3. 750 psi
4. 900 psi

5-66. A hydrostatic test at 150 percent of design pressure is basically what type of test?

1. Tightness of gaskets
2. Strength of boiler
3. Tightness of valve seats
4. Each of the above

5-67. After repairs are made to a boiler and before applying a hydrostatic test, you should perform each of the following actions with what exception?

1. Gauging boiler safety valves
2. Flushing out the boiler with water
3. Closing all boiler connections and vents
4. Inspecting the boiler for scale and dirt

5-68. When hydrostatically testing a boiler, you can avoid complications due to temperature changes by

1. continuously operating the main feed pump
2. using water of the same temperature as the boiler and the fireroom
3. using water with temperature below 70°F
4. using hot water from the deaerating feed tank

5-69. A tube seat can be considered tight under which of the following circumstances?

1. It has been rerolled
2. It is bone dry
3. It has been renewed
4. It is only slightly cracked

5-70. The purpose of a 5-year test and inspection is to check what boiler elements?

1. Welds and nozzle connections
2. Handhole and manhole seats
3. Safety valves and welded parts
4. Internal fittings and air vents

ASSIGNMENT 6

Textbook Assignment: "Boilers." Pages 12-14 through 12-37.

6-1. Boiler firesides are inspected for signs of damage and deterioration when the boiler is secured for fireside cleaning. At what other intervals should this type of inspection be performed?

1. Each day the boiler is secured
2. Each time the boiler is secured
3. When material inspection is inevitable
4. When NAVFAC requests an inspection

6-2. Slag is injurious to refractories chiefly because it results in which of the following problems?

1. Cracking of the refractories
2. Filling of expansion joints
3. Peeling off a portion of the refractory surface
4. Powdering of the refractories

6-3. Increasing the temperature of a furnace at an excessively rapid rate is likely to result in what type of problem?

1. Burner cone sag
2. Anchor bolt shrinkage
3. Firebrick breakage at the anchor bolts
4. Deep firebrick fractures

6-4. An improperly closed expansion joint has which of the following indications?

1. Excessive slag formation near the joint
2. A light discolored surface inside the joint
3. Deep fissures in the firebrick adjacent to the joint
4. A dark discolored surface inside the joint

6-5. A plastic burner front is inspected after its first firing period. Which of the following conditions indicate(s) defective workmanship?

1. Radial cracks only
2. Parallel cracks only
3. Radial and parallel cracks
4. Fallen slabs of plastic from the burner front surface

6-6. What are the two most likely causes of failure in a castable burner front surface that has recently been installed?

1. Partial set of the material before installation and too much water in mixing
2. Too much water in mixing and long storage in a place that is too dry
3. Too little water in mixing and long storage in a place that is too dry
4. Partial set of the material before installation and too little water in mixing

6-7. What condition(s) contribute(s) to the damage of boiler refractories?

1. Poor boiler operating procedures only
2. Severe boiler operating conditions only
3. Poor boiler operating procedures or severe boiler operating conditions
4. Failure to remove all crumbly material from a castable burner front when installed

6-8. Under which, if any, of the following conditions may a boiler be steamed with married tubes?

1. The married tubes are 1 inch in diameter, are located in the main generating bank, and are tight under hydrostatic test
2. The married tubes are 2 inches in diameter and are located in the fire row
3. The married tubes are 1 inch in diameter, are located in the main tube bank, and leave a gas passage of 2 inches to the superheater
4. None of the above

Tube Defect	Appearance	Usual Causes	Typical Locations
Circumferential grooving	Bands or strips around the circumference	1. Tube seat leakage 2. Dampened soot deposits on horizontal drums or headers	1. Header ends of horizontal tubes 2. Vertical generating tubes
A	Deep, irregular, straight-walled cavities	1. Leakage of water entrapped between tube metal and surrounding refractory 2. Improper drying of boiler firesides after washing	Header ends of waterwall tubes and division wall tubes that are surrounded by refractory
B	Wandering, straight-walled, canyonlike cavities	1. Leakage of water entrapped between tube metal and surrounding refractory 2. Improper drying of boiler firesides after washing	Header ends of waterwall tubes and division wall tubes that are surrounded by refractory
General fireside thinning	Uniform loss of metal over a relatively large area	G	1. Superheater tube ends between headers and seal plates 2. Water drum ends of generating tubes
C	E	1. Waterside deposits 2. Dry or steam-bound tube	Anywhere
D	F	Steam jets	Anywhere

Figure 6A

IN ANSWERING QUESTIONS 6-12 THROUGH 6-17, REFER TO FIGURE 6A.

6-9. When a blistered tube suggests a waterside deposit, the nature and extant of this deposit can be determined in what manner?

1. By punching the tube with tube cleaning equipment and inspecting the substance loosened by the wire brush
2. By hitting the blister a sharp blow with a hammer and inspecting the particles knocked loose
3. By removing the tube and an adjacent tube, splitting both, and comparing them
4. By removing the tube, splitting it, and examining the watersides of the blistered tube

6-10. By what means can you measure the amount of enlargement of a tube if calipers are not available to you?

1. A micrometer
2. A section of string and a ruler
3. A depth gauge
4. A straight pin through a 3- by 5-inch card

6-11. What is the most common cause of circumferential grooving on a superheater?

1. Leaking of the economizer plugs
2. Leaking of the tube seats in the top pass of the superheater
3. Soot deposits around the tubes where they enter the headers
4. Water washing the firesides without properly drying them

6-12. What tube defects should be entered in spaces A and B?

1. Craters and water tracks
2. Fireside burning and craters
3. Steam gouging and fireside burning
4. Water tracks and steam gouging

6-13. At what point does cratering and water tracking occur almost exclusively?

1. On the fire row tubes
2. On the tube ends at the water drum
3. At the header ends of the waterwall tubes
4. At the steam end of the waterwall tubes

6-14. What information should be entered in space G?

1. Tube seat leakage
2. Soot or vanadium corrosion
3. Improper drying of boiler firesides after washing
4. Steam jets

6-15. What appearance should be entered in space F?

1. Irregular, smooth-surfaced cavities
2. Coarse, brittle tube metal
3. Uniform loss of metal over a small area
4. Bands around the circumference

6-16. What tube defects should be entered in spaces C and D?

1. Craters and steam gouging
2. Fireside burning and steam gouging
3. Steam gouging and water tracks
4. Water tracks and craters

6-17. What appearance should be entered in space E?

1. Irregular, smooth-surface cavities
2. Coarse, brittle tube metal
3. Uniform loss of metal over a small area
4. Irregular, straight-wall cavities

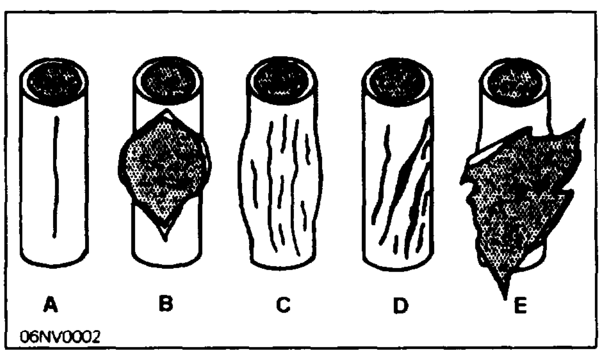

Figure 6B

IN ANSWERING QUESTIONS 6-18 THROUGH 6-21, REFER TO FIGURE 6B.

6-18. What casualties are NOT necessarily caused by overheating?

1. A, C
2. A, E
3. B, D
4. C, E

6-19. What casualty is caused by the most severe overheating?

1. A
2. B
3. D
4. E

6-20. What type of rupture is common in generating tubes?

1. B
2. C
3. D
4. E

6-21. What casualty results from the least severe overheating?

1. B
2. C
3. D
4. E

BOILER TUBE DEFORMITIES
A. Melting
B. Warping
C. Sagging
D. Cracking

Figure 6C

IN ANSWERING QUESTIONS 6-22 THROUGH 6-25, REFER TO FIGURE 6C.

6-22. Very mild overheating for a short period of time:

1. A
2. B
3. C
4. D

6-23. Caused by a mechanical process, such as flexing:

1. A
2. B
3. C
4. D

6-24. Low water for an extended period of time at high furnace temperatures:

1. D
2. C
3. B
4. A

6-25. Sudden cooling of overheated tubes:

1. D
2. C
3. B
4. A

6-26. Improper fabrication of tubes is most likely to result in which of the following conditions?

1. Upset tubes
2. Swaging
3. Wall lamination
4. Mechanical fatigue cracks

6-27. The basic reason for tube failure caused by fireside and waterside deposits is that the deposits result in which of the following conditions?

1. Oxygen pitting
2. Tube wall lamination
3. Localized overheating
4. Tube abrasion

6-28. Abundant water combining with soot on firesides of tubes may result in the formation of what substance?

1. Slag
2. Iron oxide
3. Ferrous sulfate
4. Saltlike granules

6-29. Steam drum protection plates are most likely to be damaged when what condition exists?

1. Gas passages are clogged
2. Superheater is overfired
3. Steam pressure is formed too fast
4. Brickwork adjacent to the superheater headers is damaged

6-30. When testing the functions of automatically or manually controlled devices that interfere with steam distribution, you should ensure that which of the following main distribution valves is/are closed?

1. Gas only
2. Gas and water
3. Main steam
4. Water and steam

6-31. When CO_2 or O_2 measuring devices are not available, you can use which of the following indications as a guide for checking the air-fuel ratio on a small boiler?

1. Fuel consumption
2. Draft gauge
3. Feedwater consumption
4. Appearance of the fire

6-32. On a fully automatic boiler, you can check the flame failure and combustion air failure devices in which of the following ways?

1. By simulating a flame failure manually
2. By observing the complete programmed sequence cycle
3. By simulating a low-water condition
4. By bypassing the draft controller

6-33. With respect to steam and water piping, you should look for which of the following conditions during an inspection?

1. Excessive expansion and contraction
2. Undue vibration in piping connections to the boiler
3. Leaking water column connections
4. Each of the above

6-34. What is the best method for determining proper operation of high- and low-water alarms?

1. Open the surface blowdown valve momentarily
2. Blow down the water column with steam on the boiler only
3. Observe the action of the water during blowdown of the gauge glass only
4. Blow down the water column with steam on the boiler and observe the action of the water during blowdown of the gauge glass

6-35. Of the following steps, which one should you take to test the operation of a float-activated low-water fuel cutoff device?

1. Drain the float bowl to the low-water level
2. Close the fuel oil solenoid valve
3. Blow down the steam drum
4. Disconnect the low-water control circuitry

6-36. Normally, a temperature controlled low-water fuel cutoff device responds to an increase in temperature inside the boiler under which of the following circumstances?

1. Stack temperature is excessively high
2. Water drops to a predetermined level
3. Steam pressure is no more than 2 percent above normal
4. Water temperature rises uniformly to the steaming level

6-37. When testing blowoff valves, you should open the valves for a few seconds to check for which of the following conditions?

1. Back pressure
2. Valve wear only
3. Restrictions only
4. Valve wear and restrictions

6-38. To check the blowoff setting of safety valves and water-pressure relief valves, you should perform which, if any, of the following actions?

1. Raise boiler pressure slowly to the blowoff pressure
2. Manually raise the valve
3. Gag all safety and relief valves
4. None of the above

6-39. A properly functioning single safety valve on a steam boiler that has a maximum allowable working pressure of 150 psi should reseat tightly at what minimum pressure?

1. 144 psi
2. 124 psi
3. 104 psi
4. 84 psi

6-40. What should be the individual settings of two pressure relief valves on a hot-water boiler having a maximum allowable working pressure of 100 psi?

1. One at 125 psi, the other at 100 psi maximum
2. Both at 110 psi
3. One at 150 psi, the other at 110 psi
4. One at 120 psi maximum, the other at 100 psi

6-41. A properly set single, pressure relief valve on a boiler with a maximum allowable working pressure of 80 psi should reseat tightly with a blowdown of what maximum pressure?

1. 15 psi
2. 20 psi
3. 25 psi
4. 30 psi

6-42. Under certain conditions, which of the following factors can be used to determine safety valve capacity?

1. Operating pressure
2. Maximum steam generating capacity only
3. Maximum evaporative capacity only
4. Maximum steam generating capacity or maximum evaporative capacity

6-43. Venting should be held to a minimum to preclude what condition in the feedwater?

1. Deaerator venting
2. Hydrogen entrainment
3. Oxygen entrainment
4. Oxygen venting

6-44. As a boiler plant supervisor, you should be able to identify which of the following indications of trouble?

1. Strange noises
2. Unusual vibrations
3. Abnormal temperatures
4. Each of the above

LOG ENTRIES
A. Steam Pressure
B. Steam flow
C. Feedwater pump
D. Feedwater pressure

Figure 6D

IN ANSWERING QUESTIONS 6-45 THROUGH 6-47, REFER TO FIGURE 6D.

6-45. Actual output recorded in pounds per hour to obtain steam flow:

1. A
2. B
3. C
4. D

6-46. Proper deaerating temperature being maintained in the heater:

1. A
2. B
3. C
4. D

6-47. Effectiveness of the boiler feed pumps:

1. D
2. C
3. B
4. A

6-48. With other conditions constant, a decrease in what type of draft indicates leaking baffles?

1. Last pass
2. Mechanical
3. Forced
4. Furnace

6-49. What reading(s) is/are an indication that heat is being lost by way of the stack?

1. Percentage of CO_2 flue gas
2. Flue-gas temperature
3. Soot-blown time and blowdown
4. Hot-water supply temperature and blowdown

6-50. What type(s) of fuel consumption is/are determined by use of a measuring stick?

1. Gallons of oil
2. Pounds of coal only
3. Cubic feet of gas only
4. Pounds of coal and cubic feet of gas

6-51. The hot-water supply temperature should be recorded because insufficiently heated water can cause which of the following conditions?

1. Abnormal soot deposits
2. Hammer knock in a steaming boiler
3. Deposits or scaling in a boiler
4. Large amounts of chemicals to accumulate in the feedwater

6-52. In what log column should you record the date a boiler was drained and washed?

1. Remarks
2. Makeup water
3. Water pressure
4. Soot-blown time and blowdown

6-53. An operator coming on duty should perform an operational inspection for which of the following reasons?

1. To ensure the boiler water level is correct
2. To ensure the system is operating normally
3. To ensure sufficient fuel is available
4. To ensure the boiler room is clean

6-54. The technical library should contain current Navy publications pertaining to your boiler plant and which, if any, of the following manuals?

1. Specific plant manufacturer's manual
2. General plant manufacturer's manual
3. Army boiler operation and repair technical manuals
4. None of the above

6-55. What term is commonly used to describe the universal solvent?

1. Oxygen
2. Water
3. Sodium phosphate
4. Caustic soda

6-56. A glass of tap water at 77°F contains a total of how many ppm of oxygen?

1. 7.5
2. 7.8
3. 8.2
4. 9.0

6-57. To prevent corrosion damage to metal in the interior of the boiler, you should perform which of the following actions?

1. Paint the interior metal surfaces
2. Chemically treat the feedwater only
3. Chemically treat the boiler water only
4. Chemically treat the feedwater and the boiler water

6-58. What is the term used for deposits on tubes and other internal surfaces caused by calcium salts, magnesium salts, and other insoluble materials?

1. Deposits
2. Scales
3. Crystals
4. Solids

6-59. Chemical treatment of boiler water causes scale-forming substances in what form?

1. Scale deposits
2. Fluid sludge
3. Carbonate of sulfate
4. Caustic soda

6-60. When required to treat boiler water containing calcium, you should use what chemical?

1. Sodium phosphate
2. Calcium phosphate
3. Calcium silicate
4. Sodium silicate

6-61. What sludge conditioner is the only dispersant approved by NAVFAC?

1. Magnesium silicate
2. Calcium sulfate
3. Sodium phosphate
4. Quebracho tannin

6-62. A small amount of seawater in the feedwater causes which, if any, of the following conditions inside a boiler?

1. Steam carry-over
2. Baked sludge
3. Heavy sludge
4. None of the above

6-63. What chemical should you add to boiler water to raise the pH value?

1. Iron oxide
2. Caustic soda
3. Sodium sulfite
4. Tannin

6-64. What chemical is often referred to as an oxygen scavenger?

1. Iron oxide
2. Caustic soda
3. Sodium sulfite
4. Tannin

6-65. Feedwater or makeup water tanks should be maintained within what temperature range?

1. 125°F to 135°F
2. 140°F to 160°F
3. 165°F to 175°F
4. 180°F to 200°F

6-66. The production of froth or unbroken bubbles on the surface of the boiler water is known by what term?

1. Foaming
2. Steam production
3. Alkalinity
4. Scum

6-67. What condition(s) in a boiler make(s) it difficult, or quite often impossible, to read the true level of boiler water on the gauge glass?

1. Foaming only
2. Priming only
3. Foaming or priming
4. Bumping or priming

6-68. What two types of solids are present in most boiler water?

1. Dissolved and gloating
2. Suspended and floating
3. Dissolved and scale-forming
4. Suspended and dissolved

6-69. The continuous blowdown should be regulated to maintain what ppm of TDS in a steaming boiler?

1. 2,000 to 3,000
2. 3,000 to 4,000
3. 4,000 to 5,000
4. 5,000 to 6,000

6-70. One boiler horsepower produces a total of how many pounds of steam per hour?

1. 3.450
2. 34.50
3. 345.0
4. 3,450

6-71. Once the boiler has stabilized and treatment test results remain reasonably balanced, you should conduct testing at what intervals, in hours?

1. 1
2. 2
3. 3
4. 4

ASSIGNMENT 7

Textbook Assignment: "Boilers," "Duct and Ventilation Systems," and "Air Conditioning and Refrigeration." Pages 12-38 through 14-26.

7-1. What person is the most important member of a boiler maintenance team?

1. The supervisor
2. The welder
3. The laboratory technician
4. The operator

7-2. Any unusual temperature change the operator cannot correct should be reported to what individual?

1. Plant supervisor
2. Watch chief
3. Relief operator
4. Maintenance supervisor

7-3. What is the main purpose for conducting preventive maintenance inspections?

1. To keep the equipment in good operating condition
2. To anticipate and prevent equipment breakdown
3. To repair broken equipment
4. To keep an accurate maintenance record of all equipment

7-4. Refer to table 12-4. What draft reading is recommended in an oil burner firebox?

1. 1.0 inch
2. 2.0 inches
3. 0.01 inch
4. 0.02 inch

7-5. When soot combines with moisture, what is the result?

1. Slag
2. Sulfur dioxide
3. Sulfuric acid
4. Hydrogen sulfide

7-6. When left untended, soot corrosion on boiler metals causes which of the following problems?

1. Extensive deterioration
2. High fuel cost
3. High operating cost
4. Dirty steam

7-7. Soot and other deposits left on boiler brickwork lower the melting point of which of the following components?

1. Boiler tubes
2. Headers
3. Refractories
4. Burners

7-8. Failure to keep boiler watersides clean can result in which of the following conditions?

1. Dirty steam
2. Overheating
3. Carry-over
4. Low temperature

7-9. What condition often signals the need for waterside and fireside cleaning?

1. Lowering of stack gas temperature
2. Lowering of steam temperature
3. Rise in stack gas temperature
4. Rise in steam temperature

7-10. When preparing to work on watersides, what must you do concerning tools and equipment?

1. Sparkproof the metal tools
2. Clean and wipe each tool dry
3. Inventory and tag the tools
4. Inventory the tools and prepare an in/out sheet

7-11. What special type of extension light, if any, is authorized inside a boiler?

1. Explosionproof
2. Dustproof
3. Watertight glove
4. None

7-12. When work on the watersides of a boiler is being performed, a person should be stationed outside the boiler for what sole purpose?

1. To act as tender only
2. To assist workers in the boiler only
3. To act as tender and to assist workers in the boiler
4. To perform first aid if necessary

7-13. What two methods can be used to boil out the watersides of a boiler?

1. Sodium metasilicate pentahydrate and trisodium silicate
2. Sodium pentahydrate and sulfuric acid
3. Sodium silicate and trisodium metasilicate pentahydrate
4. Sodium metasilicate pentahydrate and trisodium phosphate

7-14. In the wet lay-up method, you should add what chemical to the water?

1. Sodium sulfite
2. Sodium hydroxide
3. Sodium silicate
4. Sodium electrolyte

7-15. In the wet lay-up method, 0.03-0.06 pounds of sodium sulfite should be added per how many gallons of water?

1. 30
2. 50
3. 100
4. 1,000

7-16. At what interval should water in an idle boiler be sampled and analyzed?

1. Daily
2. Weekly
3. Monthly
4. Quarterly

7-17. In the dry lay-up method, a minimum of how many pounds of quicklime should be used as a drying agent per 100 boiler horsepower?

1. 5
2. 10
3. 20
4. 40

7-18. A high-pressure or high-velocity ductwork system has a fan that operates within what static-pressure range?

1. 1 inch to 5 inches WC
2. 2 inches to 6 inches WC
3. 3 inches to 7 inches WC
4. 4 inches to 8 inches WC

7-19. Duct velocities greater than how many feet per minute (fpm) are normally unwarranted?

1. 2,000
2. 3,000
3. 4,000
4. 6,000

7-20. In a low-velocity system, the duct velocity is normally less than how many feet per minute?

1. 2,000
2. 1,500
3. 1,000
4. 500

7-21. What type of duct system is no longer legal?

1. Fiber glass
2. Asbestos
3. Sheet metal
4. Aluminum

7-22. When possible, you should use what shape of duct system ?

1. Square
2. Rectangular
3. Round
4. Trapezoidal

7-23. What is/are the primary disadvantage(s) of a double-duct system?

1. Unstable air quantities
2. High air velocities only
3. Unstable duct pressures only
4. High air velocities and unstable duct pressures

7-24. The type of material used for duct lining and covering must have what characteristic?

1. It must be nonbacteriological
2. It must be noncombustible
3. It must be sound absorbent
4. It must be inflexible

7-25. The power required by the fan for delivering air at a given quantity increases rapidly according to what change, if any, in duct size?

1. An increase only
2. A decrease only
3. An increase or a decrease
4. None

7-26. Rectangular fiber-glass ducts 24 inches or less in diameter must be supported every how many feet?

1. 10
2. 8
3. 6
4. 4

7-27. What type of joint is used to absorb expansion and contraction in a duct system?

1. Accordion
2. Bellows
3. Shiplap
4. Fabric

7-28. When computing duct size, you should first perform what calculation?

1. Air pressure
2. Air volume
3. Air velocity
4. Air movement

7-29. You can gain efficiency by installing what type of elbow in a duct system?

1. Long, sweeping
2. Short, 90 degree
3. Unidirectional
4. S curve

7-30. Short, 90-degree elbows can be used effectively in which of the following locations within an air duct system?

1. Before registers only
2. Before diffusers only
3. Before grilles only
4. Before registers, diffusers, and grilles

7-31. When designing a duct system, you should use what publication as a source of technical information?

1. Mechanical Engineering Manual
2. Duct Design and Fabrication
3. Construction Engineering Handbook
4. ASHRAE Handbook of Fundamentals

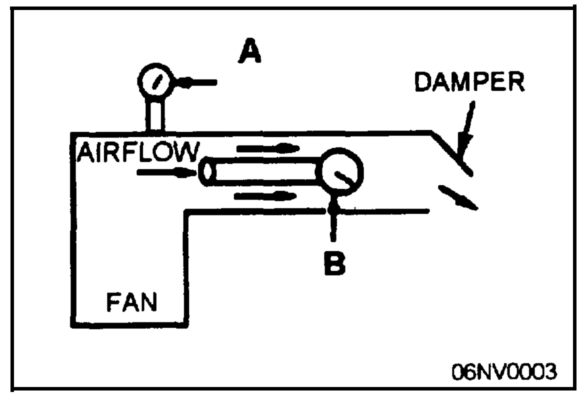

Figure 7A

IN ANSWERING QUESTIONS 7-32 AND 7-33, REFER TO FIGURE 7A.

7-32. The total pressure of the duct system is equal to the pressure reading of what gauge(s)?

1. A only
2. B only
3. B plus A
4. B minus A

7-33. The velocity pressure of the duct system is equal to the pressure reading of what gauge(s)?

1. A plus B
2. A only
3. A minus B
4. B minus A

7-34. A newly installed duct system is balanced in what manner?

1. By adjusting the speed of the fan
2. By drilling small holes in branch holes
3. By adjusting air outlets to the design rate of flow
4. By installing dampers in the main duct

7-35. What is the main purpose of pressure measurements after a newly installed system is balanced and operating properly?

1. To check the design of the system
2. To provide information for required reports
3. To provide information for future tests
4. To ensure proper adjustment of the fan and air outlets

MEASURING PROBES
A. Pitot
B. Low-flow
C. Static pressure
D. Velometer

Figure 7B

IN ANSWERING QUESTIONS 7-36 THROUGH 7-38, REFER TO FIGURE 7B.

7-36. Measures air currents in open spaces:

1. A
2. B
3. C
4. D

7-37. Measures pressure drop across blowers in duct systems:

1. A
2. B
3. C
4. D

7-38. Measures internal air velocities in duct systems:

1. D
2. C
3. B
4. A

7-39. When used in conjunction with the diffuser probe, what device permits the rapid change of measuring ranges without shifting to separate jets for different velocities?

1. Manometer
2. Range selector
3. Tachometer
4. Anemometer

7-40. Which of the following is NOT a unit by which a manometer measures air pressure?

1. Pounds per square inch
2. Inches of mercury
3. Inches of water
4. Cubic feet per minute

7-41. One of the preliminary steps in air-balancing operations is to prepare a working sketch of the system. Which of the following items should be included in the sketch?

1. Duct dimensions
2. Air flow volumes and velocities
3. Air-delivery design of each outlet and type of diffuser
4. Each of the above

7-42. When balancing an air distribution system, you should first determine fan performance for which of the following reasons?

1. To pinpoint problems caused by blockages in the duct system
2. To ensure the fan is rotating correctly
3. To ensure that sufficient static pressure and air volume are being handled at the fan
4. To ascertain whether the air filters are clean

7-43. What factors influence the performance of a fan in a ventilation system?

1. Static pressure and rpm of the fan
2. Voltage and amperage of the fan motor
3. Total airflow in the ventilation system
4. Each of the above

7-44. What instruments are used to measure the static pressure of an operating fan?

1. Velometer and static-pressure probe
2. Rotating vane anemometer and low-flow probe
3. Velometer and Pitot tube
4. Manometer and diffuser probe

7-45. Which of the following air distribution problems in ducts can be located quickly by measuring static pressure?

1. Leakage
2. Blockage
3. Slippage
4. Each of the above

7-46. Velocity pressure readings should be taken to determine the total air volume of a fan from which, if any, of the following areas?

1. Fan suction
2. Fan distribution spaces
3. Downstream of the fan in an area with minimum turbulence
4. None of the above

7-47. Velocity pressure readings should be taken at what location inside a rectangular duct?

1. Along the perimeter at equal intervals
2. From the center of equally divided areas of the cross section
3. Along the horizontal center line at equal intervals
4. At any accessible location

7-48. When the average velocity pressure is 120 fpm and the cross-sectional measurements are 18 inches by 24 inches, what is the total airflow, in cfm, within the duct?

1. 120
2. 270
3. 320
4. 360

7-49. The measured total air flow, in cfm, should exceed the design cfm by approximately 10 percent for which of the following reasons?

1. To allow for slippage
2. To ensure maximum fan speed
3. To allow for leakage
4. Each of the above

7-50. At what location, in respect to the duct configuration, should the final balancing procedure be started?

1. Downstream of the main air return
2. In the immediate area of the fan discharge
3. At the last outlet on the farthest branch from the fan discharge
4. In the largest spaces served by the duct

7-51. During the final balancing procedure, an air outlet that should be discharging 90 cfm is found to be discharging 125 cfm. Which of the following actions should you take?

1. Leave the damper open and proceed to the next outlet
2. Adjust the damper until the output drops to 90 cfm
3. Decrease the fan speed
4. Restrict the flow of return air

7-52. What term is commonly used to identify fresh air leakage into a building or room?

1. Infiltration
2. Exfiltration
3. Ventilation
4. Defiltration

7-53. A minimum amount of how much fresh air is necessary to provide sufficient oxygen and to remove carbon dioxide for each person in a typical office space?

1. 8 cfm
2. 2 cfm
3. 6 cfm
4. 4 cfm

7-54. A total of how many changes of air per hour is required for a conditioned space in a residence during the heating season?

1. One
2. Two
3. Three
4. Four

7-55. A sleeping person gives off approximately how many Btu per hour of heat?

1. 50
2. 100
3. 150
4. 200

7-56. When installing a natural ventilation system, you should consider location and what other factor regarding ventilation openings?

1. Wind
2. Control
3. Humidity
4. Temperature

7-57. You should use mechanical ventilation equipment under which, if any, of the following circumstances?

1. The outside air is high in humidity
2. The outside air has a high ambient temperature
3. The outside air cannot be supplied continually by natural forces
4. None of the above

7-58. When areas to be air-conditioned are in close proximity to each other, you should use what type of air-conditioning system?

1. Chilled water only
2. Hot and chilled water
3. Forced air
4. Natural draft

7-59. What type of air-conditioning system is recommended for use in a hospital?

1. Chilled water only
2. Hot and chilled water
3. Forced air
4. Natural draft

7-60. In heat load calculations, what factor denotes heat leakage?

1. H
2. K
3. P
4. R

7-61. In heat load calculations, what factor denotes insulation values?

1. R
2. P
3. K
4. H

7-62. When working on an ammonia-absorption refrigeration system, you need what type of manifold gauges?

1. Brass
2. Copper
3. Steel
4. Bronze

7-63. An expendable evaporator system works within what temperature range?

1. 32°F to 0°F
2. 15°F to -5°F
3. 10°F to -10°F
4. -20°F to 60°F

7-64. When you want to preserve the freshness of fruits and vegetables, you should use what type of evaporator system?

1. Expendable
2. Eutectic
3. Spray
4. Thermoelectric

7-65. What type of refrigeration system has no moving parts?

1. Expendable
2. Eutectic
3. Spray
4. Thermoelectric

7-66. What maximum temperature can be maintained in a cascade refrigeration system?

1. - 50°F
2. -100°F
3. -150°F
4. -250°F

7-67. What maximum temperature can be attained in a three-stage compound system?

1. -80°F
2. -135°F
3. -150°F
4. -250°F

7-68. Refer to figure 14-22B. The pressure at P1 is 7 pounds, P2 is 4 pounds, and P3 is 21 pounds. The valve is in what position?

1. Equilibrium
2. Closed
3. Open
4. None of the above

7-69. An external equilizer line is required when what pressure drop exists across an evaporator coil?

1. 1 pound
2. 5 pounds
3. 3 pounds
4. 7 pounds

7-70. When adjusting a thermal expansion valve, you must make how many turns of the valve stem at each interval?

1. One
2. Two
3. Three
4. Four

7-71. Of the following considerations, which one is most important when you are mounting a condenser on a roof?

1. The roof load strength
2. The noise level
3. The availability of water
4. The availability of electricity

7-72. What types of metal are used in a bi-metal thermostat?

1. Tin and antimony
2. Tin and steel
3. Copper and steel
4. Brass and invar

7-73. What type of thermostat uses 115 volts?

1. Line voltage
2. Low voltage
3. Millivoltage
4. High voltage

7-74. What is the most commonly used metering device?

1. The AEX
2. The capillary tube
3. The TEV
4. The low-side float

7-75. The additional starting torque of a capacitor-start, induction-run motor over that of a split-phase motor is provided by a

1. run capacitor in parallel with the start winding
2. start capacitor in series with the run winding
3. run capacitor in parallel with the run winding
4. start capacitor in series with the start winding

ASSIGNMENT 8

Textbook Assignment: "Air Conditioning and Refrigeration," Solar Energy," and "Environmental Pollution Control." Pages 14-17 through 16-3.

8-1. Which of the following types of motors should be used for a 5-horsepower, high-starting torque requirement?

1. Split-phase
2. Capacitor-start, capacitor-run
3. Permanent split-phase
4. Capacitor-start, induction-run

8-2. The permanent split-phase motor circuit differs from a split-phase in which, if any, of the following ways?

1. It requires a start capacitor in series with the start winding
2. It uses a run capacitor in series with the start winding
3. It requires a start relay
4. None of the above

8-3. Start windings are used in single-phase motors designed for use with hermetic refrigeration for which of the following reasons?

1. The motors start under load conditions
2. The compressors are operated at two speeds
3. The motors start under no-load conditions
4. The start winding is a standby winding

8-4. The opposition to the flow of alternating current caused by the inductance and capacitance in the run winding is a result of

1. low reactance
2. high reactance
3. low resistance
4. high resistance

8-5. When using an ohmmeter to identify motor terminals, you should perform what action first?

1. Remove the wires connected to the terminal
2. Mark the wires for later identification
3. Remove power to the motor circuit
4. Disconnect the ground

IN ANSWERING QUESTIONS 8-6 THROUGH 8-8, REFER TO FIGURE 14-30. ASSUME THE METER IS FUNCTIONING PROPERLY.

8-6. The R to S test indicates that the remaining terminal is the common terminal because the resistance of

1. the run winding is high
2. both windings in parallel are high
3. the start winding is low
4. both windings in series are high

8-7. The C to S test indicates that the remaining terminal is the run terminal for which, if any, of the following reasons?

1. It has the greatest resistance
2. It has a much lower resistance
3. It has the same resistance
4. It has medium resistance

8-8. If, during either the R to S or the C to S test, the ohmmeter needle fails to move, you should check for what problem?

1. An open start relay
2. A defective winding
3. An open run capacitor
4. A shorted start capacitor

8-9. Which of the following components is considered a load?

1. Thermostat
2. High-pressure switch
3. Set of contacts
4. Coil of a contactor

8-10. An ohmmeter shows a resistance of infinity between the R and C motor terminals during a continuity test. Which of the following faults is indicated?

1. A grounded run winding
2. An open start winding
3. A shorted start winding
4. An open run winding

8-11. Assume that you are using a test lamp to check the continuity between the C and S terminals of a motor. What fault is indicated when the light fails to come on?

1. An open in the start winding
2. A short in the start winding
3. An open in the run winding
4. A short in the run winding

8-12. Which of the following conditions exists in the case of a shorted winding?

1. A wire is burned in half
2. The winding has a high resistance
3. A loop of copper wire is in contact with another wire
4. A wire is touching the hermetic shell

8-13. An ohmmeter indicates a start winding resistance of 4 ohms for a motor that has a run winding resistance of 2.5 ohms. The low resistance of the motor start winding is most likely due to what fault?

1. An open
2. A short
3. A grounded start capacitor
4. A burned current relay

8-14. Refer to figure 14-33. What fault is indicated by continuity between one of the motor terminals and the shell?

1. A short
2. An open
3. A ground
4. An overload

8-15. Which of the following devices can be used to test a hermetic motor for grounds?

1. Ohmmeter
2. Test lamp
3. Megger
4. Each of the above

8-16. Refer to figure 14-26. At what time should the contact points be in the open position?

1. The off-cycle only
2. The start winding is de-energized
3. The motor reaches about three-fourths rated speed
4. Each of the above

8-17. Unlike the current relay that responds to starting current in the motor circuit, the voltage relay responds to which, if any, of the following conditions?

1. Current flow through the run winding only
2. Voltage induced in the start winding
3. Leveling effect of the run capacitor
4. None of the above

8-18. When the circuit draws excessive current, which of the following starting relays is capable of de-energizing the running winding circuit?

1. Hot wire
2. Voltage
3. Current
4. Each of the above

8-19. Refer to figure 14-38. When an overload protector is open, the opening action is the direct result of what condition?

1. Voltage
2. Heat
3. Current
4. Capacitance

8-20. What device, if any, is used in the starting circuit of an induction motor to provide leading current through one winding?

1. Overload protector
2. Starting capacitor
3. Running capacitor
4. None

8-21. Assume that you are testing the contacts of a voltage-type starting relay with an ohmmeter. The normally closed contacts are working properly in which of the following circumstances?

1. Contacts lack continuity
2. Negligible resistance exists in the relay coil
3. Current is not flowing through the contacts
4. Continuity exists through the contacts

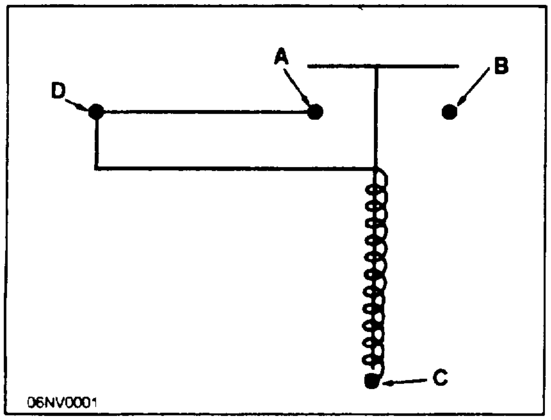

Figure 8A

IN ANSWERING QUESTIONS 8-22 THROUGH 8-24, REFER TO FIGURE 8A.

8-22. At what points should an ohmmeter be connected to test the relay coil?

1. A and B
2. B and C
3. C and D
4. D and B

8-23. At what points should an ohmmeter be connected to test the relay contacts?

1. A and B
2. B and D
3. C and B
4. D and C

8-24. Which of the following ohmmeter test results indicates the contacts of a current relay are satisfactory?

1. Continuity through points A and B
2. Lack of continuity through points A and C only
3. Lack of continuity through points A and B only
4. Lack of continuity through points A, B, and C

8-25. Refer to figure 14-40. Assuming the test is accomplished, which of the following meter readings indicates an open coil?

1. 110 volts
2. 2 ohms
3. Infinity
4. 4 amps

8-26. When a starting relay fails, you can start the compressor motor by bypassing the relay manually using which of the following devices?

1. A test lamp and cable
2. An ohmmeter with four lead wires
3. A test line cord, fuse, and capacitor
4. A jumper placed across terminals C and R and a test lamp

8-27. Which, if any, of the following circuit conditions indicates an internal current temperature overload protector is open in a hermetic motor?

1. Continuity across C and S, C and R, and S and R
2. Open across C and S, C and R, and continuity across S and R
3. Continuity across C and R, and an open across S and R and C and S
4. None of the above

8-28. You are testing a capacitor with an ohmmeter. What general reading on the meter indicates the capacitor is good?

1. Zero resistance and then climbs to high resistance
2. Low resistance
3. Medium resistance

8-29. Which of the following electrical components is NOT part of a load circuit shown in a hermetic system schematic wiring diagram?

1. Compressor motor
2. Start capacitor
3. Thermostat
4. Fan motor

8-30. If you are reading voltage across a set of contacts, the contacts are

1. burned
2. open
3. shorted
4. closed

8-31. Energy from the sun is received by the earth in what form?

1. Conduction
2. Radiation
3. Convection
4. Diffusion

8-32. What term describes the amount of solar energy per unit area per unit of time striking the earth's surface?

1. Solar isolation
2. Solar radiation
3. Solar insolation
4. Solar collection

8-33. Which of the following expressions describes the solar constant?

1. 418 Btu/hr-ft^2
2. 2,453 watts/m
3. 1.940 Langleys/min
4. Each of the above

8-34. What percentage of solar energy is absorbed by the atmosphere?

1. 10% to 20%
2. 20% to 30%
3. 30% to 40%
4. 40% to 50%

8-35. What is the average solar intensity in Btu per square foot per day on the ground?

1. 1,200
2. 1,300
3. 1,400
4. 1,500

8-36. What is the best and most frequent choice as to the orientation of a solar collector?

1. Grid south
2. True south
3. Slightly east of south
4. Slightly west of south

8-37. During what hours of the day does most of the useful energy collection take place?

1. 0700 to 1700
2. 0800 to 1600
3. 0900 to 1500
4. 0900 to 1700

8-38. What are the two basic types of solar collectors?

1. Direct and indirect
2. Oriented and disoriented
3. Parallel and horizontal
4. Liquid and air

8-39. The absorber plate absorbs solar energy and converts it to which of the following types of energy?

1. Heat
2. Radiant
3. Thermal
4. Electrical

8-40. What type of collector is most suitable for low-temperature applications?

1. Air
2. Liquid
3. Flat plate
4. Convex plate

8-41. Some collectors are made with a black coating for which of the following reasons?

1. To emit low-frequency infrared radiation
2. To emit low-frequency ultraviolet radiation
3. To emit high-frequency incoming solar radiation
4. To absorb high-frequency incoming solar radiation

8-42. What is the most commonly used substance for collector covers?

1. Film
2. Glass
3. Plastic
4. Transparent tape

8-43. What is the percentage of transmissivity for standard plate glass?

1. 86%
2. 76%
3. 66%
4. 56%

8-44. What is the cheapest and most obtainable collector fluid?

1. Air
2. Water only
3. Alcohol only
4. Water and alcohol

8-45. Air is not preferred as the collector fluid in domestic solar water heating for which of the following reasons?

1. It freezes
2. It corrodes
3. It has a high density
4. It has a low-heat capacity

8-46. What freeze protection method has a pump to circulate the water through the collectors until the freezing temperatures are over?

1. Drain-up method
2. Drain-down method
3. Recirculating method
4. Supercirculating method

8-47. What are the types of heat transfer fluids?

1. Silicones and hydrocarbon oils
2. Nonaqueous and aqueous
3. Inhibited distilled water and silicones
4. Inhibited glycol/water mixtures and hydrocarbon oils

8-48. What is the flash point of silicone fluids?

1. 450°F
2. 400°F
3. 350°F
4. 300°F

8-49. Silicone fluids are limited to systems with what maximum temperature?

1. 350°F
2. 400°F
3. 450°F
4. 500°F

8-50. What substance is added to water to make it a useful collector fluid?

1. Ethylene glycol
2. Methylene glycol
3. Silicone glycol
4. Aluminum glycol

8-51. A 50-50 water and glycol mixture will protect against freezing down to about what temperature?

1. -10°F
2. -20°F
3. -30°F
4. -40°F

8-52. Which of the following types of collectors uses a vacuum between the absorber and the glass outer tube to reduce convection and conduction heat losses?

1. Evacuated tube
2. Flat plate
3. Concentrating
4. Intensifying

8-53. Which of the following types of collectors intercepts direct radiation over a large area and focuses it onto a small absorber area?

1. Evacuated tube
2. Flat plate
3. Concentrating
4. Intensifying

8-54. Which of the following collectors collects energy by reflecting direct solar radiation off a large curved mirror and onto a small absorber tube?

1. Linear-trough fresnel lens
2. Parabolic trough
3. Compound parabolic mirror
4. Simple parabolic mirror

8-55. Which of the following collectors focuses incoming rays onto a small absorber plate or tube through which the heat transfer liquid is circulated?

1. Linear-trough fresnel lens
2. Parabolic trough
3. Compound parabolic mirror
4. Parabolic fresnel lens

8-56. what amount of water storage is needed per square foot of collector?

1. 10 pounds
2. 15 pounds
3. 20 pounds
4. 25 pounds

8-57. In air collector systems, latent heat is stored in a material as it changes phase from a

1. liquid to a gas
2. gas to a liquid
3. liquid to a solid
4. solid to a liquid

8-58. More expensive, specially fabricated fiber glass or plastic tanks can withstand heat up to what temperature?

1. 450°F
2. 350°F
3. 250°F
4. 150°F

8-59. For typical family residences, each person accounts for approximately how many gallons of hot water per day?

1. 10
2. 20
3. 30
4. 40

8-60. What is the primary advantage of a thermosiphon system of water storage?

1. It uses a lightweight tank
2. It needs no pump or controller
3. It connects directly to the potable water supply
4. It can use a heat exchanger

8-61. What factors contribute to the reduction of heat loss from a rock bed?

1. The density and proclivity
2. The intensity and range
3. The conduction and convection is considerable
4. The conduction and convection is small

8-62. What type of heat storage is well suited for warehouses and factories that have mainly daytime operations?

1. No-storage air heating
2. Rock bed
3. Air type of space heating
4. Thermosiphon

8-63. Most baseboard heaters require approximately what temperature?

1. 150°F
2. 160°F
3. 170°F
4. 180°F

8-64. During the winter, a liquid type of solar system is rarely operated at delivery temperatures above

1. 130°F
2. 140°F
3. 150°F
4. 160°F

8-65. The water-to-air heat pump can effectively use heat from solar storage at what temperature?

1. 25°F
2. 35°F
3. 45°F
4. 55°F

8-66. Midday collection temperatures are usually within what range?

1. 120°F to 150°F
2. 130°F to 170°F
3. 140°F to 160°F
4. 150°F to 180°F

8-67. An oil slick on a water surface blocks the flow of what element from the atmosphere into the water?

1. Hydrogen
2. Ozone
3. Oxygen
4. Carbon dioxide

8-68. On a naval base, what department normally disposes of oil waste residues?

1. PWD
2. DPDO
3. NPDO
4. DDPO

8-69. In what type of approved container should you store oil-soaked absorbent materials for proper disposal?

1. DPDO
2. NPDO
3. APE
4. EPA

8-70. After observing contaminated water from a vehicle washrack polluting the water, you should immediately contact what person?

1. Washrack operator
2. Washrack supervisor
3. Company commander
4. Assistant company commander

8-71. When unburned hydrocarbons and various other fuel components combine chemically, which of the following by-products is normally formed?

1. Carbon monoxide
2. Carbon dioxide
3. Sulfur dioxide
4. Lead sulfite

8-72. What three terms are associated with asbestos dust particle size?

1. Centimeter, millimeter, micron
2. Millimeter, micron, angstrom
3. Centimeter, micron, manometer
4. Micron, nanometer, angstrom

8-73. Air must be scrubbed with a special air filtration machine to remove what size of asbestos dust particles?

1. Millimeter
2. Micron
3. Angstrom
4. Nanometer

8-74. When involved in an asbestos removal project, you should obtain which of the following instructions for guidance?

1. DPDOINST 5100.24
2. OPNAVINST 5100.23
3. OPNAVINST 5110.23
4. OPNAVINST 5200.23